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Morphological characterization of released groundnut, *Arachis hypogaea* L. cultivars for the DUS requirement

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Abstract

In the present era of Intellectual Property Rights (IPR), the distinctness of the cultivar from other released cultivars is the first of the triad of the DUS for granting any form of protection to the rights of its breads. Keeping this in view, basis of distinctness among seventy released groundnut (*Arachis hypogaea* L.) cultivars of which 17 each belongs to the virginia bunch and virginia runner type of the ssp. *hypogaea* and 33 belongs to the spanish type and three to valencia type of ssp. *fastigiata*, were studied. Each cultivar was scored for 17 traits, stem, leaf, flower, fruit and seed traits, and reaction to biotic stresses using the Descriptors for Groundnut developed by IPGRI/ICRISAT. The cultivars showed overlapping of descriptor states in various combinations of traits. The branching pattern and leaf colour could distinguish up to sub-species level. The testa colour was distinct in some of the cultivars that can be used as a diagnostic tool for identification of a few cultivars. In cluster analysis, a combination of 11 characters could distinguish all cultivars. The study indicated that distinction is possible between 70 cultivars using the 11 traits. However, the total number of groundnut cultivars released exceeds 120 and hence to meet DUS criteria as identification of cultivars, some of the distinct morphological characters in coalition with molecular characters may be necessary.

Key words: *Arachis hypogaea*, morphology, descriptors, distinctness, uniformity, stability

Introduction

In India, four botanical types of groundnut *viz.*, virginia bunch (HYB) and virginia runner (HYR) of the ssp. *hypogaea* var. *hypogaea*, spanish (VUL) of the ssp. *fastigiata* var. *vulgaris* and the valencia (FST) of ssp. *fastigiata* var.. fastigiata are under cultivation. (Krapovickas and Gregory, 1994). During the last eight decades about 120 improved cultivars have been released for commercial cultivation in India.

The cultivars released have not so far been extensively described for various heritable morphological traits to enable the identification of these cultivars and for unambiguous ascertainment of distinctness. To meet the requirement of the Plant Breeder's and Farmers rights, it is imperative to identify a set of morphological traits, which can be used for DUS (Distinctness, Uniformity and Stability) testing. In the present study, 17 heritable morphological traits were scored over three years on 70 released cultivars to understand the extent of variation which can be used for distinction of cultivars based on single trait or combinations of traits.

Materials and methods

Seventy groundnut cultivars developed in India were evaluated at the National Research Centre for Groundnut, Junagadh (21.31°N latitude, 70.36°E longitude and altitude of 61 m) in the Gujarat state. The soil is calcareous and medium black Vertisol. Fifty-six of the cultivars comprising four habit types, were assembled in summer 1995 and the rest fourteen in 1996. Twenty-eight of the cultivars were developed by pure line selection, 34 by hybridization and three by mutation breeding, two cultivars were direct introductions, and the pedigree of three cultivars are not known (Table 1). Fifty-six cultivars were evaluated for three *kharif* (rainy season) seasons of 1995, 1996 and 1997 and all 70 were evaluated for two years, 1996 and 1997. The entries were grown in a randomized block design with three replications. The cultivars of different habit forms were randomized within the block. A plot consisted of three rows of 4 m length. The experimental details were as follows.

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Year	HYB	HYR	FST	VUL	Date of Sowing	Spacing (row-to-row x plant-to- plant)	Total rainfall (mm)	Rainy days
1995	12	15	2	27	12 July	60cmX10cm	505	38
1996	17	17	3	33	9 July	60cm X10cm	731	68
1997	17	17	3	33	30 June	75cm X10cm	856	50

Table 1 Passport information on the released cultivars

Name	Pedigree	YOR	Centre
Virginia bunch			
ALR 1	Pol.2 x PPG 4	1987	TNAU, Aliyarnagar
B 95	M 13 x Shulamith	1993	MPKV, Rahuri
BAU 13	BAU 6 x M 13	1993	BAU, Kanke
BG 2	X ray mutant of 41-C	1979	BAU, Kanke
GG 20	GAUG 10 x Robut 33-1	1991	GAU, Junagadh
HNG 2	—	--	RAU, Hanumangarh
ICGS 5	(Robut 33-1 x NCAc 316) F2	1992	ICRISAT, Patancheru
ICGS 76	TMV 10 x Chico	1989	ICRISAT, Patancheru
ICGV 86325	ICGS 20 x G 201	1994	ICRISAT, Patancheru
Kadiri 3	Selection from Robut 33-1	1978	ANGRAU, Kadiri
M 145	A1-1 x D 3	1968	PAU, Ludhiana
M 522	Punjab 1 x F 334-AB 14	1995	PAU, Ludhiana
RS 138	Selection from Brazilian culture	1989	RAU, Durgapura
RSB 87	Selection from Brazilian culture	1961	RAU, Durgapura
T 28	Selection from Bombay collection	1960	CAUA&T, Mainpuri
T 64	Selection from EC1664	1966	CAUA&T, Mainpuri
TMV 10	Natural mutant from Argentine	1970	TNAU, Tindivanam
Virginia runner			
Chandra	Selection from Ah114	1977	CAUA&T Mainpuri
Chitra	Spanish 5B-1 x EC1688	1984	CAUA&T Mainpuri
CSMG 84-1	Selection from MA10	1992	CAUA&T Mainpuri
GAUG 10	G 224-3 x GO 343	1973	GAU, Junagadh
GG 11	M 13 x GAUG10	1984	GAU, Junagadh
GG 12	Shulamith x GAUG 10	1991	GAU, Junagadh
GG 13	GAUG 10 x TMV 10	1994	GAU, Junagadh
Karad 4-11	Selection from local	1957	MPKV, Karad
Kaushal	Selection from T 28	1984	CAUA&T Mainpuri
M 13	Selection from NC13	1972	PAU, Ludhiana
M 197	C501 x U 4-7-2	1982	PAU, Ludhiana
M 335	M 13 x F7	1986	PAU, Ludhiana
M 37	A 1 x C 6-4-7-2	1980	PAU, Ludhiana
Punjab 1	Selection from Samrala local	1953	PAU, Ludhiana

Table 1 (Contd...)

Name	Pedigree	YOR	Centre
RS 1	Selection from local collection	1953	RAU, Durgapura
Somnath	TG 18 A (Induced mutant of TG 18 A x M13)	1990	GAU, Junagadh
UF 70-103	Introduction from USA	1984	PKV, Akola
Spanish			
AK 12-24	Selection from Local	1940	PKV, Akola
ALR 2	Selection from ICGV 86011	1997	TNAU, Aliyarnagar
Co 1	Ah 6279 x TMV 3	1979	TNAU, Coimbatore
Dh 3-30	Spanish Improved x US 4	1975	UAS, Dharwad
Dh 8	Selection from RS 144	1984	UAS, Dharwad
GG 2	J 11 x EC 16659	1983	GAU, Junagadh
GG 3	GAUG 1 x JL 24	1991	GAU, Junagadh
GG 4	CGC 3 x Chico	1993	GAU, Junagadh
Girnar 1	X 14-4-B-19-B x NCAc17090	1988	NRCG, Junagadh
ICGS 1	Selection from Robut33-1	1990	ICRISAT, Patancheru
ICGS 11	Selection from Robut33-1	1986	ICRISAT, Patancheru
ICGS 44	Selection from Robut33-1	1988	ICRISAT, Patancheru
ICGV 86590	X 14-4-B-19-B x PI 259747	1991	ICRISAT, Patancheru
J 11	Ah 4218 x Ah 4354	1964	GAU, Junagadh
JL 24	Selection from EC 94943	1978	MPKV, Jalgaon
K 134	Kadiri 3 x JL 24	1993	ANGRAU, Kadiri
MH 1	Selection from Faizpur 1-5	1975	CCSHAU, Hisar
RG 141	Robut 33-1 x NCAc 2821	1989	RAU, Durgapura
SB XI	Ah 4213 x Ah 4354	1965	GAU, Junagadh
SG 84	Selection from ICGS 1	1986	PAU, Ludhiana
Spanish improved	Selection from Spanish peanut	1905	UAS, Dharwad
TAG 24	Selection from TGS 2	1991	BARC, Trombay
TG 17	Dark green Mutant x TG1	1982	BARC, Trombay
TG 22	Robut 33-1 x TG 17	1992	BARC, Trombay
TG 26	BARCG 1 x TG 23	1995	BARC, Trombay
TG 3	Mutant of Spanish improved	1985	BARC, Trombay
TKG 19 A	TG 17 x TG 1	1993	KVK, Dapoli
TMV 2	Selection from Gudhiatham bunch	1940	TNAU, Tindivanam
TMV 7	Selection from Tenesse white	1967	TNAU, Tindivanam
TMV 12	Selection from Ugandan culture	1978	TNAU, Tindivanam
Tirupati 1	Selection from EC 106983/3-1	1989	ANGRAU, Tirupati
Tirupati 2	GAUG 1 x NCAc FLA-14	1991	ANGRAU, Tirupati
Valencia			
Gangapuri		--	JNKVV, Khargaon
MH 2	Selection from GDM	1978	CCSHAU, Hisar
MH 4	--	1990	CCSHAU, Hisar

*YOR = Year of release, ** Centre = Centre of release

Recommended agronomic practices were followed. The crop was protected from insect-pests by insecticides. No fungicide was sprayed so that the entries could be scored for three economically important diseases viz., early leaf spot (ELS), late leaf spot (LLS) and rust, which occur in sufficient intensity each year. The cultivars were scored for 25 morphological traits using IBPGR/ICRISAT descriptors for groundnut (1992) at various phenophases in each of three years. But only those 17 characters out of the 25, which are stable across the years, have been used for further analysis. Most of these descriptors are common with those specified by UPOV (1985) for studying distinctness in groundnut.

Cluster analysis was done on the basis of squared euclidian distance, first using all the 17 characters to understand the grouping among the cultivars. Then the analysis was repeated by excluding one character at a time. Then the analysis was repeated by excluding two characters in all combinations at a time and this elimination of characters combinations continued till any two cultivars failed to remain distinct.

Results and discussion

The branching pattern in the HYB and HYR cultivars was either alternate or irregular on the n+1 branches but invariably there was no flowers on the main axis (n). The VUL and FST cultivars had flowers on the main axis, and their n+1 branches had sequential or irregular arrangement of flowering nodes (Table 2). The stem surface was sub-glabrous in most of the HYB and HYR cultivars and moderate hairiness was observed in six cultivars of VUL and one of FST. The stem was devoid of pigmentation in most of the cultivars. Most of the HYB and HYR types had multiple pegs from the nodes whereas both single and multiple pegs were present in VUL and FST types. The standard petal colour was orange in most of the cultivars with a few exceptions of dark orange petals. The leaflet shape, leaflet tip and peg pigmentation did not show any particular pattern specific to any habit type. In general, leaflet colour was either green or dark green among the HYB, HYR and FST types and light green in the VUL types. However, the spanish type cultivar ALR 2 had dark green leaves, which is of a rare occurrence in this group. The cultivars had predominantly slight pod beak and slight pod reticulation and moderate pod constriction, but most of the descriptor states of these traits were found among the cultivars. Pod reticulation was absent in the cultivars JL 24, TG 26 and Gangapuri whereas prominent reticulation was observed in the cultivars BAU 13, TG 64, ALR 2 and TKG 19 A. A wide range of testa colours was observed among the cultivars although the majority of the cultivars had rose or salmon coloured testa. Among the HYB types, four cultivars, ALR 1, BAU 13, RS 138 and RSB 87 had red testa and one M 145, had dark red testa. The cv. TMV 10 had white flecks on red testa, which is a unique feature of this cultivar. Among the HYR collection, the cultivars Chitra and CSMG 84-1 had rose testa with white flecks, which distinguish these two from other cultivars. Among the FST group, Gangapuri could be identified by its smooth pods and red testa whereas MH 2 was distinguishable by its dwarf stature. The cultivars ALR 1, Chitra and CSMG 84-1 showed moderate resistance to ELS, LLS and rust whereas, AK 12-24, GG 2, GG 4, J 11, JL 24, SB XI, TMV 7 and MH 4 showed high susceptibility to these diseases. There was overlapping of descriptor states for many pf the traits among the cultivars although some patterns were found to distinguish among the cultivars (Table 3).

On the basis of seventeen traits, the cluster analysis gave many groups as there were cultivars. The squared euclidian distances between pairs of cultivars have been given in Table 4. By excluding six characters viz., branching pattern, nature of inflorescence, stem pigmentation, leaflet shape, leaflet tip and peg pigmentation similar grouping obtained with 17 characters was obtained and all the cultivars remained distinct. Thus these 11 traits were sufficient for distinguishing among the 70 cultivars. (Fig.1). Further reduction in number of characters for cluster analysis failed to distinguish between the cv. TMV 12 (cv no.63) and the cv. Dh 3-30 (cv no.38), and between the cv. Chandra (cv no.18) and the cv. M 335 (cv no.29) as the distance between the members of these pairs was zero (Table 4).

The study indicated no one morphological trait could distinguish a cultivar except by instances of testa colour. The study conducted by Bhagat *et al.*, (1984) with 34 released cultivars indicated a similar situation. Even alternate branching of vegetative and reproductive nodes on n+1 and lack of flowers on the main axis used to describe virginia types could not hold true among cultivars. For example cv. Somanth has irregular branching (n+1) and flowers on main axis. Due to hybridization for the development of new cultivars, several intermediate types have been developed (Singh *et al.*, 1992).

The pedigrees of the cultivars show that only a few parents have been involved in the development of the cultivars released so far. The cultivars predominantly used for incorporation of high yield in developing the cultivars through hybridization were M 13, GAUG 1, GAUG 10 and Robut 33-1. Similarly, RS 138, RSB 87 were developed through selection from a Brazilian culture and ICGS 1, ICGS 11, ICGS 44 and, Kadiri 3 were all developed from Robut 33-1. The narrow genetic base of the improved cultivars may be the reason for finding high degree of morphological homology among the released cultivars.

Table 2 The descriptors and their states for 17 qualitative traits among the released groundnut cultivars

Cultivar	BP	SH	SP	IN	FC	LC	LS	LT	PP	PB	PC	PR	SS	TC	EL	RU	LL
Virginia bunch																	
ALR 1	1	3	0	2	1	2	1	1	1	5	3	3	2	13	3	3	3
B 95	1	3	0	2	2	3	2	2	0	0	0	3	2	10	5	5	5
BAU 13	1	3	0	2	2	2	2	2	1	5	5	7	1	13	5	5	5
BG 2	1	3	0	2	2	2	2	2	1	3	3	3	2	10	5	5	5
GG 20	1	3	0	1	1	2	2	2	0	5	5	5	1	10	5	5	5
HNG (HPS) 2	4	3	0	2	2	2	2	2	1	3	5	5	2	10	5	5	7
ICGS 5	4	1	0	2	1	2	2	2	1	5	5	3	2	11	5	5	5
ICGS 76	1	1	0	2	1	2	2	2	1	5	5	3	1	11	5	5	7
ICGV 86325	4	3	0	1	1	2	2	2	0	0	3	3	1	11	5	5	5
Kadiri 3	4	3	0	2	1	2	2	2	0	0	3	3	1	10	5	7	7
M 145	1	1	0	2	1	2	2	2	1	5	5	3	1	14	5	5	5
M 522	4	1	0	2	1	2	2	2	1	3	5	5	1	11	7	5	7
RS 138	1	3	0	1	1	2	2	2	1	3	5	3	1	13	3	3	5
RSB 87	1	3	1	2	1	3	2	2	1	3	5	3	2	13	3	3	5
T 28	4	1	0	2	1	2	2	2	0	3	5	3	2	10	3	5	3
TG 64	4	3	0	2	1	2	2	2	1	3	5	7	1	10	5	5	7
TMV 10	1	3	0	1	1	3	2	2	1	5	3	0	1	13+2	5	5	7
Virginia runner																	
Chandra	1	3	0	2	1	2	2	2	1	3	5	5	2	11	5	5	5
Chitra	4	3	0	2	1	3	2	2	1	3	5	5	2	10+2	3	3	3
CSMG 84-1	4	3	0	2	1	2	2	2	1	0	5	5	2	10+2	3	3	3
GAUG 10	1	3	0	2	2	2	2	2	0	3	3	3	2	10	5	3	3
GG 11	1	3	0	1	2	2	2	2	0	3	3	3	2	10	5	3	5
GG 12	1	3	0	2	1	2	2	2	0	3	5	3	2	10	7	5	7
GG 13	1	3	0	2	1	2	2	2	1	3	3	3	2	10	3	3	5
Karad 4-11	4	3	0	2	2	1	2	2	0	0	3	3	2	10	3	5	3
Kaushal	4	1	0	2	2	2	2	2	0	3	5	3	2	10	5	5	5
M 13	1	1	0	2	1	2	2	2	1	3	5	5	2	11	3	5	5
M 197	1	3	0	2	1	2	2	2	1	3	5	3	2	10	3	5	5
M 335	4	1	0	2	1	2	2	2	1	3	5	5	2	11	5	5	5
M 37	4	1	0	1	2	3	2	2	0	3	5	3	2	10	5	5	5
PG 1	4	1	0	2	1	2	2	2	0	3	3	3	2	10	3	5	5
RS 1	1	3	1	2	2	2	2	2	1	0	3	5	2	10	5	5	5
Somnath	3	1	0	2	2	2	2	2	1	5	5	5	2	10	5	5	7
UF 70-103	4	1	0	2	1	2	2	2	0	3	3	3	2	10	5	7	7

Table 2 (Contd..)

Cultivar	BP	SH	SP	IN	FC	LC	LS	LT	PP	PB	PC	PR	SS	TC	EL	RU	LL
Spanish																	
AK 12-24	2	3	0	1	1	1	2	2	1	3	3	3	1	10	7	7	9
ALR 2	2	3	0	2	2	3	2	2	1	0	5	7	1	11	5	5	7
CO 1	3	3	0	1	1	1	2	2	1	3	5	3	1	11	5	5	7
Dh 3-30	2	1	0	1	1	1	2	2	1	3	3	3	1	10	5	5	5
Dh 8	2	3	0	1	1	1	1	1	1	0	5	3	2	11	5	7	7
GG 2	2	3	0	2	1	2	2	2	1	3	3	3	1	10	7	7	9
GG 3	2	3	0	1	1	1	2	2	1	3	3	5	1	11	5	5	9
GG 4	3	3	0	1	1	1	2	2	1	5	5	5	2	11	7	7	9
Girnar 1	2	5	0	2	2	1	2	2	1	5	5	5	1	10	7	3	9
ICGS 1	3	3	0	2	1	1	2	2	0	0	3	3	1	10	5	7	7
ICGS 11	2	3	0	2	1	2	2	2	1	0	5	3	1	10	5	7	7
ICGS 21	2	1	0	2	1	2	2	2	1	5	3	3	2	10	5	7	7
ICGS 44	2	3	0	2	1	2	2	2	0	0	5	3	2	10	5	7	7
ICGV 86590	2	1	0	2	1	2	2	2	0	5	5	5	2	11	3	3	5
J 11	2	3	0	2	1	1	2	2	0	3	5	3	1	11	7	7	9
JL 24	2	3	0	1	1	2	2	2	0	3	5	0	1	11	7	7	9
K 134	2	3	0	1	2	2	2	2	1	3	5	3	2	10	5	5	7
MH 1	2	5	0	1	1	1	2	2	1	3	5	3	1	11	7	9	9
RG 141	2	3	0	1	2	2	2	2	1	0	3	3	1	11	7	7	7
SB XI	2	3	0	1	2	1	2	2	1	3	3	3	1	11	7	7	9
SG 84	2	1	0	2	1	2	2	2	0	0	5	3	2	10	5	5	7
Spanish Improved	2	5	0	2	1	1	2	2	0	3	5	5	1	11	5	7	7
TAG 24	2	3	1	2	2	2	2	2	1	3	5	3	1	11	7	5	9
TG 17	2	3	0	2	1	2	2	2	1	5	5	5	2	10	5	5	7
TG 22	2	1	0	2	2	2	2	2	0	5	5	5	2	10	5	7	7
TG 26	2	3	0	2	2	2	2	2	0	3	3	0	1	10	7	5	7
TG 3	2	3	0	2	1	1	2	2	1	3	5	3	1	10	5	5	7
TKG 19 A	2	3	0	2	2	2	1	1	1	5	5	7	2	10	5	5	7
TMV 12	2	5	0	1	1	1	2	2	1	3	3	3	1	10	5	5	5
TMV 2	2	5	0	1	1	2	2	2	1	3	3	3	1	11	7	5	7
TMV 7	3	3	0	1	1	1	2	2	1	3	3	3	1	11	7	7	9
TPT 1	3	1	0	1	1	1	2	2	1	3	3	3	1	11	5	7	7
TPT 2	3	5	0	1	1	1	2	2	1	0	3	3	1	11	7	5	7
Valencia																	
MH 2	2	5	0	1	1	2	2	2	1	3	5	3	1	13	5	5	7
MH 4	2	1	0	2	1	2	2	2	1	3	5	3	2	10	7	7	9
Gangapuri	2	3	0	1	2	1	2	2	1	3	3	0	1	13	5	5	7

BP= branching pattern, SH = stem hairiness, SP=stem pigmentation, IN= Nature of inflorescence, FC= colour of standard petal, LC= leaf colour, LS= leaflet shape, LT= leaflet tip, PP= peg pigmentation, PB= pod beak, PC = pod constriction, PR= pod reticulation, SS= seed size, TC= testa colour, EL= Susceptibility to early leaf spot, RU= Susceptibility to rust , LL= Susceptibility to late leaf spot

Table 3 Distribution pattern of qualitative traits among the released groundnut cultivars

Trait	Virginia bunch			Virginia runner			Spanish			Valencia		
Branching pattern	1(10)	4(7)	--	1(8)	3(1)	4(8)	2(27)	3(6)	--	2(3)	--	--
Stem hairiness	1(5)	3(12)	--	1(7)	3(10)	--	1(6)	3(21)	5(6)	1(1)	3(1)	5(1)
Stem pigmentation	0(16)	1(1)	--	0(16)	1(1)	--	0(32)	1(1)	--	0(3)	--	--
Inflorescence	1(4)	2(13)	--	1(2)	2(15)	--	1(16)	2(17)	--	1(2)	2(1)	--
Flower colour	1(13)	2(4)	--	1(10)	2(7)	--	1(24)	2(9)	--	1(2)	2(1)	--
Peg pigmentation	1(5)	2(12)	--	1(8)	2(9)	--	1(9)	2(24)	--	1(3)	--	--
Leaf colour	--	2(14)	3(3)	1(1)	2(14)	3(2)	1(17)	2(15)	3(1)	1(1)	2(2)	--
Leaf shape	1(1)	2(16)	--	--	2(17)	--	1(2)	2(31)	--	--	2(3)	--
Leaflet tip	1(1)	2(16)	--	--	2(17)	--	1(2)	2(31)	--	--	2(3)	
Pod beak	0(3)	3(7)	5(7)	0(3)	3(13)	5(1)	0(8)	3(18)	5(7)	3(3)	--	--
Pod constriction	0(1)	3(5)	5(11)	--	3(7)	5(10)	--	3(14)	5(19)	--	3(1)	5(2)
Pod reticulation	0(1), 3(11), 5(3), 7(2)			-	3(10)	5(7)	0(2), 3(22), 5(7), 7(2)			0(1)	3(2)	-
Seed shape	1(10)	7(2)	-	-	2(17)	-	1(23)	2(10)	-	1(2)	2(1)	-
Testa colour	10(7), 11(4), 13(4), 14(1)		13-2(1),	10-2(2)	10(12)	11(13)	10(16)	11(17)	-	10(1)	13(2)	-
Susceptibility to ELS	3(4)	5(12)	7(1)	3(7)	5(9)	7(1)	3(1)	5(18)	7(14)	-	5(2)	7(1)
Susceptibility to rust	3(3)	5(13)	7(1)	3(5)	5(11)	7(1)	3(2), 5(14), 7(16), 9(1)			-	5(2)	7(1)
Susceptibility to LLS	3(2)	5(9)	7(6)	3(4)	5(10)	7(3)	5(3)	7(19)	9(11)	-	7(2)	9(1)

Figures in parenthesis indicate number of cultivars

Table 4 Squared euclidian distance (rounded to second place after decimal) between pairs of cultivars based on three different sets of number of characters

17 characters			11 characters			10 characters		
CV. No.	CV No.	Distance	CV No.	CV No.	Distance	CV No.	CV No.	Distance
54	65	2.00	54	65	1.00	38	63	0.00
58	62	2.00	6	51	1.00	18	29	0.00
47	55	2.00	10	47	1.00	54	65	1.00
10	44	2.00	35	40	1.00	33	62	1.00
35	40	2.00	15	31	1.00	47	55	1.00
4	32	2.00	26	30	1.00	49	52	1.00
15	31	2.00	27	29	1.00	26	51	1.00
26	30	2.00	24	28	1.00	34	46	1.00
7	29	2.00	21	22	1.00	10	45	1.00
24	28	2.00	49	54	1.50	35	40	1.00
18	27	2.00	10	45	1.50	28	31	1.00
21	22	2.00	18	27	1.50	18	27	1.00
19	20	2.00	4	6	1.50	21	22	1.00
64	68	3.00	10	44	1.67	33	59	1.50
37	66	3.00	64	68	2.00	10	44	1.50
45	61	3.00	37	66	2.00	26	30	1.50
33	59	3.00	61	63	2.00	15	28	1.50
49	50	3.00	58	62	2.00	4	21	1.50
6	16	3.00	33	59	2.00	33	58	1.67
13	14	3.00	34	55	2.00	6	33	1.75
33	58	3.50	19	20	2.00	23	69	2.00
35	69	4.00	13	14	2.00	17	68	2.00
38	63	4.00	7	8	2.00	64	67	2.00
41	54	4.00	4	32	2.33	56	66	2.00

Table 4 (Contd...)

17 characters			11 characters			10 characters		
CV. No.	CV No.	Distance	CV No.	CV No.	Distance	CV No.	CV No.	Distance
23	47	4.00	35	69	2.50	38	61	2.00
10	34	4.00	2	26	2.50	49	54	2.00
15	26	4.00	49	52	2.67	8	37	2.00
4	24	4.00	64	67	3.00	15	24	2.00
7	12	4.00	38	61	3.00	19	20	2.00
64	67	4.50	23	60	3.00	13	14	2.00
49	57	4.50	16	58	3.00	7	18	2.33
45	51	4.50	53	57	3.00	10	47	2.50
37	41	4.50	33	46	3.00	7	48	2.75
4	21	4.50	37	41	3.00	4	26	2.89
1	13	4.50	15	24	3.00	9	64	3.00
23	45	4.67	1	30	3.00	12	57	3.00
39	53	5.00	2	21	3.17	39	56	3.00
18	48	5.00	10	34	3.25	49	50	3.00
33	46	5.25	49	50	3.50	2	32	3.00
37	39	5.50	37	39	3.67	5	16	3.00
49	52	5.67	7	18	3.67	9	53	3.33
8	18	5.67	2	4	3.95	23	35	3.50
2	4	5.67	5	16	4.00	8	12	3.50
37	64	5.9[illegible]	7	12	4.20	5	6	3.50
37	70	6.10	49	53	4.30	4	15	3.67
23	35	6.22	2	15	4.67	23	34	3.75
23	60	6.44	37	56	4.75	39	41	4.00
15	25	6.50	5	33	4.83	1	13	4.00
49	56	6.75	10	23	4.83	10	38	4.20
1	8	6.92	9	64	5.00	8	39	4.50
37	49	6.96	11	17	5.00	42	49	4.60
5	38	7.00	7	48	5.17	10	23	4.75
11	17	7.00	10	35	5.17	8	9	4.78
6	33	7.70	9	37	5.25	2	4	4.90
37	42	7.94	42	49	5.57	11	17	5.00
3	36	8.00	2	25	5.77	1	7	5.00
7	9	8.00	9	70	5.89	2	25	5.25
2	5	8.05	10	38	5.97	10	60	5.36
10	15	8.13	9	42	6.07	8	42	5.55
6	23	9.00	1	7	6.76	1	19	6.38
7	19	9.50	3	36	7.00	8	70	6.53
1	3	10.29	2	19	7.21	5	43	6.57
2	6	10.42	5	10	7.64	3	36	7.00
7	10	10.96	2	5	8.33	2	10	7.34
2	43	12.74	1	3	9.00	2	5	7.69
1	11	12.94	1	9	10.83	1	3	9.40
2	37	14.29	1	2	12.61	2	8	11.40
2	7	15.58	1	43	14.46	1	2	12.38
1	2	18.36	1	11	21.37	1	11	20.87

Cv. No.= Cultivar number

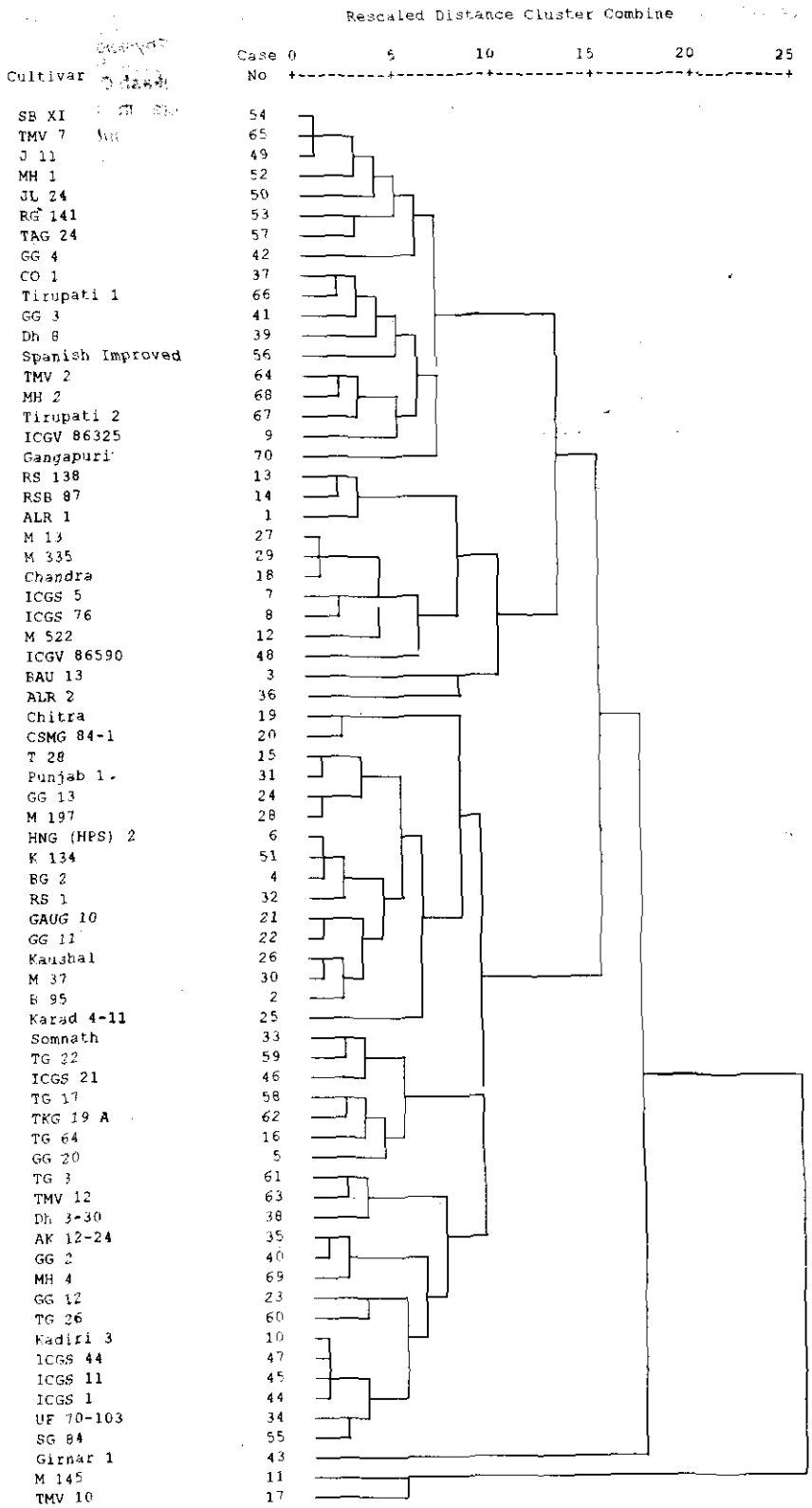

Fig.1 Dendogram of 70 released cultivars based on 11 morphological traits

With more than 120 released cultivars of groundnut in India, morphological traits alone may not suffice for the DUS criteria. Also, some of these traits may be influenced by environment. The electrophoretic studies on groundnut seed protein indicated variation in arachin polypeptides (Krishna *et al.*, 1986) and polypeptide composition (Bisha, 1979). DNA polymorphism was also detected in groundnut using AFLP technique (He and Prakash, 1997). Hence, collaboration through more consistent biochemical and molecular characters, which are less influenced by environment need to be explored for the delineation of groundnut cultivars for varietal protection.

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Genetic analysis of yield components and confectionery traits in crosses involving large seeded genotypes of groundnut, *Arachis hypogaea* L.

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Abstract

Genetic analysis of four yield components and three confectionery traits was carried out in five inter sub-specific crosses involving five Virginia and Spanish genotypes of groundnut, *Arachis hypogaea* L. Two confectionery traits namely sugar and protein contents exhibited predominantly additive genetic effects while pod yield and oil content were governed by dominance. Both additive and dominance genetic effects were observed in case of shelling out-turn and sound mature kernel. Kernel weight exhibited complex genetic control indicating higher order gene interaction. Population improvement procedures like biparental mating and modified recurrent selection scheme were suggested to improve pod yield and confectionery traits simultaneously.

Key words: Groundnut, genetic analysis, *confectionery traits*, *additive*, dominance, genetic effects, **recurrent** selection, large seeded

Introduction

Groundnut seeds are characterized by high oil (32-55%) and protein content (16-34%) and a low percentage of sugar and ash. The oil from the seed is of high quality and a large percentage of world production of groundnut is used as an edible oil source. In India, groundnut seeds contribute to 80% of the edible oil reserve and a substantial quantity of hand graded, large seeded genotypes from other wise small seeded genotypes are also exported to different countries for confectionery purposes. The popularity of groundnut seeds in human food make them a natural candidate for source of vegetable protein ingredients. A number of products with protein content ranging from 25-90% have been developed and used for the commercial production of flakes, flours, meals, concentrates and protein rich isolates. Significant amount of work has been accomplished in selection (Wynne and Cofflet, 1982) and development of large seeded genotypes (Dwivedi *et al.*, 1989). However, studies on the genetic systems governing these valuable confectionery traits like oil, protein and sugar contents in addition to trade yield components like kernel weight, sound mature kernels and shelling percent the appropriate breeding methodologies to be followed involving large seeded genotypes are very limited. The preset study aims at elucidating the genetics of these trade related quality characters in five inter sub-specific crosses involving large seeded genotypes of groundnut.

Materials and methods

The experimental material consisted of six generations *viz.*; P_1, P_2, F_1, F_2, BC_1 and BC_2 derived from five inter sub *specific crosses involving five Virginia parents namely* ICGV 93080, GG 20, ICGV 94225, ICGV 86564 and BAU 13 and five Spanish parents *viz.*, GG 5, J 38, TG 17, TG 19A and ICGS 21. Five crosses were effected in a crossing block during summer 1999 to obtain the F_1 hybrid seeds. The F_1 plants were backcrossed with the parents, P_1 and P_2, keeping the F_1s as the ovule parents to get their respective backcross families, BC_1 and BC_2 in *kharif*, 1999. The F_1s were also grown to obtain the F_2 seeds during the same season. With the reserved seeds of direct F_1 hybrids of the five cross combinations, seeds for all the six generations namely, P_1, P_2, F_1, F_2, BC_1 and BC_2 were obtained for the experiment. All the six generations were raised in a Randomized Block Design with three replications during summer season 2000. Each *replication consisted of a single row of 5 m length for each* P_1, P_2 and F_1, two rows for each of BC_1 and BC_2 and four rows of F_2 progenies. A uniform inter and intra row spacing of 60 and 20 cm was maintained uniformly for raising all the generations. Recommended agronomic practices and plant protection measures were adopted to raise a successful crop.

Observations on pod yield/plant (g), shelling (%), 100-kernel weight (g), protein content (%), sugar content (%) and oil content (%) were recorded on 10 randomly chosen plants in each of P_1, P_2 and F_1 generations while they were recorded on twenty plants in each plot of BC_1 and BC_2 families and forty plants in F_2s. The protein, total sugar and oil content in composite sample of 10-15 seeds of individual plant were estimated by Micro-Kjeldahl *method (Bremmer, 1965), Nelson-Somogyi colorimetric* method (Nelson, 1944), and nuclear magnetic resonance spectrometer (Model PC-20, Bruker India Scientific Co.

Pvt. Ltd), respectively. The data were subjected to generation mean analysis as suggested by Hayman (1958) and Jinks and Jones (1958). Scaling and non-scaling tests for each character were analysed as per the method suggested by Mather (1949) and Cavalli (1952). The genetic effects were estimated through Hayman's (1958) approach.

Results and discussion

The genetic effects of all the seven characters for the five crosses are presented in Table 1 along with the scales and respective X^2 values. Significant results are discussed character wise below.

Pod yield

The scaling test was significant in all the crosses for pod yield indicating that additive-dominance variance is inadequate to explain the observed variation for pod yield and indicated the presence of non-allelic interactions. Joint scaling tests further confirmed our results. Among the five crosses, three crosses namely GG 5 x ICGV 93080, J 38 x GG 20 and TG 19A x ICGV 86564 exhibited the importance of significant dominance effects in the presence of additive x additive and dominance x dominance interaction effects. Importance of dominance in governing pod yield in groundnut has been reported already (Sangha and Labana, 1982). Duplicate epistasis was detected in two crosses, J 38 x GG 20 and TG 19A x ICGV 86564 with the dominance components (h and l) exhibiting opposite signs.

Considering the segmental polyploidy in groundnut having two different genomes, role of duplicate epistasis in the inheritance of several quantitative and qualitative traits cannot be over ruled as evident from the present findings. Exploitation of dominance through hybrid breeding for improving pod yield in groundnut is not feasible looking into the operation of cleistogamy and consequent poor seed set upon hybridization (20%). Besides, the larger estimates of the non-fixable dominance x dominance variation may also hinder the pace of improvement of pod yield through simple selection methods. Hence, biparental mating in early segregating generations or few cycles of recurrent selection followed by pedigree selection may be effective for improving pod yield in large seeded groundnut cultivars.

100-kernel weight

The scaling and joint scaling tests were significant in all the crosses except for one cross, J 38 x GG 20 suggesting that additive-dominance model is insufficient to account for the variations observed for hundred kernel weight in these crosses. However, non-significance of the genetic components (d or h) in the cross, J 38 x GG 20 indicated the role of complex genetic systems governing kernel weight. The absence of significant additive and or dominance gene effects in the three other crosses viz., GG 5 x ICGV 93080, TG 19A x ICGV 86564 and ICGS 21 x BAU 13 further confirmed the above findings. However results conflicting to our present findings were reported in the literature (Sandhu and Khehra, 1976; Halward and Wynne, 1991). This may be due to the genotypes employed, method of analysis and the environmental conditions. In addition, most of the genotypes studied either directly or indirectly possessed exotic blood in them indicating the importance of selection of genotypes to breed special purpose varieties like confectionery groundnuts.

In the present study, only one cross holds promise for improving kernel weight, which exhibited significant dominance effect in the presence of all the three interaction effects. Duplicate epistasis was also detected in this cross, which may hinder with the selection at the early generations.

Kernel weight is an important criterion deciding the premium price of the export groundnuts. The complex genetic system observed in the present study cautions the early generation selection advocated (Sandhu and Khehra, 1976; Basu *et al.*,1988) for the improvement of kernel weight in the crosses involving small seeded genotypes and suggested postponing of selection to later filial generations to isolate superior large seeded genotypes.

Shelling out-turn

Epistasis was detected in all the five crosses. Predominance of dominance genetic effect was observed in all the crosses along with fixable additive x additive interaction effect. While both additive and dominance genetic effects were important in the cross, ICGS 21 x BAU 13. Importance of additive (Kumar and Patel, 1999) and dominance (Makne and Bhale, 1989) components of variation in the inheritance of shelling out-turn has been already reported by several authors.

Shelling out-turn is an important quality trait that determines the market value of bold seeded groundnut genotypes either for local consumption or for export purpose. Although the presence of both additive and dominance components may aid in developing high shellers through pedigree method, delaying the selection till the non-fixable interactions are eliminated in the population would yield desired results.

Sound mature kernel

The scaling and joint scaling tests detected epistasis in all the five crosses except for TG 17 x ICGV 94225. Predominance of additive genetic effect was observed in two crosses, TG 17 x ICGV 94225 and ICGS 21 x BAU 13, while additive and dominance genetic effects were observed in three crosses with greater magnitude of dominance components. Importance of additive and dominance components for sound mature kernel (%) has already been reported (Wynne *et al.*,1970; 1975; Bhagat *et al.*,1986). Among the interaction effects, the fixable additive x additive genetic components were significant only in cross, ICGS 21 x BAU 13, while dominance x dominance effect was significant and negative in one cross, TG 19A x ICGV 86564. While both additive x additive and dominance x dominance effects were significant in GG 5 x ICGV 93080.

Table.1 Components of generation means with 3 and 5 parameter models for different characters in groundnut.

Cross	Scales				Parameters					
	A	B	C	$X^2_{(3)}$	m	(d)	(h)	(i)	(j)	(l)
Pod yield										
GG 5 x ICGV 93080	-5.79 ± 1.73**	-4.33 ± 2.22	-12.35 ± 3.47**	18.42**	14.13 ± 0.70**	-2.56 ± 1.15*	7.99 ± 3.79*	2.22 ± 3.65	-0.72 ± 1.27	7.89 ± 5.79
J 38 x GG 20	-2.58 ± 2.31	-1.92 ± 2.32	-20.12 ± 2.99**	53.12**	13.03 ± 0.57**	-2.69 ± 1.39	15.92 ± 3.73**	15.62 ± 3.61**	-0.33 ± 1.58	-11.12 ± 6.32
TG 17 x ICGV 94225	-0.56 ± 1.32	-4.22 ± 1.29**	-6.94 ± 2.16**	16.15**	11.09 ± 0.39**	-0.07 ± 0.67	2.31 ± 2.20	2.15 ± 2.08	1.82 ± 0.84*	2.63 ± 3.45
TG 19 A x ICGV 86564	0.72 ± 1.89	-2.17 ± 1.78	-13.08 ± 2.99**	24.03**	12.87 ± 0.55**	-1.32 ± 0.93	9.83 ± 3.07**	11.63 ± 2.90**	1.45 ± 1.22	-10.18 ± 4.80*
ICGS 21 x BAU 13	-2.55 ± 1.84	-6.12 ± 2.10**	-17.64 ± 3.35**	25.65**	12.98 ± 0.63**	0.99 ± 0.99	14.00 ± 3.46**	8.96 ± 3.24**	1.78 ± 1.19	-0.29 ± 5.32
100 kernel weight										
GG 5 x ICGV 93080	-1.14 ± 2.61	-18.18 ± 2.03**	-20.30 ± 4.62**	86.09**	48.28 ± 0.96**	-0.98 ± 1.33	-4.08 ± 4.87	0.97 ± 4.70	8.52 ± 1.44**	18.35 ± 7.07**
J 38 x GG 20	1.01 ± 2.51	-3.61 ± 2.92	-10.84 ± 5.66	6.87	48.76 ± 0.85**	-3.38 ± 0.83**	1.28 ± 1.47	[illegible]	[illegible]	[illegible]
TG 17 x ICGV 94225	5.68 ± 2.53*	-4.19 ± 2.89	-2.01 ± 5.39	7.96*	50.77 ± 1.22**	-0.93 ± 1.62	2.15 ± 5.97	3.49 ± 5.86	4.93 ± 1.85*	-4.98 ± 8.45
TG 19 A x ICGV 86564	15.17 ± 4.24**	-1.76 ± 3.82	-15.56 ± 6.81*	21.83**	62.56 ± 1.51**	-1.51 ± 2.50	33.23 ± 8.01**	28.97 ± 7.85**	8.46 ± 2.76**	-42.38 ± 12.11**
ICGS 21 x BAU 13	-2.44 ± 2.79	-12.88 ± 3.90**	-26.72 ± 6.40**	25.09**	53.57 ± 1.46**	-4.45 ± 2.12*	12.09 ± 7.35	11.39 ± 7.24	5.21 ± 2.31*	3.93 ± 10.64
Shelling out turn										
GG 5 x ICGV 93080	-8.60 ± 1.74**	-3.57 ± 2.10	-19.63 ± 3.30**	47.39**	66.54 ± 0.58**	0.46 ± 0.99	7.87 ± 3.29*	7.45 ± 3.08*	-2.51 ± 1.19*	0.47 ± 5.17
J 38 x GG 20	-5.58 ± 1.48**	-5.01 ± 1.68**	-30.06 ± 3.31**	66.59**	63.45 ± 0.75**	-0.05 ± 0.93	16.39 ± 3.60**	19.47 ± 3.54**	-3.29 ± 1.07**	-8.88 ± 4.99
TG 17 x ICGV 94225	-0.98 ± 2.29	-2.66 ± 2.69	-16.83 ± 4.09**	17.29**	60.97 ± 0.90**	-0.63 ± 1.58	11.45 ± 4.90**	13.18 ± 4.81**	0.84 ± 1.67	-9.54 ± 7.54
TG 19 A x ICGV 86564	0.07 ± 1.83	-2.47 ± 1.52	-12.61 ± 3.61**	14.49**	63.82 ± 0.83**	0.11 ± 1.08	9.08 ± 4.00*	10.21 ± 3.95*	1.27 ± 1.14	-7.81 ± 5.51
ICGS 21 x BAU 13	-9.09 ± 2.33**	-8.83 ± 2.82**	-25.30 ± 4.18**	50.10**	63.63 ± 0.94**	3.97 ± 1.69**	8.33 ± 5.15	7.37 ± 5.07	-0.12 ± 1.79	10.56 ± 7.96
SMK %										
GG 5 x ICGV 93080	-18.17 ± 3.42**	-22.38 ± 4.28**	-19.30 ± 5.34**	55.78**	79.74 ± 1.16**	8.41 ± 2.51**	17.11 ± 6.96*	21.24 ± 6.83**	2.10 ± 2.64	61.80 ± 11.37**
J 38 x GG 20	-19.24 ± 2.94**	-10.63 ± 3.72**	-65.00 ± 7.01**	90.55**	71.75 ± 1.57**	-1.51 ± 2.02	28.33 ± 7.65**	35.13 ± 7.50**	-4.31 ± 2.18	-5.26 ± 10.72
TG 17 x ICGV 94225	-8.31 ± 4.10*	-15.33 ± 3.83**	-33.40 ± 7.11**	33.44**	61.25 ± 1.57**	7.37 ± 2.39**	6.15 ± 8.07	9.75 ± 7.90	3.51 ± 2.70	13.88 ± 11.92
TG 19 A x ICGV 86564	13.51 ± 4.67**	11.20 ± 4.24**	12.53 ± 9.28	10.80*	74.00 ± 1.67**	1.82 ± 2.07	17.24 ± 8.50*	12.17 ± 7.86	1.15 ± 2.27	-36.88 ± 12.26**
ICGS 21 x BAU 13	-0.86 ± 2.76	-3.84 ± 3.76	-18.80 ± 6.28**	9.61*	78.46 ± 1.33**	7.22 ± 1.88**	12.82 ± 6.74	14.08 ± 6.34*	1.48 ± 2.15	-9.37 ± 9.82

*,** Significant at 5% and 1% levels, respectively.

Table.1 (conti.) Components of generation means with 3 and 5 parameter models for different characters in groundnut

Cross	Scales				Parameters					
	A	B	C	$X^{2(3)}$	m	(d)	(h)	(i)	(j)	(l)
					Protein content					
GG 5 x ICGV 93080	-6.42 ± 1.00**	-6.09 ± 0.94**	-18.00 ± 1.51**	205.06**	21.06 ± 0.36**	0.62 ± 0.66	6.67 ± 1.97**	5.48 ± 1.96**	-0.16 ± 0.67	7.03 ± 3.05*
J 38 x GG 20	-1.77 ± 1.19	-2.06 ± 1.21	-4.80 ± 1.88*	10.02*	20.14 ± 0.44**	3.66 ± 0.81**	0.17 ± 2.42	0.95 ± 2.40	0.14 ± 0.82	2.88 ± 3.76
TG 17 x ICGV 94225	-1.54 ± 0.89	-1.05 ± 0.94	-5.88 ± 1.54**	17.63**	20.08 ± 0.37**	-1.82 ± 0.62**	2.57 ± 1.95	3.29 ± 1.95	-0.24 ± 0.64	-0.69 ± 2.94
TG 19 A x ICGV 86564	2.03 ± 1.19	5.58 ± 1.03**	20.25 ± 1.63**	211.68	20.97 ± 0.35**	2.21 ± 0.72**	9.41 ± 2.05**	9.34 ± 2.01**	0.21 ± 0.75	1.61 ± 3.30
ICGS 21 x BAU 13	-3.30 ± 0.94**	-3.66 ± 0.88**	-10.68 ± 1.52**	60.55**	19.53 ± 0.33**	-1.16 ± 0.38*	4.07 ± 1.81*	3.70 ± 1.77*	0.18 ± 0.60	3.26 ± 2.78
					Sugar content					
GG 5 x ICGV 93080	-3.67 ± 0.78**	-3.74 ± 0.69**	-16.77 ± 1.63**	104.05**	7.08 ± 0.29**	1.40 ± 0.48*	9.61 ± 1.53**	9.36 ± 1.51**	0.03 ± 0.52	-1.95 ± 2.30
J 38 x GG 20	-2.36 ± 0.83*	-3.41 ± 0.80**	-4.61 ± 1.69*	77.84**	6.71 ± 0.39**	2.50 ± 0.53**	-1.34 ± 1.93	-1.16 ± 1.91	0.52 ± 0.56	6.93 ± 2.71*
TG 17 x ICGV 94225	2.84 ± 0.78**	-1.38 ± 0.81	-0.64 ± 1.87	18.41**	7.61 ± 0.31**	-1.37 ± 0.52*	1.56 ± 1.65	2.10 ± 1.63	2.11 ± 0.55**	-3.56 ± 2.49
TG 19 A x ICGV 86564	-3.93 ± 0.69**	-1.67 ± 0.65*	-1.66 ± 1.55	46.90**	7.67 ± 0.36**	1.17 ± 0.40**	-2.53 ± 1.69	-3.94 ± 1.67*	-1.13 ± 0.45*	9.54 ± 2.24**
ICGS 21 x BAU 13	-0.28 ± 0.76	-5.82 ± 0.85**	-5.90 ± 1.56**	33.28**	8.29 ± 0.37**	-1.44 ± 0.52**	-0.53 ± 1.81	-0.20 ± 1.79	2.77 ± 0.55**	8.30 ± 2.61*
					Oil content					
GG 5 x ICGV 93080	-5.10 ± 0.68**	-2.64 ± 0.53**	-7.20 ± 1.24**	88.63**	46.72 ± 0.28**	-1.64 ± 0.38**	-0.11 ± 1.39	-0.50 ± 1.37	-1.21 ± 0.40**	8.25 ± 1.98**
J 38 x GG 20	-6.72 ± 0.97**	-2.29 ± 0.57**	-11.05 ± 1.33**	120.32**	46.36 ± 0.2**	-4.14 ± 0.54**	-0.88 ± 1.69	2.03 ± 1.68	-2.21 ± 0.55**	6.98 ± 2.56*
TG 17 x ICGV 94225	-8.87 ± 0.64**	-10.40 ± 0.60**	-15.24 ± 1.27**	567.36**	48.18 ± 0.30**	2.28 ± 0.41**	-1.25 ± 1.29	-4.04 ± 1.49*	0.76 ± 0.42	23.33 ± 2.10**
TG 19 A x ICGV 86564	-6.69 ± 0.69**	-5.78 ± 0.71**	7.34 ± 1.08**	275.85**	46.95 ± 0.26**	0.66 ± 0.48	-7.35 ± 1.43**	-5.13 ± 1.43**	-0.45 ± 0.48	17.60 ± 2.22**
ICGS 21 x BAU 13	-11.53 ± 0.82**	-9.71 ± 0.68**	-14.99 ± 1.19**	520.96**	47.44 ± 0.28**	0.57 ± 0.52	-5.92 ± 1.56**	-6.29 ± 1.55**	-0.92 ± 0.52	27.58 ± 2.39**

*,** Singnificant at 5% and 1% levels, respectively.

Higher % of SMK is an important character which provides uniform seed lot. For improvement of this character the cross, ICGS 21 x BAU 13, which exhibited positive additive and additive x additive interaction effects holds promise. Transgressive variation may likely to appear in the early segregating generation. Hence simple selection through pedigree breeding for high SMK% is suggested. How ever postponing the selection to later generations may result in desirable results.

Protein content

For protein content, all the crosses exhibited significance of the scaling tests (Table 1), indicating the role of epistasis. Additive, dominance genetic effect was predominant in one cross each *viz.*, J 35 x GG 20 and GG 5 x ICGV 93080 respectively. Whereas, both additive and dominance gene actions were significant in TG 19A x ICGV 86564 indicating the importance of both additive and dominance genetic effects in governing protein content. Similar (Layrisse *et al.*, 1980; Makne and Bhale, 1989) and contradictory reports (Basu *et al.*,1988) to the present finding were also available in the literature. Three crosses, GG 5 x ICGV 93080, TG 19A x ICGV 86564 and ICGS 21 x BAU 13 exhibited the importance of additive x additive gene interaction effects. These crosses may be utilized through pedigree breeding for improving protein content as transgressive variation may be expected in the segregating population. In addition, the absence of dominance x dominance and additive x dominance gene interaction effects may also result in greater gain through selection and offer enough scope to effect selection at early generation. The cross GG 5 x ICGV 93080 exhibited complementary epistasis with **h** and **I** effects having same sign. This cross too holds promise to isolate superior recombinants with high protein content even in early segregating generations.

Sugar content

Epistasis was detected both in scaling and joint scaling tests. The additive genetic effect was significant in four crosses whereas both additive and dominance effects were significant in GG 5 x ICGV 93080. The results indicated the preponderance of additive genetic effect for sugar content. Studies on gene action governing sugar content are very scanty in the literature. However few workers indicated the role of additivity in the inheritance of sugar content (Basu *et al.*, 1988).

Our results clearly demonstrated the role of additive type of gene action in all the five crosses studied. The lower magnitude of ***h*** and ***I*** effects further encourages the improvement of sugar content in groundnut through pedigree selection. However to nullify the effects of non-fixable genetic components, selection for high sugar lines at later generation may yield desirable results.

Oil content

Significance of scaling and joint scaling tests indicated the presence of epistasis. Dominance was found to be important in governing oil content in two crosses, TG 19A x ICGV 86564 and ICGS 21 x BAU 13. The direction of dominance in these crosses was negative indicating low oil content was dominant over high oil content, a condition more favourable for developing confectionery groundnuts where low oil content in the seeds helps in manufacture of peanut butter and margarines with good shelf-life. Additive gene effect was significant and positive in only one cross, TG 17 x ICGV 94225 further confirming the observed role of dominance in the inheritance of oil content. Earlier reports of Makne and Bhale, 1987, Basu *et al.*, 1988, and Upadhyaya and Nigam, 1999 also corroborate with the present findings.

Oil content is most important quality attribute, which decides the market value of groundnut. The millers prefer cultivars with high oil content whereas lines with low oil content but having high protein and sugar contents are exported as confectionery grade groundnuts. The negative relationship between oil and protein (Holley and Hammons, 1968) and positive relationship between protein and sugar (Layrisse *et al.*, 1980) encourages the direct selection for high protein content that may eventually result in high sugar but low oil content. To improve the protein content a selection scheme as followed in soybean (Brim and Burton, 1979) may be followed in groundnut also.

Breeding for confectionery quality is of recent origin in groundnut in India. Our present findings indicated that the confectionery qualities like sugar and protein contents are predominantly under additive gene action while pod yield and oil content are controlled by dominance. Hence the breeding procedures aiming to improve confectionery qualities and pod yield in a population should accumulate favorable additive genes while simultaneously maintaining the heterozygosity. Population improvement procedures as followed in other self-pollinated crops may be difficult to apply in groundnut owing to the difficulties associated with cleistogamous inflorescence of groundnut. However use of recurrent selection scheme as followed in soybean (Brim and Burton, 1979) and other self-pollinated crops (Hanson *et al.*, 1967) may be adopted to improve the protein and sugar content.

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Stability analysis in large seeded groundnut, *Arachis hypogaea* L. genotypes for pod yield and its component traits

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Abstract

Evaluation of large seeded groundnut genotypes was carried out over the seasons to know the existence of genotype x environmental (G x E) interactions for pod yield and its important traits. Significant genotype x environmental interactions was noticed for pod yield and its important traits like number of pods, shelling percent, kernel weight and per cent sound mature kernels, indicating that genotypes behaved differently in different environments in expression of these traits. Both predictable and unpredictable component of environmental variations prevailed for pod yield and kernel weight. Stability analysis revealed that none of the genotypes were stable for pod yield or kernel yield while genotypes M 13, ICGV 86564, ICGV 94217, TGLPS 3 and TGLPS 7 were stable for kernel weight. Only one genotype ICGV 94217 was stable for shelling per cent across the environments. In view of the better expression of certain characters under specific environmental conditions the study helps to isolate genotypes adapted to particular seasons.

Key words: G x E interactions, stability analysis, large seeded groundnut

Introduction

Unlike groundnut cultivated for the purpose of oil extraction, there is a need to satisfy several quality attributes in large seeded groundnut (Dwivedi and Nigam, 1995) meant for export. This assumes importance in view of stringent conditions laid by the importers on large seeded groundnut especially European market. As cultivation of groundnut in India is predominantly during *kharif* season both biotic and abiotic stresses determine the pod yield and also expression of component traits like number of pods per plant, shelling per cent, kernel weight and per cent sound mature kernels. The information pertaining to the role of genotype x environmental interactions (G x E) in the inheritance of pod yield and its related traits although quite ample in groundnut, is almost negligible in large seeded types. In view of the importance of large seeded groundnut for export there is a need to identify genotypes having stable pod yield across the environments with desirable kernel characteristics. Therefore, an attempt has been made in the present study to evaluate different groundnut genotypes with large kernels across the seasons to know the role of G x E interactions and also to analyze the stability of genotypes for different traits.

Materials and methods

The experimental material consisted of 13 large seeded groundnut genotypes from different habit groups exhibiting diversity for morphological and kernel characteristics. Out of 13 genotypes, two varieties M 13 and HPS-II-9701 were Virginia runner maturing in 130-140 days; seven varieties *viz.*, Somanath, ICGV 86564, ICGV 94217, TKG 19 A, TGLPS 1, TGLPS 3 and BAU-13 were virginia bunch types maturing in 115-120 days and four spanish bunch types TGLPS 4, TGLPS 7, JI 24 and TAG-24 maturing in 100- 110 days. The latter two were small seeded types, and they were used as checks since the kernels of these varieties are graded and used for export in Northern Karnataka.

A field experiment involving all the genotypes was laid out in a Randomized Complete Block Design with three replications during three different seasons *viz.*, *kharif*, 1999, *kharif*, 2000 and summer 2001 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The experimental crop was raised by adopting a suitable spacing of 45 x 10 cm and normal dose of fertilizers during rainy seasons of 1999 and 2000. However the crop was raised under irrigation during summer 2001 by following all the agronomic practices including application of gypsum at the rate of 250 kg/ha. Pod yield was recorded on net plot basis and expressed as kg/ha. Further, the observations on shelling percent, sound mature kernels and 100-kernel weight were recorded from the bulk of individual plants in each genotype and replications.

Data collected was subjected to a two-way analysis of variance and the stability parameters were computed following the model proposed by Eberhart and Russell (1966).

Results and discussion

Analysis of variance (Table 1) for pod yield and its component traits revealed that the genotypes differed significantly for all the characters except shelling % indicating the presence of variability in the material. Similarly, environments in which the genotypes were grown were also differing significantly for all the characters except sound mature kernels. Variance due to G x E interactions was highly significant for all the characters indicating the differential response of genotypes in expression of the characters to varying environments. The existence of G x E interactions for pod yield and its important component traits has also been reported by several workers in groundnut (Wynne and Coffelt 1980, Kandaswami *et al.*,1986, Vindhiya Varman *et al.*,1989). Considering the stability of performance of genotypes for different characters across the environments, it was observed that the variance due to non linear component of environments (pooled deviations) was significant for pod yield indicating the role of unpredictable portion of environment influencing this trait. Similar results were also reported by Bhole *et al.*,1987,Vindhiya Varman *et al.*,1989 and Moinuddin *et al.*,1998.

Stability parameters like regression coefficients (b_i) and the deviations from the regression coefficients (S^2d_i) indicated that none of the genotypes were stable over the environments for pod yield except BAU 13 and ICGV 94217 as the deviations of these genotypes were non significant (Table 2). Expression of stability of genotypes for pod yield has also been reported by Yadava *et al.*, 1980, Kandaswami *et al.*,1986, Vindhiya Varman *et al.*,1989 and Moinuddin *et al.*,1998. However, five genotypes TGLPS 3 followed by TKG 19 A, TGLPS 4, TGLPS 7 and TGLPS 1 had below average stability and were specifically adapted to favourable environments (*kharif* 1999 and summer 2001) as they possessed high mean pod yield and b_i values greater than unity. The variety Somanath had high mean coupled with significant b_i as well as S^2d_i values indicating the unpredictable nature of this genotype across the environments. The checks JL 24, TAG 24 and M 13 were poorly adapted to unfavourable environments in view of b_i values less than the unity and low mean pod yield. Kernel yield being the function of pod yield and shelling percent was in line with the results of pod yield as regards to stability parameters.

Table 1 Pooled analysis of variance for stability in receipt of pod yield (kg/ha), kernel yield (kg/ha), number of pods/plant, shelling (%), 100-kernel weight and sound mature kernels

Source of variance	d.f.	Mean sum of squares					
		Pod yield (kg/ha)	Kernel yield (kg/ha)	No. of pods/plant	Shelling (%)	100 kernel weight (g)	Sound mature kernel (%)
Genotypes	12	1226917.3**	677522.3**	53.9**	17.750	204.699**	19.23**
Environment	2	19798656.0**	104273.1**	399.5**	70.77**	3193.268**	2.561
G x E	24	275746.6**	180544.6**	11.8**	9.98**	37.89**	6.69**
Environment (Linear)	1	39597266**	20854611**	798.9**	141.48**	6386.50**	5.10
G x E (Linear)	12	307763.7	2671585.6	10.0	12.30	23.36	8.28
Pooled deviation	13	224984.6**	1661495.4**	12.6**	7.08**	48.39**	4.71**
Pooled error	72	11496.5	2004.6	1.7	1.694	6.321	2.44

* and ** indicates significance at 5% and 1% probability levels, respectively.

Stability analysis of number of pods per plant revealed that the genotypes HPS II-9701 and TGLPS 3 were quite stable across the environments. The genotypes TGLPS 4, TGLPS 7 and Somanath were adapted to favourable environments (b_i>1, higher mean and significant deviations), while the genotypes ICGV 86564 and BAU 13 were specifically adapted to unfavourable environments. The results obtained are in accordance with the earlier reports of Kandaswami *et al.* (1986) and Moinuddin *et al.* (1998).

Table 2 Stability parameters of large seeded groundnut genotypes for pod yield (kg/ha), kernel yield (kg/ha), number of pods/plant, shelling (%), 100 kernel weight, sound mature kernels

Genotypes	Pod yield (kg/ha)			Kernel yield (kg/ha)			No. of pods/plant			Shelling (%)			100-kernel weight			Sound mature kernel		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
M 13	2301	0.90	676007**	1527	0.79	428036**	13.38	0.58	2.99	65.93	0.13	10.35*	57.78	1.03	-1.12	92.72	-0.99	1.67
ICGV 86564	1954	0.75	150581**	1311	0.68	54508**	18.06	1.29	21.2**	67.54	-0.50	-0.47	65.08	1.23	-1.44	93.49	-5.11	-0.56
JL 24	2359	0.59	196289**	1640	0.54	155592**	22.18	0.63	10.0**	69.42	-0.15	7.92	44.57	0.96	99.22**	92.09	4.48	17.34**
ICGV 94217	2084	0.77	2825	1420	0.77	-99	16.23	1.13	-0.1	67.33	0.97	-0.56	65.65	1.12	-1.61	93.53	-0.11	-0.63
TGLPS 1	3002	1.20	458810**	2142	1.33	273755**	22.73	0.64	14.8**	69.83	2.10	3.76	51.77	1.01	15.74	94.75	-2.78	0.51
TGLPS 3	3564	1.17	44440**	2461	1.21	-942	21.59	0.87	3.1	68.22	0.85	10.05*	59.19	1.10	21.65	95.71	-1.51	5.45
TGLPS 4	3229	1.23	107582**	2205	1.28	87685**	23.20	1.37	26.5**	67.17	1.46	6.65	62,62	1.31	39.64*	95.42	0.26	-0.81
TGLPS 7	3005	1.06	502878**	2079	1.09	324196**	24.28	1.10	18.6**	68.36	0.71	10.69*	58.07	0.94	0.85	94.88	-0.73	0.14
TKG 19A	*3361*	*1.40*	*429499***	*2282*	*1.40*	*171496***	*21.63*	*0.87*	*0.01*	*66.47*	*1.64*	*0.56*	56.49	0.87	48.06**	94.70	1.95	0.79
BAU 13	1762	0.75	5965	1109	0.67	-1324	18.10	0.87	38.9**	62.00	1.50	15.16**	63.17	1.22	319.90**	93.39	4.65	8.07
Somanath	3754	1.64*	152055**	2652	1.68*	60621**	30.22	1.91	20.5**	69.49	1.28	-0.54	54.32	0.98	26.10*	94.82	1.58	0.14
HPS II-9701	2550	0.60	40490**	1606	0.48	63106**	24.57	1.28	-0.4	63.01	-0.28	16.08**	47.14	0.72	8.25	91.17	-1.99	1.47

* and ** indicate significance at 5% and 1% probability levels, respectively.

Significant role of G x E interactions was evident for shelling per cent which is in conformity with the earlier reports of Mercer-Quarshie (1980), Norden *et al.* (1986) and Moinuddin *et al.* (1998). Shelling per cent in large seeded groundnut observed to be low when compared to normal groundnut with the exception of TGLPS lines and they were comparable to JL 24 check. The genotype ICGV 94217 was stable (b_i » 1, higher mean and significant deviations) for shelling with a mean of 67.4 per cent across the environments. The genotypes TGLPS 1, TKG 19A, TGLPS 4 and Somanath had higher shelling per cent exhibiting specific adaptation to only favourable environments and hence considered to have below average stability ($b_i > 1$). Whereas the genotypes JL 24 and ICGV 86564 possessed above average stability (b_i <1) and higher shelling per cent, hence, these were specifically adapted to unfavourable environments.

Among the different yield traits, kernel weight is the most important character for determining quality of HPS groundnut. The study revealed that seven out of 13 genotypes *viz.*, M 13, ICGV 86564, ICGV 94217, TGLPS 1, TGLPS 3, TGLPS 7 and HPS-II 9701 were stable in performance for kernel weight as seen from non-significant deviations and b_i values being nearer to unity. The genotypes M 13, ICGV 94217, TGLPS 1, TGLPS 3, TGLPS 7 revealed higher mean values, regression co-efficient equal to one and the least deviations from regressions. Therefore, these genotypes were almost stable in expression of kernel weight despite the varying environments and the results are in concomitant with the earlier reports of Kandaswami *et al.*,1986 and Vindhiya Varman *et al.*,1989. Non linear component of environment was highly significant for this trait indicating the unpredictable nature of the environment which is also in agreement with the earlier reports of Wynne and Coffelt (1980), Kumar *et al.* (1984) and Moinuddin *et al.* (1998). The check varieties TAG 24 and JL 24 were more of a unpredictable in nature on account of their significant deviations. Genotypes BAU 13 and TKG 19A were suitable for favourable environments in view of their high mean kernel weight. Further, genotype ICGV 86564 was specifically adapted to favourable environments exhibiting below average stability (i.e. $b_i > 1$) with superior overall mean (65.08) than the population mean. Whereas the genotype HPS -II- 9701 possessed lower kernel weight than the population mean with b_i lesser than unity thus considered to be having above average stability.

As regards to per cent sound mature kernels, all the genotypes except checks TAG 24 and JL 24 exhibited non significant deviations. Genotypes TKG 19 A, BAU 13 and Somanath exhibited below average stability (b_i >1) with specific adaptation to favourable environments. The lines TGLPS 1, TGLPS 3, TGLPS 4, TGLPS 7, ICGV 86564 and ICGV 94217 exhibited above average stability with specific adaptation to unfavourable environments.

In general, none of the genotypes were stable for pod yield across the environments (seasons). However, ICGV 94217 and BAU 13 were widely adapted to varying environments. The genotype TGLPS 4 was suited to favourable environments in view of better expression of pod yield, number of pods and shelling per cent. Among the yield traits kernel weight was less influenced by the environment and was the most stable trait in HPS groundnut. Therefore, the desired seed weight of HPS groundnut could be maintained both during kharif and summer by cultivating the genotypes ICGV 86564 followed by ICGV 94217 and TGLPS 3 due to their better stability.

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Response to selection for seed dormancy in groundnut, *Arachis hypogaea* L.

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Abstract

Dormancy being transient in nature and highly influenced by environment, studies on inheritance are inconclusive. Attempts towards dormant genotypes have met with limited success due to lack of simple selection methodology. In the present study among six selection schemes, selection in segregating generations at advanced generation was more effective than either early generation selection or continued selection. Continuous selection at all stages has resulted in elimination of potential segregants for pod yield combining dormancy. A simple strategy of breeding for dormancy could be crossing dormancy donors with adapted non-dormant cultivars, advancing segregating material either through bulk or single seed descent, evaluating single plant for dormancy at F_4 seed level and eventually testing for pod yield in replicated trials in later generations.

Key words: Groundnut, dormancy, response, selection, strategy

Introduction

Spanish bunch groundnut, *Arachis hypogaea* L. cultivars of subspecies *fastigiata* are popular because of early maturity, ease of harvesting, desirable pod features and suitability in multiple cropping under rainfed conditions. But they lack seed dormancy and hence suffer loss due to *in situ* germination when the matured crop is caught under rains. Virginia cultivars of subspecies *hypogaea* have dormancy but mature late. Dormancy being transient in nature and highly influenced by environment, studies on inheritancy are inconclusive. Many attempts were made for selecting dormant genotypes in available germplasm (Muhammed *et al.*, 1965), and material from intra- (Ramachandran *et al.*, 1967) and inter-sub-specific hybridization (Reddy *et al.*, 1985). But success was less because of lack of simple selection methodology. Present study envisages assessing the response to selection for dormancy and suggesting a breeding strategy to select dormant segregants in Spanish type groundnut.

Materials and methods

Material comprised of 24 populations derived from four crosses involving one ruling Spanish bunch cultivar (JL 24) and two Spanish dormant genotypes (Dh 8 and R 8972). Parents (JL 24, Dh 8 and R 8972) were studied along with populations for percent germination and pod yield per plant. The populations were advanced through different selection schemes *viz.*, no selection at any generation (NNN), selection at F_2 F_3 (DDN), at F_3 alone (NDN), at F_3 & F_4 (NDD), at F_4 alone (NND) and at all generations (DDD), under single seed descent method. 500 seeds were made into two halves, one half was tested for dormancy and other not for dormancy. The dormant seeds were treated with ethrel for advancing to next generation. The same procedure was followed in each generation.

Fifty seeds were sown in two rows of 2.5 m length in each of the selection schemes, 20 random plants were selected for analyzing seed dormancy and yield per plant both in selection schemes and parents. Based on the germination behaviour of the parents in the laboratory, the plants showing less than 50 % germination were considered as dormant (Table 1). Germination test was done at 7 days after harvesting by maintaining 10 % moisture in the seeds. Germination was assessed by drawing 25 random matured seeds from each plant. The seeds were rolled in 15 x 12 cm sized germination paper and stapled at both the ends. The rolls were covered with polythene sheet to ensure minimum loss of water through evaporation. These were then transferred to germination chamber and germination was recorded after five days. Dry weight of pods (g) was recorded on each plant and average weight per plant was computed for each population.

Results and discussion

In general, selection was effective for dormancy over non-selection (NNN), as indicated by higher percent of dormant plants lower germination. A single selection at advanced (F_4 seed level) generation (NND) was more effective than either

Table 1 Germination behaviour and frequency of dormant plants under different selection schemes

Selection scheme		JL 24 x Dh 8	Dh 8 x JL 24	JL 24 x R 8972	R 8972 x JL 24	Mean
DDD	(a)	61.5 ± 6.7 (30	45.5 ± 7.9 (55)	38.5 ± 8.5 (65)	23.5 ± 4.8 (85)	42.3 ± 7.0 (59)
	(b)	12.4 ± 0.4	13.5 ± 0.4	13.5 ± 0.4	13.6 ± 0.3	13.25 ± 0.4
DDN	(a)	55.5 ± 8.1 (50)	48.5 ± 6.6 (50)	31.0 ± 5.9 (55)	34.5 ± 7.3 (70)	42.4 ± 7.0 (56)
	(b)	17.6 ± 0.5	17.1 ± 0.6	15.8 ± 0.4	19.0 ± 0.4	17.4 ± 0.5
NDD	(a)	41.0 ± 6.3 (50)	25.5 ± 5.3 (80)	42.5 ± 7.9 (45)	22.0 ± 6.2 (70)	32.8 ± 6.4 (61)
	(b)	18.1 ± 0.5	17.8 ± 0.4	17.5 ± 0.3	18.8 ± 0.3	18.1 ± 0.4
NDN	(a)	42.5 ± 7.3 (60)	58.5 ± 6.5 (35)	42.5 ± 8.1 (45)	37.0 ± 6.0 (50)	45.1 ± 7.0 (48)
	(b)	18.9 ± 0.3	17.8 ± 0.3	18.1 ± 0.3	17.9 ± 0.4	18.2 ± 0.3
NND	(a)	36.5 ± 7.0 (60)	38.5 ± 5.6 (65)	33.5 ± 6.6 (60)	22.5 ± 5.2 (85)	32.8 ± 6.1 (68)
	(b)	18.8 ± 0.4	19.5 ± 0.5	17.0 ± 0.4	18.9 ± 0.5	18.6 ± 0.5
NNN	(a)	55.0 ± 5.5 (40)	68.5 ± 5.9 (20)	66.0 ± 6.5 (20)	65.0 ± 5.5 (25)	63.6 ± 5.9 (26)
	(b)	17.9 ± 0.3	17.6 ± 0.4	18.2 ± 0.3	17.3 ± 0.3	17.8 ± 0.3
Parents		**JL 24**	**Dh 8**	**R 8972**		
	(a)	88.0 ± 9.2	18.0 ± 9.2	2.0 ± 9.2		
	(b)	17.1 ± 1.8	15.0 ± 1.8	15.5 ± 1.8		

Where (a) Mean ± SE of germination %; (b) Mean ± SE of pod yield/plant
Figures in parenthesis indicate % dormant plants

early generation selection or continued selection (DDD, DDN and NDD), in all the crosses (Table 1). This could be due to fixation of alleles at later generations. Though correlation was non-significant between pod yield and germination (-0.294), the continuous selection (DDD) for dormancy has led to distinct reduction in pod yield (13.3g). This could be attributed to elimination of potential segregants for pod yield by early and continued selection for dormancy. In contrast, a single selection at F_4 did not affect pod yield (18.6 g) indicating its potential to give high yielding dormant lines. Further, except the selection schemes *in case of Dh 8 x JL 24, crosses involving* dormant genotypes as ovule parents, have shown better response to selection which could be due to maternal influence on the expression of dormancy (Ketring and Morgan, 1972). Based on heritability values, Khalfaoui (1991), suggested pedigree selection, which could be more cumbersome. Manoharan *et al.*, 1989, suggested selection at early stage followed by evaluation for dormancy at F_6/F_7 generation. However, this could lead to elimination of potential segregants for other characters as revealed in the present study. But, mass selection (seed level) for dormancy was more effective over plant selection in early generations (Hemanth, 1990), which could be due to independence of embryo genotype to the phenotype of the parent plant.

In the light of these discussions, a simple strategy of breeding for dormancy could be suggest. It could involve crossing dormancy donors with adapted non-dormant cultivars, advancing segregating material either through bulk or single seed descent method, evaluating single plants for dormancy at F_4 seed level and eventually testing for pod yield in replicated trials in later generations (Fig 1).

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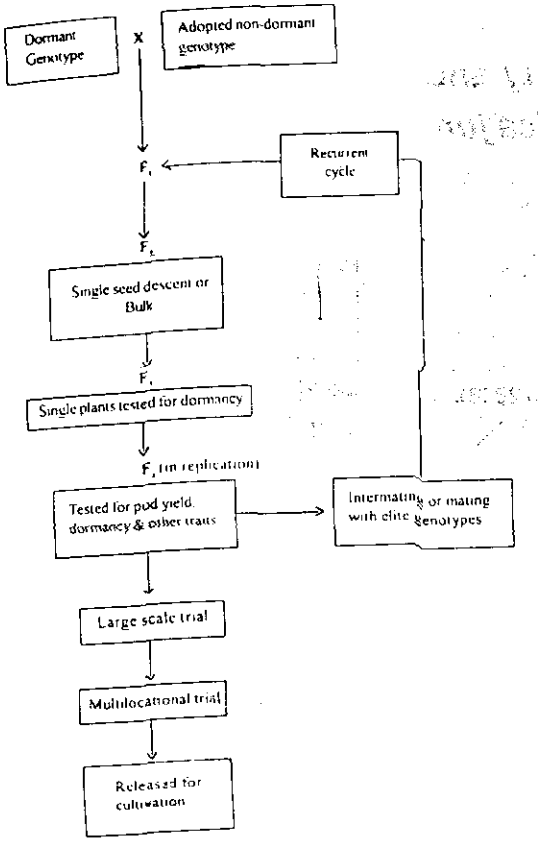

Fig-1 A strategy of selection for dormancy

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Comparative studies on combining ability and heterosis for yield and yield components in Indian mustard, *Brassica juncea* (L.) Czern & Coss. on normal and saline soils

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Abstract

The nature and magnitude of combining ability and heterosis were studied for yield and its components in Indian mustard, *Brassica juncea* (L.) Czern & Coss. following 8 x 8 diallel analysis on normal (ECe 1.8 ds/m) and saline (ECe 106 dS/m) soils. Significant differences for *gca* and *sca* components were observed for all the traits on normal soil, whereas on saline soil, differences were significant for days to flowering for *gca* and pods/plant for *sca* only. Among the parents, CS-52 showed significant positive gca on both soils for pods/plant, whereas on saline soil, SAL-3 showed significant positive *gca* for seed yield. The parent CS-52 was also a good general combiner for early flowering on normal soil. The crosses NDR-9501 x RH-30 and Kranti x NDR-9501 showed maximum significant *sca* effects for yield on normal soil whereas, the only cross CSTR 338-1 x CZM-2 was characterized with maximum significant *sca* for this trait on saline soil. The crosses CSTR 338-1 x CZM-2 (33.61 %) and CSTR 338-1 x SAL-2 (5.2 %) showed maximum heterotic effects for seed yield on saline soil. However, on normal soil Kranti x NDR 9501 (29.8 %) and NDR 9501 x RH-30 (23.2%) showed maximum heterotic effects for seed yield. There was no cross showing significant positive heterosis for seed yield on both soils.

Key words: Indian mustard, saline soil, combining ability, heterosis

Introduction

Brassicas commonly known as rapeseed-mustard are considered the most valuable oilseed group of crops grown world wide. In India, progress in rapeseed-mustard production has been amazing in Rajasthan state, contributing almost 38 % of total *Brassica* production. However, due to obvious reasons, salinity of irrigation water is posing serious threat for maintaining pleatue of its productivity in arid Rajasthan. Agrotechniques for *Brassica* improvement for saline situations (seed rate, increased fertilization and irrigation management, etc.) are available (Kumar, 1995), but, these are the energy intensive technologies, therefore, proving costlier and unpopular on the commercial scale. However, use of salt tolerant genotypes and exploitation of heterosis and the selection of parents on the basis of combining ability may prove possible steps in accelerating pace of genetic improvement of this crop on saline lands, which may prove more harmful in arid situations. Information on this aspect are scarce and scattered (Thakral and Singh, 1995; Sood *et al.*, 2000). Hence, present study on eight genetically divergent parents was undertaken for assessing the heterosis and combining ability on normal and saline soil situations.

Materials and methods

Eight genotypes of Indian mustard [*Brassica juncea* (L.) Czern & Coss.] *viz.*, CS-52, CSTR 338-1, CZM-2, Kranti, NDR-9501, RH-30, SAL-2 and SAL-3 representing salt tolerance and susceptible nature were crossed in all possible combinations excluding reciprocals. The 28 F_1s and their 8 parents were grown in normal (ECe 1.8 dS/m) and saline soil (ECe 10.6 dS/m) situations in a Split Plot Design with three replications at CAZRI experimental farm during *rabi* season of 1998-99. Each treatment had 3.5 m long single row, the spacings between and within lines being 30 and 10 cm, respectively. Five irrigations each of 6 cm including presowing with the saline water (ECe 6.5 dS/m) were applied during the cropping season. Observations were recorded on five randomly selected plants for five characters. The combining ability analysis was done following method II model I of Griffing (1956) and heterosis (%) was assessed as per usual method. Salt build up in 0-30 and 30-60 cm soil depths was assessed at sowing and at crop harvest.

Results and discussion

An examination of the magnitude of mean squares revealed significant differences for general and specific combining ability for all the traits on normal soil, whereas

on saline soil differences in respect of *gca* and *sca* were significant only for days to flowering and number of pods/plant, respectively (Table 1). The *gca* values were of greater magnitude than the corresponding *sca* values for days to flowering, days to maturity, pods/plant, and 1000-seed weight on both soils, indicating involvement of additive genetic variances for them on normal soil. The *sca* component was more for seed yield on saline soil. Thus, genetic variances appeared to differ for the traits with the soil conditions. This was probably due to differences in soil properties in respect of nutrient and water availability, therefore, affecting uptake behaviour of the plants at the critical growth stages hence, allowing significant interaction between morphological traits and the soil types, leading to differences in genetic variance.

The variance ratio was much higher than unity for number of pods/plant on normal soil and 1000-seed weight on saline soil, which signified the involvement of additive gene effects for their expression, on respective soils. Days to flowering also looked more or less to be influenced by additive genetic variance irrespective of the soil situations. These results fall in line with those of Asthana and Pandey (1977), Bhadouria *et al.* (1991) and Singh *et al.* (2001) in Indian mustard. The seed yield appeared to be influenced through non-additive variance across the soil types confirming earlier findings of Thakral and Singh (1995) on saline soils and Singh and Mittal (1993), Sood *et al.* (2000) and Rao and Gulati (2000) on normal soils in this crop.

General combining ability effects: The parents *viz.*, CS-52, CSTR 338-1, CZM-2 and RH-30 earliest to flower (42 days) also showed significant negative *gca* effects for days to flowering on normal soil, revealing therefore, possibility of using these parents for earliness on such soils. On saline soil, the parents CSTR 338-1, CZM-2 and Kranti had significant negative *gca* estimates. The latter two parents with early flowering (44-46 days) might therefore, represent source of early partitioning on problem soils (Table-2). Of eight parents, CS-52 on both normal and saline soils had significant positive *gca* effects for number of pods/plant. This parent also exhibited higher number of pods across the soils. On saline soil, the only parent SAL-3 had significant positive *gca* effects for seed yield thus, providing good combiner for high yield on poor soil. SAL-3 being a salt tolerant genotype, having higher *per se* yield on such soils is likely to be good general combiner of yield. A general view on *gca* effects revealed that there was no parent as a good general combiner for all the traits in both the soils. However, CS-52, a salt tolerant parent appeared as good combiner for earliness and number of pods/plant on both soils.

Specific combining ability effects: Out of 28 crosses, three *viz.*, CS-52 x CSTR-338-1, CS-52 x SAL-3 and CSTR-338-1 x NDR-9501 exhibited significant negative *sca* effects for days to flowering on normal soil, these crosses also showed early flowering (39-43 days) tendency. However, the only cross CSTR-338-1 x Kranti was found to have significant negative *sca* effects for early flowering on saline soil but its *per se* performance was not adequate as it took 47 days to flower, thus, its use on saline soil was doubtful. As far maturity is concerned, the cross conditions and took almost equal number of days to mature (105-106 days) across the soils.

In normal soil, the two crosses *viz.*, NDR-9501 x RH-30 and Kranti x NDR-9501 showed maximum significant positive *sca* effects for seed yield. Appreciably their *per se* performance for grain yield was also maximum (245 and 250 g, respectively) on normal soil. On the contrary, the cross (CSTR-338-1 x CZM-2) with higher *per se* performance and significant positive *sca* effects for seed yield was also notable for significant *sca* value for pods/plant on two types of soil situations. The cross combinations with significant *sca* effects for yield and yield components are expected to give a high heterotic response in respective soils.

Heterosis: Heterosis for early flowering ranged from -1.05 to -7.0 % in normal and from -1.07 to -7.22 % in saline soils. The crosses *viz.*, CSTR 338-1 x NDR 9501, CZM-2 x SAL-2 and CSTR 338-1 x SAL-3 depicted heterosis of almost similar magnitude for earliness on two types of soils. Thus, possibility of development of early flowering hybrids existed for both soil situations. The parents involved in the hybrid combinations exhibited marked variations in flowering behaviour in respect of two soil types i.e., either being early or late in flowering.

The heterotic values for early maturity were of lower magnitude irrespective of the soil conditions confirming earlier findings of Asthana and Pandey (1977) and Choudhary and Sharma (1982) in normal soil conditions. Lower heterotic values for maturity could be due to less variation in maturity behaviour of the parents and their F_1s over two types of soils. Thus, it looked difficult to get early maturity hybrids in this crop.

The cross combination RH-30 x SAL-3 (132.62 %) showed maximum heterosis for number of pods/plant on saline soil, whereas SAL-2 x SAL-3 (11.57 %) and NDR 9501 x SAL-2 (7.17 %) showed positive heterosis with comparatively less magnitude on these soils. RH-30 with less number of pods (385/plant) was ill adapted parent to problem soil. RH-30 x SAL-3 was however, characterized with maximum *sca* effects (368.6) on saline soil.

The crosses NDR 9501 x RH-30 (30.25 %) followed by CZM-2 x RH-30 (23 %), Kranti x NDR 9501 (16.12 %) on normal soil and NDR 9501 x SAL-2 (43.33 %) followed by Kranti x NDR 9501 (32.2 %), CSTR 338-1 x NDR 9501

(28.15 %), CSTR-338-1 x CSM-2 (23.52 %) maintained maximum significant heterosis for 1000 seed weight on saline soils. Thus, possibility of hybrids with bolder seeds existed on both soil situations.

Heterotic values for seed yield were of greater magnitude in respect of Kranti x NDR 9501 (29.8 %) and NDR 9501 x RH-30 (23.2 %) on normal soil, confirming earlier results of Gupta *et al.* (1993); Sood *et al.* (2000) and Singh *et al.* (2001) in Indian mustard in normal soil conditions. Heterotic values on saline soils were of lesser magnitude, therefore, restricting possibility of developing high yielding hybrids for saline soils barring the only cross, CSTR-338-1 x CZM-2 (33.61 %) which had maximum significant *sca* effects also. Mean performance of these parents differed considerably, wherein CSSTR 338-1 proved less adapted to saline situations. The parents SAL-2, SAL-3 and RH-30 with good adaptation to saline conditions gave poor heterotic effects.

Table 1 ANOVA for combining ability in F_1s for phenological, yield and yield components in Indian mustard on normal (N) and saline (S) soils

Source of variation	D.f.	Days to 1st flowering		Days to maturity		Pods/plant		1000-seed weight		Seed yield	
		N	S	N	S	N	S	N	S	N	S
gca	7	40.6**	70.4**	6.5**	2.0	54735**	22407.7	0.31**	0.25	1370.8**	657
sca	28	6.5**	12.3	2.5**	1.7	25836**	21107.3*	0.23**	0.20	1009.8**	772
Error	35	1.9	14.4	1.5	1.2	15138	11320.9	0.11	0.18	545.9	455
$\sigma^2G/2\sigma^2$ σ^2S	-	0.92	0.91	0.83	0.69	2.99	0.67	0.72	1.40	0.73	0.06

Table 2 *gca* effects for phenological, yield and yield components on normal (N) and saline (S) soils

Parents	Days to 1st flowering		Days to maturity		No. of pods/plant		1000-seed weight		Seed yield	
	N	S	N	S	N	S	N	S	N	S
CS-52	-0.84*	-0.20	-0.95*	-0.49	94.25*	66.85*	0.08	0.14	-7.14	5.72
CSTR-338-1	-1.79**	-2.02*	-0.85*	-0.19	-64.96	-70.40*	-0.29**	-0.08	7.11	-8.02
CZM-2	-1.59**	-2.15*	-0.15	-0.44	-140.04	-62.35	-0.03	-0.14	-18.80**	-1.52
Kranti	-0.64	-2.35*	-0.45	0.46	24.74	16.50	0.14	-0.12	6.86	-6.53
NDR-9501	-0.39	0.35	-0.10	0.21	54.40	11.95	0.02	-0.04	6.36	0.73
RH-30	-0.94*	0.45	0.50	-0.49	-20.65	2.75	-0.03	-0.15	6.96	3.22
SAL-2	3.96	5.90**	0.50	0.56	15.66	43.30	-0.16	0.26*	-14.14*	-8.77
SAL-3	2.21	0.00	1.50*	0.36	36.65	-8.60	0.29**	0.15	12.16	15.18*
SE (gi) ±	0.41	1.00	0.36	0.31	36.30	31.4	0.10	0.10	6.90	6.30
SE (-gi-gj) ±	0.62	1.65	0.54	0.48	55.55	47.16	0.10	0.10	10.44	9.53

*P=0.05; ** P=0.01

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Development and characterization of low erucic acid/low glucosinolate lines in Indian mustard, *Brassica juncea* (L.) Czern & Coss

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Abstract

Swarna [TERI (OE) M 21] (INGR 98001), a yellow seeded strain of *Brassica juncea* [L.] Czern. & Coss. was utilized as a source of low erucic acid (< 2%) and BJ 1058 was used as a low glucosinolate source to transfer the trait(s) to the high yielding varieties of Indian mustard, Varuna and Rajat. The selection for low erucic acid in F_2 generation brought forth enormous variation in different fatty acid profiles in subsequent generations, especially, oleic, linoleic and linolenic + eicosenoic acid. The oleic acid varied from 34.0- 50.3 %. Nevertheless, there were several plants possessing 55% oleic acid. Selected lines, except a few had comparable oil content with the parents, Varuna (39.2%) and TERI (OE) M 21 (38.4%). In general, the lines had higher 1000-seed weight and oil content in F_5 generation than in F_4 generation. The pattern of correlations for fatty acids was variable in F_2, F_3 and F_4 generations except for oleic acid which showed consistent relationship with linoleic and linolenic + eicosenoic acid in different generations. Parent -offspring regression revealed variable heritability estimates for different fatty acids, which declined from F_2 to F_3 generation. Six F_5 progenies having less than 40 μ moles glucosinolate content were characterized for days to maturity, plant height. 1000-seed weight, oil and protein content. Efforts are underway to combine low erucic and low glucosinolate traits to develop double low lines.

Key words: Indian mustard, erucic acid, *glucosinolate content*, *B. juncea*, heritability, correlations

Introduction

Mustard oil is the major edible oil in the Indian diet, especially in northwest and eastern parts. Except for the presence of high erucic acid (about 50 %), mustard oil is nutritionally better than other edible oils such as groundnut, sunflower and soybean as it contains low amount of saturated fatty acids and substantial amount of α-linolenic acid, which is an essential fatty acid. Large in take of oil with high erucic acid has been reported to be associated with myocardial fibrosis and lipidosis from studies on rats and monkeys (Gopalan *et al.*, 1974; Renard and Mc Gregor, 1976).Presence of glucosinolates in the seed meal restricts its diversified use as feed for poultry and piggery otherwise seed meal being high protein feed. Moreover, Indian seed meal fetches low price in international market as compared to that of United Kingdom and Germany. Further, yellow seeded varieties have higher oil, protein content and lower crude fibers than brown seeded varieties of the same species (Woods 1980). The Indian mustard breeding programme has been oriented to develop low erucic acid (<2%) and / or low glucosinolate (<30 μ moles/ g defatted seed meal) mustard cultivars in mid 80's. The present paper describes our attempts to improve oil and meal quality in Indian mustard.

Materials and methods

Low erucic acid: Swarna [TERI (OE) M 21] (INGR 98001), a yellow seeded strain of Indian mustard (*Brassica iuncea* [L.] Czern. & Coss.) was utilized as a source of low erucic acid (< 2%) to transfer the trait to the high yielding varieties, Varuna and Rajat. During 1996-97, F_1 crosses of Swarna were made with Varuna and Rajat and the advanced breeding lines were developed (Fig. 1). The single selfed plants were analyzed for different fatty acid profiles using gas liquid chromatography as described earlier (Chauhan *et al.*, 2001). The DEGS column was used in the GLC which does not separate linolenic and eicosenoic acid profiles. The peaks get merged to a single peak. During the crop season of 1999-2000 and 2000-2001, the F_4 and F_5 low erucic progenies were characterized for maturity, plant height. 1000-seed weight, oil content, seed yield/plant. Range, mean, coefficients of variability and correlations for different fatty acids were computed in different segregating generations following Gomez and Gomez (1984). Parent-offspring regression (Lush, 1940) analysis was used to estimate heritability in narrow-sense for different fatty acids.

Low glucosinolate: The only available source of low glucosinolate content, BJ 1058 was hybridized with Rajat to transfer alleles for low glucosinolate. Three hundred sixty five selfed F_2 plants of the cross BJ 1058 x Rajat were analyzed for glucosinolate content by TES TAPE method. The plants were grouped into four categories, *viz.*, + (low), ++ (medium), +++ (medium -high) and ++++ (high). The F_3 progenies of the plants showing +/++ reaction were generation advanced (Fig. 1). The F_5 and F_6 lines having less than 40 μ moles glucosinolate/g of defatted seed meal were characterized during 2000-2001 crop season for agro-morphological traits.

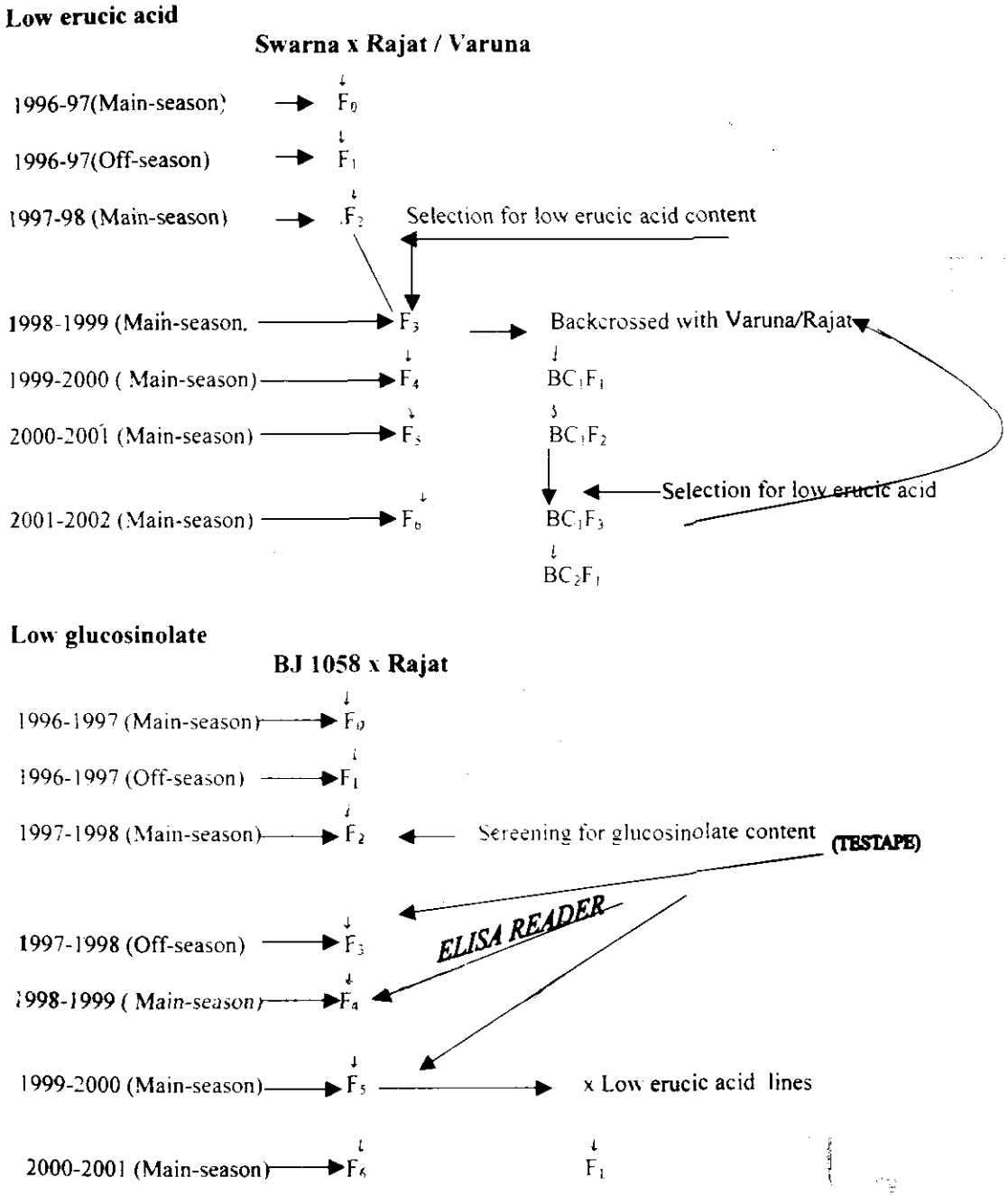

Fig. 1 Development of low erucic acid/low glucosinolate lines of Indian mustard

Results and discussion

Erucic acid content of TERI (OE) M 21 ranged from 0 to 6.1 % with mean value of 1.6 %. Similarly, erucic acid varied between 41.5 - 50.2 and 44.0 - 52.2 % in Varuna and Rajat, respectively. The F_1 of both the crosses TERI (OE) M 21 x Varuna and TERI (OE) M 21 x Rajat, showed intermediate level of erucic acid, being 33.2 % in the cross TERI (OE) M 21 x Varuna and 28.6% in the cross TERI (OE) M 21 x Rajat. The erucic acid content of the F_2 segregants ranged from 0 to 49.6%. Only 5 and 3.5% of the F_2 segregants had less than 2% erucic acid in the crosses TERI (OE) M 21 x Rajat and TERI (OE) M 21 x Varuna, respectively. Selection for low erucic acid practiced in F_2/F_3 generation brought forth significant variation in different fatty acid profiles, especially, oleic, linoleic and linolenic + eicosenoic acid (Table 1). Selection in F_3 generation was done for high oleic acid, oil content and 1000-seed weight.

The oleic acid varied from 24.6 - 50.3 % among the F_4 progenies. Nevertheless, there were several plants possessing about 55.0 % oleic acid. The mean saturated fatty acids were around 4% in F_3 and F_4 generations. Mean of fatty acids were marginally higher (2-3 %) in F_4 than F_3 generation. Several promising high oleic acid lines were identified and characterized for agro morphological characters (Table 2). Many low erucic acid lines, had comparable oil content with the parents, Varuna and TERI (OE) M 21. Nevertheless, these lines had low 1000-seed weight as compared to Varuna. In general, the lines had higher 1000-seed weight and oil content in F_5 generation than in F_4 generation. Similarly, in the cross. TERI(OE)M 21x Rajat, two PS lines had higher oleic acid than the low erucic parent, TERI (OE) M 21. In the back cross progenies, of both the crosses, oleic acid varied from 21.3 - 43.9 %. The F_5 progenies were intermitted to broaden the genetic base and recombine yield attributes. The selected low erucic acid BC_1 plants were further backcrossed.

Heritability: To predict the efficiency of selection in segregating generations it is imperative to know heritability, especially heritability in narrow-sense. Three methods of parent-offspring (F_2 vs F_3, F_2 vs F_4 and F_3 vs F_4) regression were used to estimate heritability to know the precise estimate as well as environment influence. Since, the F_2 and other two generations (F_3 and F_4) were grown in different years, the estimates could be biased. But F_3 and F_4 generations were grown simultaneously and hence the effects of environment were largely common to both the generations. Thus the heritability estimates based on F_3 vs F_4 regression may be more realistic. The heritability estimates varied widely. Palmitic acid showed high heritability in F_2 generation, which declined in advance generations (Table 3). The heritability estimates for stearic and linoleic acid were relatively consistent. Hence, selection in early generation for this trait could be effective. Oleic acid showed low heritability as estimated by F_2 vs F_3 and F_2 vs F_4 regression, but the estimate was relatively high (0.17) based on F_3 vs F_4 regression, thereby suggesting that selection for high oleic acid should be based on progeny performance in advance generations rather than single plant performance in early segregating generation. The linolenic + eicoseonic acids showed high heritability estimates, in general, which ranged between 0.40-0.80 suggesting the usefulness of single plant selection in F_2 segregating generation. Variable estimate of heritability could due to genotype, environment or their interaction (G x E).

Correlations: Pattern of correlations of fatty acids in different segregating generations was analyzed to predict the simultaneous selection for desirable combination of fatty acids. In the F_2 generation, erucic acid content was negatively and significantly correlated with palmitic (r= 0.411**), stearic (r= - 0.282**), oleic (r= - 0.839**), linoleic (r= -0.691**) and linolenic + o eicosenoic (r= -0.301**) acid. The pattern of correlation was variable in F_2, F_3 and F_4 generations except for oleic acid content which showed consistently negative relationship with linoleic and linolenic + eicosenoic acid content in F_3 and F_4 generations and positive relationship in F_2 generation (Table 4). Palmitic acid was positively correlated with stearic, oleic and linoleic acid in F_2 generation but this association was positive only with oleic acid in F_4 progenies (r=0.231**). Palmitic acid in F_2, F_3 and F_4 progenies were negatively and significantly correlated with linolenic + eicosenoic acid (Table 4). Stearic acid had negative and significant association with linolenic + eicosnoic acids in F_3 and F_4 progenies.

The relationship of palmitic acid with oleic acid was positive and significant only in F_2 and F_4 generation whereas stearic acid had similar association with oleic acid in F_2 and F_3 generation. Palmitic and stearic acid showed variable association with linoleic acid in F_3 and F_4 generation.

It seems that precursor of eicosenoic acid is oleic acid and same extra amount which was desaturated in biosynthetic pathway resulted in increased levels of linoleic and linolenic acids. Oleic acid increased with concomitant decrease in both linolenic and eicosenoic acids in zero erucic acid lines, hence estimation of linolenic + eicosenoic acid together will not affect the correlations. The negative correlation of erucic acid with oleic and linoleic acids is of paramount significance to develop varieties with low erucic acid and high contents of oleic and linoleic acids. The variable relationship between

fatty acids in different segregating generations could be the consequence of recombination of gene(s) controlling the inheritance of fatty acid profiles.

Glucosinolate content: Of the 365 selfed F_2 plants of the cross BJ 1058 x Rajat, only 98 plants showed ++ reaction and the remaining had either +++ or ++++. BJ 1058 also showed variable reaction + or ++. The number of plants with less than 50 μ moles increased with the generation advancement (Table 5). The selection was made for the lowest amount of glucosinolate content within and between families. Six plants having less than 40 μ moles glucosinolate content were characterized for days to maturity, plant height, 1000-seed weight, oil and protein contents (Table 6). These progenies had lower oil content and 1000-seed weight as compared to high yielding variety, Rajat. Hence, there is a need to improve the agronomic base of these lines.

Table 1 Range, mean and coefficient of variability (CV) for fatty acid profiles in F_2 (226 plants), F_3 (205 lines) and F_4 (199 lines) generation of the cross TERI (OE) M 21 x Varuna

Fatty acid	Range (%)			Mean ± SEm			CV (%)		
	F_2	F_3	F_4	F_2	F_3	F_4	F_2	F_3	F_4
Palmitic	1.3 - 5.6	2.1 - 5.3	1.3 - 6.5	3.2 ± 0.04	3.6 ± 0.04	3.3 ± 0.10	20.0	10.8	25.1
Stearic	T* - 2.7	T* - 2.7	T* - 2.6	0.5 ± 0.04	1.3 ± 0.06	0.3 ± 0.10	122.0	57.1	220.0
Oleic	8.5 - 53.6	33.6 - 53.7	24.6 - 50.3	22.0 ± 0.50	44.0 ± 0.28	39.3 ± 0.30	33.0	9.1	10.3
Linoleic	18.0 - 49.3	29.4 - 57.5	30.2 - 52.7	28.2 ± 0.34	38.1 ± 0.29	40.5 ± 0.30	18.0	10.6	9.2
Linolenic + Eicosenoic	11.2 - 39.3	0.9 - 21.3	3.8 - 25.9	20.7 ± 0.30	12.9 ± 0.15	16.4 ± 0.22	20.0	16.1	19.1
Erucic	0 - 49.6	0	0	25.4 ± 0.8	0	0	46.0		

*T : Traces

Table 2 Characteristics of some promising low erucic lines (F4) with high oleic acid, moderate seed weight, oil content and seed yield derived from the cross TERI (OE) M 21 x Varuna

Progeny	Seed colour	Oleic acid (%)	Maturity (days)		1000-seed weight (g)		Seed yield/plant (g)		Oil content (%)	
		F_4	F_4	F_5	F_4	F_5	F_4	F_5	F_4	F_5
166-50-1	Brown	48.7	133	128	4.5	4.7	11.3	13.5	35.9	37.2
91-6-6	Yellow	48.8	133	128	3.3	3.7	21.5	18.6	38.0	37.9
166-35-1	Brown	47.7	133	132	3.6	4.2	7.5	15.0	34.4	34.0
166-26-4	Brown	47.6	131	130	2.5	3.9	19.6	12.4	33.4	35.6
205-10-5	Brown	46.6	131	134	3.6	3.9	14.8	17.3	38.2	38.3
205-11-3	Brown	46.6	135	135	3.6	3.9	7.0	17.4	38.7	40.1
166-27-1	Brown	45.8	132	130	3.6	3.9	28.6	11.0	36.0	35.2
91-8-2	Yellow	43.8	134	128	2.6	2.9	14.0	12.3	39.1	39.9
91-32-3	Yellow	41.6	133	125	4.9	3.8	12.7	11.7	40.2	38.1
91-50-5	Yellow	45.7	136	130	2.6	3.5	17.6	26.5	38.3	39.6
91-22-1	Yellow	42.8	134	131	3.5	3.5	13.4	14.3	38.8	39.3
91-60-1	Yellow	43.5	134	125	3.2	3.9	14.5	14.5	36.3	38.7
91-61-3	Yellow	46.3	134	131	3.5	4.2	8.2	14.5	38.8	38.1
Varuna	Brown	9.3	140	134	5.7	6.2	15.2	31.5	39.8	39.2
TERI (OE) M 21	Yellow	43.5	126	127	2.9	3.6	12.5	15.2	38.2	38.4

Table 3 Heritability (narrow sense) estimates of different fatty acids in F_2 and F_3 generations of low erucic acid lines in the cross TERI (OE) M 21 x Varuna

Fatty acid	Regression		
	F_2 vs F_3 Heritability	F_2 vs F_4 Heritability	F_3 vs F_4 Heritability
Palmitic acid	0.56	0.36	0.02
Stearic acid	0.31	0.23	0.14
Oleic acid	0.03	0.05	0.17
Linoleic acid	0.09	0.18	0.11
Linolenic + Eiocosenoic acid	0.80	0.69	0.40

Table 4 Correlation coefficients (r) between different fatty acid profiles in F_2, F_3 and F_4 generations of the cross TERI (OE) M 21 x Varuna

Fatty acid	Generation	Stearic acid	Oleic acid	Linoleic acid	Linolenic + eicosenoic
Palmitic acid	F_2	0.249**	0.269**	0.518**	-0.122**
	F_3	-0.047	-0.084	0.096	-0.192**
	F_4	-0.178*	0.0231**	-0.193*	-0.336**
Stearic acid	F_2		0.298**	0.150**	-0.088
	F_3		0.608**	-0.686**	-0.150**
	F_4		-0.102	-0.129	-0.146*
Oleic acid	F_2			0.300**	-0.073
	F_3			-0.851**	-0.398**
	F_4			-0.706**	-0.573**
Linoleic acid	F_2				-0.015
	F_3				-0.087
	F_4				-0.074

*, ** significant at P=0.05 and 0.01, respectively.

Table 5 Frequency distribution for glucosinolate content (micro moles / g defatted seed meal) in the segregating generation of the cross BJ 1058 x Rajat

Range	Generation					
	F_3 (N=450)	F_4 (N=420)	F_5 (N=861)	F_6 (N=13)	BJ 1058 (N=54)	Rajat (N=39)
30-40	-	-	5	1	-	-
40-50	17	19	47	11	12	-
51-60	51	41	148	-	8	-
61-70	87	58	36	-	14	-
71-80	35	109	88	-	-	-
81-90	22	99	171	-	5	3
91-100	107	54	152	1	8	14
101-110	30	19	115	-	7	15
111-120	32	16	59	-	-	4
121-130	38	3	28	-	-	3
131-140	17	2	9	-	-	-
141-150	9	-	3	-	-	-
151-160	3	-	-	-	-	-
161-170	2	-	-	-	-	-

Table 6 Characteristics of low glucosinolate lines (F_5) derived from the cross BJ 1058 x Rajat

Strain	Glucosinolate content*	No. of plants	Maturity (days)	Plant height (cm)	Seed weight (g)	Oil content (%)	Protein content (%)
BPR 47-92-6-50	37.0-38.8	2	142	178	2.7	33.4	23.8
BPR 47-92-6-8	40.0	2	139	152	3.0	36.1	22.1
BPR 47-92-6-45	40.0	1	141	145	2.6	36.5	22.1
BPR 47-324-2-143	40.0	1	137	171	3.0	36.6	22.2
BJ 1058	33.0-40.0	8	132-139	150	2.9	38.0	21.4
Rajat	115.3	5	134	172	5.4	38.8	20.6

*micro moles / g defatted seed meal.

Future strategies:

- There is an imperative need for refining analytical techniques for fatty acid and glucosinolate content estimation to facilitate rapid and mass screening in early segregating generations.
- Intermating among selected low erucic/ low glucosinolate lines and back crossing with high yielding recurrent parent to broaden genetic base and improve yield potential.
- Further, hybridization between low erucic acid lines with low glucosinolate lines to combine double low trait.
- Utilization of double haploid technique tor early fixation of double low trait to hasten breeding efficiency.

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Modified triple test cross in sunflower, *Helianthus annuus* L.

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Abstract

Two genetically divergent CMS lines DCMS-5 and CMS 7-1A and eight proven restorer lines viz., RHA265, RHA271, RHA298, RHA341, RHA344, RHA345, RHA346 and DRS1 of sunflower, *Helianthus annuus* L. were crossed in a modified Triple Test Cross fashion. The resulting 16 hybrids were evaluated to study the components of genetic variance governing yield and its component traits. The additive component was significant for all the traits except days to maturity and plant height. The dominance component was significant for all the traits except plant height while the epistasis component was significant for all the characters studied. The three types of gene action were playing a significant role in the Sunflower population used in the study.

Key words: Triple test cross, sunflower, epistasis

Introduction

Genetic control of quantitative traits is the pre-requisite for designing an efficient breeding programme. However for yield is a complex phenomenon and breeder has to thoroughly understand the gene action controlling the component traits. Various biometrical designs are in vogue to understand the gene action controlling different traits. Most of the designs assume absence of the epistasis, which in reality is an important integral part of genetic variance. One of the best designs for detection of epistasis is triple test cross (Kearsey and Jinks, 1968). Though this design is efficient, however it requires four populations P_1, P_2, F_1 and F_2, hence it is a tedious and time consuming process. So, Jinks *et al.*, (1969) proposed a modification for this model in which a set of lines are crossed to two extreme testers. This design is simpler, instead of F_2 population a set of inbred lines (P_i) are crossed to two testers (L_1 and L_2) of opposite extreme to generate $\bar{L}_{1i}$ and $\bar{L}_{2i}$ families. Thus it requires only tester parents, inbreds and F_1s. In the present investigation an attempt was made to assess the genetic components of variance *viz.*, additive, dominance and epistasis in Sunflower using the modified triple test

Materials and methods

Eight inbred lines of sunflower with proven restoring ability and two testers (CMS lines) were crossed to generate 16 F_1 hybrids during *kharif*, 2001. The two testers DCMS-5 and CMS 7-1A even though belonged to single male sterile source (Petiolaris), they differed morphologically to a great extent for majority of the characters confirming that they contain several uncommon genes for the traits under study. The 16 F_1 hybrids along with their parents and four standard checks were evaluated during *rabi*, 2001 in a Randomized Block Design replicated twice. Each entry was sown in a single row of 3 m length with a spacing of 60 x 30 cm. Observations were made on five competitive plants per treatment in each replication on days to first flowering, days to 50 % flowering, days to maturity, plant height, stem diameter, head diameter, number of filled and unfilled seeds per head, seed filling %, 100 seed weight, seed yield per plant and oil content. The data were subjected to modified triple test cross analysis (Jinks *et al.*, 1969).

Results and discussion

To test the epistatic gene action, which is an integral part of genetic architecture, modified triple test cross (T.T.C) model was adopted using two extreme testers, which differed morphologically for several characters. The results so obtained (Table 1) gave the realistic information on additive, dominance and epistasis components of genetic variance without any inflation or deflation.

For testing variance due to epistasis instead of $\bar{L}_{3i}$ mean that is used in normal T.T.C, mean of a set of inbreds used (P_i) was taken in to consideration. The results revealed that variance due to epistasis ($\bar{L}_{1i} + \bar{L}_{2i} - P_i$) was significant for all the nine characters studied indicating the predominant role of epistasis in the genetic variance.

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Table 1 Detection of additive, dominance and epistatic components of variation in sunflower using modified T.T.C model over extreme testers NODL 2 and CMS 7-1A

Source	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No. of filled seeds	100 seed weight (g)	Seed yield/plant (g)	Oil content (%)
Mean										
DCMS-5		57	88	90.9	1.22	7	427	2.22	9.45	37.06
CMS 7-1A		72	96	115	0.94	18	254.5	2.92	7.5	29.56
Additive										
Replications	1	0.6	0.76	190.4	0.02	0.2	14.1	0.1	0.5	0.2
Sums, $L_{1i} + L_{2i}$ (additive)	7	63.56**	12.7	211.3	0.062**	15.40**	35519.56**	4.53**	193.31**	57.20**
Sums x Blocks (Error)	7	1.70	4.56	167.8	0.008	2.01	212.06	0.052	1.04	1.015
Dominance										
Replications	1	1.56	1.00	0.81	0.066**	0.051	3.06	0.03	0.03	0.62
Differences, $L_{1i} + L_{2i}$ (dominance)	7	9.70**	7.53**	360.11	0.62**	32.96**	22239.84**	4.08**	263.42**	77.32**
Differences x Blocks (Error)	7	2.41	1.42	100.83	0.002	0.88	144.49	0.08	3.38	1.23
Epistasis										
Replications	1	0.00	2.25	3.5	0.01	0.425	4.92	0.05	1.45	0.0043
Sums, $L_{1i} + L_{2i} - P_i$	7	80.28**	25.67**	182.98**	0.20**	12.36**	76600.88**	4.73**	329.69**	77.82**
Sums x Blocks (Error)	7	1.87	2.23	3.5	0.0057	1.81	73.6	0.04	1.29	0.72

Note: L_1 and L_2 in the ANOVA represent the two testers employed, whereas P_i represents inbred lines
*, ** = Significant at 5% and 1% level, respectively.

The variance due to sums ($L_{1i} + L_{2i}$) was significant for all the traits except days to maturity and plant height. This revealed that additive component of genetic variance (D) was significant for all the traits excluding days to maturity and plant height.

The analysis of variance due to differences ($L_{1i} - L_{2i}$) measuring the dominance component (H) was significant for eight out of nine traits leaving plant height.

The degree of dominance ($\sqrt{H/D}$) was also significant (more than unity) for all the traits except days to maturity and plant height. This indicates that over dominance was the cause of high level of expression of these traits while characters days to maturity and plant height were governed by partial or incomplete dominance. Gupta and Khanna (1982) and Gangappa *et al.* (1997) reported presence of all the three types of gene action from generation mean analysis. Singh *et al.* (1987) studied three sets of T.T.C. and indicated that epistasis was integral part of genetic variation in sunflower. Satyanarayana *et al.* (2001) reported the significance of epistasis in sunflower.

Therefore it may be concluded that all the three components of genetic variance i.e. additive, dominance and epistasis were playing significant role in controlling the traits so the breeding programme to be followed should not only exploit fixable gene effects but also ponder the non-additive gene effects for further improvement of base population and broadening the genetic base.

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Genotype x Environment interaction and stability analysis for oil content in American cotton, *Gossypium hirsutum* L.*

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Abstract

Fifty five genotypes of American cotton (*Gossypium hirsutum* L.) comprising of 10 parents and their 45 hybrids produced in a diallel fashion (without reciprocals) were evaluated for stability for oil control in four different environments. Both linear and non-linear components of Genotype x Environment interaction were important for oil content. The study of stability parameters revealed that NDLH 1678 x CWROK 165 and L 604 x NDLH 1678 and MCU 5 x NA 1325 were found stable over environments for oil control with high mean seed cotton yield.

Key words: Stability, cotton, G x E interaction

Introduction

The seed oil content (on dry weight basis) in Indian cultivars of *Hirsutum* cotton ranged from 20.9 to 27.6 % (Dani, 1984). Cotton seed oil is one of the rich source of edible oils in our country. In order to meet the growing demand for edible oils, it can be considered as one of the substitute to overcome their shortage. The consistency in performance over environments is essential to develop a stable variety or hybrid. The present studies were carried out to identify a cotton variety/hybrid which can perform consistently better over wide range of environmental conditions.

Materials and methods

The experimental material consisted of 45 F_1's obtained by crossing 10 diverse parents *viz.*, MCU 5, BN 1, L 389, NA 1325, AC 738, L 604, NDLH 1678, ARB 8824, CWROK 165 and ICMF 82 obtained from different cotton research stations produced in a diallel fashion (excluding reciprocals). Above material was grown in a Randomized Block Design with 3 replications in 4 environments during 1999-2000 at Regional Agricultural Research Station, Lam (Table 2). Recommended package of practices for the region were followed. Each genotype was grown in a 2 row plot of 6 m length adopting a spacing of 120 cm between rows and 60 cm within a row. Five competitive plants were randomly selected for recording data on oil percentage and seed cotton yield/plant(g). Seed oil content was analyzed by non-destructive Nuclear Magnetic Resonance Technique with New Port Analyser. The data were analyzed for stability as per Eberhart and Russell (1966).

Results and discussion

The pooled analysis of variance revealed that the mean squares due to genotypes were significant for oil content indicating the wider genetic diversity (Table 1). Mean squares due to environments (linear) were significant, indicating that the environments tested are different. The G x E interaction was also significant indicating the differential response of the genotypes to the environmental conditions. Genotype x Environment interaction for oil content was earlier reported by Dani (1989 a, b).The partitioning of the G x E interactions indicated that both linear and non-linear components of variance were important for seed oil content, indicating the importance of regression coefficient (bi) and deviation from regression (S^2di) for assessing the stability of the genotypes for oil content.

A perusal of mean performance for oil control indicated that, in general the hybrids had higher oil content compared to the parents in different individual environments and also in pooled over environments (Table 2). Seed oil control in parents ranged from 20.28 to 22.9% with a mean oil content of 21.5%, while in hybrids it ranged from 20.44 to 24.1% with a mean of 22.4% over environments. Similar results were earlier reported by Dani (1989a). In normal sowing conditions, the oil content was more in rainfed conditions (E_2) compared to the crop raised under irrigated conditions.

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Similar trend was observed both in parents and hybrids. While such differences between the samples of irrigated and rainfed crop when grown under delayed sowing conditions i.e. E_3 and E_4 were not observed. However, on an average there was reduction in the oil content by about 2 to 2.5% under delayed sowing conditions, indicating the influence of rainfall distribution pattern on oil control in cotton seed.

Three stability parameters *viz.*, the grand mean over the environments, the regression coefficient and squared deviation from the regression were considered to be important for stability of a genotype (Table 3). A genotype is considered stable in performance if it has high mean performance, unit regression coefficient (bi=1) and least deviation from regression (S^2di).

The crosses, MCU 5 x NA 1325 and L 389 x NDLH 1678 with high mean, recorded average response and predictable performance for oil control and hence these are considered as stable genotypes over environments. The cross NA 1325 x L 604 with high mean for oil content and above average response showed predictable performance under favourable environments. The crosses NDLH 1678 x CWROK 165 and L 604 x NDLH 1678 recorded high mean for seed cotton yield per plant also recorded mean above general mean, above average response and predictable performance for oil content. Among the parents, AC 738 exhibited high mean performance (22.93), average response (1.03) but its performance was unpredictable as it recorded significant S^2di (1.06**).

In the present investigation, among the high yielding hybrids MCU 5 x NA 1325 and L 389 x NDLH 1678 showed stable performance for oil content. The crosses NDLH 1678 x CWROK 165 and L 604 x NDLH 1678 which recorded high mean for seed cotton yield/ plant also recorded mean above general mean, above average response and predictable performance for oil content. In conclusion, the hybrids NDLH 1678 x CWROK 165 and L 604 x NDLH 1678 and MCU 5 x NA 1325 with high mean seed cotton yield and stable performance for oil content deserved further confirmatory tests over wide range of environments for exploitation as hybrids besides using for further exploitation in the segregating generations, as high oil content in the seed hybrids can be considered as value addition.

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Table 1 Analysis of variance for oil content and seed cotton yield

Source of Variation	d.f	Oil content (%)	Seed Cotton Yield/Plant(g)
Genotypes(G)	54	3.11**	1839.61**
G x E	162	1.33**	147.05**
Environment (linear)	1	538.62**	84505.51**
G x E (linear)	54	1.13**	263.27**
Pooled Deviation	110	1.41**	87.33**
Pooled error	432	0.73	30.97
Linear component	-	44.49	75.09
Non-linear component	-	55.51	24.91

*,** Significant at 5% and 1% level of probability, respectively

Table 2 Mean performance of parent and Hybrids for oil content (%)

Parents/Hybrids	E_1	E_2	E_3	E_4	Pooled
Parents	22.50	23.20	20.24	20.05	21.50
Hybrids	23.33	24.61	20.89	20.88	22.42
Average	23.18	24.35	20.77	20.73	22.25

E_1 = Normal saving - irrigated; E_2 = Normal sowing - rainfed; E_3 = Delayed sowing - irrigated and E_4 = Delayed sowing - rainfed

Table 3 Stability Parameters for Oil content and yield of cotton

S. No.	Parents/Crosses	Oil content (%)			Seed Cotton Yield (g/plant)		
		x	bi	S^2di	x	bi	S^2di
1	MCU 5	21.76	1.10	2.25**	110.50	0.85	-30.68
2	BN 1	20.28	0.80	1.18**	73.00	0.61	-13.32
3	L 389	20.97	0.87	-0.57	101.33	0.66	-28.42
4	NA 1325	22.42	0.72	-0.01	121.00	1.15	1.94
5	AC 738	22.93	1.03	1.06**	92.58	0.71	-29.10
6	L 604	20.46	1.19	-0.55	104.25	0.89	-19.22
7	NALH 1678	21.67	1.20	0.38**	123.58	1.32	-23.37
8	ARB 8824	21.40	0.67	0.34**	102.25	0.93	-27.06
9	CWROK 165	22.49	0.67	0.70**	120.67	0.93	-25.06
10	ICMF 82	20.64	0.51	-0.59	94.92	0.86	-7.99
11	MCU 5 x BN 1	22.07	1.14	-0.72	97.17	0.91	1.01
12	MCU 5 x L 389	22.74	0.98	-0.63	115.50	0.78	-7.66
13	MCU 5 x NA 1325	24.12	1.05	0.02	152.92	1.69	43.83**
14	MCU 5 x AC 738	21.56	1.76	-0.63	101.67	1.12	3.72
15	MCU 5 x L 604	22.80	1.26	1.36**	104.33	0.77	-25.68
16	MCU 5 x NDLH 1678	23.38	1.34	-0.35	121.08	0.90	-18.41
17	MCU 5 x ARB 8824	22.32	0.87	2.20**	104.17	0.59	-26.72
18	MCU 5 x CWROK 165	23.13	1.02	1.41**	145.50	1.75	6.16
19	MCU 5 x ICMF 82	20.65	1.51	-0.37	94.42	0.23	-19.48
20	BN 1 x L 389	21.92	1.66	1.66**	102.08	0.82	-2.92
21	BN 1 x NA 1325	22.75	1.01	-0.53	132.08	1.58	64.05**
22	BN 1 x AC 738	21.64	1.21	-0.44	119.50	1.33	-27.26
23	BN 1 x L 604	21.90	1.07	0.62**	113.25	1.24	486.04**
24	BN 1 x NDLH 1678	22.21	1.13	0.95**	136.25	1.58	-4.97
25	BN 1 x ARB 8824	22.95	1.40	-0.51	118.50	1.71	256.86**
26	BN 1 x CWROK 165	21.09	0.72	1.60**	143.08	1.17	17.74**
27	BN 1 x ICMF 82	22.29	0.66	-0.60	98.83	0.73	44.34**
28	L 389 x NA 1325	23.66	0.43	1.43**	147.25	1.35	17.59**
29	L 389 x AC 738	21.73	1.01	-0.26	82.67	0.06	-20.27
30	L 389 x L 604	22.23	1.28	2.87**	112.75	0.98	-29.68
31	L 389 x NDLH 1678	23.78	1.02	-0.56	142.17	1.53	158.04**
32	L 389 x ARB 8824	22.22	0.91	0.28*	89.42	0.18	-29.41
33	L 389 x CWROK 165	22.85	1.77	0.84**	117.92	0.99	-11.52
34	L 389 x ICMF 82	20.44	0.85	6.37**	78.08	0.64	107.18**
35	NA 1325 x AC 738	21.98	1.07	0.65**	122.50	1.30	11.79**
36	NA 1325 x L 604	23.98	1.12	-0.29	141.25	1.04	853.32**
37	NA 1325 x NDLH 1678	23.11	0.62	3.04**	148.67	1.46	399.2**
38	NA 1325 x ARB 8824	22.95	0.90	0.22	139.58	1.08	-16.25
39	NA 1325 x CWROK 165	22.72	0.75	2.39**	143.08	1.53	436.73**
40	NA 1325 x ICMF 82	21.86	0.41	0.09	104.17	0.90	-30.14
41	AC 738 x L 604	21.76	1.08	0.52**	91.50	0.72	49.62**
42	NA 738 x NDLH 1678	22.87	1.08	-0.23	117.42	1.00	-20.90
43	AC 738 x ARB 8824	22.21	0.55	5.97**	97.08	0.90	-10.40
44	AC 738 x CWROK 165	22.04	0.54	0.10	118.17	0.88	456.22**
45	AC 738 x ICMF 82	21.67	0.63	2.97**	72.25	0.45	70.83**
46	L 604 x NDLH 1678	22.60	1.53	-0.43	153.58	1.39	211.67**
47	L 604 x ARB 8824	23.83	0.91	0.50**	132.08	1.05	46.85**
48	L 604 x CWROK 165	22.16	1.31	0.96**	124.50	0.83	-11.68
49	L 604 x ICMF 82	22.72	1.12	0.30**	105.83	0.62	18.55**
50	NDLH 1678 x ARB 8824	22.60	1.04	0.06	140.25	1.32	55.82**
51	NDLH 1678 x CWROK 165	22.47	1.35	-0.35	162.42	2.16	18.51**
52	NDLH 1678 x ICMF 82	22.29	0.44	0.60**	103.92	0.55	65.09**
53	ARB 8824 x CWROK 165	22.30	1.16	-0.51	129.17	0.80	26.12**
54	ARB 8824 x ICMF 82	22.33	0.30	-0.59	106.08	0.46	-22.65
55	CWROK 165 x ICMF 82	22.44	1.29	0.38**	129.25	1.03	-12.53
	General mean	22.26	0.99		116.41		
	SEm ±	0.68	0.38		5.55		

*,** Significant at 5% and 1% level of probability, respectively

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Eco-physiology of yield expression in groundnut, *Arachis hypogaea* L. genotypes during post-monsoon season

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Abstract

A Field experiment was conducted on medium deep Vertisol for two years at Marathwada Agricultural University farm at Parbhani to study eco-physiological responses of elite groundnut cultures to identify optimum planting window and genotypes adopted to post monsoon (*rabi*) season. Crops sown on 15th Sept. recorded significantly highest pod yield. The subsequent delay in sowing at 15 days interval significantly reduced the pod yield. TAG-24 and ICGS-11 were comparable in yield and both proved significantly superior to rest of the cultures in the post monsoon season. For 15th and 30th October sowing TAG-24 should be preferred.

Key words: Eco-physiology, genotypes, sowing dates, post-monsoon, adaptability

Introduction

Groundnut (*Arachis hypogaea*. L) is an important oilseed crop in India and accounts for 45% of the area and 55% of the total oilseeds production in the country. However, average productivity is very low (0.8 to 1.0 t/ha) compared to China and USA (3.0 t/ha).

The productivity of rainfed groundnut is unpredictable due to large variation in rainfall leading to drought or water logging, temperature, radiation and high incidence of pests and diseases. The productivity of summer groundnut is doubled than rainfed crop. However the crop demands large water requirements, often suffer from high temperature and also faces excessive vegetative growth and other problems associated with soil and water management. Most of the groundnut in Maharashtra is grown in black soil.

Opportunities exist for gain in productivity of groundnut based on crop's phenology and agroclimatological conditions prevailed during post monsoon season in Maharashtra. There is greater opportunity for matching the phonological developments of groundnut to desired temperature and photo periods in post-monsoon season (Sept.-Feb.) so as to minimize the coincidence of critical phases of growth with periods of environmental stress there by enhancing groundnut yield through eco-physiological approach.

Materials and methods

A field experiment was conducted on medium black Vertisol at Marathwada Agricultural University, Parbhani during 1996-97 and 1997-98 post-mansoon season. The Soil was clayey in texture with slightly alkaline in reaction. It was medium in available nitrogen and phosphorus and rich in potash with moderate available water holding capacity. A Split Plot Design was used with three replications. Four sowing dates (15th Sept., 30th Sept., 15th Oct. and 30th Oct.) constituted main plots and six genotypes (ICGS-11, ICGS-44, LGN-2, SB-XI, JL-24, and TAG-24)were subplots. The net plot size was 5.4 x 3.0 m. A uniform basal dose of 25 kg nitrogen and 60 kg P_2O_5/ha was applied. Seeds were treated with Bavistin @ 2.5 g/kg seed and sown on broad ridge and furrow with two lines on ridge at 30 x 10 cm inter and intra raw spacing. The crop was irrigated 5-6 times, each receiving 0.75 IW/CPE water.

Results and discussion

Yield and Yield attributes: Dry pod yield of groundnut was influenced significantly by sowing dates, genotypes as well as sowing dates (environment x genotypes interactions during both years.

Effect of sowing dates: Dry pod yield of groundnut was affected significantly by dates of sowing (Table 1). Early sowing on 15th September gave significantly higher dry pod yield than late sowing in both the years and in pooled analysis. The increase in dry pod yield of groundnut sown on 15th Sept. over sowing on 30th Sept. 15th Oct. and 30th Oct. was 25.7 %, 60.60 % and 69.5 %, respectively. The differences in the dry pod yield of groundnut sown in post-monsoon season at different sowing dates was also noticed by many research workers (Shelke *et al.*, 1987; Ghadekar, 1989; Padole *et al.*, 1994; Lodh, 1994; Bhoje, 1996) which is due to increase in the yield attributing

character like highest number of pods, shelling percentage and test weight.

The pod yield is a complex character which depends upon the expression of yield attributing character. The increase in pod yield of groundnut sown on 15th Sept. compared to later sowings was the result of increase in number of total and two seed pods/plant, shelling percentage and 100 seed weight. This may be attributed to crops exposure to favourable temperature regime during vegetative and reproductive stages, when sown on 15th and 30th September (Fig.1) which corroborates the results of Emery *et al.* (1981) and Bell (1986).

Table 1 Effect of sowing dates and genotypes on pod yield and yield attributes of groundnut

Treatment	Pod yield (kg/ha)			Yield attributes							
				Pods/plant				Shelling (%)		100 kernel weight (g)	
	1996-97	1997-98	Pooled	Two kernel pods		Total pods					
Sowing dates (D)				1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
15th September	2815	1078	1976	19	9	26	13	71.1	65.3	45.0	36.6
30th September	2293	601	1446	17	8	27	11	69.1	60.0	41.9	29.9
15th October	1132	400	766	9	4	15	7	66.1	58.4	37.2	25.3
30th October	614	571	593	5	8	8	11	62.7	62.9	32.9	41.6
SEm±	39	55	32	1.11	0.17	1.56	0.30	0.2	0.45	0.38	0.32
CD (P=0.05)	107	151	99	3.09	0.49	4.34	0.84	0.42	1.25	1.06	0.90
Genotype (V)											
ICGS-11	2140	743	1441	12	7	20	11	67.5	61.9	41.0	34.0
ICGS-44	1733	804	1269	12	7	19	11	68.6	63.5	43.2	35.4
LGN-2	1341	701	1019	13	7	19	10	67.1	65.6	38.4	34.9
SB-XI	1309	498	903	14	7	19	10	6.0	61.3	35.1	29.1
JL-24	1224	603	914	10	7	15	10	66.5	59.5	38.0	35.1
TAG-24	2534	628	1581	15	7	22	11	67.9	61.4	39.7	31.5
SEm±	34	47	30	0.68	0.28	0.93	0.34	0.39	0.39	0.53	0.45
CD (P=0.05)	94	130	84	1.89	NS	2.58	NS	1.09	1.08	1.47	1.25
Interaction (D x V)											
SEm±	77	94	61	1.37	0.57	1.86	0.69	0.78	0.79	1.06	0.90
CD (P=0.05)	214	260	168	NS	1.59	5.16	1.92	NS	2.16	2.94	2.50

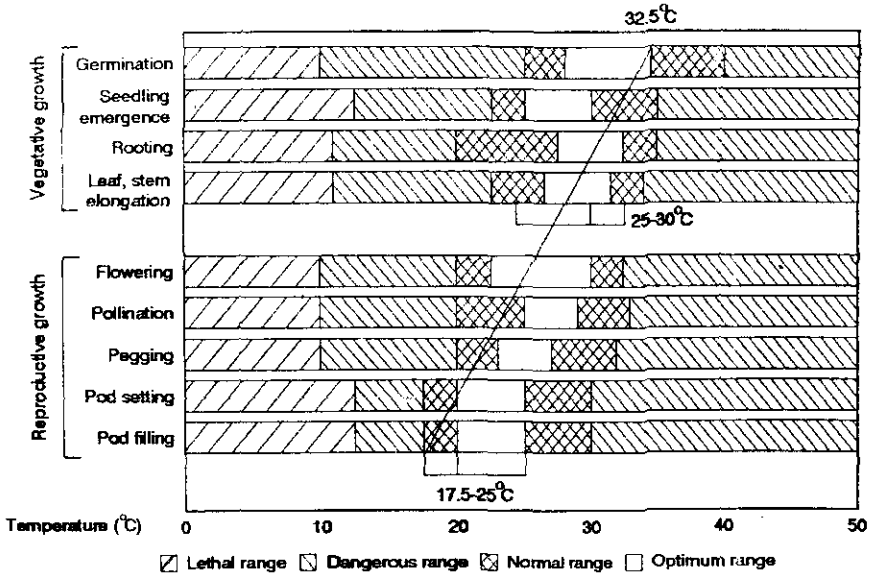

Fig 1 Critical temperatures of developmental processes in groundnut (Based on Ketring, 1986 and Ong, 1983b)

Table 2 Mean dry pod yield (kg/ha) as influenced by sowing dates x genotypes interaction at harvest

D/V	ICGS-11	ICGS-44	LGN-2	SB-XI	JL-24	TAG-24
			1996-97			
15th Sept.	3471	2686	2487	2634	2490	3300
30th Sept.	3539	2457	1484	1233	1605	3442
15th Oct.	1128	1409	784	760	582	2126
30th Oct.	423	580	610	587	220	1264
SEm±	77					
CD (P=0.05)	214					
			1997-98			
15th Sept.	1097	1360	1201	928	814	1067
30th Sept.	658	772	511	390	488	789
15th Oct.	598	495	394	280	388	248
30th Oct.	618	590	698	394	720	407
SEm±	94					
CD (P=0.05)	260					
			Pooled			
15th Sept.	2284	1924	1844	1791	1651	2184
30th Sept.	2099	1615	991	812	1047	2116
15th Oct.	863	952	589	520	485	1188
30th Oct.	519	585	654	491	470	837
SEm±	61					
CD (P=0.05)	168					

D/v = Dates/genotypes

Effect of genotypes: The pod yield of groundnut was markedly influenced by genotypes tested during both the seasons of experimentation. Genotype TAG-24 and ICGS-11 produced significantly highest pod yields during both the years and in pooled analysis. JL-24 and SB-XI produced lowest yield during first and second year, respectively. Similarly results were obtained by Lodh (1994) and Bhoje (1996).

Interaction effects: The interaction effect between genotypes and sowing dates was noticed during 1996-97 and 1997-98 (Table 2). The highest dry pod yield of 3539 kg/ha was recorded in 15th Sept. sown crop by ICGS-11. Pooled results revealed that ICAS-11 and TAG-24 were adopted to the second fortnight of Sept. [37-39 Meteorological weeks] (MW). Beneficial effects of early sowing of groundnut in *rabi* season (Sept.-Oct.) were also reported by other workers (Shelke *et al.*, 1987; Lodh, 1994; Bhoje, 1996).

In view of the above, it could be inferred that the optimal planting window (sowing time) of groundnut during post-monsoon season (Sept. to Feb.) is around 15th Sept. (37-38 MW). Erect spanish bunch genotype, TAG-24, and semi spreading genotype ICGS-11 are suitable for post-monsoon cultivation as both showed wider adaptability for second fortnight of September (37-38 MW).

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Groundnut, *Arachis hypogaea* L. growth and yield as influenced by evapotranspiration deficits

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Abstract

A field study was conducted during 1997-98 and 1998-99 on a sandy loam soil to study the response of groundnut to evapotranspiration deficits imposed at specific crop growth sub periods .The crop in fully irrigated control recorded maximum seed yield (2830 Kg/ha). The evapotranspiration deficits in all the crop growth sub periods significantly reduced the seed yield relative to the yield in fully irrigated control. The pod yield reduction in moisture stress at flowering and pegging, moisture stress at pod initiation and addition period, moisture stress at pod filling period was 20.6, 19.3 and 16.4 %, respectively as compared to control. Moisture stress at pod initiation and addition period was more sensitive to ET deficits than the other crop growth stages. However, the susceptibility of crop to ET deficits at flowering-pegging period, pod initiation addition period and pod filling period has found to be greatly reduced if the crop is conditioned by prior ET deficits.

Key words: Sunflower, groundnut, evapotranspiration deficit and pod/seed yield

Introduction

Irrigation planning is commonly predicted on complete avoidance of water deficits during crop growing season. In years of deficient water supply the irrigated acreage is therefore, reduced so that the evapotranspiration requirements of a crop can be met in full. An increase in the frequency of droughts, declining ground water table levels, increased cost of irrigation water resource development and indiscriminate use of fertilizers necessitate the need to shift out objective from producing maximum yield /unit area to maximum yield /unit amount of water (or) nutrients. The extent to which the crop yield can be maximized /unit amount of water (or) nutrient depends on how well field irrigation schedules are planned in time and quantity, considering periods of water scarcity to meet crop evapotranspiration requirements. Sunflower during *kharif* followed by groundnut is the most remunerative sequence (Reddy and Babu,1996) in the southern Telangana zone of Andhra Pradesh. Groundnut crop raised during winter season is often subjected to ET deficits during crop growing season leading to heavy yield expression. The present study was therefore, designated to find out the critical crop growth sub periods of groundnut as to their order of relative sensitivity to evapotranspiration deficits and to suggest optimal irrigation programmed to minimize yield losses under scarce water supply situation.

Materials and methods

The field experiment was conducted on a sandy loam soil during *kharif* and *rabi* seasons of 1997-98 and 1998-99 at the college farm of Acharya N G Ranga Agricultural University, Hyderabad (17 °.19' N, 78 °23' E and 542.3 m above mean sea level). The experimental soil had N,P and K_2O at 255,11.2 and 472 Kg/ha respectively, with PH 7.5, bulk density 1.66g/cm^3 and EC 0.12 dS/m. The available soil moisture determined as difference between moisture held at -0.03 Mpa and -1.5 Mpa was 84.4mm in 60 cm soil profile. The weekly mean maximum and minimum temperatures during *rabi*-groundnut cropping period was 29.87°C and 16.08° C. The seasonal growing degree-days amounted to 1642 and 1657 during 97-98 and 98-99 respectively The mean pan evaporation during the cropping period was 3.46 mm / day. The mean relative humidity was 65.79 %. The total precipitation was 154.7 and 29.0 mm during first and second years respectively. Since the rainfall occurred during the establishment -vegetative stage, the effective rainfall was deducted from the net irrigation requirement, while scheduling irrigations in different treatments.

The treatments included were four phosphorus levels i.e. 0, 30, 60 and 90 kg P_2O_5/ha to sunflower during *kharif*, combination of residual P (0,30,60 and 90 kg P_2O_5/ha applied to sunflower) and irrigation (I_1, I_2, I_3 and I_4) levels as main plots and four direct P levels (0,30,60 and 90 kg

P_2O_5/ha) as sub plots to groundnut during *rabi* season. The source of phosphorus applied was single super phosphate. The irrigation treatments comprised of fully irrigated control (I_1) moisture stress at flowering and pegging (I_2), moisture stress at pod initiation and addition (I_3) and moisture stress at pod filling period (I_4). Thus constituted sixty-four treatments in groundnut were tested in Split Plot Design with three replications during the *rabi* season.

Perusal of irrigation treatments revealed that in I_1 treatment the groundnut crop was fully irrigated based on soil - crop - climatic data, so that Eta is proceeded at maximum rate or it was not irrigated (Eta deficit) at all, as is the case in I_2 (Eta deficit at flowering and pegging period), I_3 (Eta deficit at pod initiation and pod addition period) I_4 (Eta deficit at pod filling period) treatments. In later treatments *viz.*, I_2, I_3 and I_4 if irrigated, the irrigation schedule that followed for the crop in fully irrigated control treatment (I_1) was duplicated and Etm for the following irrigation interval was assumed. If unirrigated, the Eta rate may have fallen below the Etm rate and the absolute difference for the period was expressed as an Eta deficit (Etd). Irrigation requirement of groundnut in I_1 treatment was based on soil-climatic parameters. The details of field water supply are given in Table 2. A 50 mm water meter was installed to deliver the required quantity of water in each plot. The gross and net plot size was 3.6 x 3.6 m and 3.0 x 3.2 m, respectively.

ICGS-11 groundnut test variety was sown on 20.10.1997 and 2.11.1998 in the first and second years, respectively by adopting a spacing of 30 x 10 cm to achieve a desired plant population of 3.33 lakh plants/ha. Other recommended agronomic practices *viz.*, a fertilizer dose of 40 N + 40 K_2O/ha and need based plant protection measures were followed. The ground water table was below six meters during the crop growth season. Hence, it was assumed that there was not any contribution from ground water table towards crop water needs.

For determination of crop Eta, the soil moisture was monitored by gravimetric method at four locations and at various depths in each treatment from surface to 60 cm soil depth before and after each irrigation and no intermediate dates as necessary (Table 1). The reference crop evapotranspiration (Eta) was estimated at specific crop growth subperiods based on Hargreaves method (Hargreaves and Samani, 1982). The crop was harvested on 11.02.1998 and 3.3.1999 in the first and second year, respectively. The water use efficiency (kg/ha - mm) was calculated as a ratio between seed yield and seasonal evapotranslation. To quantify the effect of Eta deficits on yield, the relationship between relative yield reduction and relative evapotranspiration deficit was worked out by regression analysis as suggested by Stewart *et al.* (1977):

$$(Ym-Ya)/Ym=Bo\ (Eta-Eta/Etm)$$

Where:

Ym=maximum yield in fully irrigated crop i.e., I

Ya=Actual seed yield of the crop as affected by Eta deficits

Etm=Seasonal evapotranspiration of fully irrigated crop

Bo=Yield reduction coefficient

Results and discussion

Yield as influenced by Eta deficits: Scheduling of irrigations at Eta=Etm through out the crop growing season (I_1) recorded the maximum pod yield (2830 kg/ha) which was significantly superior over other treatments (Table 3). Moisture stress at any one stage of the crop growth sub-periods reduced the pod yield I_2 (20 %), I_3 (19 %) and I_4 (16%) relative to fully irrigated control. The differences in pod yield between I_2 and I_3 were statistically not significant during both the years. Lowest pod yield was registered by I_2 treatment in both the years and on pooled basis. This could be attributed to a favourable soil water balance in I_1 treatment as was evident from mean Kc values (Eta/Eto ratio, nearer to 1.0 at flowering and pod initiation and addition period in both the years of study) an indicator of soil water deficit.

Adequate soil moisture balance in I_1, promoted the plants to produce significantly more plant height, which in turn put-forth more leaf area contributing to more drymatter (Table 3).

Boote and Hammond (1981) reported that stem morphology was altered by water deficits. Main axis and cotyledonary branches are shorter for water stressed groundnut plants because soil water deficit has been shown to cause drastic reduction in internodal length and rate of node development. Leaf area showed positive and significant (P=0.01) dependence on plant height (r=0.890). LAI accounted for 73.5% of variability in crop Eta on pooled basis.

Dry matter accumulation in groundnut is a result of leaf and stem growth during vegetative phase and a combination of pod and kernel growth concurrent with shifts in leaf and stem mass during reproductive phase. Therefore, reduced dry matter production in I_2 ,I_3 and I_4 treatments could be traced to similar reduction in plant height and leaf area index under these treatments. Dependence of dry matter on plant height (r=0.874),LAI (r=0.815) was apparent from significant correlation it had with these growth traits (Table 4).

Table 1 Determination of irrigation requirement of groundnut (1997-98 and 1998-99) in I_1 treatment based on soil-crop-climate parameters

Crop growth subperiod	Duration (days)	Eto mm/day	Kc	Etm mm/day	Root zone depth (cm)	Sa.D (cm)	P fraction	I=Sa.D.P/Etm	IRR
Vegetative	31	3.02	0.75	2.27	45	63.3	0.70	20	43.92
Flowering and pegging	26	2.78	1.03	2.84	60	84.4	0.59	18	43.98
Pod initiation and addition	29	3.46	1.03	3.58	60	84.4	0.59	14	49.76
Pod filling and maturity	33	4.61	0.80	3.68	60	84.4	0.625	15	53.28

Sa.D = Available soil moisture in the root zone
Etm = Maximum evapotranspiration
I = Irrigation interval
Eto = Reference crop evapotranspiration
P = Readily available soil moisture
Kc = Crop coefficient; IRR = Irrigation water depth

Table 2 Field water supply at various crop growth sub-periods

Treat-ment	Irrigation water supply-crop growth subperiods								Seasonal IRR (mm)		AWP mm		Effective rainfall (mm)		Field water supply (mm)	
	Vegetative		Flowering and pegging		Pod initiation and pod addition		Pod filling									
	98	99	98	99	98	99	98	99	98	99	98	99	98	99	98	99
I_1	0	36.5	49.8	100.3	105.7	102.4	52.8	107.5	208.3	346.8	84.4	84.4	67.4	9	360	440
I_2	0	58.2	0	0	129.2	173.8	52.8	107.5	182.0	339.6	84.4	84.4	81.6	9	348	423
I_3	0	36.5	49.8	100.3	0	0	137.2	191.9	186.9	328.7	84.4	84.4	67.4	9	338	422
I_4	0	36.5	49.8	100.3	105.7	102.4	0	0	155.4	239.3	84.4	84.4	67.4	9	307	333

Table 3 Yield, water use efficiency and seasonal Eta of groundnut as influenced by evapotranspiration deficits

Treatment	Pod yield (kg/ha)			Water use efficiency (kg/ha-mm)		Eta (mm seasonal)	
	1998	1999	Pooled	1998	1999	1998	1999
I_1	2757	2903	2830	8.18	7.83	338.4	370.8
I_2	2186	2309	2247	7.33	7.16	298.5	323.4
I_3	2223	2344	2283	7.54	7.28	295.1	322.9
I_4	2304	2427	2365	7.74	7.43	298.2	327.7
SEm±	18	27	21	0.12	0.14	-	-
CD (P=0.05)	55	80	62	0.35	0.42	-	-

Table 4 Growth and yield attributes of groundnut as influenced by evapotranspiration deficits at the time of harvest

Treatment	Plant height (cm)		Leaf area index		Drymatter (g/plant)		Average pods/plant		Average No. of matured pods/plant		100-kernel weight (g)		Shelling (%)		Harvest index	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
I_1	23	23	5.0	4.8	27.5	27.3	12.5	12.8	11.1	11.0	41.8	43.1	62.1	62.4	41.7	43.8
I_2	21	20	4.6	4.3	26.7	25.4	11.2	11.3	9.1	9.3	39.2	40.4	59.8	59.9	33.7	35.7
I_3	21	18	4.5	4.1	26.1	25.6	10.8	10.0	8.4	8.6	38.0	39.2	58.6	58.8	34.6	36.6
I_4	21	21	4.9	4.4	25.4	25.5	11.3	11.5	9.3	10.3	36.9	38.2	57.3	56.9	35.1	37.4
SEm±	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.3
CD (P=0.05)	0.5	0.3	0.2	0.4	0.4	0.3	0.2	0.3	0.3	0.2	0.4	0.3	0.2	0.2	1.5	0.9

Thus accumulated photosynthates might have been responsible for significantly more number of pods per plant under I_1 treatment in comparison to other treatments. The number of pods per plant (r=0.875) and matured pods per plant (r=0.903) were found to be significantly and positively correlated to leaf area index. Further these trends may be assigned to the fact that irrigation water application at high frequency (Eta/Etm=1) during flowering, pegging and pod addition period seem to have provided favorable soil water balance in the top 4-5 cm soil layer for peg penetration and pod initiation. The higher 100-kernel weight was associated with I_1 treatment where in the crop was fully irrigated during pod filling period. Like wise I_2 (moisture stress at flowering and pegging period) and I_3 (moisture stress at pod initiation and addition period) treatments also registered superior 100 kernel weight over I_4.These results emphasized the importance of adequate water supply starting from flowering period in general and at pod filling period in particular for obtaining more number of pods with higher mean weight in turn contributing to higher kernel weight. However, improved kernel weight in treatments where water deficits were imposed during flowering and pegging period (I_2) and pod initiation and addition period (I_3) in comparison to (I_4) pod filling period treatment could be possibly through the mechanism of limited sink capacity i.e pods/plant (Reddy *et al.*, 1996).

The dependence of pod yield on number of pods per plant (r=0.845) mature pods per plant (r=0.901) and 100-kernel weight (r=0.811) was evident from significant (P=0.05) and positive association between them. The unfavourable soil moisture condition brought about significant reduction in yield contributing characters like number of pods per plant, matured pods/plant 100 kernel weight, shelling percentage and harvest index through reduction in photosynthetically active leaf area drymatter accumulation.

The greater sensitivity of flowering and pegging through pod addition period to Eta deficits could be partly related to the fact that the crop reaches its peak Eta rate (3.34 mm/day on mean basis) and LAI during this period. Therefore Eta deficit during this period reduced the final pod yield in one of the several possible ways. First, low soil moisture or water deficits during flowering and pegging period in I_2 treatment might have reduced turgour potential and leaf area expansion as evident from low LAI affecting the flowering. This effect could be an important impediment to pegging, pod initiation and addition as apparent from significantly lower number of pods per plant in I_3 treatment. Secondly, soil water status in the top centimeter or two of the soil is critical for peg entrance into the soil. Once pegs are in the soil, adequate soil moisture is needed for development of pegs into pods and that adequate water in the root zone could not compensate for lack of water in pegging zone for the first 30 days of peg development. After 30 days of sufficient pegging zone moisture, pods could continue normal growth in dry soil if roots had adequate moisture Suneetha Devi (1998) reported that seed growth could continue after full pod expansion with root supplied water even if surface moisture was inadequate.

Water use efficiency: Provision of favorable soil water balance duly accounting for evaporative demand of the atmosphere (Eta/Etm=1) was shown to enable in effective use water contributing to higher pod yield as well as water use efficiency as is evident from the fully irrigated control I_1 treatment. On the other hand Eta deficits at crop growth sub periods of flowering and pegging, pod initiation and addition and pod filling period caused significant reduction in water use efficiency as is evident from I_2, I_3 band I_4 treatments, owing to appreciable reduction in pod yield relative to Eta reduction in respective treatments.

Thus based upon the yield sensitivity coefficients (Ky) (Table 5) it can be deduced that the relative sensitivity of groundnut pod yield to moisture stress is highest in flowering and pegging period, moderate in pod initiation and addition period and least during pod filling period. The above information will enable the groundnut farmers in allocating of available limited water supplies to crop growth sub periods where in the response is highest leading to maximization of productivity per unit amount of water.

Table 5 Empirical estimates for the relationship between relative yield deficit (1-Ya/Ym) and relative evapotranspiration deficit (1-Eta/Etm) for groundnut under different treatments on pooled basis

Stage of the crop	Intercept(a)	Yield sensitivity coefficient (Ky)	Coefficient of determination R^2
Flowering and pegging period (I_2)	0.00001	1.673546**	0.986
Pod initiation and addition period (I_3)	0.00001	1.5003059**	0.989
Pod filling period (I_4)	0.00001	1.397579**	0.996

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Effect of residual fertility of different nitrogen management practices to *kharif* rice on the performance of *rabi* groundnut, *Arachis hypogaea* L.*

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Abstract

Field experiment was conducted during *rabi* seasons of 2000 and 2001, to evaluate the response of groundnut (*Arachis hypogaea* L.) to the residual effect of different nitrogen management practices adopted to preceding *kharif* rice. Residual effect of *kharif* rice treatments exerted marked influence on the dry matter production, yield attributes, yield and nitrogen uptake of groundnut. Application of 100% N through FYM to preceding rice crop has resulted in the highest total dry matter, number of pods/plant, pod weight, kernel weight, pod and haulm yield as well as nitrogen uptake of groundnut. The increase in pod yield of groundnut with application of 100% N through FYM to preceding rice crop was 14.84 and 18.24 % over no nitrogen to rice and 10.71 and 13.73 % over 100% N through fertilizer to rice during 2000 and 2001, respectively.

Key words: Residual fertility, *rabi* groundnut, nitrogen management, *kharif* rice

Introduction

Until recently, crop production research has been focusing attention on individual crops, disregarding the fact that each crop is only a component of cropping system. Nutrient prescription for crops is usually made based on the responses of individual crops without considering the cropping system as a whole, with the result that the recommendations often become unremunerative. Further, the nutrient needs of a crop in a cropping system are greatly influenced by the nature of preceding crop and the quantity of nutrients it received. For maintaining balanced nutrition in a cropping system, residual effect on the succeeding crop deserves a careful docideratum and quantitative evaluation to sustain the level of productivity on one hand and the soil health on the other.

Materials and methods

Field experiment was conducted during (2000 and 2001) on sandy loam soils of wetland block of S.V. Agricultural College Farm, Tirupati, with rice during *kharif* and groundnut during *rabi* and laid out in randomized block design replicated thrice. The same layout was followed during both the years of study. The soil was sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon (0.27%) and available nitrogen (157.5 kg/ha) and medium in available phosphorous (22 kg/ha) and available potassium (190 kg/ha) at the start of the experiment. The treatments consisted of twelve N management practices to rice (T_1- No N, T_2-*Azospirillum* alone, T_3-GM N_{100}, T_4-GLM N_{100}, T_5-FYM N_{100}, T_6-F N_{100}, T_7-GM N_{50} + F N_{50}, T_8-GLM N_{50} + F N_{50}, T_9-FYM N_{50} + F N_{50}, T_{10}-GM N_{50} + F N_{50} + *Azo.*, T_{11}-GLM N_{50} + F N_{50} + *Azo.* and T_{12}-FYM N_{50} + F N_{50} + *Azo.*) and groundnut was raised in *rabi* to find out the residual effect of the treatments applied to *kharif* rice. The recommended dose of fertilizer was 80 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. *Azospirillum* @2.5 kg/ha was thoroughly mixed with FYM and sand in the ratio of 1:10:20 and applied to the treatmental plots just before transplanting. The test variety of rice was Swarnamukhi (NLR-145) and that of groundnut was Vemana (K-134). The N content in different organic matters was determined (dhaincha, 0.61%; neem leaf, 0.54% and FYM, 0.58%) and the amount of these materials required to substitute the specified amount was incorporated into the soil 10 days prior to transplanting of rice. Rice was sown during 03-07-2000 and 05-07-2001 and groundnut was sown during 03-12-2000 and 14-12-2001 during the 1st and 2nd year of experimentation.

Results and discussion

Residual effect of different nitrogen management practices imposed on *kharif* rice has exerted marked influence on the dry matter production, yield attributes, yield and nitrogen uptake of groundnut.

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Supply of 100 per cent N through FYM (T_5) to preceding rice has recorded the highest dry matter production (Table 1), which was significantly superior to only the treatments of no N (T_1), *Azospirillum* alone (T_2) and F N_{100} (T_5) imposed to preceding rice. This might due to substantial amount of residual nutrients left by the treatments of preceding rice crop on succeeding groundnut crop (Table 3).

Table 1 Drymatter production and yield attributes of *rabi* groundnut as influenced by residual effect of different *kharif* rice treatments

Treatments to rice	Drymatter production (kg/ha)		No. of pods/plants		100 pod weight (g)		100 kernel weight (g)	
	2000	2001	2000	2001	2000	2001	2000	2001
T_1: No N	6453	5609	12.3	11.8	87.1	78.8	32.9	33.2
T_2: *Azospirillum* alone	6463	5642	12.4	11.8	87.6	79.6	33.0	33.2
T_3: GM N_{100}	6893	6008	13.4	13.0	88.5	83.2	34.2	34.6
T_4: GLM N_{100}	6913	6163	13.5	13.2	89.9	83.3	34.5	34.6
T_5: FYM N_{100}	7213	6441	13.8	13.6	91.9	85.7	35.6	35.1
T_6: F N_{100}	6540	5787	12.7	11.9	87.7	79.9	33.3	33.3
T_7: GM N_{50} + F N_{50}	6730	5836	12.8	12.2	88.6	82.3	33.9	33.8
T_8: GLM N_{50} + F N_{50}	6773	5997	12.9	12.3	89.3	82.9	34.0	34.0
T_9: FYM N_{50} + F N_{50}	7170	6330	13.7	13.4	91.4	84.8	35.2	34.9
T_{10}: GM N_{50} + F N_{50} + *Azo.*	6653	5795	12.8	12.0	88.0	82.2	33.8	33.8
T_{11}: GLM N_{50} + F N_{50} + *Azo.*	6750	5978	12.8	12.3	88.9	82.8	34.0	33.9
T_{12}: FYM N_{50} + F N_{50} + *Azo.*	7003	6315	13.6	13.3	90.1	84.2	34.9	34.8
SEm ±	149.0	148.0	0.20	0.38	1.34	1.64	0.65	0.51
CD (P = 0.05)	437	434	0.6	1.1	3.9	4.8	1.9	1.5

Table 2 Pod and haulm yield (kg/ha) as well as nitrogen uptake (kg/ha) of *rabi* groundnut as influenced by residual effect of different *kharif* rice treatments

Treatments to rice	Rice yield		Pod yield		Haulm yield		Nitrogen uptake	
	2000	2001	2000	2001	2000	2001	2000	2001
T_1: No N	3275	3525	2223	1962	4208	3575	81.6	77.4
T_2: *Azospirillum* alone	3572	3750	2243	2023	4234	3647	82.5	80.2
T_3: GM N_{100}	4773	4704	2433	2176	4460	3985	91.2	88.6
T_4: GLM N_{100}	4852	4801	2449	2228	4460	3985	91.5	90.6
T_5: FYM N_{100}	4606	4561	2553	2320	4627	4145	96.4	94.4
T_6: F N_{100}	5284	5181	2306	2040	4234	3715	84.1	80.7
T_7: GM N_{50} + F N_{50}	5140	5060	2356	2069	4376	3767	88.5	83.9
T_8: GLM N_{50} + F N_{50}	5168	5099	2397	2092	4410	3876	89.7	86.5
T_9: FYM N_{50} + F N_{50}	4994	4977	2544	2296	4662	4122	96.2	93.0
T_{10}: GM N_{50} + F N_{50} + *Azo.*	5191	5130	2331	2067	4338	3747	87.9	82.9
T_{11}: GLM N_{50} + F N_{50} + *Azo.*	5195	5143	2489	2080	4388	3852	89.6	85.0
T_{12}: FYM N_{50} + F N_{50} + *Azo.*	5006	4979	2475	2267	4527	4098	94.4	91.3
SEm ±	117.2	120.0	2.27	1.56	1.52	1.56	5.93	7.29
CD (P=0.05)	344	431	6.7	4.6	4.5	4.6	17.4	21.4

Table 3 Post-harvest soil nutrient status (kg/ha) and organic carbon (%) after rice as influenced by different nitrogen management practices

Treatment	*Kharif*, 2000				*Kharif*, 2001			
	Available N	Available P_2O_5	Available K_2O	Organic carbon	Available N	Available P_2O_5	Available K_2O	Organic carbon
T_1: No N	130.8	23.8	115.8	0.30	143.3	24.7	146.7	0.32
T_2: *Azospirillum* alone	136.5	24.0	119.2	0.30	149.7	24.7	150.7	0.32
T_3: GM N_{100}	187.5	25.8	138.3	0.39	190.6	26.3	176.3	0.42
T_4: GLM N_{100}	187.5	25.0	149.2	0.38	189.3	25.0	181.0	0.40
T_5: FYM N_{100}	198.3	29.7	174.2	0.40	194.5	30.6	204.7	0.43
T_6: F N_{100}	166.5	25.7	125.0	0.31	171.5	26.0	156.7	0.32
T_7: GM N_{50} + F N_{50}	170.8	26.3	134.2	0.36	181.5	27.3	172.0	0.38
T_8: GLM N_{50} + F N_{50}	173.3	27.3	139.2	0.36	182.7	27.8	180.7	0.38
T_9: FYM N_{50} + F N_{50}	177.7	29.3	154.2	0.39	187.5	30.3	189.7	0.40
T_{10}: GM N_{50} + F N_{50}+*Azo.*	177.5	26.5	138.3	0.37	186.7	27.7	179.5	0.39
T_{11}: GLM N_{50} + F N_{50}+ *Azo.*	170.0	27.0	137.5	0.36	180.5	27.7	175.3	0.38
T_{12}: FYM N_{50} + F N_{50}+ *Azo.*	175.8	28.3	151.5	0.37	183.7	29.0	186.5	0.39

The yield attributes of groundnut *viz.*, number of pods/ plant, hundred-pod weight and hundred-kernel weight (Table 1) as well as pod yield, haulm yield and nitrogen uptake (Table 2) were the highest with application of 100 per cent N through FYM to preceding rice crop (T_5), which was however, comparable with FYM N_{50} + F N_{50} (T_9), FYM N_{50} + F N_{50}+*Azo.* (T_{12}), GLM N_{100} (T_4) and GM N_{100} (T_3). This might be due to the residual effect with the treatments of the combination of FYM and the exclusive organic sources of N, which was comparatively higher than that of other combinations of organics and fertilizer N applied to preceding rice crop. Among the organic sources, differential residual response with different sources can be attributed to their pattern of mineralisation and proportion of their substitution. In the present study, the residual effect of organic sources at higher proportions was evident from higher dry matter accrual, number of pods/plant, 100-pod weight, pod and haulm yield as well as nitrogen uptake.

This clearly indicates that organic sources at higher proportions can only sustain the nutrient status of soil to produce reasonable residual effect. Organic manures, besides supplying nutrients to the current crop, quite often leave substantial residual effect on succeeding crops in the cropping system (Maskina and Meelu, 1984). Significant carry over effect due to substitution of nitrogen with higher proportions of organic sources to rice crop on the succeeding crops was also reported by Thimmegowda and Devakumar (1994) and Paulraj and Velayudham (1995). Residual effect of fertilizer nitrogen applied to rice was not traceable on the succeeding groundnut crop (Ramaseshaiah *et al.*, 1985).

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Moisture sensitive growth periods and optimal sequencing of evapotranspiration deficits in Indian mustard, *Brassica juncea* (L.) Czern & Coss

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Abstract

The field experiment was conducted on a sandy loam soil during the winter season of 1995-96 and 1996-97 at Hyderabad to study the response of mustard, *Brassica juncea* (L.) Czern & Coss to deficit (ET) imposed at specific crop-growth subperiods *viz.*, vegetative, flowering-pod initiation and pod filling period besides, a fully irrigated control treatment. The crop in fully irrigated control treatment produced maximum mean pod yield of 1571 kg/ha. Water deficits at specific crop-growth subperiods except vegetative period caused drastic reduction in pod yield relative to fully irrigated control treatment. The yield sensitivity coefficient (Ky) indicated that the pod filling period in mustard was sensitive to Eta deficits than in vegetative and flowering-pod initiation periods, respectively. Likewise, the flowering-pod initiation period was more sensitive to Eta deficits than is vegetative period. Hence, it was concluded to sequence Eta deficits at vegetative period and direct the available water supplies to flowering-pod initiation period followed by pod filling period under deficient water supply situation to minimise yield losses.

Key words: Mustard, evapotranspiration deficit, yield sensitivity coefficient

Introduction

Pressure for improved efficiency in the use of irrigation water is mounting. This impetus is derived from dwindling ground water resumes and an increase in restrictions being placed on the abstraction from surface water resources will mean greater competition between those who seek water for irrigation, those who require its use for non-agricultural purposes, and those who simply with that the water resource be untouched and conserved. Irrigation planning in future is therefore, more likely to be based on a purposeful imposition of water (Eta) deficits controlled in intensity and time, and to meet the specified objectives.

Mustard an important oilseed crop in India, during winter season is often subjected to Eta deficits during crop growing season leading to heavy yield depression. The present study was, therefore, designed to quantify the relative sensitivity of crop to water deficit at specific crop-growth subperiods for optimal allocation of limited water supplies to minimise yield losses.

Materials and methods

The field experiment was conducted on a sandy loam soil during the winter season of 1995-96 and 1996-97 at the College Farm of Acharya N.G. Ranga Agricultural University, Hyderabad (17° 19' N, 78° 23' E and 542.3 m above mean sea level).

The weekly mean maximum temperature for the crop period ranged from 28.3°C to 34.6°C with an average of 30.0°C in the first year (1995-96) and from 26.8°C to 31.9°C with an average of 29.2°C in the second year (1996-97). The weekly mean relative humidity ranged from 29 to 93.0% with an average of 68.6% in 1995-96 and 21 to 88% with an average of 63.3% in 1996-97. Evaporation from (USWB Class A Pan evaporimeter) during the crop period in 1995-1996 ranged from 2.8 to 3.8 mm/day and from 2.1 to 4.9 mm/day in 1996-97 with *a wind velocity of 1.5 to 3.6 km/hr and1.6 to 4.2 km/hr in* 1995-96 and 1996-97, respectively. A total rainfall of 144 mm spread over two rainy days in 1995-96 was received during the vegetative period i.e., 20 days after sowing. Since the rainfall occurred during the establishment - vegetative stage, the effective rainfall (Dastane, 1974) was deducted from the net irrigation requirement, while scheduling irrigation's in different treatments.

The treatments consisted of seven variable water supply levels designed to allow moderate to severe Eta (water) deficits to develop in one or more of three specific crop-growth sub-periods *viz.*, vegetative (0-27 DAS),

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flowering and pod initiation and addition period (27-63 DAS) and pod filling (63-85 DAS) sub-periods including a fully irrigated control treatment (W-W-W). In any given growth sub-period, the crop in a given treatment was either irrigated (W) based on soil-crop-climatic data (Table 1) to ensure Eta proceeded at the potential rate (Etm) or it was not irrigated (D) at all. For instance the crop in D-W-W was not irrigated during vegetative growth sub-period i.e., from 0-7 DAS and was irrigated during the latter two crop-growth subperiods by supplying the water equivalent that lost in Eta. Likewise in treatments W-D-W, W-W-D, D-D-W, W-D-D, D-W-D, if the crop was irrigated (W) in a given crop-growth sub-period, the schedule followed in W-W-W was duplicated. Following an Etd in water deficit treatment at the end of the crop growth sub-period the root zone depth of the crop was replenished to field capacity moisture content. A 50-mm water meter was installed to deliver the required quantity of water in each plot.

Table 1 Determination of irrigation requirement for mustard (mean of 1995-96 and 1996-97) in treatment based on soil-crop climatic parameters

Crop growth sub period	Duration (days)	Etm (mm/day)	Rooting depth (D) (m)	Sa.D (cm)	P fraction	$I = \frac{(Sa.D.P)}{Etm}$	IRR (mm)
Vegetative	24	4.22	0.45	6.34	0.50	8	31.7
Flowering-pod initiation and addition	40	4.20	0.60	0.85	0.50	10	43.0
Pod filling	30	4.00	0.60	8.50	0.50	11	42.5

Etm = Maximum evapotranspiration
Sa.D = Available soil water in crop root zone depth
P = Critical soil moisture level
I = Irrigation interval
IRR = Irrigation requirement

The seven treatments were laid out in Randomized Block Design with four replications. Mustard variety, TM-4 was sown on 2nd November during 1995-96 and 29th October in second year (1996-97), respectively by adopting a spacing of 30 cm between rows and 10 cm between plants in a row with plot size of 7.2 m x 3.5 m. The fertilizer dose applied was 60 Kg N, 60 Kg P_2O_5 and 40 kg K_2O/ha with phosphorus and potash as basal (broadcast) and N in two split doses *viz.*, basal (broadcast) and 30 DAS (pocket application). The crop was subjected to Eta deficits by withholding water at different crop-growth sub-periods. The ground water table was below six meters during the crop-growing season hence; it was assumed that there was not any contribution from ground water table towards crop water needs.

The experimental soil had N, P_2O_5 and K_2O @ 270, 18.2 and 508 kg/ha, respectively with pH 7.5, bulk density 1.66 g/cm^2 and EC 10.3 dS/m. The available soil moisture determined as difference between moisture held at -0.03 MPA (Field capacity) 17.23% and -1.5 MPA (permanent wilting point 8.72%) was 84.4 mm in 60 cm soil profile.

For determination of crop Eta the soil moisture was monitored by gravimetric method at four locations and at various depths in each treatment from surface to 60 cm soil depth before and after each irrigation and on intermediate dates as necessary. The reference crop evapotranspiration deficit was estimated at specific crop growth sub-periods as per Hargreaves and Samani (1982). The crop was harvested on 2nd February and 31st January in (1995-96 and 1996-97) respectively.

To quantify the effect of Eta deficits on yield the relationship between relative yield reduction and relative evapotranspiration deficit was worked out by regression analysis as suggested by Stewart *et al.* (1977). The relationship is as follows:

$$[(Ym - Ya)/Ym] = Ky\ [(Etm - Eta)/Etm] \quad \ldots\ldots\ (1)$$

Where,

Ym = Maximum seed yield in fully irrigated crop i.e., W-W-W treatment

Ya = Actual seed yield of the crop as affected by Eta deficits

Etm = Seasonal evapotranspiration of fully irrigated crop

Eta = Seasonal evapotranspiration in water deficit treatments

Ky = Yield sensitivity factor

Results and discussion

Seed yield versus Eta deficit: The crop in fully irrigated control treatment (W-W-W) produced significantly higher pod yield in both the years (1488 kg/ha in 1995-96 and 1655 kg/ha in 1996-97) and on pooled basis (1571 kg/ha) (Table 2). Eta deficits at any crop growth sub-period except vegetative period (D-W-W) caused significant reduction (25.9 to 85.0 % on pooled basis) in pod yield relative to W-W-W treatment in both the years and on pooled basis. The better performance of the crop in W-W-W could be traced to favourable soil water balance in these treatments as evident from the Eta values and Eta/Eto ratios.

Growth stage sensitivity to Eta deficits: To examine the sensitivity of seed yield of mustard to Eta deficits the Stewarts S_2 function was adopted and the resultant yield response sensitivity coefficients (Ky) for specific crop growth subperiods were calculated by regression analysis and presented in Table 3.

The test statistic R^2 indicated that the explained total variation in relative seed yield deficit varied between 0.921 to 0.999, 0.808 to 0.999 and 0.967 to 0.999 in 1995-96, 1996-97 and on pooled basis, respectively. The R^2 values were highly significant in all the functions under different treatments in both the years and on pooled basis. Likewise, the Ky values in all the treatments were significant at P=0.01 in both the years and on pooled basis. This implies that the function is statistically acceptable with regard to fitting of the observed data considering the time of Eta deficit at specific crop-growth subperiods.

The Ky values which reflect the relative sensitivity of seed yield to Eta deficit varied with the crop-growth subperiod and with the magnitude of Eta deficit imposed at various growth periods and were positive and significantly different from zero.

Comparison of Ky values in D-W-W (Eta deficits at vegetative period alone), W-D-W (Eta deficits at flowering-pod initiation period) and W-W-D (Eta deficits at pod filling period alone) treatments indicated that the relative yield decrease for a given level of Eta deficit was least in vegetative period, intermediate in flowering-pod initiation period and highest in pod filling period. In the instance at hand the data on Ky values in Table 4 for D-W-W, W-D-W and W-W-D treatments revealed that the pod filling period of mustard is inherently 2.17 (or 217%) and 0.159 (15.9%) times in 1995-96, 2.57 (or 257%) and 0.006 (0.67%) times in 1996-97 and 2.75(275%) and 0.096 (9.6%) on pooled basis, is more sensitive to Eta deficits than in vegetative period and flowering and pod initiation period, respectively. Likewise, the flowering -pod initiation period of mustard is 1.73 (or 173%), 2.55 (or 255%) and 2.41 (or 241%) times more sensitive to Eta deficits than is vegetative period in 1995-96, 1996-97 and on pooled basis, respectively.

On the other hand when the magnitude as well as duration of ETa deficits was extended to two crop-growth subperiods as in case of D-D-W (Eta deficits both at vegetative period plus flowering-pod initiation period), and W-D-D (Eta deficits both at flowering-pod initiation period plus pod filling period) treatments, the Ky values obtained were low in comparison to W-D-W and W-W-D treatments where in Eta deficits were imposed only at a single crop-growth subperiod. However, it was interesting to note that the Ky values in D-W-D treatment where in the crop was subjected to ETA deficits both at vegetative period plus pod filling period had Ky values almost similar to that registered in W-W-D treatment. The Ky values under D-D-W, W-D-D and D-W-D treatments varied between 1.4060 to 2.0477 in 1995-96, 1.4399 to 2.0929 in 1996-97 and 1.4915 to 2.0663 on pooled basis. However, the sensitivity of seed yield to Eta deficits was more by sequencing them at vegetative period plus pod filling period (D-W-D) instead of a continuous stress either from sowing to the end of pod addition period (D-D-W) or from flowering to the end of pod filling period (W-D-D).

Table 2 Seed yield and crop evapotranspiration of mustard as influenced by Eta deficit at different crop growth subperiods

Treatment			Seed yield (kg/ha)			Seasonal crop evapotranspiration (mm)	
GS1	GS2	GS3	1995-96	1996-97	Pooled	1995-96	1996-97
W	W	W	1488	1655	1571	345.0	333.3
D	W	W	1395	1572	1484	309.5	299.6
W	D	W	677	642	660	239.4	233.1
W	W	D	1178	1150	1164	311.0	283.7
D	D	W	522	445	484	220.4	163.7
W	D	D	294	175	2345	148.1	143.3
D	W	D	967	1104	1036	286.1	280.2
SEm±			47.1	44.9	43.0	-	-
CD (P=0.05)			140.4	133.0	128.2	-	-

GS = Growth stage

Table 3 Crop coefficients for mustard as influenced by evapotranspiration deficits at different crop growth subperiods

Treatment	Crop growth sub-period											
	Establishment (0-9 DAS)		Vegetative (9-25 DAS)		Flowering-pod initiation (25-65 DAS)		Pod filling (65-87 DAS)		Maturity (87-96 DAS)		Total growing season (0-96 DAS)	
	1995-96	1996-97	1995-96	1996-97	1995-96	1996-97	1995-96	1996-97	1995-96	1996-97	1995-96	1996-97
W-W-W	0.632	0.555	0.880	0.804	0.960	0.944	1.037	1.000	0.808	0.520	0.937	0.884
D-W-W	0.596	0.425	0.672	0.620	0.868	0.873	0.959	0.927	0.808	0.480	0.840	0.795
W-D-W	0.608	0.546	0.849	0.779	0.462	0.461	0.904	0.895	0.782	0.536	0.650	0.619
W-W-D	0.620	0.534	0.813	0.779	0.946	0.861	0.812	0.698	0.404	0.300	0.844	0.753
D-D-W	0.538	0.518	0.701	0.627	0.468	0.212	0.882	0.763	0.364	0.428	0.598	0.434
W-D-D	0.624	0.530	0.849	0.808	0.416	0.407	0.104	0.107	0.126	0.108	0.402	0.380
D-W-D	0.571	0.405	0.708	0.646	0.858	0.885	0.788	0.740	0.409	0.244	0.777	0.744

Table 4 Empirical estimates for the relationship between relative yield deficit (1-Ya/Ym) and relative evapotranspiration deficit (1-Eta/Etm) for mustard under different treatments

Treatment	Regression constants, coefficients and test statistics			
	Intercept (a)	Yield sensitivity coefficient (Ky)	*T-value for testing (Ky)*	Coefficient of R^2 determination
		1995-96		
D-W-W	-0.00373	0.6503**	5.920	0.921**
W-D-W	-0.00022	1.7811**	113.374	0.999**
W-W-D	0.00372	1.7963**	160.384	0.999**
D-D-W	0.00027	1.7963**	160.384	0.999**
W-D-D	-0.00006	1.4060**	313.675	0.999**
D-W-D	0.00035	2.0477**	130.057	0.999**
		1996-97		
D-W-W	-0.00614	0.5714**	3.559	0.808**
W-D-W	0.00104	2.0316**	60.767	0.999**
W-W-D	0.00060	2.0453**	49.923	0.998**
D-D-W	0.00003	1.4399**	159.378	0.999**
W-D-D	0.00003	1.5686**	631.131	0.999**
D-W-D	-0.00040	2.0929**	82.895	0.999**
		Pooled		
D-W-W	-0.00092	0.5592**	9.428	0.967**
W-D-W	0.00025	1.9117**	114.524	0.999**
W-W-D	0.00068	2.0971**	27.218	0.995**
D-D-W	0.00005	1.5963**	364.169	0.999**
W-D-D	-0.00002	1.4915**	578.006	0.999**
D-W-D	-0.00005	2.0663**	104.915	0.999**

** Significant at P=0.01

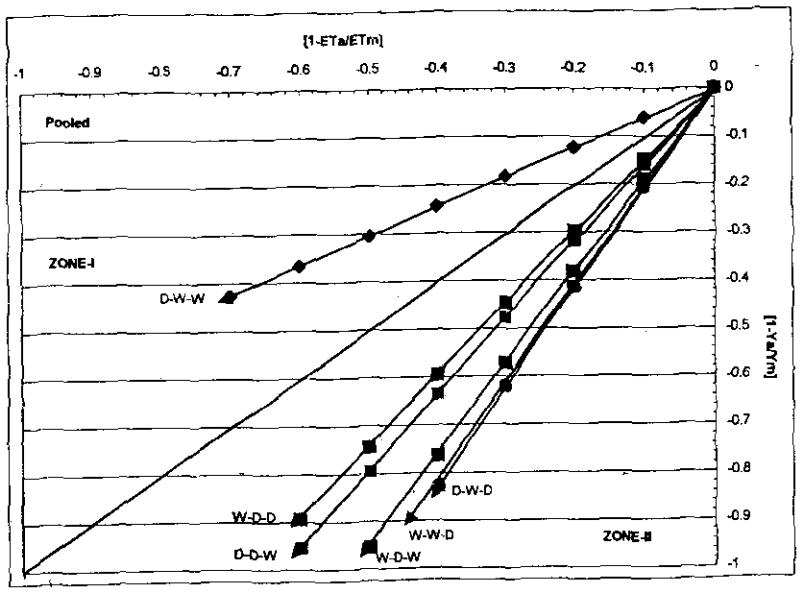

Fig.1. Relationship between relative yield deficit (1-Ya/Ym) and relative evapotranspiration deficit (1-Eta/ETm) under different treatments imposed on mustard crop

Optimal sequencing of Etd: To quantify 'optimal' and *'sub-optimal' sequencing of Etd, the treatments causing* large yield reduction were separated from those which brought about *minimum reduction in seed yield from Ym.* For spectrum of results in each growth subperiod the slope Ky value of the *relative yield reduction versus* relative Eta deficit relationship was established (Table 4). The Fig.1 represents the *yield sensitivity coefficients* ranging from 0.5592 to 2.0971 in 1995-96, 1996-97 and on pooled basis, respectively. The Etd sequence resulting in a Ky value of <0.6503 in 1995-96, <0.5714 in 1996-97 and <0.5592 on pooled basis (see Ky values in Zone 1 as shown in Fig.1) were considered to represent the 'optimal' sequencing of Etd. The 'optimal' Etd sequencing refers to the timing of Etd intensities which resulted in minimum reduction in yield (6.22%, 5.00% and 5.55% below Ym in 1995-96, 1996-97 and pooled basis, respectively. For the total seasonal Etd, the Etd timings which brought about 20.8 to 80.2 per cent in 1995-96, 30.5 to 89.4 per cent in *1996-97 and 25.9 to 85.0 per cent on pooled basis,* reduction in yield below Ym were denoted as *'sub-optimal'.*

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Production potential and economic feasibility of soybean, *Glycine max* (L.) Merrill based cropping systems

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Abstract

A field experiment conducted during 1994 to 1997 indicated that soybean, *Glycine max* (L.) Merrill - wheat (*Triticum aestivum* L. emend. Fiori and Pool) cropping system with 100 % NPK emerged as the most productive and remunerative cropping system than soybean - linseed and soybean - mustard. The energy analysis revealed that the soybean-wheat consumed significantly. Energy inputs and subsequently enhanced the energy net returns, energy use efficiency and energy productivity. While soybean-mustard was found the most energy intensive cropping system. Energy inputs increased with the fertility levels.

Key words: Cropping system, fertility level, energy

Introduction

The role of legumes in improving the sustaining soil fertility as well as the growth and yield of succeeding crops is well documented (Dhama and Sinha, 1985). Soybean, a legume cum oilseed crop has acquired a special niche in traditional cropping patterns in Madhya Pradesh in a short span of past three decades after its commercial cultivation picked up. Short duration, compact stature, availability of high yielding cultivars, comparative tolerance to adverse climatic conditions enabled the crop to fit in well in various cropping patterns (Bhatnagar *et al.*, 1996). Crops grown in *rabi* after soybean warrant evaluation for agronomic feasibility, economic viability and stability. The present study was therefore initiated to evaluate important *rabi* crops grown in sequence with soybean under varied fertility levels.

Materials and methods

A field study was conducted during 1994 to 1997, at Indore on Typic Chromusterts. The soil of experimental site analyzed: pH - 7.86, EC-0.14 dS/m, organic carbon - 0.30%, available P - 4.80 kg/ha and available K > 99.48 kg/ha. The treatments comprised of soybean followed by 3 *rabi* crops *viz.*, wheat (Sujata), linseed (R 17) and mustard (Pusa bold) grown on 3 fertility levels created by application of 0, 50 and 100% of the recommended fertilizer levels to respective crops which were replicated thrice. All the treatments were laid out on fixed plots in *Split Design with three replications*. The recommended NPK levels were: 100 : 21.5 : 24.9 kg NPK/ha for wheat, 60 : 13 : 17 kg NPK/ha for mustard and 30 : 7 : 0 kg NPK/ha for linseed. Soybean (JS 71 05) was grown with 100% recommended fertilizer level (20 : 26 : 17 kg NPK/ha). All these crops were grown by following standard cultivation practices.

The economics of each treatment was calculated as per the prevailing prices of inputs and outputs. The energy budget of the treatments were determined by using the conversion factors for each and every input, output and cultural activities as suggested by Mittal and Dhawan (1988). Energy intensiveness (EI) and energy productivity (EP) were worked out as per Burnett (1982) and Fluck (1979).

Results and discussion

Cropping system: Soybean was most productive in soybean-mustard crop sequence (Table 1). Among the *rabi* crops, wheat was the most productive followed by linseed and mustard. When systems were compared, soybean-wheat sequence emerged as the most productive and remunerative followed by soybean-linseed and soybean-mustard. Wheat is known to be more productive and cost effective when grown after pulse crop (Sawarkar *et al.*, 1995; Verma, 1997).

Enhancement in fertility levels remarkably improved the yield of all the crops (Table 1). The magnitude of yield enhancement was highest in soybean-wheat followed by soybean-linseed or soybean-mustard. On comparing the individual crops, the magnitude of residual fertility response was lower in soybean than in different *rabi* crops. The maximum enhancement in yield due to fertility was recorded in soybean-mustard followed by soybean-wheat and soybean-linseed. The net returns and B:C ratio

increased as the fertility levels increased. On the basis of net returns and B:C ratio, soybean-wheat was found to be most remunerative. The differential response of cropping systems may be due to the cereals, which are more fertilizer responsive than oilseeds and pulses. Similarly, Mahadev and Das (1997) reported that application of 100% of the recommended dose led to higher economic return in rice-based (wheat/mustard/groundnut) cropping system.

The interaction effect between cropping systems and fertility levels was found significant during all the years of study. Almost all the maximum values for different parameters were associated with soybean-wheat system. The residual effect of 100% fertility level was highest in soybean when grown after mustard and linseed.

Energy budget: Energy analysis of different treatments revealed that the soybean-wheat consumed maximum energy inputs followed by soybean-mustard and soybean-linseed (Table 2). The differences in energy inputs may be ascribed to soybean-wheat requiring higher doses of NPK, particularly N, which shared maximum energy input among the inputs (Billore *et al.*, 1996). Similarly, soybean-wheat possessed significant higher values of gross and net energy returns, energy use efficiency and energy productivity. Energy use efficiency increased as the levels of fertility increased in soybean-linseed and soybean-mustard, while in case of soybean-wheat, it increased only upto 50% fertility level and subsequently declined. The differences in energy indices might be due to the differences in yield levels and inputs in respective treatments. The most energy intensive cropping system was the soybean-mustard followed by linseed and wheat because energy intensiveness is the function of the yield, price and energy inputs. Similar views were extended by Vyas *et al.* (1993) and Billore *et al.* (1994; 1996). The interaction effect of cropping systems x fertility levels was found significant in case of all the energy indices.

Table 1 Yield and economical parameters of soybean based cropping systems under varied fertility levels (Pooled over 1994-97)

Cropping system	Fertility level	Seed yield (kg/ha)		Soybean equivalent yield (kg/ha)	Net returns (Rs/ha)	B:C ratio
		Kharif	*Rabi*			
Soybean-wheat	0 %	1089	2410	2666	17265	2.15
	50 %	1158	3085	3177	18111	2.40
	100 %	1243	3803	3770	22799	2.65
	Mean	1164	3100	3208	18281	2.40
Soybean-linseed	0 %	1077	846	2283	11787	2.06
	50 %	1091	946	2524	13146	2.15
	100 %	1326	1053	2920	16731	2.44
	Mean	1164	948	2575	13889	2.17
Soybean-mustard	0 %	1108	340	1741	4047	0.68
	50 %	1264	477	1840	6445	1.54
	100 %	1366	600	2090	8238	1.67
	Mean	1243	472	1812	6662	1.57
CD (P=0.05)	Cropping system and fertility level	57	651	354	3162	0.30
	Interaction	99	1128	588	5477	0.53

Table 2 Energy budget of soybean based cropping systems under varied fertility levels

Cropping system	Fertility level	Energy input (MJ/h)	Energy output (MJ/ha)		Energy use efficiency	Energy productivity (MJ/kg)	Energy intensiveness (Rs/MJ)
			Gross	Net			
Soybean-wheat	0 %	20887	51435	30548	2.46	0.115	0.795
	50 %	25039	62372	37333	2.49	0.123	0.799
	100 %	29142	74176	45034	2.45	0.130	0.790
	Mean	25023	63281	38258	2.53	0.122	0.795
Soybean-linseed	0 %	20112	36982	16870	1.84	0.113	0.878
	50 %	21153	39688	18535	1.88	0.119	0.863
	100 %	22146	45817	23671	2.07	0.132	0.781
	Mean	21470	41105	19635	1.91	0.120	0.850
Soybean-mustard	0 %	19637	24788	5151	1.26	0.090	1.340
	50 %	21743	30506	8763	1.40	0.085	1.210
	100 %	23789	35080	11291	1.47	0.088	1.330
	Mean	21743	30072	8329	1.38	0.083	1.230
CD (P=0.05)	Cropping system and fertility level	1506	6684	5535	0.20	0.010	
	Interaction	2607	11577	9587	0.36	0.220	

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Screening of pigeonpea, *Cajanus cajan* varieties for their suitability as intercrop in soybean, *Glycine max* L.

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Abstract

A field experiment was conducted during *kharif*, 1995 and 1997 to study the compatibility of pigeonpea varieties in soybean based intercropping system. Of the six pigeonpea varieties tested, ICPL 871 19 and ICPL 940 63 were found most compatible with soybean variety Ahilya 3 in 4:2 row ratio as adjudged by higher yield levels, soybean equivalent yield, land equivalent ratio (LER), relative crowding coefficient (RCC), monetary returns and income equivalent ratio (IER) with low competition ratio. Aggressivity values indicated that soybean dominated pigeonpea varieties except ICPL 840 31. This system also produced higher energy, energy use efficiency and energy productivity. ICPL 850 10 + soybean was found the most energy intensive.

Key words: Energy, intercropping, soybean, pigeonpea

Introduction

Soybean has now assumed the status of a prominent cash crop in Central India which has above 80% area of total coverage under the crop. Crop diversification appears to be a key to the sustainability of the cropping system. It is known that intercropping of soybean with pigeonpea offers yield stability and improved total production from the system (Prasad *et al.*, 1997) than its sole cropping. It also ensures adequate yield of one of the crops under aberrant weather conditions (Rao and Willey, 1980). Biological efficiency of any intercropping systems depends on the varietal compatibility of component crops and their spatial arrangement. However, information on this aspect is inadequate. Therefore, the present investigation was undertaken to evaluate the productivity, competitive indices, monetary advantage and energy balance of pigeonpea varieties in soybean based intercropping system under two spatial arrangements.

Materials and methods

A field experiment was conducted at Indore during *kharif*, 1995-96 and 1997-98. The soil was clayey, having pH 7.86, EC 0.14 ds/m, organic carbon 0.3 %, available P 4.86 kg/ha and available K > 99 kg/ha. The experiment was laid out in Randomised Block Design with three replications. Treatment combinations comprised sole soybean (Ahilya 3), sole pigeonpea (ICPL 850 10, ICPL 87, ICPL 840 31, ICPL 871 19, ICPL 940 62 and ICPL 940 63) and their combinations with soybean in 2:2 and 4:2 row arrangements were evaluated. The crops were sown in first week of July during both the years. A fertilizer dose of 20:26:17 kg NPK/ha to soybean and 20:22:0 kg NPK/ha to pigeonpea was applied as basal through urea, single super phosphate and muriate of potash in sole cropping systems. Intercropping treatments received only fertilizer level recommended for soybean.

The competitive ratio (Willey and Rao, 1980), the relative crowding coefficient (de Wit, 1960) and aggressivity (Mc Gilchrist 1965) were calculated. Energy inputs and outputs were computed using the conversion factors as suggested by Mittal and Dhawan (1988). Energy productivity and energy intensiveness were worked out as per Fluck (1979) and Burnett (1982), respectively. The total rainfall received during the crop period was 939 and 1106 mm in 1995-96 and 1997-98, respectively.

Results and discussion

Seed and soybean equivalent yield: Significant reduction in seed yield of soybean (24 to 40%) and pigeonpea (25 to 74%) was noticed when planted in intercropping systems as compared to their sole plantings (Joshi *et al.*, 1999). Although soybean yielded lower under 2:2 row ratio, the tendency of reduction when intercropped with ICPL 850 10, ICPL 87 and ICPL 840 31 was more than combination with other pigeonpea varieties. Soybean invariably yielded higher in 4:2 row ratio. Among the sole planted pigeonpea genotypes, seed yield of ICPL 940 63 (2134 kg//ha) was the maximum closely followed by ICPL 871 19 (2088 kg/ha). The lowest yield was observed with ICPL 840 31 (1122 kg/ha). The beneficial effect of intercropping could be judged by considering the total productivity in terms of soybean equivalent yield and comparing with sole soybean. The highest soybean

equivalent yield was recorded in soybean + ICPL 871 19 (4:2) which was at par with its 2:2 combination, soybean + ICPL 940 63 (4:2) and soybean + ICPL 940 63 in 2:2 row ratio. While, rest of the treatments differed non-significantly with sole soybean. These results are in agreement with) the earlier findings of Joshi *et al.* (1999). It may be noted that the intercropping systems reduced the quantum of fertilizer input.

Land equivalent ratio: Land equivalent ratio varied from 1.20 - 1.53 for different intercropping systems denoting their greater biological efficiency (Table 1). The planting of soybean + pigeonpea in 4:2 row ratio was more efficient than planting in 2:2 row ratio. Planting of ICPL 871 19 and ICPL 940 63 with soybean in both the planting patterns gave higher land equivalent ratio, while remaining pigeonpea varieties showed greater biological efficiency in 4:2 row arrangements. The higher value of land equivalent ratio indicated greater biological efficiency and lower competition between crops (Holkar *et al.*, 1991).

Table 1 Effect of planting pattern and pigeonpea varieties on productivity, competition functions and monetary returns of soybean and pigeonpea intercropping system

Treatment	Yiel (kg/ha)		SEY (kg/ha)	Land equivalent ratio (LER)	Competitive ratio (CR)	Aggressivity (A)	Relative crowding coefficient (RCC)	Monetary advantage (Rs/ha)	Income equivalent ratio (IER)	
	Soybean	Pigeonpea							Soybean	Pigeonpea
Soybean (Ahilya 3)	2391	-	2391	1.00	-	-	-	-	-	-
ICPL 850 10	-	1416	2361	1.00	-	-	-	-	-	-
ICPL 87	-	1704	2841	1.00	-	-	-	-	-	-
ICPL 840 31	-	1122	1870	1.00	-	-	-	-	-	-
ICPL 871 19	-	2088	3481	1.00	-	-	-	-	-	-
ICPL 940 62	-	1548	2581	1.00	-	-	-	-	-	-
ICPL 940 63	-	2134	3557	1.00	-	-	-	-	-	-
ICPL 850 10 (4:2)	1820	557	2749	1.20	1.74	0.43	1.36	4425	1.11	0.83
ICPL 850 10 (2:2)	1539	759	2806	1.24	1.08	0.05	2.08	5181	1.12	0.84
ICPL 87 (4:2)	1671	887	3150	1.22	1.35	0.23	2.52	5412	1.25	0.78
ICPL 87 (2:2)	1551	1062	3322	1.27	1.04	0.14	3.05	6684	1.31	0.82
ICPL 840 31 (4:2)	1737	884	3212	1.51	0.92	0.05	9.87	10345	1.28	1.21
ICPL 840 31 (2:2)	1457	781	2760	1.30	0.87	-0.00	3.57	6065	1.10	1.04
ICPL 871 19 (4:2)	1815	1601	4485	1.53	0.99	0.12	10.40	14604	1.76	0.89
ICPL 871 19 (2:2)	1736	1510	4254	1.45	1.00	0.13	6.91	12417	1.67	0.85
ICPL 940 62 (4:2)	1736	987	3382	1.36	1.14	0.25	4.66	8513	1.34	0.92
ICPL 940 62 (2:2)	1615	872	2570	1.24	1.20	0.16	2.70	5657	1.22	0.84
ICPL 940 63 (4:2)	1798	1500	4299	1.45	1.07	0.14	7.17	12563	1.69	0.84
ICPL 940 63 (2:2)	1741	1437	4137	1.40	1.08	0.15	7.66	11131	1.63	0.81
CD (P=0.05)	251	512	867	0.21	0.25	0.12	3.44	3850	0.27	0.13

Competition ratio: Soybean was found more competitive, except with pigeonpea varieties ICPL 840 31 and ICPL 871 19 as these varieties showed faster vegetative growth during early stage. The results are in agreement with Rao and Willey (1 980) who reported that the competitive ability of crops increased with the development of plant canopy. The low competition ratio value of crop indicated lower yield levels of respective crop.

Aggressivity: Soybean, in general, showed positive values of aggressivity in intercropping systems indicating its dominance over pigeonpea. It was only early maturing ICPL 840 31 with speedy early growth was an exception. Holkar *et al.* (1991) and Prasad *et al.* (1997) made similar observations while working with soybean based intercropping systems.

Relative crowding coefficient: Relative crowding coefficient of soybean was greater than unity in all the intercropping systems, thereby clearly establishing the dominance of soybean over the varieties of pigeonpea tested. Similarly, the product of relative crowding coefficient of component crops was also more than unity in all the intercropping treatments revealing a non-competitive interference than the competitive one. The higher relative crowding coefficient values indicated better compatibility of pigeonpea varieties with soybean and resulted in higher yields. The result corroborates with the findings of Holkar *et al.* (1991) and Prasad *et al.* (1997).

Monetary advantages and income equivalent ratio: Maximum monetary advantage and income equivalent ratio was associated with ICPL 871 19 (4:2) (Rs 14,604/ha) closely followed by ICPL 940 63 (4:2), ICPL 871 19 (2:2), ICPL 940 63 (2:2) and ICPL 840 31 (4:2) (Rs 10,335). While the values for remaining treatments varied from Rs. 4,425 to 8,513/ha over sole cropping of soybean. Similarly, income equivalent ratio values for soybean were greater than one, revealing that intercropping of soybean with any of the pigeonpea varieties was beneficial than sole soybean. While the value of income equivalent ratio lower than unity for pigeonpea except of variety ICPL 840 31 indicated that pigeonpea in intercropping was not beneficial as compared to its sole cropping.

Energy budget: Working out the energy budget for the treatments revealed that the intercropping of pigeonpea with soybean consumed more energy inputs than their sole crops (Table 2). Among the pigeonpea varieties, ICPL 871 1 9 followed by ICPL 940 63 intercropping with soybean in both the planting patterns (2:2 and 4:2) produced highest energy output and proved better in energy use efficiency, and energy productivity as compared to other varieties of pigeonpea as well as their sole crops. Among the sole cropping systems, ICPL 940 63 being the maximum and remained at par with ICPL 871 19 and ICPL 87. While the lowest energy output, energy use efficiency and energy productivity was recorded in ICPL 840 31. The differences in energy indices may be due to differences in their yield levels and energy inputs of the respective treatments. However, the ICPL 850 10 was found most energy intensive in both the cropping systems. The variation in energy intensiveness might be due to variation in yield, price and energy inputs. Similar views were also extended by Deka and Pal (1995) in pigeonpea based intercropping systems and Verma *et al.* (1997) in wheat + mustard intercropping.

Table 2 Energy productivity as influenced by planting pattern and varieties of pigeonpea with soybean i- intercropping system

Treatment	Energy input (MJ/ha)	Energy output (MJ/ha)		Energy use efficiency	Energy productivity (MJ/kg)	Energy intensiveness (Rs/MJ)
		Sole cropping				
Soybean (Ahilya 3)	7504	35148	27644	4.68	0.31	0.313
ICPL 850 10	5426	31223	25797	5.75	0.39	0.250
ICPL 87	5426	37573	32147	6.92	0.47	0.212
ICPL 840 31	5426	24740	19314	4.56	0.31	0.320
ICPL 871 19	5426	46040	40614	8.84	0.58	0.173
ICPL 940 62	5426	34133	28707	6.29	0.43	0.233
ICPL 940 63	5426	47055	41629	8.67	0.59	0.170
		Intercropping soybean + pigeonpea				
ICPL 850 10 (4:2)	9003	39028	30025	4.33	0.29	0.340
ICPL 850 10 (2:2)	9003	39352	30349	4.37	0.30	0.330
ICPL 87 (4:2)	9003	44115	35112	4.90	0.33	0.300
ICPL 87 (2:2)	9003	46217	37214	5.13	0.35	0.290
ICPL 840 31 (4:2)	9003	45026	26023	5.00	0.34	0.290
ICPL 840 31 (2:2)	9003	38632	29629	4.29	0.29	0.340
ICPL 871 19 (4:2)	9003	61975	52972	6.88	0.47	0.210
ICPL 871 19 (2:2)	9003	58815	49812	6.53	0.44	0.220
ICPL 940 62 (4:2)	9003	47275	38272	5.25	0.36	0.280
ICPL 940 62 (2:2)	9003	42968	33965	4.77	0.32	0.300
ICPL 940 63 (4:2)	9003	59506	50503	6.61	0.45	0.220
ICPL 940 63 (2:2)	9003	57271	48268	6.36	0.43	0.230
CD (P=0.05)	-	11257	10338	1.49	0.10	0.060

Mean results of two years showed that intercropping of pigeonpea varieties with soybean was beneficial than sole soybean. Among the pigeonpea varieties, ICPL 871 19 and ICPL 940 63 emerged as better compatible for intercropping with soybean as evidenced from higher land equivalent ratio, relative crowding coefficient, monetary advantages, income equivalent ratio and lower values of competition ratio.

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Phosphorus management in soybean, *Glycine max* (L.) Merr. - sunflower, *Helianthus annuus* L. cropping system

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Abstract

Optimum phosphorus requirement for soybean (*Glycine max* L. Merr.)- sunflower (*Helianthus annuus* L.) cropping sequence was studied during 1995-96 to 1999- 2000 through integrated use of organics and phosphorus solubilizing bacteria (PSB). The soybean (*kharif*)- sunflower (*rabi*) cropping system fertilized with 100% phosphorus for both the crops of higher productivity resulted in more productivity. However, for high benefit : cost ratio (2.36) and phosphorus economy, it was possible to reduce 50% dose of phosphorus needs of sunflower with seed treatment with PSB culture along with application of 5 t FYM/ha. The available phosphorus status of soil has enhanced where sunflower received 100% P. Substantial build up of available P was noticed in 100% P applied for both crops after each crop sequence.

Key words: Phosphorus, productivity, organics, PSB, BCR

Introduction

Among all the oilseed crops, soybean has occupied third place in the edible oil production in India. The area under soybean crop is increasing day by day as it can profitably replace the other legumes. Phosphorus plays important role in growth and development as well as maturity of crops. An adequate supply of phosphorus in the early stages helps in initiating its reproductive parts. It hastens maturity and improves quality of seed. Soybean-sunflower cropping sequence plays an important role in oilseed production in India. The phosphorus management involving the conjunctive views of fertilizers and organic sources assumed great importance recently due to paucity of phosphatic fertilizers and need to sustain productivity (Nambiar and Abrol, 1989).

Soybean and sunflower are the most nutrient exhaustive crops. The existing system is based on the nutrient requirement of individual crop ignoring the carryover effect of the fertilizer or manure to the preceding crop. Organic sources of nutrients applied to the preceding crop benefit the succeeding crop to a great extent (Hegde, 1998). Hence a study was conducted to find out the optimum phosphorus management through organic and phosphorus solubilizing bacteria (PSB).

Materials and methods

The field experiments were conducted at Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* and *rabi* seasons of 1995-96 to 1999-2000 on fixed sites in Randomized Block Design with four replications. Ten treatments were imposed in the experiment (Table 1). The soil of the plot was Vertisol with pH 7.9. Initial available P status of soil was 14.3 kg /ha with available N 147.2 kg/ha and available K 372 kg/ha, respectively. Soybean variety PKV-1 and sunflower variety PKVSH-27 were grown as test crops with a recommended dose of fertilizer 30:75:30 NPK kg /ha (soybean) and 80:60:40 NPK kg/ha (sunflower) during all the years. Recommended dose of N and K was applied uniformly to all the treatments. Diammonium phosphate (DAP) was used as a source of P. The phosphorus solubilizing bacteria (PSB culture) was used for seed dressing as per treatment.

Results and discussion

System productivity

Application of 100% recommended P (75 kg P_2O_5/ha) to *kharif* soybean recorded significantly the highest seed yield (2284 kg /ha) over 50% recommended P and no phosphorus application. Highest seed yield was obtained with higher levels of P application as reported by Kesavan and Morachan (1973).

The pooled data of five years indicated that any reduction in application to soybean had significant adverse effect on its productivity even where the preceding sunflower received full P (Table 1). In sunflower, it was possible to reduce 50% P need when PSB and 5 t FYM/ha were used along with 100% P to preceding soybean.

Any reduction in P application had significant adverse effect on seed yield of sunflower. However, when PSB and 5 t FYM /ha were used, the yield was at par with treatment receiving 100% P by both crop sequences. The results also showed that 50% P needs of sunflower could be substituted by application of 5 t FYM/ha when the preceding crop of soybean receiving 100% P. Similar results was also reported by Bobde *et al.* (1998).

Table 1 Influence of phosphorus management on ancillary characters and seed yield of soybean-sunflower cropping system (five years average)

Treatment		Soybean				Sunflower					Seedyield (kg/ha)		B:C ratio
Soybean	Sunflower	Plant height (cm)	No. of pods/ plant	Seed yield/plant (g)	100 seed weight (g)	Plant height (cm)	Head diameter (cm)	Seed yield/plant (g)	100 seed weight (g)	Oil content	Soybean	Sunflower	
T_1 : 100% P	100 % P	48	39	9.9	11.9	118	11.4	17.5	3.3	40.1	2284	1122	2.40
T_2 : 50%	100% P	44	34	7.8	9.7	120	10.9	15.7	3.2	40.3	1806	1093	2.16
T_3 : 0% P	100% P	41	31	6.5	8.7	118	10.9	16.8	3.0	39.6	1500	1070	2.04
T_4 : 100% P	50% P	45	36	8.7	11.1	118	10.4	13.3	2.7	39.5	2118	884	2.21
T_5 : 100% P	50% P + PSB	45	38	9.0	12.2	118	10.1	13.6	2.9	39.7	2192	1000	2.36
T_6 : 100% P	50% P + 5 t FYM/ha	44	39	9.1	11.3	125	10.6	14.9	3.1	40.0	2227	1058	2.12
T_7 : 100% P	50% P + PSB + 5 t FYM/ha	43	34	9.6	11.1	127	10.7	15.7	3.1	40.1	2264	1100	2.16
T_8 : 100% P	PSB	42	36	8.8	11.1	118	9.6	12.9	2.9	40.6	2097	769	2.22
T_9 : 100% P	5 t FYM/ha	45	37	8.8	10.9	118	9.9	14.4	2.8	40.3	2131	909	2.06
T_{10} : 100% P	PSB + 5 t FYM/ha	45	37	9.0	11.5	120	10.1	14.3	2.9	40.0	2143	1011	2.14
SEm±		0.69	1.09	0.30	0.22	0.12	0.04	0.30	0.07	0.30	24	14	
CD (P=0.05)		2.07	3.02	0.91	0.67	0.37	0.12	0.61	0.21	NS	72	39	

The total productivity measured in terms of soybean seed equivalents showed the maximum with 100% P applied to each crop of the system. Similar results were also reported by Bhatnagar *et al.*,(1996) and Raskar *et al.*, (2000). The crop productivity was declined by 34 and 21% when the recommended P was reduced to 50% P and 0%P. Either one crop, the 50% substitution of P to sunflower by 50% P with PSB could also recorded slightly higher net monetary returns and benefit cost ratio (2.36) than 100% P to both crops. The net monetary returns from the system also indicated the possibility of reducing 50% P to sunflower by application of PSB and/or 5 t FYM/ha with marginal decline in profitability.

Soil fertility

There was substantial build up of soil P in all the treatments over years, while the mean available phosphorus content in the soil (21.03 kg/ha) was increased by 47.6% over its initial P value of 14.3 kg/ha. The build up was maximum with application of 100% P to both crops. Shanti and Sreenivasa Raju (2001) observed that application of P at different levels resulted in increase in content of available P after harvest of sunflower.

Yield and yield components

The data pertaining to yield components of soybean *viz*, pods/plant, yield/plant and test weight and with regard to sunflower *viz*, oil content, head diameter and yield/plant also followed similar trend and recorded highest with application of 100% P to both crops. Application of P significantly increased seed yield, number of pods/plant, seed yield/plant and oil yield. This might be due to abundance of P in seeds which stimulated the formation to filled compact seeds and increase in seed number (Kesavan and Morachan , 1973; Mishra *et al.*, 1995).

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Effect of tillage and plant density on performance of sunflower, *Helianthus annuus* L. in rice fallows

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Abstract

Field experiments were conducted during summer seasons of 1998-99 to 2000-01 to study the influence of tillage and plant density on performance of sunflower in rice fallows on Vertisols. Highest yield of sunflower was obtained with conventional tillage (i.e. ploughing twice with country plough followed by harrowing twice with blade harrow), which was significantly higher over minimum and reduced tillage. Recommended plant population resulted in highest seed yield compared to 75% and 200% of recommended population. The oil yield was also maximum under conventional tillage practice with recommended plant population.

Key words: Sunflower, tillage, spacing, plant population density

Introduction

The limitations of water resources in command, tankfed and well-irrigated areas demands the cultivation of irrigated dry crops after rainy season puddled rice. Pulses and oilseeds hold promise in such situations by virtue of their low water requirement. Sunflower has emerged as a potential oilseed crop after rice. Krishna and Reddy (1997) reported higher production efficiency and net returns from rice – sunflower sequence in Andhra Pradesh. The soil condition after puddled rice poses limitation for growing arable crops and thus yield levels of crops following rice are generally low as compared to the normal yield of these crops. The main problems for crops grown after puddled rice are low plant stand establishment due to larger clods formed by rice stubbles, restricted root growth and poor aeration due to formation of hard pan in sub soil and low nutrient use efficiency due to adverse physical, chemical and biological environment in the rhizosphere. In order to determine the optimum tillage requirement for better plant stand establishment and to trade off between tillage practices and seed rate, the present investigation was carried out for achieving optimum tilth and plant stand for normal yield of sunflower.

Materials and methods

Field experiments were conducted on Vertisols of Regional Agricultural Research Station, Nandyal, Andhra Pradesh during summer seasons of 1998-99, 1999-2000 and 2000-01 wherein rainy season puddled rice was the previous crop. Sunflower hybrid APSH 11 was sown under three tillage practices (*viz.*, conventional tillage, reduced tillage and minimum tillage) as main plots and four spacings *viz.*, 75 x 30 cm (75% of recommended plant population: 44,444 plants/ha); 60 x 30 cm (Recommended plant population: 55,555 plants/ha); 45 x 30 cm (125% of recommended plant population: 74,074 plants/ha); and 45 x 20 cm (200% of recommended plant population: 1,11,111 plants/ha) as sub plots. The Split Plot Design was adopted with three replications. The soil of the experimental field was low in available nitrogen (192 kg N/ha), high in available phosphorus (28.6 kg P/ha) and medium in available potassium (218 kg K_2O/ha) with a pH of 7.6. Conventional tillage comprised of ploughing twice with country plough (criss-cross) followed by harrowing twice with blade harrow (criss-cross), reduced tillage consisted of ploughing once with country plough followed by harrowing once with blade harrow and in minimum tillage, the surface biomass of weeds and paddy stubbles were suppressed by using herbicide and after a week's time, with a pre-sowing light irrigation furrows were opened in between rows of paddy stubbles and sowing was done by hand dibbling as per the sub plot treatments during last week of January. The crop received three irrigations during the crop growth period.

Results and discussion

Effect of tillage: During 1998-99, tillage treatments significantly influenced the plant population, head diameter, seed yield and oil yield of sunflower. The seed yield was higher with conventional tillage (1006 kg/ha) followed by minimum tillage (990 kg/ha), which were almost similar (Table 1). Significantly lower yield (734 kg/ha) was obtained with reduced tillage. Like seed yield, the oil yield was also significantly higher with conventional tillage (344 l/ha) followed by minimum tillage (328 l/ha). Lowest oil yield was with reduced tillage (253 l/ha).

Table-1 Effect of tillage and plant population on yield attributes and yield of sunflower in rice fallows

Treatment	Final plant population ('000/ha)				Head diameter (cm)				Seed yield (kg/ha)				Oil yield (l/ha)			
	1998-99	1999-00	2000-01	Mean	1998-99	1999-00	2000-01	Mean	1998-99	1999-00	2000-01	Mean	1998-99	1999-00	2000-01	Mean
Tillage																
Conventional	40.9	43.3	42.2	42.1	9.0	8.3	7.8	8.4	1006	1180	1047	1078	344	409	345	366
Reduced	39.5	39.5	39.8	39.8	8.1	7.9	7.4	7.8	734	977	780	814	253	307	253	271
Minimum	37.8	38.1	39.0	39.0	8.5	7.8	7.5	7.9	990	830	690	836	328	278	218	275
SEm±	0.6	2.0	0.4	0.4	0.2	0.3	0.3	0.1	20	105	41	66	5	33	14	21
CD (P=0.05)	2.1	NS	1.7	1.7	0.5	NS	NS	0.3	77	NS	161	259	20	NS	51	82
Spacing																
75 x 30 cm	24.9	25.9	26.0	26.0	8.9	8.5	8.0	8.5	970	887	741	866	330	297	238	288
60 x 30 pm	30.7	33.0	32.0	32.0	8.7	8.3	7.6	8.2	923	1072	913	969	313	363	302	326
45 x 30 cm	44.8	44.2	45.0	44.7	8.6	7.8	7.4	7.9	966	1033	900	966	326	355	290	324
45 x 20 cm	57.3	58.2	58.0	57.9	8.0	7.3	7.2	7.5	780	924	803	836	265	312	258	278
SEm±	0.5	1.4	0.7	0.3	0.3	0.3	0.1	0.1	25	69	38	26	8	21	12	9
CD (P=0.05)	1.4	4.2	2.1	0.9	NS	NS	0.3	0.3	76	NS	114	78	24	NS	36	26
Interaction																
SEm±	0.8	2.4	1.2	0.6	0.4	0.6	0.2	0.2	44	119	66	46	14	37	21	15
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	131	NS	NS	136	42	NS	NS	45

Table 2 Interaction effect of tillage and plant population on seed and oil yield of sunflower in rice fallows

Tillage/ Spacing	Seed yield (kg/ha)										Oil yield (l/ha)									
	1998-99					Pooled mean					1998-99					Pooled mean				
	75x30 cm	60x30 cm	45x30 cm	45x20 cm	Mean	75x30 cm	60x30 cm	45x30 cm	45x20 cm	Mean	75x30 cm	60x30 cm	45x30 cm	45x20 cm	Mean	75x30 cm	60x30 cm	45x30 cm	45x20 cm	Mean
Conventional	911	1148	1062	902	1006	947	1284	1111	969	1078	323	394	357	303	344	322	442	377	323	366
Reduced	833	789	735	580	734	782	841	857	775	814	285	267	250	210	253	261	277	286	260	271
Minimum	1167	832	1101	858	990	869	782	931	764	836	382	277	371	281	328	282	258	309	250	275
Mean	970	923	966	780		866	969	966	836		330	313	326	265		288	326	324	278	

Interaction	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
For comparing two spacing means at same tillage practice	43.8	131.4	45.2	135.6	13.8	41.4	14.9	44.7
For comparing two tillage means at same or different spacings	44.0	130.7	45.8	136.1	14.1	41.9	15.4	45.8

The superior performance of sunflower in conventional and minimum tillage over reduced tillage can be attributed to more number of plants at maturity and increased head diameter (Table 1). During 1999-2000, yield attributes and yield of sunflower were not influenced significantly due to tillage treatments. During 2000-01, tillage practices markedly influenced the yield of sunflower. The seed yield, oil yield and final plant population were higher in conventional tillage and lower in minimum tillage. The magnitude of yield increase in conventional tillage was 52% over minimum tillage. Oil yield obtained in conventional tillage was significantly higher compared to minimum and reduced tillage.

The results of the pooled data over three years revealed that the performance of sunflower in conventional and minimum tillage was on par with respect to seed yield and the yield recorded in conventional tillage was significantly superior to that in reduced tillage. On an average, conventional tillage gave an increase in seed and oil yields to the tune of 32.4% and 35.1%, respectively over reduced tillage. The better performance of sunflower by practicing tillage operation through ploughing followed by rotovation is reported by Pratibha *et al.* (1994).

Effect of population: *During 1998-99, seed yield among* 75, 100 and 125% recommended plant population was on par and all the three treatments were significantly superior to 200% recommended plant population (Table 1). This was due to significantly higher head diameter. During 1999-2000, number of plants at maturity was significantly higher at 200% of recommended plant population, which can be attributed to optimum competition for the growth. However, different plant populations did not influence the seed and oil yields of sunflower in rice fallows. During 2000-01, seed and oil yield between 100% and 125% recommended plant population were on par but *significantly superior to 200% and 75% of recommended* plant populations while all the yield attributes recorded were significantly higher at 75% of recommended plant population level. Significantly lower plant population than optimum might have resulted in lower seed yield of sunflower at 75% of recommended plant population.

The pooled data revealed that higher seed yield could be obtained when sunflower was grown at its recommended and 125% of recommended plant population i.e. 55,555 and 74,074 plants/ha. Decreased per plant productivity at 200% of recommended population and reduced number of plants at 75% of recommended population could not compensate the yield that was achieved under 100% recommended plant population.

Interaction effect: During 1998-99, the interaction effects between tillage and plant population were found to be significant in respect of seed and oil yield (Table 2). The minimum tillage either at 75% or 125% of recommended plant population recorded significantly higher seed and oil yield. The interaction effect was not significant regarding yield attributes and yield of sunflower grown after *kharif* rice in 1999-2000. During 2000-01, head diameter, seed and oil yields were not significant.

The mean seed yield over three years recorded significant increase in conventional tillage over reduced and minimum tillage practices. The 100% and 125% recommended plant population gave significantly higher seed yield (Table 2). Any decrease or increase in plant population adversely affected the seed yield. Similar trend was observed in case of oil yield due to the interaction effect. The overall low yield levels of the crop in rice fallows might be due to formation of larger clods, which have interfered in prolific root distribution and development of sunflower crop while the plant emergence and plant population was normal in the treatments. The effect is seen with the reduction in head diameter and number of filled seeds thereby affecting seed setting and filling resulting in lower test weight and final yield (Reddy and Sudhakara Babu, 1999).

Conventional tillage is quite effective on the productivity of sunflower. Further, seed rate recommended for normal crop can also be used for growing sunflower in rice fallows.

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Isolation of salt endurant sunflower, *Helianthus annuus* L. genotypes through *in vitro* screening techniques

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Abstract

To identify the salt tolerant sunflower genotypes, *in vitro* techniques *viz.*, cell membrane stability test, tetrazolium test and paper towel method were employed. The critical or base concentration limit has been fixed as 3.39 dS/m through tetrazolium test. The assessment of seedling characters using paper towel method indicated a general reduction in shoot and root length, vigour index and drymatter production with increasing salt concentration. A maximum critical concentration to study the growth attributes has been fixed as 13 dS/m. The inhibition dose for 50% reduction in plant height was estimated using probit analysis and the graph plotted against coefficient of variation (CV) and mean to identify salt endurant genotypes. The genotypes GP 255, GP 336 and SF 54 were identified as salt endurant whilst Morden, 336 B and SF 7 were categorized as susceptible.

Key words: Sunflower, salt stress, *in vitro* screening

Introduction

Sunflower, the few among the prime oilseed crops of India gained momentum because of its quality worth oil content, but the productivity gets eclipsed due to the unsuitable soil environment especially soil salt content. Chemical reclamation of soil is cost effective and thus the better option is to deploy the genotypes that withstand and yield better. Screening genotypes in natural salty lands sometimes may give erroneous results. Hence, it is imperative to screen the genotypes *in vitro* and it could further ease the breeding cycle (Delgado and Sanchez-raya, 1998; Sajjan *et al.*, 1999). Earlier workers *viz.*, Muralidharadu *et al.* (1998); Tekin and Bozcuk (1998) and Sajjan *et al.* (1999) attempted *in vitro* screening of sunflower genotypes and enlightened the salt provoked alterations in the seed and young seedlings. They were limited only to single salt mostly NaCl to identify the salt induced effects. The present inquest utilized the triple salt for screening sunflower genotypes in controlled environment in different modes to fix the critical salt concentration and to identify **salt tolerant sunflower** genotypes.

Materials and methods

Twenty five diverse sunflower genotypes were utilized for the study. The experiments were carried out at induced salt combinations *in vitro* at Tamil Nadu Agricultural University, Coimbatore. The salt solution comprised of Cl: CO_3: HCO_3 ions with sodium base and prepared by mixing of one molar solution of NaCl, Na_2CO_3 and $NaHCO_3$ in 7:2:1 ratio as per the report of Singh and Singh (1999). The mixture was diluted five times with double distilled water. From these base concentrations known aliquots *viz.*, 10, 25, 50, 50, 100 and 150 ml were taken and diluted with one litre of ½ strength Hoagland solution (Hoagland and Arnon, 1936) depending upon the concentration required for the experiment. Final salt concentration of the solution was measured using EC meter and expressed as dS/m.

Cell membrane stability test: Five dehulled seeds in each genotype were immersed in solution with different concentrations of known electrical conductivity *viz.*, 2.05, 4.83, 8.70, 12.64 and 17.38 dS/m along with control (EC of 0.06 dS/m). The experimental set up was kept at room temperature for 48 hr and replicated twice in Factorial Complete Randomized Block Design. At the completion of the stipulated time the final conductivity was recorded using EC meter. The rate of the injury to cell membrane was estimated through the measurement of electrolyte leakage from the cells. The injury to cells due to the salt was worked out as per Blum and Ebercon (1981).

Tetrazolium test: Free hand tangential sections of tissues from the hypocotyl region of the stem (10 days old) in each genotype were placed in tubes at 0.61, 3.39, 6.19 and 8.77 dS/m EC for 24 hr at room temperature. After the prescribed time, the solution was drained and sections were washed free of salts with distilled water. Adequate quantity of 0.1% tetrazolium chloride solution was added to each vial containing the sections and kept for a day Later tissues were examined for colouration as per Monk and Wiebe (1961).

Growth analysis: Five seeds of each genotype were germinated in 2.32, 9.48, 13.65 or 17.36 dS/m EC concentrations. Concentration range was fixed based on the reports of Ashok Kumar *et al.* (1997). Paper towel method (ISTA, 1999) was used for germination test and was replicated twice. The experimental setup was maintained in germination room with a relative humidity of 70% and temperature of 27±1 °C. The growth parameters *viz.*, root length, shoot length and dry matter production were determined on the 10th day after sowing besides recording the germination percentage on the 4th day of the treatment. The observations were taken on five seedlings in each genotype at each concentration. Vigour index and percent reduction in seedling height with increasing salt concentrations were computed. The data were subjected to probit analysis to fix the ID 50 level for each genotype , the mean of the genotype across the environment and its co-efficient of variation were estimated using AGRISTAT. Genotypes were grouped as tolerant and susceptible by plotting the mean values against the co-efficient of variation in a graph.

Results and discussion

The extent of damage to the cell membrane is commercially used as a measure of tolerance to various stresses including salt (Leopold and Willing, 1983). In this experiment the degree of injury to cell membrane in a fixed concentration of salt was considered for grouping genotypes as tolerant and susceptible to surfeit salt. It is inferred that the sunflower genotypes suffered a cell membrane injury of 20.2 to 38.3 % at the concentration of 2.05 dS/m EC and injury percent escalated approximately to 20.4 % more with every 4 dS/m increase in the salt concentration (Fig. 2). The percent increase in the injury of cell membrane showed declining trend up to 17.38 dS/m EC. At this concentration (17.38 dS/m) all the genotypes exhibited more than 95% injury to the cell membrane. Genotypes among themselves exhibited greater variation in terms of percent injury towards differential salt concentrations and at any given EC level. Accordingly the genotypes *viz.*, CO2, 6B, GP 93, GP 255, GP 336 and SF 60 which had shown relatively very low injury at various salt concentrations were grouped as tolerant genotypes, concurrently 336 B, Morden, 86 B3 and CO3 were categorized as susceptible. It can be argued that tolerant genotypes adopt to stress through osmotic adjustment with an increase in cellular K^+ ions and organic acid concentrations (Blum and Ebercon, 1981).

Tetrazolium test: The highest EC salt concentration in which all the tissues developed colour in tetrazolium salt was recorded as the critical salt concentration and the genotypes were screened accordingly. The results indicated that all the genotypes developed medium red to dark red colour at the salt concentration of 0.61 dS/m EC. At the next level of salt concentration (3.39 dS/m) certain genotypes as Surya, 86B3, GP 86, SF 83, SF 30, SF 60 and SF 7 did not develop colour and categorized as susceptible genotypes. This concentration (3.39 dS/m) can be considered as critical for screening sodicity in sunflower. The genotypes SF 54, SF 34, GP 93 and 6B were grouped as tolerant as their tissues exhibited colour in the extreme concentration of 8.77 dS/m. Apart from this the genotypes CO 4, GP324, SF83, SF45 have developed colour up to 6.19 dS/m EC concentrations and this can be considered as moderately tolerant.

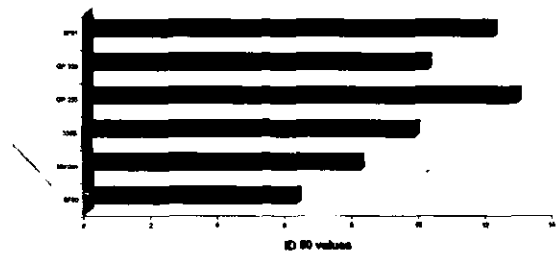

Fig 1 Effect of salt stress on seedling height reduction

Seedling growth: Owing to salt stress, the genotypes showed a general decrease in shoot length, root length, drymatter production and vigour index along with more reduction in percent germination with the increasing levels of salt *viz.*, 2.32, 5.35 and 9.48 dS/m. Such reduction in stress is attributed to the inhibition of hydrolysis of endosperm reserves (Ramana and Rama Das, 1978) and the translocation of food reserves from endosperm to embryo (Sheoran and Garg, 1978; Sharma, 1996) or induced earlier aging of tissues and extensive lignifications of the xylem elements due to salinity. Similar findings were also reported in sunflower by earlier workers (Muralidharudu *et al.*, 1998; Tekin and Bozcuk, 1998; Sajjan *et al.*, 1999).

A perusal of data on reduction in seedling height with increasing salt concentration denoted the differential responsiveness of the genotypes towards salt stress (Fig. 1). Fifty percent reduction in seedling height was attained by the genotypes at different concentrations depending upon the genotype buffering capacity to adjust with stress. The inhibition dose (ID 50) for sunflower to sodium chloride stress was reported as 66 m mol/l (Santos *et al.*, 1999). In the present study the inhibition dose ranged from 6.30 dS/m (SF 60) to 12.87 dS/m (GP

255) EC. This ID 50 value was extrapolated to group tolerant and susceptible genotypes. The genotypes that attained ID 50 at lower concentration itself were grouped as susceptible.

Based on this, SF 7, Morden, CO 2, 302 B and SF 60 were grouped as susceptible while CO 4, GP 255, SF 54, GP 161, 336 B and Surya were catagorised as tolerant. It can also be concluded that the maximum critical concentration for studying the impact of salt stress on the growth attributes is 13 dS/m.

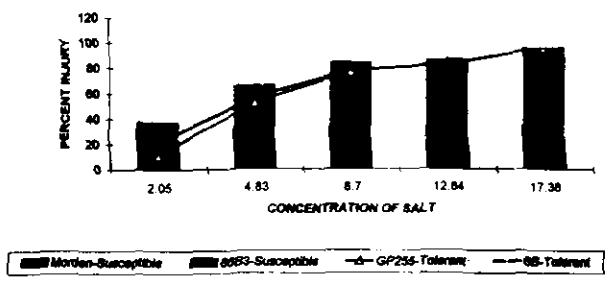

Fig 2 **Response of tolerant and susceptible genotypes to salt stress - per cent injury of cell membrane**

It is general consensus that, lower salinity or alkaline condition stimulates growth and dry matter production in certain crops (Sam Cherian *et al.*, 1999). In contrast, inhibitory effect on dry matter production and plant height is seen at higher concentrations (Polijakoff - Mayber and Lerner, 1999). Hence, the consistent performance of the genotypes at various salt concentrations can be taken as effective selection criteria for screening them for salt stress. Keeping this in view, two parameters *viz.*, dry matter production and vigour index (computed from root length +shoot length and germination%) were considered for screening tolerant and susceptible genotypes. In CV and mean plot, high mean with less CV indicates susceptibility. Thus genotypes SF 54, GP 86, CO4, 6B and GP 336 are endurant whereas 302B, Morden, 326 B and 86B3 were found out as susceptible genotypes (Fig 3 & 4).

The susceptible genotypes attained ID 50 at the concentration of 6.75 dS/m EC but the tetrazolium test and membrane integrity test revealed 50 % injury at EC values of 3.39 and 4.83 dS/m, respectively. Hence, it is concluded that 3.5 to 7.0 dS/m is the range of critical salt concentration to screen the sunflower genotypes for salt tolerance at seedling level. Based on different experiments, The genotypes GP 255, GP 336 and SF 54 were identified as tolerant while Morden, 336 B, 86B3 and SF 7 were identified as susceptible to salt stress at seedling level.

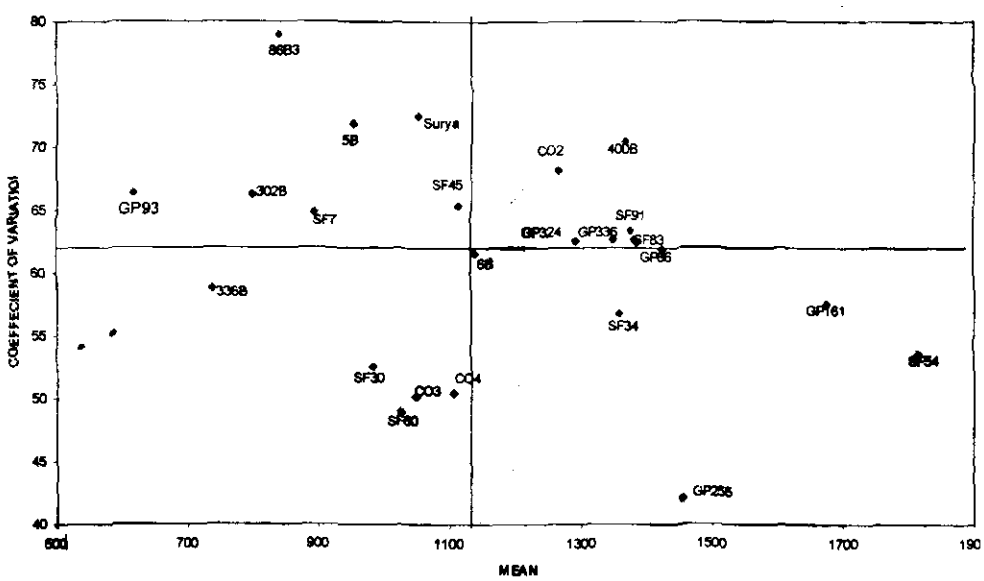

Fig 3 Genotype grouping based on vigour index

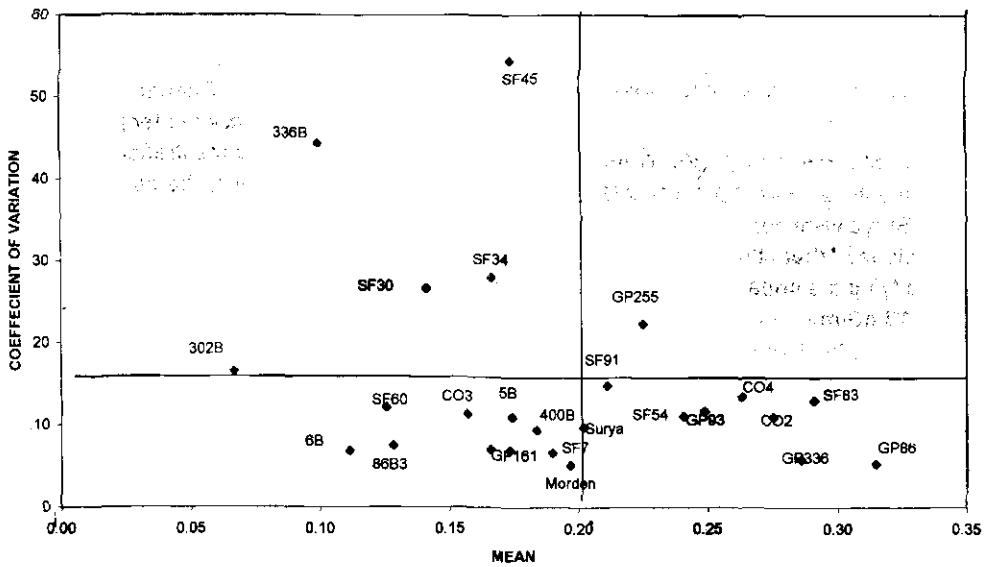

Fig-4 Genotype grouping based on drymatter production

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Alley cropping and green leaf manures - effective means of integrated nutrient management for sustained returns of rainfed castor, *Ricinus communis* L.

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Abstract

In a two years study, the seed yield of castor, *Ricinus communis* L. was significantly high when alley cropped with *Dalbergia sissoo* during both the years of 1996 (659 kg/ha) and 1997 (689 kg/ha) than sole cropping. Green leaf manuring with *Leucaena* resulted in much higher yields of castor with values of 626 kg/ha (1996) and 704 kg/ha (1997) when compared with other green leaf manures of *Dalbergia* and *Albizia*. Application of nitrogen significantly influenced the seed yield of castor. Conjunctive use of green leaf manure + 40 kg N/ha produced significantly on par yields of castor under alley cropping with that of 80 kg N/ha under sole cropping. Both net returns and B:C ratio were significantly high under alley cropping (Rs. 2621, 0.59) during 1996 and 1997 (Rs. 3683, 0.91). Leucaena green leaf manuring resulted in higher net returns and B:C ratio of Rs. 1626 and 0.40, respectively (1996) and Rs. 2802 and 0.69 (1997). Other sources, green leaf manures also produced equally better yields of castor. Nitrogen applied at 80 kg/ha produced higher net returns and B:C ratio. Integrated use of organic and inorganic sources of nitrogen had produced much higher returns than sole application of nitrogen or green leaf manures.

Key words: Alley cropping, green leaf manuring, castor, *Dalbergia, Albizia*

Introduction

Castor is an important oilseed crop of the country and state of Andhra Pradesh as well, largely cultivated as rainfed crop. The productivity of the crop is very low owing to poor management practices. Adoption of cropping systems and integrated nutrient management practices was the immediate thrust in oilseed research to maximise the production of oilseeds. Alley cropping, version of agroforestry, a system approach ensures use of green leaf manures, as the trees are pruned during cropping. Green leaf manures which are eco-friendly, augments the efficiency of applied fertilizer nitrogen and increases the yields and returns besides sustain the soil health (Kang *et al.*, 1990). Practices of such nature are imperative to boost the yields and returns of castor on sustainable basis in drylands. It was reported that the yields and returns of castor were high under alley cropping with subabul with green leaf manuring (Bheemaiah *et al.*, 1998). Therefore, the present study was initiated.

Materials and methods

The field experiment on response of rainfed castor to application of green leaf manures and nitrogen alley cropped with *Dalbergia sissoo* was carried out during *kharif* seasons of 1996 and 1997 at Students' Farm, College of Agriculture, Hyderabad. Double Split Plot Design was used with three replications. The soil of the experiment was low in organic carbon and available nitrogen in sole cropped area while in alley cropped area both organic carbon and available nitrogen were found medium. Similar status was observed in respect of P and K. Green leaf manures of *Albizia* and *Leucaena* were obtained from the stands nearby while *Dalbergia* green leaf was obtained by pollarding trees of the experimental area and applied along with recommended dose of P at 5 t/ha 15 days before sowing in the plots earmarked both in alley cropping and sole cropping by opening furrows. Nitrogen was applied as per the treatments. The gross and net plot size was 8 m x 4 m and 4 m x 4 m in alley and sole cropped area, respectively. The crop variety Aruna was sown on 17.7.1996 and 14.7.1997 by dibbling at a spacing of 60 x 30 cm both in alley cropped and sole cropped area and harvested on 15th October 1996 and 30th October, 1997. The gross returns were calculated taking into account the volume of wood obtained from *Dalbergia* in each plot and converted on hectare basis.

Results and discussion

Seed yields: Significant differences were observed in seed yield of castor (Table 1) due to cropping systems

with values of 659 kg/ha (1996) and 689 kg/ha (1997) under alley cropping and found superior to sole cropping of castor (505 and 607 kg/ha). The reasons attributed are reduced bulk density and improved organic matter leading to better growth and yield components. From alley cropping studies, Bheemaiah *et al.* (1998) reported similar results.

Leucaena green leaf manure (GLM_1) had resulted in significantly higher seed yield of castor during 1996 (626 kg/ha) and 1997 (704 kg/ha) over without green leaf manuring (511 and 526 kg/ha). Seed yield of castor with *Albizia* (GLM_2) and *Delbergia* (GLM_3) was also equally higher over GLM_0. However, both *Leucaena* and *Albizia* green leaves produced much better seed yields over *Dalbergia* due to less fibre and lignin content and more concentration of polyphenols as reported by Hussain *et al.* (1994).

80 kg N/ha had produced an increase of 94.5% (1996) and 98.4% (1997) seed yield over N_0 (374 and 410 kg/ha) but the increase was not much over N_{40} in both the year and significantly superior to both N_0 and N_{40}.

All the interaction effects were found significant. Alley cropping with GLM_1, AC with 80 kg N/ha and GLM_1 with 40 kg N/ha produced higher seed yields when compared to other treatments during both the years. However, alley cropping with GLM_1 at N_{40} had 760 kg/ha (1996) and 828 kg/ha (1997) which was superior over without green leaf manuring at N_{80} (745 and 725 kg/ha). Similar trend was observed under sole cropping. *Albizzia* (GLM_2) and Dalbergia (GLM_3) also produced similar effects under alley cropping with N_{40}. Presumably timely decomposition and release of nutrients as per crop demand under integrated use of GLMs and nitrogen might have lead to increased yields. Escalada and Ratilla (1998) also found that green leaf manures with nitrogen application would enhance mineralization leading to higher yields.

Table 1 Seed yield (kg/ha) of castor as influenced by cropping systems, green leaf manures and nitrogen levels

Treatment	1996				1997			
	N_0	N_{40}	N_{80}	Mean	N_0	N_{40}	N_{80}	Mean
Sole cropping (SC)								
GLM_0	263	470	570	434	271	516	663	483
GLM_1	349	618	679	548	402	743	818	654
GLM_2	335	585	666	528	406	743	823	657
GLM_3	347	529	653	510	386	694	817	632
Mean	323	551	642	505	366	674	780	607
Alley cropping (AC)								
GLM_0	348	672	745	588	352	630	725	569
GLM_1	500	760	851	704	521	828	914	754
GLM_2	428	753	833	671	480	811	883	725
GLM_3	425	756	831	671	468	791	872	710
Mean	425	735	815	659	455	765	848	689
GLM_0	305	571	657		311	573	694	
GLM_1	524	689	765		461	785	866	
GLM_2	381	669	749		443	777	853	
GLM_3	386	643	742		427	742	844	
Overall means of M.T. - Cropping systems, S.T. - Green leaf manures, S.S.T - Nitrogen levels								
M.T.	505	659			607	689		
S.T.	511	626	600	590	526	704	691	**671**
S.S.T.	374	643	728		410	719	814	

Interaction	SEd±	CD	SEd±	CD
MT	1.98	8.2	5.39	23.22
ST	5.09	11.10	7.46	16.25
MT x ST	6.54	13.83	10.61	22.59
SST	4.30	8.78	4.80	9.79
MT x SST	5.34	12.57	7.73	24.30
ST x SST	8.68	18.12	10.82	22.79
MT x ST x SST	8.22	18.51	11.97	30.90

GLM_0 - No green leaf manuring; MT = Main treatment; GLM_1 - *Leucaena* greenleaf manuring; ST = Sub-treatment
GLM_2 - *Albizia* greenleaf manuring; SST = Sub-sub treatment; GLM_3 - *Dalbergia* greenleaf manuring

Net returns: Alley cropping had higher net returns of Rs. 2621/ha (1996) and Rs. 2683/ha (1997) with an increase of 303% (1996) and 142.5% (1997) over sole cropping through increased seed yield associated with additional biomass from the trees and improved site conditions. Sharma *et al.* (1997) reported that higher net returns from alley cropping could be due to effect of trees in providing wood yield and improved soil physical properties. Significant differences were observed in net returns due to green leaf manures application with Rs. 2802/ha in GLM_1 followed by GLM_2 (Rs. 2544/ha) and GLM_3 (Rs. 2542/ha) during 1997. However, during first year, noticeable effect was not observed due to low yields of crop because of high rainfall during capsule formation stage. Application of 80 kg N/ha resulted in significantly higher net returns of Rs. 2369/ha (1996) and Rs. 3651/ha (1997) with an increase of 20.4% (1996) and 10.2% (1997) over 40 kg N/ha due to increased availability of nutrients resulting in higher yield (Table 2).

Table 2 Net returns (Rs/ha) of castor as influenced by cropping systems, green leaf manures and nitrogen levels

Treatment	1996				1997			
	N_0	N_{40}	N_{80}	Mean	N_0	N_{40}	N_{80}	Mean
Sole cropping (SC)								
GLM_0	0.0	824	1183	669	0.0	1647	2656	1434
GLM_1	0.0	955	1202	719	0.0	2324	2727	1683
GLM_2	0.0	691	1096	595	0.0	2327	1923	1417
GLM_3	0.0	646	992	546	0.0	1908	2715	1541
Mean	0.0	779	1218	665	0.0	2051	2505	1519
Alley cropping (AC)								
GLM_0	1287	2640	2978	2301	1992	4113	4680	3595
GLM_1	1255	3094	3248	2532	2170	4547	5046	3921
GLM_2	1000	3035	3438	2491	1820	4405	4779	3668
GLM_3	1000	3061	3421	2494	1727	4235	4680	3547
Mean	1135	2958	3271	2621	1927	4325	4796	3683
GLM_0	643	1732	2080		996	2880	3668	
GLM_1	627	2025	2225		1085	3436	3886	
GLM_2	500	1863	2267		910	3366	3788	
GLM_3	500	1653	2206		863	3072	3697	
Overall means of M.T. - Cropping systems, S.T. - Green leaf manures, S.S.T - Nitrogen levels								
M.T.	649	2621			1519	3683		
S.T.	1485	1626	1543	1453	2515	2802	2542	2544
S.S.T.	567	1968	2369		963	3188	3651	
Interaction		SEd±	CD		SEd±	CD		
MT		17.07	7349		103.49	445.35		
ST		47.87	104.30		113.76	247.89		
MT x ST		61.06	128.11		173.56	366.96		
SST		48.95	99.86		91.95	187.59		
MT x SST		59.05	131.64		148.27	465.97		
ST x SST		93.17	193.50		188.39	393.86		
MT x ST x SST		83.21	183.42		203.46	547.47		

All the treatments interactions influenced the net returns. Alley cropping with GLM_1 at 80 kg N/ha produced more net returns in both the years. However, the net returns obtained under alley cropping with GLM_1 at 40 kg N/ha were Rs. 3094/ha (1996) and Rs. 4547/ha (1997) and were comparable with GLM_0 at 80 kg N/ha (Rs. 2978 and Rs. 4680/ha) indicating advantage of conjunctive use of green leaf manures, nitrogen levels which might have increased the seed yield due to increased availability of nutrients. Palled *et al.* (1997) reported similar results.

Benefit cost ratio (BCR): During both the years of study alley cropping had higher BCR (0.59 and 0.91) due to high seed yield and additional wood yield. Green leaf manure had significant influence on BCR with higher values of 0.40 (1996) and 0.69 (1997) under GLM_1 followed by GLM_2, GLM_3 and GLM_0. The increase of BCR with GLM_1 over GLM_0 is marginal due to additional cost of green leaf manure application but green leaf manures would help to sustain soil health on long term basis. From an alley cropping study Bheemaiah *et al.* (1998) obtained similar B:C ratios with green leaf manuring of *Leucaena*. B:C ratio was found significantly higher with 80 kg N/ha with values of 0.59 (1996) and 0.92 (1997) (Table 3).

Interaction of different treatments significantly influenced the B:C ratio of castor in both the years. Alley cropping with green leaf manure of tree leaves with 40 kg N/ha had resulted in B:C ratio of 0.81 (1996) and 1.13 (1997) which were found higher than no green leaf manure at 80 kg N/ha (0.60 and 1.10). Therefore, that alley cropping helped to increase the yield and returns of castor than sole cropping. Green leaf manures of these nitrogen fixing trees with 50% recommended dose of nitrogen resulted in much higher yields and returns from rainfed castor.

Table 3 Benefit cost ratio of castor as influenced by cropping systems, green leaf manures and nitrogen levels

Treatment	1996				1997			
	N_0	N_{40}	N_{80}	Mean	N_0	N_{40}	N_{80}	Mean
Sole cropping (SC)								
GLM_0	0.00	0.37	0.30	0.22	0.00	0.60	0.89	0.49
GLM_1	0.00	0.24	0.28	0.17	0.00	0.58	0.65	0.41
GLM_2	0.00	0.21	0.28	0.16	0.00	0.58	0.66	0.41
GLM_3	0.00	0.19	0.25	0.15	0.00	0.48	0.64	0.37
Mean	0.00	0.25	0.27	0.17	0.00	0.56	0.71	0.42
Alley cropping (AC)								
GLM_0	0.34	0.62	0.60	0.52	0.53	1.03	1.10	0.89
GLM_1	0.34	0.77	0.77	0.75	0.58	1.13	1.19	0.97
GLM_2	0.27	0.76	0.81	0.63	0.48	1.11	1.13	0.91
GLM_3	0.27	0.77	0.81	0.61	0.44	1.06	1.10	0.87
Mean	0.31	0.73	0.75	0.59	0.51	1.08	1.13	0.91
GLM_0	0.17	0.50	0.45		0.27	0.82	0.99	
GLM_1	0.17	0.51	0.53		0.29	0.86	0.92	
GLM_2	0.14	0.49	0.56		0.24	0.85	0.89	
GLM_3	0.14	0.48	0.53		0.22	0.77	0.87	
Overall means of M.T. - Cropping systems, S.T. - Green leaf manures, S.S.T - Nitrogen levels								
M.T.	0.17	0.59			0.42	0.91		
S.T.	0.33	0.40	0.39	0.38	0.69	0.69	0.66	**0.62**
S.S.T.	0.15	0.53	0.59		0.25	0.82	0.92	

Interaction	SEd±	CD (P=0.05)	SEd±	CD (P=0.05)
MT	0.008	0.019	0.012	0.028
ST	0.011	0.024	0.013	0.031
MT x ST	0.015	0.032	0.021	0.045
SST	0.012	0.026	0.011	0.022
MT x SST	0.017	0.036	0.017	0.037
ST x SST	0.023	0.049	0.022	0.047
MT x ST x SST	0.021	0.046	0.024	0.054

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Soil test based fertiliser recommendation for sunflower, *Helianthus annuus* L. in Inceptisols of Tamil Nadu

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Abstract

Soil Test Crop Response (STCR) correlation studies were conducted with sunflower on Inceptisols of Coimbatore during *kharif*, 2000 and *rabi*, 2001 and fertiliser prescription equations under Integrated Plant Nutrition System (IPNS) were developed. Using these equations, test verification trial was conducted at University farm and the fertiliser prescription equations were refined to achieve the yield targets aimed at. A ready reckoner of fertiliser doses at varying soil test values for attaining 1.5 and 2.0 t/ha yield target of sunflower have been worked out. The results have been verified in farmers' field of Coimbatore district. The percent achievement of the targets aimed was more than 90 indicating the validity of the equations for prescribing fertiliser doses for sunflower. STCR treatments recorded relatively higher Response Ratio (RR) and Benefit-Cost Ratio (BCR) over general recommended dose and farmer's practice and STCR-IPNS treatments recorded relatively higher RR and BCR over STCR-NPK alone treatments. Post – harvest soil sample analysis for NPK revealed that there is maintenance of soil fertility.

Key words: Sunflower, Inceptisols, STCR studies, test verification trials

Introduction

Oilseed crops constitute the second largest agricultural produce in India after food grains. It is observed that the energy rich oilseed crops are grown in energy starved conditions. Oilseeds are grown on poor soils, which are further becoming poorer day by day. This is the main reason for low productivity of these crops. Sunflower is one of the important oilseed crops with a very low productivity of 550 kg/ha and hence the productivity has to be improved (Mandal *et al.*, 2002). Again, increasing the crop productivity demands higher inputs, which are costly. Therefore, there is a need for improvement of input use efficiency through proper utilisation of the interaction effects of plant nutrients, by balanced nutrition of crops. However, the constant escalation of fertiliser prices in the recent years has caused a severe set back to balanced nutrition of sunflower crop too. So there is much scope to increase the productivity by exploiting full potential of sunflower by better management practices and balanced nutrition. Hence, the present study was undertaken to verify the validity of fertiliser prescription equations under IPNS for sunflower in mixed black soils of Coimbatore district and to advocate which yield target gives the highest Benefit Cost Ratio (BCR) and Response Ratio (RR) to the farmers in that region.

Materials and methods

Following the Inductive cum Targeted yield model of Ramamoorthy *et al.* (1967), Soil Test Crop Response (STCR) correlation studies were carried out and fertiliser prescription equations under IPNS were developed for sunflower as below:

$$FN = 10.29\,T - 0.45\,SN - 0.68\,ON$$
$$FP_2O_5 = 7.36\,T - 2.18\,SP - 0.80\,OP$$
$$FK_2O = 12.69\,T - 0.45\,SK - 0.64\,SK$$

To test verify these equations on mixed black soils (Perianaickenpalayam soil series), verification trial was conducted at TNAU farm, Coimbatore during *kharif*, 2000 with variety CO 2. To achieve the targeted yields, the equations were refined as below using this trial data.

$$FN = 9.60\,T - 0.49\,SN - 0.68\,ON$$
$$FP_2O_5 = 4.20\,T - 1.87\,SP - 0.80\,OP$$
$$FK_2O = 9.24\,T - 0.45\,SK - 0.64\,OK$$

where, FN, FP_2O_5, FK_2O are fertiliser doses and SN, SP, SK are soil test values in kg/ha.

NR - Nutrient requirement in kg /q of seed yield

Cs, Cf and Co is the per cent contribution of nutrients from soil, fertiliser and organic manures respectively.

T is the yield target in q/ha.

A ready reckoner of fertiliser doses at varying soil test values for attaining 1.5 and 2.0 t/ha yield targets of

sunflower have been worked out. The results were verified in farmer's field of Coimbatore district (Kalipalayam, Kovilpalayam block) during *rabi*, 2001 with variety CO 2. The initial soil $KMnO_4$-N, Olsen-P and NH_4OAC-K of TNAU farm soil were 196, 9.0 and 810 kg / ha and that of farmer's field were 204, 30 and 560 kg/ha respectively. There were six treatments, which were replicated four times in a randomized block design. The treatment details and doses of fertilisers applied are furnished in Tables 1 and 2. Based on initial soil tests for NPK and targets aimed at, fertiliser doses were applied for STCR treatments.

For IPNS treatments, FYM @ 12.5 t/ha was applied basally, along with 50% N, and full P_2O_5 and K_2O. Fifty per cent of N was top dressed on 30th day after sowing. Routine agronomic practices were carried out periodically. Seed yield was recorded at harvest. Using the data on seed yield, fertiliser doses applied and cost of fertiliser inputs and produce, the parameters *viz.*, Response Ratio (RR) and Benefit – Cost Ratio (BCR) were worked out (Response Ratio = Response in kg/ha/Quantities of fertiliser N, P_2O_5 and K_2O applied in kg/ha; Benefit–Cost Ratio = Cost of additional seed yield over control/Cost of fertiliser N, P_2O_5 and K_2O applied).

Post-harvest soil samples were also collected and analysed for the status of available N (Subbiah and Asija, 1956), available P (Olsen *et al.*, 1954) and available K (Hanway and Heidal, 1952).

Results and discussion

In both the locations, the highest seed yield was recorded with 2.0 t/ha – IPNS treatment, which was on par with 2.0 t/ha – NPK alone followed by 1.5 t/ha - IPNS and 1.5 t/ha - NPK alone (Table 1 and 2). The seed yields recorded under STCR treatments were significantly higher than that under general recommended and farmer's practice/control. The mean seed yield ranged from 530 kg/ha in control to 1665 kg/ha in 2.0 t/ha – IPNS treatment in TNAU Farm and from 1346 kg/ha in farmer's practice to 1890 kg/ha in 2.0 t/ha IPNS treatment. The highest percent achievement of the yield targets aimed at was recorded with 1.5 t/ha yield targets (97.0 – 101.7). However, the 2 t/ha yield target was not achieved during *kharif*, 2000 and hence, the basic parameters *viz.*, the nutrient requirement, the contribution of nutrients from soil and fertiliser were refined using this trial data (Table 3). The refined fertiliser prescription equations were again test verified during *rabi*, 2001 and it was found that both the yield targets (1.5 and 2.0 t/ha) tested were achievable. Yield targeting with IPNS recorded relatively higher percent achievement than that aimed under NPK alone (Tables 1 and 2). This might be ascribed to the release of nutrient ions with mineralisation of organic manures, which helps in maintaining the continuous availability of nutrients throughout the crop growth (Khatik and Dikshit, 2001). The positive influence of IPNS in increasing the seed yield of sunflower was also reported by Mandal *et al.* (2002).

Table 1 Test verification trial on sunflower (TNAU Farm, Coimbatore)

Treatment	Fertiliser nutrient doses applied (kg/ha)			Seed yield (kg/ha)	% achieve-ment	RR (kg/kg)	BCR	Post-harvest soil sample value (kg/ha)		
	N	P_2O_5	K_2O					N	P	K
General recommended dose	40	20	20	925	-	4.94	2.33	192	9.0	796
1.5 t/ha - NPK alone	66	91	10*	1360	90.7	4.97	3.39	200	11.0	804
2.0 t/ha - NPK alone	118	128	10*	1610	80.5	4.22	2.95	214	12.0	795
1.5 t/ha - IPNS**	26	69	5*	1455	97.0	9.25	3.91	210	13.0	834
2.0 t/ha - IPNS**	78	106	5*	1665	83.3	6.00	3.17	228	12.0	851
Control	0	0	0	530	-	-	-	180	8.0	650
SEd±				58				7	0.84	12
CD (P=0.05)				124				16	1.79	24

* Maintenance dose; ** IPNS-FYM @ 12.5 t/ha

Table 2 Test verification trial on sunflower (Farmer's field, Coimbatore)

Treatment	*Fertiliser nutrient doses applied (kg/ha)*			Seed yield (kg/ha)	% achieve-ment	RR (kg/kg)	BCR	*Post-harvest soil sample value (kg/ha)*		
	N	P_2O_5	K_2O					N	P	K
Blanket	40	20	20	1400	-	6.26	4.88	200	28	560
1.5 t/ha - NPK alone	44	7	10	1415	94.3	7.66	5.19	202	32	576
2.0 t/ha - NPK alone	92	28	10	1812	90.6	6.86	5.24	210	30	565
1.5 t/ha - IPNS**	14	5*	5*	1526	101.7	8.81	7.67	220	34	580
2.0 t/ha - IPNS**	62	13	5*	1890	94.5	7.33	7.40	224	32	584
Farmer's practice	50	40	50	1346	-	4.76	4.35	202	34	580
SEd±				53				6	3	9
CD (P=0.05)				113				13	7	20

RR = Response Ratio; BCR = Benefit Cost Ratio; * Maintenance dose; **IPNS-FYM @ 12.5 t/ha

Table 3 Soil test based fertiliser recommendations for various yield targets of sunflower (kg/ha)

	Basic data				*Fertiliser adjustment equations*	*Response ratio (kg/kg)*
	NR (kg/q)	CS (%)	CF (%)	CO (%)		
N	2.56	13.2	26.78	18.21	$FN = 9.60\ T - 0.49\ SN - 0.68\ ON$	4.3
P	1.44	27.93	34.20	11.95	$FP_2O_5 = 4.20\ T - 1.87\ SP - 0.80\ OP$	
K	2.68	10.79	29.00	15.34	$FK_2O = 9.24\ T - 0.45\ SK - 0.64\ OK$	

Soil Test Values (kg/ha)			Yield targets (t/ha)					
			1.5 t/ha of seed yield			2.0 t/ha of seed yield		
$KMnO_4$-N	Olsen-P	NH_4OAC-K	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O
150	8	200	70	48	49	119	70	95
160	10	210	66	44	44	114	65	90
170	12	220	61	41	40	109	62	86
180	14	230	56	36	35	104	58	81
190	16	240	51	33	31	99	54	77
200	18	250	46	29	26	94	50	72
210	20	260	41	26	22	89	47	68
220	22	270	36	22	17	84	43	63
230	24	280	31	18	13	79	39	59
240	26	290	26	14	8	74	35	54

The mean response ratio (RR) for various treatments ranged from 4.94 kg/kg in general recommended dose to 9.25 kg/kg in 1.5 t/ha – IPNS treatment in TNAU Farm and from 4.76 kg/kg in farmer's practice to 8.81 kg/kg in 1.5 t/ha – IPNS treatment. Between the two targets tried, targeting for 1.5 t/ha recorded relatively higher RR than with 2.0 t/ha though it has recorded significantly higher yields. Likewise IPNS treatments recorded higher RR when compared to the respective NPK alone treatments. General recommended dose recorded 4.94 – 6.26 kg/kg, which is lower than STCR treatments (Tables 1 and 2).

The mean BCR ranged from 2.33 in blanket to 3.91 in 1.5 t/ha – IPNS in TNAU farm and from 4.35 in farmer's practice to 7.67 in 1.5 t/ha–IPNS. The trend of results is same, as that of RR. Between the targets aimed, 1.5 t/ha recorded higher BCR over 2.0 t/ha. When NPK alone and IPNS treatments were compared, IPNS recorded higher BCR (Tables 1 and 2). Though the yields recorded under NPK alone and IPNS were statistically on par there is saving of fertiliser inputs and utilisation of FYM available in the farm holdings, which has reflected in terms of BCR. The beneficial effect of organics on the economics of crop production was also reported by Khatik and Dikshit (2001).

The data on $KMnO_4$-N, Olsen-P and NH_4OAc-K indicated the built up and maintenance of soil fertility due to soil test based fertiliser recommendation and IPNS. The increase could be due to the contribution of nutrient sources and enrichment of available pool of the soil. The favourable effect of FYM on fertility status of soil may be attributed to greater availability of nutrients to plants in the presence of organic manures due to their solubilising effect of different forms of nutrients present in soil and their own contribution (Subba Rao *et al.*, 1998). Therefore for getting targeted yields and profit with sunflower in black soils of Tamil Nadu, soil test based fertiliser recommendation under IPNS could be followed (Table 3).

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Effect of preceding *kharif* legumes and levels of NPK on the succeeding *rabi* sunflower, *Helianthus annuus* L.

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Abstract

Field experiments were carried out for three years in *kharif-rabi* sequence to evaluate the performance of *rabi* sunflower raised with different levels of NPK succeeding *kharif* leguminous crops *viz.*, urdbean, mungbean, soybean and groundnut. Sunflower succeeding *kharif* groundnut recorded the highest seed yield in all the three years of experimentation and the increase was 38, 70 and 86% over fallow-sunflower system. Recommended dose of NPK to sunflower recorded higher plant height, head diameter, 100 seed weight and seed yield compared to 75, 50% NPK and no fertilizer application. The *interaction indicated that application of 100%* recommended NPK to *rabi* sunflower grown after *kharif* groundnut recorded significantly higher seed yield than the other sequences in all the three years of study.

Key words: Legumes, fertilizer and sequence

Introduction

Crop rotation assumes greater significance in sustaining the crop productivity and soil fertility. Continuous cultivation of exhaustive crops impairs the soil fertility (Sanjay Kumar and Prasad, 1999). Monocropping has a negative effect on enzymatic activities particularly in soils of rainfed areas showing lower values of microbiological and biochemical properties than native soils (Pascual *et al.*, 2001). Continuous cropping of maize, wheat/sunflower recorded lower yields as compared to growing these crops in sequence with legumes. The low yield under monocropping can be attributed to removal of nutrients and moisture from the same soil depth over years (Palaniappan, 1985). Sunflower yields are often low when grown after small grains or corn than after legumes. Crop rotation supported by scientific fertilizer management can lead to sustained productivity besides, maintaining soil fertility and keeping weeds, insects, and pests under control. Studies are available with nutrient management for sunflower in different context. The present study is aimed at selection of suitable *kharif* legumes preceding *rabi* sunflower and to appraise the nutrient requirement of sunflower succeeding legumes for maximum and profitable productivity.

Materials and methods

Field experiments were conducted in the research farm of Tamil Nadu Agricultural University, Coimbatore for three years (1997-1999) in *kharif* (June-September) - *rabi* (November-February) sequence. The experiment was laid out in Split Plot Design with three replications. The type of the experimental site was sandy loam and neutral in reaction. The soil available nutrient status of nitrogen, phosphorus and potash was medium, low and high, respectively.

The study was carried out under protective irrigation. During *kharif* season, the legume crops *viz.*, groundnut, soybean, mungbean and urdbean along with one fallow treatment for comparison were assigned to the main plots and sowing was taken up during June-July. After the harvest of legume crops, sunflower was raised during *rabi*, dividing each main plot into four subplots and assigning the fertilizer levels (Table 2). The recommended dose of 40:20:20 kg/ha NPK was applied to sunflower as per treatment through urea, single super phosphate and muriate of potash, respectively. Entire quantity of phosphorus and potassium and 50% nitrogen was applied as basal at the time of sowing. The remaining 50% nitrogen was applied as top dressing 30 days after sowing. Sunflower was raised on ridges and furrows with a spacing of 45 cm between rows and 30 cm between plants. The yield and yield attributing data was recorded and economics was worked out.

Results and discussion

The data on growth and yield attributes showed that the plant height, head diameter and test weight were favourably influenced by both the cropping sequences and fertilizer levels tried (Table 1). Among the crop sequences studied, sunflower, succeeding groundnut significantly influenced the yield parameters in all three years of experimentation recording the highest plant height, head diameter and test weight of seed. Application of 100% of

NPK fertilizer positively influenced all the yield attributing characters. The interaction effect of crop sequence and fertilizer levels was found to be significant. Application of 100% recommended dose of fertilizer to sunflower under groundnut-sunflower sequence recorded the highest values of growth and yield parameters.

Sunflower succeeding groundnut recorded highest seed yield in all the three years of study (Table 2). The seed yield increase in groundnut-sunflower sequence was 70% compared with that of fallow sunflower sequence. Similarly legumes preceding sunflower also increased the seed yield of sunflower compared with that grown after fallow and the increase was 37, 34 and 30% with urdbean, mungbean and soybean, respectively. The beneficial residual effect of legumes on the succeeding crops in sequence is quite evident, supporting the findings of many earlier workers (Misra and Rout, 1996; Dwivedi *et al.*, 1998; Sanjay Kumar and Prasad, 1999).

With regard to application of fertilizers, a linear increase was noticed with increasing levels of fertilizer and the highest seed yield was recorded with application of 100% recommended dose of NPK to sunflower. The interaction effect of crop sequences and fertilizer levels was significant during all the three years of study and a linear and progressive yield increase was observed under groundnut-sunflower cropping sequence combined with the application of graded levels of fertilizer. The highest seed yield of 1239 kg/ha of sunflower was recorded under groundnut-sunflower cropping sequence with application of 100% of recommended dose of fertilizer. The yield increase with application of full recommended dose under groundnut-sunflower sequence was 51.5% compared with that of fallow-sunflower with 100% fertilizer application to sunflower. Thus the beneficial influence of groundnut as a preceding legume was much pronounced with application of higher levels of fertilizer in increasing the productivity of succeeding sunflower.

The economic analysis of the results (Table 3) indicated that among the crop sequences, groundnut-sunflower was most remunerative in terms of gross and net returns with the benefit cost ratio of 4.78. Urdbean and mungbean were also found to be remunerative compared with that of fallow treatment registering increased returns and cost benefit ratio. Among the fertilizer levels a progressive increase in gross returns, net returns and benefit cost ratio was observed with the increasing levels of fertilizer application. The maximum benefit cost ratio of 3.68 was obtained with the application of 100% recommended dose of fertilizer.

It is evident from the study that groundnut must be preferred as a preceding legume during *kharif* for enhancing the productivity of succeeding sunflower and 100% recommended dose of fertilizer to sunflower may be applied for maximizing the system productivity.

Table 1 Morphological attributes of sunflower as influenced by treatments

Treatment	Plant height (cm)			Head diameter (cm)			100 seed weight (g)		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
Crop sequence									
Urdbean-Sunflower	135	134	136	10.6	10.9	11.2	4.0	3.9	3.8
Mungbean-Sunflower	132	130	132	10.4	10.7	10.9	3.9	3.9	3.9
Soybean-Sunflower	132	131	133	10.3	10.5	10.6	3.8	3.8	3.9
Groundnut-Sunflower	138	139	140	11.9	12.3	12.4	4.1	4.1	4.1
Fallow-Sunflower	126	124	127	9.7	9.1	9.8	3.7	3.7	3.8
SEm±	0.75	0.56	0.75	0.10	0.11	0.12	0.04	0.03	0.04
CD (P=0.05)	2.4	1.8	2.4	0.33	0.37	0.41	0.14	0.10	0.13
Fertilizer Levels									
Control	125	126	128	10.0	10.1	10.2	3.5	3.5	3.5
50% NPK	131	130	132	10.8	10.5	11.0	4.0	3.8	4.0
75% NPK	134	134	135	11.2	10.9	11.7	4.0	4.0	4.1
100% NPK	138	137	137	11.8	11.3	12.3	4.2	4.1	4.2
SEm±	0.60	0.53	0.60	0.06	0.05	0.06	0.02	0.02	0.02
CD (P=0.05)	1.7	1.5	1.7	0.17	0.14	0.18	0.07	0.06	0.06

Varieties : Groundnut cv. VIR 2; Soybean cv. CO 1; Mungbean cv. CO 3; Sunflower cv. CO 3

Table 2 Seed yield of sunflower (kg/ha) as influenced by the treatments

Treatment	Fertilizer levels				
	Control	50% NPK	75% NPK	100% NPK	Mean
First year (1997)					
Urdbean-Sunflower	582	854	994	1051	870
Mungbean-Sunflower	565	844	987	1019	854
Soybean-Sunflower	575	781	854	1058	817
Groundnut-Sunflower	568	935	985	1184	918
Fallow-Sunflower	381	553	795	940	667
Mean	534	793	923	1050	
Second year (1998)					
Urdbean-Sunflower	650	874	992	1264	945
Mungbean-Sunflower	646	846	1070	1194	939
Soybean-Sunflower	654	790	987	1269	925
Groundnut-Sunflower	1136	1258	1296	1294	1246
Fallow-Sunflower	536	644	696	744	655
Mean	724	882	1008	1153	
Third year (1999)					
Urdbean-Sunflower	568	774	922	1022	822
Mungbean-Sunflower	544	757	897	1001	800
Soybean-Sunflower	544	755	846	978	781
Groundnut-Sunflower	743	934	1149	1238	1016
Fallow-Sunflower	443	748	634	769	599
Mean	568	754	890	1002	

	1997		1998		1999	
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Sequence	17	56	16	36	5	17
Fertilizer	25	72	7	14	5	15
F at S	23	52	15	31	11	32
S at F	24	59	15	33	11	33

Table 3 Economic analysis of the treatments (Rs/ha)

Treatment	Mean over three years				
	Sunflower Equivalent yield (kg/ha)	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio (Rs/ha)
Crop sequence					
Urdbean-Sunflower	2425	6364	23356	16992	3.67
Mungbean-Sunflower	2541	6380	24472	18092	3.84
Soybean-Sunflower	2067	7656	19902	12246	2.60
Groundnut-Sunflower	3626	7303	34921	27618	4.78
Fallow-Sunflower	640	3056	6161	3005	1.95
Fertilizer levels to sunflower					
Control	-	5789	19417	13628	3.35
50% NPK	-	6123	21313	15190	3.48
75% NPK	-	6304	22509	16205	3.57
100% NPK	-	6470	23810	17340	3.68

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Comparative performance of some water production functions for spring sunflower, *Helianthus annuus* L.

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Abstract

Results are presented of a two-year study comparing performance of some water production functions for spring sunflower under four irrigational treatments, *viz.*, one irrigation at seedling; two, one each at seedling and buttoning; three, one each at seedling, buttoning and flowering; four, one each at seedling, buttoning, flowering and seed developing stage, along with a no post sown irrigation – control, averaged over four antitranspirant treatments, *viz.*, kaolin ($H_2 Al_2 Si_2 O_8 H_2 O$ @ 7 %), Alar (B9 / $C_5 H_{12} N_2 O_3$ @ 0.001 %), potassium sulphate ($K_2 SO_4$ @ 4 %) along with a no antitranspirant – control. Crop production functions, relating seed yield of sunflower with consumptive use of water (CU)/ evapotranspiration (ET) with and without consideration of time of water deficit during crop growth sub-periods, were derived. The total growing season of sunflower was divided into five sub–periods. Eleven water production functions, including seven that did not consider growth stage during water deficit and four that did, were tested to quantify the relationship between sunflower seed yield and CU. Values of R^2 for water production functions relating seed yield of sunflower and total season CU (ET) were significant ($P < 0.05$ or $P < 0.01$) and ranged from 0.92 to 0.99. Sunflower was sensitive to water deficit during buttoning, flowering to seed development / maturity stage (reproductive phase). In general, water production functions that considered growth stages during water deficit explained well-observed yield differences.

Key words: Irrigation, seasonal evapotranspiration /consumptive use, seed yield, sunflower, water production functions, water stress

Introduction

Crop production depends on the environmental factors and genetic constitution of crop plant. Climatic, biotic and adaphic parameters are some of major components of the crop environment and may be manipulated by management towards increased crop yields (Flinn, 1971). Water is scarce in most of the dry regions of the world. Limited availability of water at any stage of crop growth, particularly at the critical stage, influences its yield. Therefore, supplemental supply of water by artificial means is inevitable. The functional form of relationship between yield and water use by plants (crop water production function) helps in optimizing the use of scarce water supply and prediction of crop yield / profitability of irrigation. The linear and non linear form of water production functions, both with and without considering the time of water deficit have been developed and used for various crops (Neghassi *et al.*, 1975; Rahman *et al.*, 1980; Singh *et al.*, 1987; Singh *et al.*, 2001[a & b]) under different conditions. The present investigation was undertaken for spring sunflower (*Helianthus annuus* L.) grown on sandy loam soil to compare the performance of some crop production functions under variable irrigations.

Materials and methods

The experiment was conducted on sunflower hybrid 'MSFH-8' during spring seasons of 1999-2000 and 2000-2001 at Chaudhary Charan Singh Haryana Agricultural University Farm, Hisar (75.46° E, 22.10° N, 215.0 m above msl). The experimental soil, a sandy loam (*Typic ustochrepts*), contained soil moisture 17.72 % at – 0.03 MPa and 7.42 % at – 1.5 MPa on gravimetric basis with bulk density of 1.39 – 1.44 g / cc. The soil contained 176.5 kg available N, 17.0 kg available P and 301.0 kg available K / ha and had alkaline reaction (pH, 8.2). The weather during 2000-2001 was dry (4.0 mm rainfall in May) but cloudy at later (reproductive phase) stage. During first year (1999-2000) 1.0, 14.0, 24.0 mm showers were received during February, May and June,

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respectively. The mean pan evaporation was 3.1, 4.8, 9.6, 10.4 and 9.9 mm / day (1999-2000) and 3.0, 4.6, 9.3, 10.4 and 11.7 mm / day (2000-2001) during February, March, April, May and June, respectively. The treatments consisted of five irrigation levels [no post sown irrigation (unirrigated), 1 irrigation at seedling, 2, one each at seedling and buttoning, 3, one each at seedling, buttoning and flowering, and 4, one each at seedling, buttoning, flowering, and seed developing stage] in main plots and four treatments of antitranspirant [Kaolin ($H_2 Al_2 Si_2 O_8 H_2 O$ @ 7.0 %), Alar (B_9 / $C_5 H_{12} N_2 O_3$ @ 0.001 %), Potassium sulphate ($K_2 SO_4$ @ 4.0%) and no antitranspirant spray –control] in sub plots, replicated thrice in split block / strip plot design. Sunflower hybrid 'MSFH-8' was sown on 18 February 1999 and 24 February 2000 by dibbling the seed at 30 cm interval in rows 60 cm apart. Phosphorus @ 50 kg / ha (uniform) and half of the nitrogen (50 kg / ha) were applied at the time of sowing and remaining half (50 kg / ha) was top-dressed after first irrigation / after seedling stage. A buffer channel of 0.5 m width was provided on all sides of main plot. The seasonal evapotranspiration (ET) / consumptive use of water (CU) was computed as water added + effective rainfall + D soil water. Due to low intensity, all the rain received was considered as effective rainfall.

The initial production functions were developed without considering the crop stage at which water deficit occurred, i.e., relationship between yield and total seasonal evapotranspiration (ET). Five such equations were adopted and compared from those summarized by Nagel (1974):

Linear: $Y = a + b\,(ET)$ (i)

Quadratic: $Y = a + b\,(ET) + c\,(ET)^2$ (ii)

Cubic: $Y = a + b\,(ET) + c\,(ET)^2 + d\,(ET)^3$ (iii)

Square root: $Y = a + b\,(ET) + c\,(ET)^{0.5}$ (iv)

Power function: $Y = a.\,(ET)^b$ (v)

Where, Y = crop yield, seed / grain yield or dry matter yield; ET = total seasonal ET and a, b, c and d = empirically drived constants.

By replacing ET in equation (i) with ET deficit (maximum seasonal ET minus actual ET), Stewart (1972) proposed the following relationship:

Stewart (1972) $$Y = a + b\left(\frac{ET_d}{ET_m}\right) \quad [vi]$$

Where, ET_d = seasonal ET deficit, and ET_m = maximum seasonal ET i.e. ET with unlimited water availability.

Water deficit (expressed as soil water deficit / plant water deficit / ET deficit) is related to the amount by which stress reduces crop yield (Hiler and Clark, 1971). Keeping this in view, Singh *et al.* (1987) proposed the following relationship to relate crop yield with the seasonal ET deficit without considering the time of water deficit:

Singh *et al.* (1987) $$Y = a + b\left\{1 - \left(1 - \frac{ET}{ET_m}\right)^2\right\} \quad [vi]$$

The timing of water deficit may be more important than the magnitude in predicting the yield as water deficit timing greatly influenced the crop yield (Hiler and Clark, 1971; Stewart, 1972; Barrett and Skogerboe, 1980). Nagel (1974) suggested that the crop growth stage during water deficit must be considered for any yield function to be representative. Therefore, crop water production functions considering time of water deficit at various stages of crop growth after Jensen (1968), Stewart (1972), Minhas *et al.* (1974) and Singh *et al.* (1987) were also considered in present analysis. These crop production functions might be expressed as:

Jensen (1969): $$\frac{Y}{Ym} = a\prod_{i=1}^{n}\left(1 - \frac{ET}{ETm}\right)_i^{\lambda i} \quad [viii]$$

Stewart (1972): $$\frac{Y}{Ym} = a + \sum_{i=1}^{n}\lambda_i\left(1 - \frac{ET}{ETm}\right)_i \quad [ix]$$

Minhas *et al.* (1974): $$\frac{Y}{Ym} = a\prod_{i=1}^{n}\lambda_i\left\{1 - \left(1 - \frac{ET}{ETm}\right)_i^2\right\}^{\lambda_i} \quad [x]$$

Singh *et al.* (1987): $$Y = a + \sum_{i=1}^{n}\lambda_i\left\{1 - \left(1 - \frac{ET}{ET_m}\right)^2\right\}_i \quad [xi]$$

Where, Y_m = maximum crop yield which occurred when a crop reached ET_m, i = integer number of crop growth stages / sub periods, å = represents series summation, Õ = represented series multiplication, a = empirically derived constant, and li= empirically developed factor which quantified crop sensitivity to water stress during different growth stages / sub-periods.

The sunflower plant growth period from sowing to maturity was divided into five growth sub-periods as: i. Sub-period I covering 0 to 30 DAS (sowing to seedling), ii. Sub-period II covering 31 to50 DAS (seedling to buttoning), iii. Sub-period III covering 51 to 70 DAS (buttoning to flowering), iv. Sub-period IV covering 71 to 90 DAS (flowering to seed development complete) and v. Sub-period V covering 91 to 115/116 DAS (seed development complete to maturity).

Results and discussion

Data on seed yield and consumptive water use (CU) / ET measured during different crop growth stages / sub-periods and seasonal CU (total) for various irrigational treatments are presented in Table 1. Individual observation of CU and seed yield (2 replications) rather than mean values were used for the development of water production functions for sunflower hybrid 'MSFH-8'.

Table 1 ***Seed yield (kg/ha), consumptive use of water (mm) during different growth stages/sub-periods and seasonal consumptive water use of sunflower as influenced by irrigation***

Treatment	Seed yield (kg/ha)	Consumptive water use (mm)					
		Crop growth stages/sub-periods*					
		a	b	c	d	e	f
1999-2000							
No post sowing irrigation (unirrigated)	727	59.63	51.93	34.51	28.50	29.85	204.42
1 irrigation at seedling stage	1212	59.63	84.82	49.67	33.82	33.52	261.46
2 irrigations one each at seedling, and buttoning stage	1583	59.63	84.82	101.13	34.66	34.46	314.7
3 irrigations one each at seedling, buttoning and flowering stage	1908	59.63	84.82	102.95	69.53	35.17	352.1
4 irrigations one each at seedling, buttoning and flowering and seed developing stage	2193	59.63	84.82	103.34	70.44	60.45	378.68
L S D (P =0.05)	145	-	-	-	-	-	-
2000-2001							
No post sowing irrigation (unirrigated)	363	62.53	54.61	26.16	24.46	15.10	182.86
1 irrigation at seedling stage	912	62.53	84.22	51.61	26.63	21.54	246.53
2 irrigations one each at seedling, and buttoning stage	1281	62.53	84.22	97.32	31.26	22.46	297.59
3 irrigations one each at seedling, buttoning and flowering stage	1540	62.53	84.22	99.50	57.05	24.77	328.07
4 irrigations one each at seedling, buttoning and flowering and seed developing stage	*1750*	*62.53*	*84.22*	*98.93*	*58.98*	*56.53*	*361.19*
L S D (P =0.05)	133	-	-	-	-	-	-
Pooled							
No post sowing irrigation (unirrigated)	545	61.08	53.27	30.34	26.48	22.47	193.64
1 irrigation at seedling stage	1062	61.08	84.52	50.64	30.23	27.53	254.00
2 irrigations one each at seedling, and buttoning stage	1432	61.08	84.52	99.23	32.96	28.45	306.24
3 irrigations one each at seedling, buttoning and flowering stage	1724	61.08	84.52	101.23	63.29	29.97	340.12
4 irrigations one each at seedling, buttoning and flowering and seed developing stage	1971	61.08	84.52	101.13	64.71	58.50	369.97
L S D (P =0.05)	142	-	-	-	-	-	-

* a sowing to seedling (0-30DAS), b seedling to buttoning (31-50 DAS), c buttoning to flowering (51-70 DAS); d flowering to seed development completion (71-90 DAS), e seed development completion to harvest maturity (91-115 / 116 DAS), f Season's total

Production functions with out considering time of water deficit

The estimated values of the regression coefficients for water production functions (linear, quadratic, third degree polynomial, square root, power, Stewart, 1972, Singh *et al.*, 1987) relating seed yield of sunflower and seasonal consumptive use (CU) / evapotranspiration (ET) with out considering time of water deficit ranged from 0.90 to 0.99 in 1999-2000, from 0.94 to 0.99 in 2000-2001, and from 0.92 to 0.99 for pooled data (Table 2). The F values for testing R^2 were significant (P=0.01) in most of the cases except Singh *et al.* (1987) where it was non significant though R^2 values were very high. One or more of regression coefficients for quadratic (Eq. 2) and square root (Eq. 4) during two years and for pooled data were non significant. Similarly, third degree polynomial (Eq. 3) had both the regression coefficients non significant during 2000-2001. The water production function after Stewart, 1972 (Eq. 6) may be expressed in linear term. Therefore, R^2, F and t values for regression coefficient equal that of the linear function (Eq. 1) – Table 2. In general, marginal yield decreased with increase in CU / ET and therefore, the relationship between yield and CU / ET should be non linear (Nagel, 1974; Barrett and Skogerboe, 1980). Considering the non linearity of CU / ET yield relation for sunflower hybrid 'MSFH-8', third degree polynomial and power functions may be considered appropriate. The linear (Eq. 1 and Eq. 6) also performed well and are simple to describe the relationship between seasonal CU/ ET and seed yield of sunflower.

Table 2 Estimated values of regression constant and coefficients and statistical parameters for testing crop production functions for sunflower without considering time of water deficit

Crop production functions	Regression constant and coefficients and t# values for testing coefficients				R^2	F values for testing R^2
	a	b	c	d		
1999-2000						
Linear [Eq. i]	-955.696	8.193(40.95)*	-	-	0.9952	1677.17**
Quadratic [Eq. ii]	-461.642	4.630(2.14)^{NS}	0.0061(1.66)^{NS}	-	0.9965	1022.41**
Third degree polynomial [Eq. iii]	-5454.571	58.869(12.07)**	-0.185(-10.81)**	0.0002(11.18)**	0.9998	12790.64**
Square root [Eq. iv]	775.154	14.333(3.26)*	-207.482(-1.40)^{NS}	-	0.9962	939.84**
Power [Eq. v]	0.067	1.753(38.02)**	-	-	0.9945	1445.23**
Stewart (1972) [Eq. vi]	2149.604	-3105.30(-40.95)**	-	-	0.9952	1677.17**
Singh *et al.* (1987) [Eq. vii]	-4215.16	6157.54(8.69)**	-	-	0.9042	75.52^{ns}
2000-2001						
Linear [Eq. i]	-1029.72	7.735(48.37)**	-	-	0.9965	2339.72**
Quadratic [Eq. ii]	-1317.69	9.988(6.43)**	-0.0042(-1.46)^{ns}	-	0.9973	1335.31**
Third degree polynomial [Eq. iii]	-1515.59	12.313(0.81)^{ns}	-0.0129(-0.22)^{ns}	-	0.9974	765.98*
Square root [Eq. iv]	-2198.58	3.243(1.07)^{ns}	146.013(1.48)^{ns}	-	0.9974	1345.15**
Power [Eq. v]	0.0026	2.291(18.63)**	-	-	0.9774	347.21*
Stewart (1972) [Eq. vi]	1769.94	-2799.66(-48.37)**	-	-	0.9965	2339.72**
Singh *et al.* (1987) [Eq. vii]	-3610.47	5172.125(10.78)**	-	-	0.9356	116.13^{ns}
Pooled						
Linear [Eq. i]	-991.536	7.967(67.13)**	-	-	0.9982	4506.81**
Quadratic [Eq. ii]	-917.235	7.410(5.31)**	0.00099(0.40)^{ns}	-	0.9982	2017.21**
Third degree polynomial [Eq. iii]	-3159.28	32.716(3.37)*	-0.0912(-2.59)*	0.00011(2.62)*	0.9991	2474.72**
Square root [Eq. iv]	-810.151	8.636(3.14)*	-22.185(-0.24)^{ns}	-	0.9982	1988.49**
Power [Eq. v]	0.019	1.959(27.83)**	-	-	0.9897	774.49*
Stewart (1972) [Eq. vi]	1960.260	-2951.8(-67.13)**	-	-	0.9982	4506.81**
Singh *et al.* (1987) [Eq. vii]	-3393.78	5645.49(9.63)**	-	-	0.9206	92.78^{ns}

The values in parenthesis are t-values, * Statistically significant (P=0.05),
** Statistically significant (P=0.01), NS= Statistically not significant (P=0.05)

Production functions considering time of water deficit

R^2 values for various production functions considering time of water deficit during different growth sub-periods have been very high (Table 3). The F values for testing R^2 for various production functions were significant (P=0.01). In general, seed yield of sunflower was represented well by different production functions under study with high R^2 and F values. The magnitude and significance of sensitivity factors (I_i), however, varied during crop growth sub-periods for different production functions. Various functions (Jensen, 1968; Stewart, 1972; Minhas *et al.*, 1974; Singh *et al.*, 1987) had significant regression coefficients (I) in 1999-2000, 2000-2001 and pooled data as well. Based upon pooled data, degree of sensitivity of seed yield by water deficit /stress during different growth stages as measured by the absolute values of the sensitivity factor (I) decreased in order of sub-period II (seedling to buttoning), III (buttoning to flowering), IV (flowering to seed development complete) and V (seed development complete to maturity) for most of the water production functions (Table 3 and Fig. 1). This indicated that sunflower crop was sensitive to water deficit spanning over buttoning, flowering to seed development/harvest maturity (reproductive phase). Field studies (Baldev Raj *et al.*, 1999; Singh *et al.*, 2001[a]) have shown water deficit during reproductive phase caused maximum reduction in seed yield of sunflower.

Table 3 Estimated values of regression constant and coefficients and statistical parameters for testing crop production functions for sunflower considering time of water deficit

Crop production functions	Regression constant and coefficients and t[#] values for testing regression coefficients					R^2	F values for testing R^2
	A (intercept)	II (I_2)	III (I_3)	IV (I_4)	V (I_5)		
1999-2000							
Jensen (1968) [Eq.viii]	0.999	0.639(42.20)**	0.350(42.79)**	0.253(29.88)**	0.258(24.29)**	0.9998	1169.13**
Stewart (1972) [Eq. ix]	0.999	-0.349(-27.22)**	-0.315(-36.29)**	-0.278(-31.41)**	-0.312(-29.90)**	0.9998	7526.55**
Minhas *et al.* (1974) [Eq. x]	0.997	1.079(13.39)**	0.766(27.38)**	0.604(20.38)**	0.725(17.05)**	0.9997	5267.13**
Singh *et al.* (1987) [Eq. xi]	-1.083	0.238(3.76)*	0.551(21.05)**	0.548(19.90)**	0.742(19.56)**	0.9995	2911.69**
2000-2001							
Jensen (1968) [Eq.viii]	0.981	1.231(11.67)**	0.431(9.84)**	0.305(6.94)**	0.135(4.45)**	0.9990	1331.66**
Stewart (1972) [Eq. ix]	0.991	-0.504(-12.92)	-0.368(-15.15)**	-0.341(-13.52)**	-0.187(-9.83)**	0.9990	1866.90**
Minhas *et al.* (1974) [Eq. x]	0.992	2.369(3.52)	0.910(6.89)**	0.712(6.02)**	0.311(4.40)**	0.9987	1031.92**
Singh *et al.* (1987) [Eq. xi]	-0.928	0.316(1.05)	0.607(7.31)	0.643(8.46)**	0.354(7.17)**	0.9983	766.13**
Pooled							
Jensen (1968) [Eq.viii]	0.993	0.844(32.61)	0.386(30.77)	0.273(21.34)**	0.192(16.00)**	0.9998	8368.32**
Stewart (1972) [Eq. ix]	0.996	-0.411(-28.69)	-0.34(-36.53)	-0.303(-31.57)**	-0.246(-27.16)**	0.9998	8850.46**
Minhas *et al.* (1974) [Eq. x]	0.994	1.434(11.37)	0.835(24.39)	0.648(19.00)**	0.479(15.09)**	0.9998	6651.34**
Singh *et al.* (1987) [Eq. xi]	-0.912	0.226(2.77)	0.584(20.63)	0.584(20.69)**	0.512(19.26)**	0.9996	3851.89**

[#] The values in parenthesis are t-values, * Statistically significant (P= 0.05),
** Statistically significant (P=0.01), NS= Statistically not significant (P= 0.05)

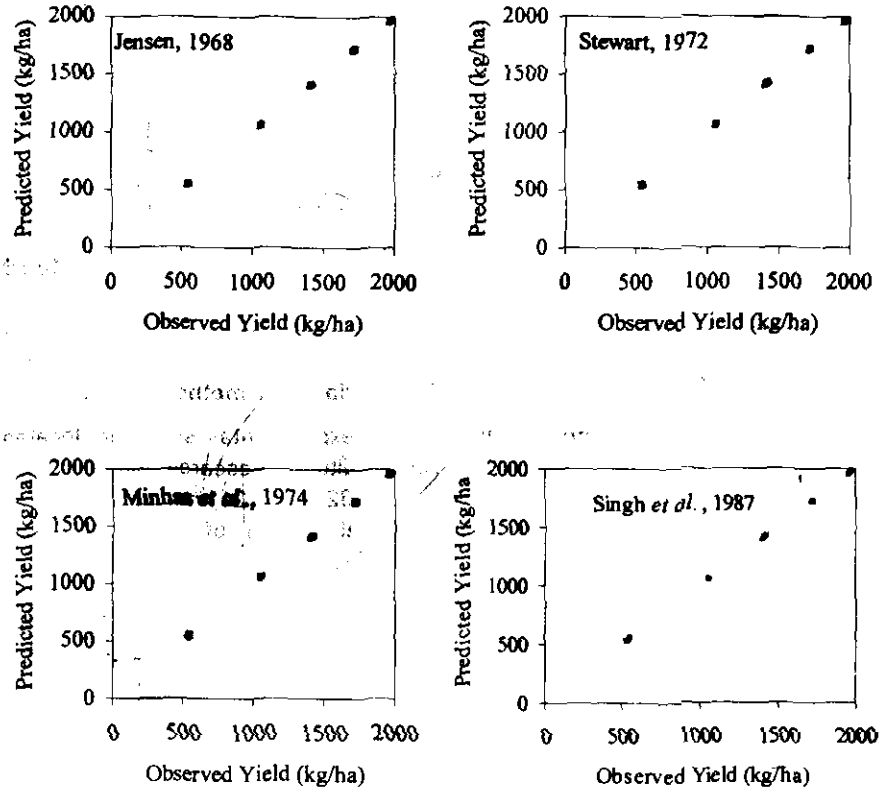

Fig-1 Relationship between observed yield (pooled) and predicted yields by four methods on sunflower hybrid "MSFH-8" subjected to water deficit at different growth stages

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Optimization of sunflower, *Helianthus annuus* L. production under resource constraints

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Abstract

Field experiments were conducted during *kharif* seasons of 2000,2001 and 2002 at Regional Agricultural Research Station, Nandyal, AP to assess the combination of production factors on growth and yield of sunflower in Vertisols. The results indicated that adoption of whole package of practices *viz.*, fertilizer + plant protection + thinning + weeding resulted in significantly higher seed yield (1217 kg/ha) and net returns (Rs. 11285/ha). Among the various single factor production constraints, weeding was found to be most crucial followed by thinning, fertilizer and plant protection. With two-factor limitation, either without fertilizer or thinning or plant protection, sunflower seed yield was reduced by 42% as compared to full package. Absence of weeding along with fertilizer and thinning together reduced the sunflower yield by 68.3%.

Key words: Sunflower, production constraints

Introduction

Sunflower, *Helianthus annuus* L. in recent years, gained importance due to its wider adaptability, short duration, photo insensitivity, allows it to be fitted into various cropping systems. Despite the impressive increase in acreage and production over the last two decades, average productivity of sunflower remained far low (681 kg/ha) (Anonymous, 2002-03). Different production factors (fertilizer, thinning, weeding and plant protection) contribute towards the crop stand, plant growth and ultimately the yield of sunflower. Though the input management had been given due importance, the percent contribution, or the losses due to their non-availability to the sunflower crop are yet to be quantified under scarce Rainfall Zone of Andhra Pradesh. Hence the experiment was conducted to identify the major constraints and their contribution in sunflower production under rainfed conditions.

Materials and methods

The experimental site was located at the Regional Agricultural Research Station, Nandyal, AP (15°29' E,78°32' N and 211 m above mean sea level and average annual rainfall of 750 mm). The experiment was conducted for three consecutive years 2000, 2001 and 2002 during *kharif* season on deep black soil with pH 8.2, low in available N (174 kg/ha), medium in available P_2O_5 (20.4 kg/ha) and high in available K_2O (284 kg/ha). The experiment was laid out in Randomized Block Design with nine treatments replicated four times on sunflower hybrid KBSH-1. Gross plot size of the experiment was 5.4 m x 4.8 m and the net plot size was 4.2 m x 4.2 m. The treatments consisted of full package and deletion of one or more inputs like fertilizer, plant protection, thinning and weeding (Table 1). Sunflower crop was sown by dropping seed behind the plough in marked row width of 60 cm. A uniform dose of 60 kg N + 60 kg P_2O_5 + 30 kg K_2O/ha through urea, single super phosphate and muriate of potash, respectively was applied to the treatments including fertilizer. Entire quantity of P and K fertilizers and half quantity of N was applied as basal and remaining half quantity of N was top dressed at 30-35 days after sowing (DAS). Plant protection measures consisted of seed treatment with Imidacloprid @ 5g/kg seed as protection against thrips and spraying of chemicals as and when the pest/disease incidence was noticed. The treatments involving thinning operation comprised of thinning the plant population at 10-15 DAS leaving one plant/hill in order to maintain optimum plant stand of 55,555 plants/ha. Weeding operation comprised of intercultivation followed by hand weeding twice at 20 and 40 DAS. Rainfall during 2000, 2001 and 2002 amounted to 1004, 371.8 and 290.6 mm, respectively.

Results and discussion

Growth and yield components : Adoption of full package of practices resulted in significant enhancement of head diameter, filled seeds/head and 100 seed weight of sunflower during all the three years of experimentation (Fig. 1a, 1b and 1c) as well as in pooled results (Table 1).

Among the single factors of production, thinning followed by weeding operations resulted in significantly lower head diameter, lowest number of filled seeds/head and 100 seed weight as compared to fertilizer and plant protection measures. With two-factor limitation, either without fertilizer or plant protection; and without thinning resulted in significantly lowest head diameter compared to exclusion of fertilizer and plant protection from full package. Deletion of fertilizer + thinning from full package resulted in 19 and 7% reduction in filled seeds/head compared to deletion of either fertilizer or thinning along with plant protection, respectively over years (Table 1). When all the three factors *viz.*, fertilizer, thinning and weeding were not adopted, reduction in head diameter, filled seeds and 100 seed weight to the extent of 38%, 52% and 23% respectively was observed as compared to adoption of full package of practices.

Table 1 Yield attributes and yield of sunflower under resource constraints (Pooled mean over three years, 2000-2002)

Treatment	Plant height (cm)	Head diameter (cm)	No. of filled seed head	100-seed weight (g)	Seed yield (kg/ha)	Percent reduction in yield over FP	Net returns (Rs/ha)	B:C ratio
Full Package (FP)	115	12	653	4.3	1217	-	11285	2.61
FP - Fertilizer (F)	104	11	552	3.8	840	31.0	7632	2.53
FP - Plant protection (PP)	116	11	574	4.1	977	19.7	8180	2.26
FP - Thinning (T)	112	9	378	3.6	758	37.7	4685	1.69
FP - Weeding (W)	104	9	440	3.7	574	52.8	1785	1.25
FP - (F + PP)	106	11	490	3.7	809	33.5	7662	2.71
FP - (PP +T)	113	9	426	3.6	712	41.5	4355	1.68
FP - (F + T)	112	9	397	3.6	737	39.4	6242	2.29
FP - (F + T + W)	108	7	316	3.3	386	68.3	1262	1.27
SEm±	405	0.6	40	0.1	96	-		
CD (P=0.05)	NS	1.8	116	0.3	281	-		

Seed yield : The production constraint factors resulted in significant yield reduction, which was in the order of weeding > fertilizer > plant protection > thinning during 2000 (Table 1). However, in subsequent years and in pooled results it was in the order of weeding > thinning > plant protection > fertilizer application (Fig 1d).

Adoption of full package of practices produced maximum seed yield of sunflower. The yields were significantly reduced in absence of any of four production factors either alone as fertilizers, plant protection, thinning and weeding or in combinations as fertilizer + plant protection, plant protection + thinning, fertilizer + thinning and fertilizer + plant protection + weeding. Studies conducted at various locations also indicated the need for adoption of full package of practices to obtain the highest yield of sunflower (Anonymous, 1998-99, 1999-2000, 2000-01 and 2001-02).

On an average, full package of practices resulted in achieving highest yield of 1217 kg/ha which was reduced to 52.8%, 37.7%, 31% and 19.7% without weeding, thinning, fertilizer and plant protection, respectively. The combinations of different resource constraints further reduced the yield of sunflower. Fertilizer, thinning and weeding operations together accounted for 68.3% of total production influencing through head diameter, filled seeds and 100 seed weight while plant height remained unchanged.

Economics: Economics indicated that full package rendered the highest gross (Rs 18255/ha) and net (Rs 11285/ha) returns while the highest value of B: C ratio (2.71) was recorded with full package without fertilizer and plant protection followed by full package (2.61).

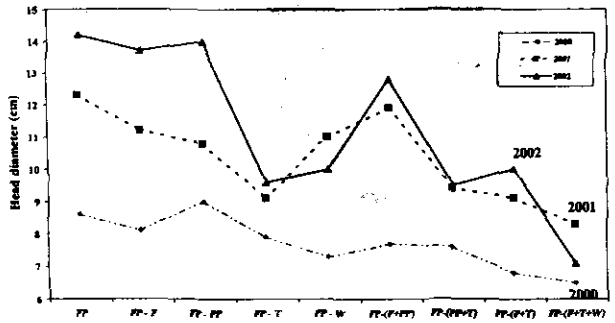

Fig 1a. Head diameter

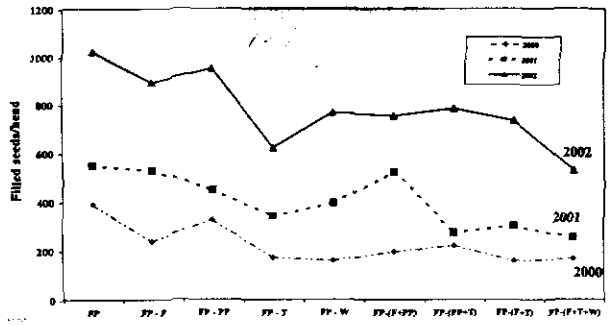

Fig 1b. Filled seeds per head

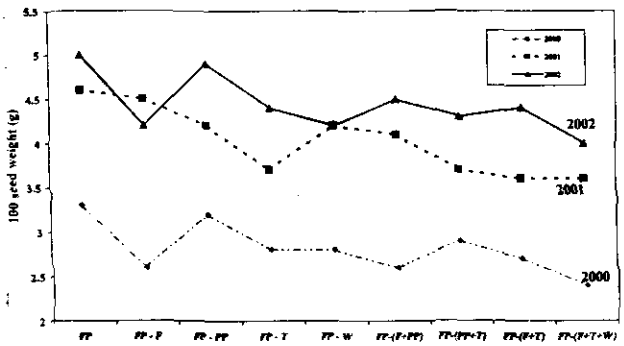

Fig 1c. 100 seed weight

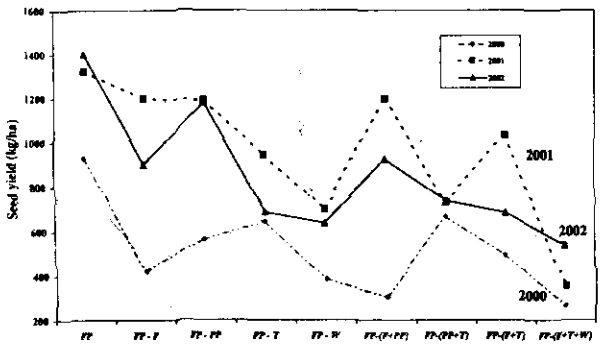

Fig 1d. Seed yield

Fig. Yield attributes and yield of sunflower during 2000, 2001 and 2002

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Herbicidal management of weeds in sesame, *Sesamum indicum* Linn.

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Abstract

A field experiment was conducted during *Kharif* seasons of 1994, 1995 and 1996 at ARS, Mandor revealed that pre plant incorporation of alachlor granules @ 2 kg/ha followed by weeding at 30 days after sowing (DAS) proved to be the best weed management tool providing maximum seed yield (713 kg/ha), net return (Rs. 10,736/ha) and B:C ratio (1: 2.17).This treatment also gave the highest weed control efficiency (86%) and the lowest weed competition index. Though hand weeding twice at 20 and 30 DAS minimized weed count and weed biomass and gave seed yield equivalent to alachlor granules PPI @ 2 kg/ha + weeding at 30 DAS but it was found to be uneconomic to the farmers because of lower benefit : cost ratio (1.89:1).

Key words: Alachlor, pendimethalin, metalachlor, hand weeding, sesame

Introduction

Weed infestation in sesame (*Sesamum indicum* Linn.) is one of the main factors for loss in yield to the tune of 15–80 %. Weeds drain the fertilizers applied and moisture conserved before sowing and thus has a greatest competitive effect on crop. The conventional method of weed control is time consuming, expensive and laborious. It is more favourable to use chemicals due to scarcity in availability of human labour during peak season (Kannan and Wahab, 1995). Therefore, the present attempt has been made to identify a suitable weed management practice in sesame grown in the arid Western plains of Rajasthan.

Materials and methods

An investigation was under taken during rainy seasons (*kharif*) of 1994, 1995 and 1996 at Agricultural Research Station, Mandor, Jodhpur on loamy sand soils (aridisol) having pH 8.1, low nitrogen (170 kg/ha), medium phosphorus (23 kg/ha) and high potassium content (330 kg/ha). The experiment, consisting of twelve treatments was laid out in Randomized Block Design with four replications (Table 1). The plot size was 5 m x 3 m. Sesame variety "RT 46" was sown with onset of monsoon in every season at 30 x 15 cm (row x plant) spacing. The crop was fertilized with 40 kg N (half as basal and half 30 DAS) and 20 kg P_2O_5/ha as basal dose. Alachlor granules were incorporated in the plots prior to sowing whereas, liquid formulations were applied with the help of knapsack sprayer fitted with flat fan T- jet nozzle at spray volume of 750 l/ha. The crop received 302, 336 and 548 mm rain during 1994, 1995 and 1996 growing seasons, respectively. The predominant weeds in crop were *Amaranthus spinosus, Cenchrus biflorus, Trianthema portulacastrum, Boerhaavia diffusa, Cynodon dactylon* (L.) Pers., *Tribulus terrestris, Euphorbia microphylla, Phyllanthus niruri, Digera arvensis, Corchorus tridens, Heliotropium ovalifolium, Portulaca oleracea* and *Celosia argentia* etc.

Results and discussion

Effect on weeds: A reference to weed data in Table 1 revealed that all the herbicidal treatments with or without weeding recorded significant reduction both in population and biomass compared to weedy check at 20, 30 DAS and harvest. The lowest weed count and biomass throughout the crop growth cycle was recorded with pre-plant incorporation of alachlor granules @ 2 kg/ha along with one hand weeding at 30 DAS. The number of weed/m^2 with this treatment was 24 at 20 DAS, which was reduced to 4 at harvest stage. At harvest stage, the weed dry matter was reduced by 435 g/m^2 with pre plant incorporation of alachlor granules @ 2 kg/ha + weeding at 30 DAS (71 g/sq. m) compared to un weeded check (506 g/sq. m).

Effect on crop: All the weed control treatments significantly improved the yield and its parameters over weedy check (Table 2). Use of alachlor granules @ 2 kg/ha along with one hand weeding at 30 DAS yielded maximum numbers of primary branches/plant (4.5), capsules/plant (63) and plant height (127 cm) which were reflected on the highest yield of sesame (713 kg/ha). These parameters were at par with that observed under hand weeding twice at 20 and 30 DAS and use of alachlor

liquid @ 1.5 kg/ha as pre emergence application followed by hand weeding at 30 DAS. On pooled basis, pre plant incorporation of alachlor granules @ 2 kg/ha + hand weeding at 30 DAS and pre emergence application of alachalor liquid @ 1.5 kg/ha + hand weeding at 30 DAS increased the seed yield by 424 and 381 kg/ha over weedy check, respectively. Chauhan and Gurjar (1998) and Singh *et al.* (2001) also reported similar results in sesame. Role of hand weeding followed by use of chemical was proven essential. Use of alachlor granules @ 2 kg/ha as pre plant incorporation with out any hand weeding gave significant increase of 211 kg/ha in seed yield over weedy check. When this treatment was super imposed with one hand weeding at 30 DAS further increase of 213 kg/ha in seed yield was observed. Similar trend of significance was observed in all weed control treatments. Pre-emergence application of metolachlor @ 2 kg/ha + one hand weeding at 30 DAS and pendimethalin @ 0.5 kg/ha were proven superior over weedy check but, the magnitude of increase in seed yield due to these treatments was not equivalent to that of alachlor granules @ 2 kg/ha and alachlor liquid @ 1.5 kg/ha + one hand weeding at 30 DAS. Results are in close conformity with the findings of Ibrahim *et al.* (1988); Kannan and Wahab (1995).

Table 1 Effect of different weed management practices on weed population, weed dry matter, weed competition index and weed control efficiency in sesame (pooled data of three seasons)

Treatment	No. of weeds/sq.m			Weed drymatter (g/sq.m)			Weed competition index (%)	Weed control efficiency (%)
	20 DAS	30 DAS	Harvest	20 DAS	30 DAS	Harvest		
Unweeded check	163	163	124	62.2	71.9	506	59.3	0
Hand weeding at 20 DAS	137	10	10	57.4	26.5	114	31.5	77
Hand weeding at 30 DAS	167	159	10	60.8	33.3	104	28.7	79
Hand weeding at 20 and 30 DAS	142	11	8	60.7	16.4	71	0.0	86
Alachlor (liquid @ 1.5 kg /ha) PE	24	24	8	13.5	18.3	210	32.3	58
Alachlor (liquid @ 1.5 kg /ha) PE + Hand weeding at 30 DAS	25	26	4	17.9	22.9	62	5.6	88
Alachlor (granules @ 2 kg/ha) PPI	19	18	4	16.7	20.9	180	29.6	64
Alachlor (granules @ 2 kg/ha) PPI + Hand weeding at 30 DAS	24	25	4	16.6	21.2	71	0.0	86
Pendimethalin (@ 0.5 kg /ha) PE	42	41	10	27.8	30.1	207	40.6	59
Pendimethalin (@ 0.5 kg /ha) PE + Hand weeding at 30 DAS	42	43	8	22.7	25.9	62	23.5	88
Metolachlor (@ 2 kg /ha) PE	39	38	10	33.5	38.2	303	39.4	40
Metolachlor (@ 2 kg /ha) PE + Hand weeding at 30 DAS	32	32	6	22.3	29.1	75	22.1	85
CD (P=0.05)	23	22	2	9.4	9.4	45	-	-

DAS = Days after sowing; PE = Pre-emergence

Table 2 **Effect of different weed management practices on yield attributes, seed yield and net returns of sesame (pooled data of three seasons)**

Treatment	Plant height (cm)	Primary branches/ plant	Capsules/ plant	Test weight (g)	Seed yield (kg/ha)				Net returns (kg/ha)	B:C ratio
					1994	1995	1996	Pooled		
Unweeded check	104	3.1	32.8	2.65	300	44	523	289	3358	1.11
Hand weeding at 20 DAS	120	4.0	49.3	2.77	565	85	808	486	6492	1.54
Hand weeding at 30 DAS	119	3.8	49.1	2.77	643	86	788	506	6932	1.65
Hand weeding at 20 and 30 DAS	125	4.3	62.0	2.83	809	128	1194	710	10220	1.89
Alachlor (liquid @ 1.5 kg /ha) PE	122	4.1	49.4	2.73	400	109	933	481	6882	1.86
Alachlor (liquid @ 1.5 kg / ha) PE + Hand weeding at 30 DAS	127	4.3	59.7	2.82	818	117	1075	670	9990	2.10
Alachlor (granules @ 2 kg /ha) PPI	122	4.2	51.1	2.76	390	111	1000	500	7000	1.75
Alachlor (granules @ 2 kg/ha) PPI + Hand weeding 30 DAS	127	4.5	61.5	2.80	825	132	1183	713	10736	2.17
Pendimethalin (@ 0.5 kg /ha) PE	112	3.6	44.1	2.74	383	82	800	422	5484	1.44
Pendimethalin (@ 0.5 kg /ha) PE + Hand weeding 30 DAS	122	3.8	54.1	2.70	590	111	927	543	7096	1.46
Metolachlor (@ 2 kg /ha) PE	121	3.7	44.4	2.74	332	85	873	430	5060	1.15
Metolachlor (@ 2 kg /ha) PE + Hand weeding at 30 DAS	121	4.0	52.3	2.75	512	108	1040	553	6716	1.23
CD (P=0.05)	7.7	0.4	05.2	0.08	143	22	137	190	-	-

HW = Hand weeding, DAS = Days after sowing, PE = Pre-emergence and PPI = Pre-plant incorporation

Economics of weed management: Pre plant incorporation of alachlor granule @ 2 kg/ha + one hand weeding at 30 DAS was the most economical treatment giving maximum net returns of Rs 10,736/ha with a benefit cost ratio of 2.17:1. Next in order was hand weeding twice at 20 and 30 DAS (Rs.10,220/ha) closely followed by pre emergence application of alachlor liquid @ 1.5 kg/ha + one hand weeding at 30 DAS (Rs 9,990/ha). Therefore, the present finding suggest that application of alachlor granule @ 2 kg/ha followed by one hand weeding at 30 DAS can provide better cost effective weed management in sesame.

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Population dynamics of aphids (*Aphis craccivora* Koch and *Hysteroneura setariae* Thomes) in relation to weather parameters in groundnut, *Arachis hypogaea* L.

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Abstract

The peak population of aphid *Aphis craccivora* Koch groundnuts was recorded between December and January and much lower populations from April to September. *Hysteroneura setariae* Thomes population was very low. The multiple correlation of *A. craccivora* population with parameters like Temperature (av.), soil temperature (10 cm depth) and vapour pressure have been found significant (r=0.59 and 0.53 for *A. craccivora* for cropped and fallow area). The multiple correlation coefficients were 0.59 and 0.53 with weather parameters for *A. craccivora* in crop and fallow respectively. The cylindrical trap with castor oil as glue worked well in trapping the aphid populations.

Key words: Population dynamics, *Aphis craccivora, Hysteroneura setariae,* groundnut

Introduction

Aphids were not considered to be a serious pest of groundnut until late 1980s (Brar and Sandhu, 1975; Brar, 1981; Padgham *et al.,* 1990; Nandagopal, 1992). Seven species of aphids were recorded on groundnut as vectors of Peanut Stripe Virus (PSTV) (Singh *et al.,* 1993), with *A. craccivora* as the major species, causing pod losses up to 40%. With a heavy infestation, plants become chlorotic and leaves curl, but Rangaswamy and Rao (1964) reported that the pod formation is also adversely affected. Another species *H. setariae* transmits four viruses in other crops.

Forecasting pest abundance and its timing are the important aspects of Integrated Pest Management (Dent, 1991). Though the presence of *A. craccivora* is recorded throughout the year, its dispersal is most noticeable when the populations are abundant, especially in summer (Dixon, 1985). Precise information is lacking on the factors affecting the population abundance and survival of aphids on groundnut in this region. Therefore the present study was initiated.

Materials and methods

Field experiments were conducted from 1993 to 2000 at NRCG, Junagadh, Gujarat. Groundnuts were sown in the first week of every month in a 25 m^2 (5 row 5m length) plot, which forms a part of 20 ha of the rainy season crop. A yellow plastic tray (36 x 24 x 6 cm) with 5 cm depth filled with water was used as a trap. Ten ml of kerosene was added to the water. A flat sticky trap was made up of a square (22 cm) 175 μm thick PVC sheet, on both sides of which castor oil was smeared. It was fitted to a bamboo stick at a height of 40 cm. A cylindrical sticky trap made up from an empty oil tin (28 cm x 20 cm diameter, fitted on a rod at 50 cm height). The surface of the tin was covered with yellow plastic sheet, the outer surface of which was smeared with castor oil. Each of these different traps were installed in the groundnut plot and a fallow area, approximately 800 m away.

Observations were made on the aphids population (*A. craccivora and H. setariae)* at Standard Week (SW) intervals from October through February. Temperature, humidity, soil temperature (10 and 20 cm depth), rainfall, rainy days, sunshine hours and wind velocity were recorded from a weather station located at the experimental site. A simple correlation and multiple regression was worked out and the prediction equations for aphids were calculated.

Results and discussion

Relatively few, *H, setariae* were trapped in comparison to *A. craccivora.* The population of *A. craccivora* was low during April to September (20/trap in Cylindrical trap/week in crop and 16/trap/week in fallow) (Fig. 1a and 1b), but reached a peak between December and January, recording over 800 *aphids*/trap/week in crop and 600/trap/week in the fallow. The period of peak activity coincided with the summer groundnut crop being the major irrigated crop, as the temperature increased.

There was a highly significant correlation for *A. craccivora* population from cropped and fallow area with average temp. soil at 10 cm depth and the vapour pressure in the area (Table 1 and 2). The regression equation for the prediction of *A. craccivora* on crop and fallow were computed. In cropped area, the number of predicted population was nearer to the actual population for both the species of aphids. During this period of observation all these weather parameter were recorded lowest, being winter season. The multiple correlation coefficient was 0.59 and 0.53 with weather parameters for *A. craccivora* in crop and fallow respectively. Weather being a complex phenomena, we have under taken stepwise regression to fix the important parameter which affected the population of these two aphid species.

The simple and multiple regression coefficient between aphid population and weather parameter indicated that temperature (av.), soil temperature (10 cm depth) and vapour pressure played a significant role on the population build up of aphids. The correlation and regression have clearly indicated the dependence of above weather parameters. The calculated value for *H. setariae* were r=0.57 and 0.56 for cropped and fallow area, respectively (Table 1) (Fig 1c and 1d).

Table 1 Simple correlation matrix of aphids with weather parameters in groundnut (October-March, 1994-95 to 1999-2000)

Aphid	R^2	Correlation with abiotic factors		
		Av. Temp. (°C)	Soil Temp. (°C)	Vapour pressure
A. craccivora				
Crop area	0.355	-0.590**	-0.585**	-0.486**
Fallow area	0.280	-0.510**	-0.524**	-0.453**
H. setariae				
Crop area	0.330	-0.564**	-0.545**	-0.509**
Fallow area	0.311	-0.544**	-0.536**	-0.500**

Fig. 1a.Weather v/s *A.craccivora* (crop) in Cylindrical trap

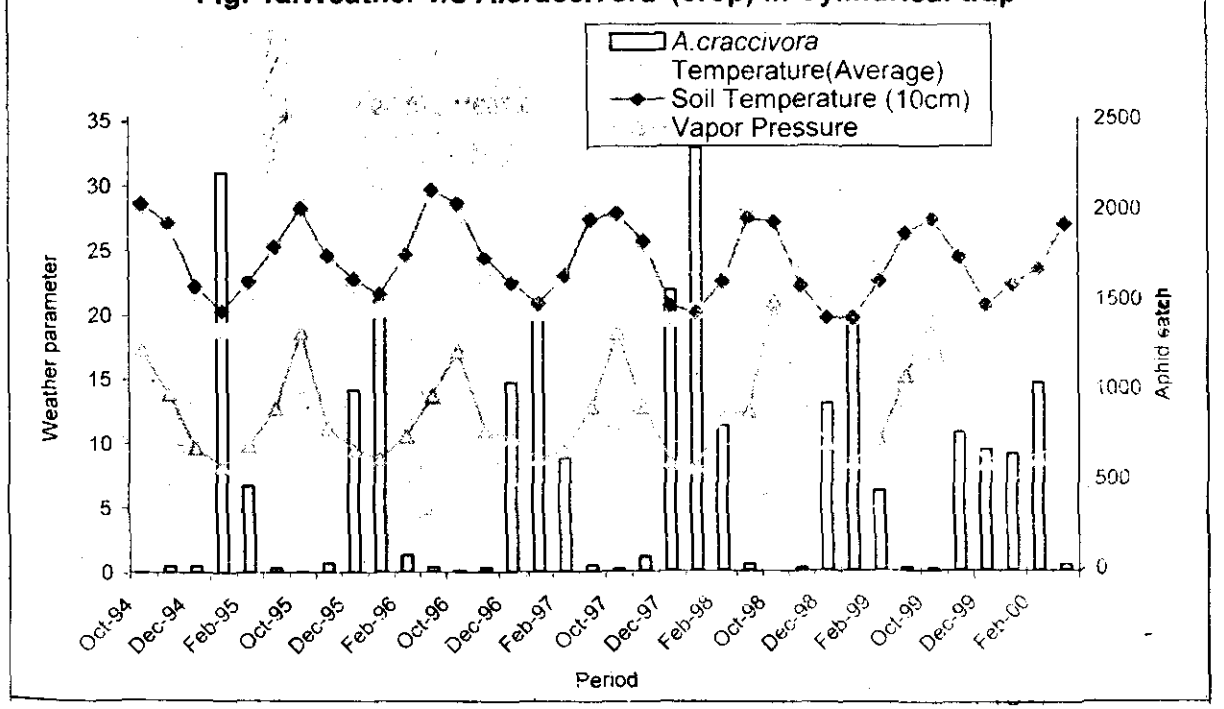

Table 2 Correlation between weather parameters and aphids population

Aphid	Weather parameter	Oct. 94 - March, 95	Oct. 95 - March, 96	Oct. 96 - March, 97	Oct. 97- March, 98	Oct. 98 - March-99	Oct. 99 - March 2000
Maximum temperature (°C)							
A. craccivora	Crop area	-0.623**	-0.516**	-0.558**	-0.674**	-0.721**	NS
	Fallow area	-0.639**	-0.521**	-0.580**	-0.588**	-0.691**	NS
H. setariae	Crop area	NS	-0.605**	-0.685**	-0.672**	-0.551**	NS
	Fallow area	-0.328*	-0.568**	-0.670**	-0.670**	NS	NS
Minimum Temperature (°C)							
A. craccivora	Crop area	-0.567**	NS	NS	-0.799**	-0.679**	NS
	Fallow area	-0.562**	NS	NS	-0.708**	-0.678**	NS
H. setariae	Crop area	NS	-0.590**	-0.638**	-0.757**	-0.664**	-0.673**
	Fallow area	NS	-0.582**	-0.657**	-0.586**	-0.590**	NS
Average temperature (°C)							
A. craccivora	Crop area	-0.604**	NS	-0.530**	-0.777**	-0.763**	NS
	Fallow area	-0.608**	NS	-0.552**	-0.684**	-0.749**	NS
H. setariae	Crop area	NS	-0.638**	-0.703**	-0.753**	-0.678**	-0.673**
	Fallow area	NS	-0.616**	-0.708**	-0.806**	-0.594**	
Soil temperature (10 cm depth) (°C)							
A. craccivora	Crop area	-0.601**	NS	-0.551**	-0.626**	-0.680**	NS
	Fallow area	-0.593**	NS	-0.581**	-0.728**	-0.680**	NS
H. setariae	Crop area	-0.529**	-0.653**	-0.762**	-0.803**	-0.677**	-0.692**
	Fallow area	NS	-0.643**	-0.763**	-0.884**	-0.599**	NS
Soil temperature (20 cm depth) (°C)							
A. craccivora	Crop area	-0.605**	NS	-0.563**	-0.819**	NS	NS
	Fallow area	-0.600**	NS	-0.701**	-0.727**	NS	NS
H. setariae	Crop area	-0.526**	-0.652**	-0.781**	-0.798**	NS	-0.681**
	Fallow area	NS	-0.649**	-0.771**	-0.860**	NS	NS
Vapour pressure							
A. craccivora	Crop area	NS	NS	NS	-0.675**	-0.651**	-0.491**
	Fallow area	NS	NS	NS	-0.587**	-0.629**	NS
H. setariae	Crop area	-0.519**	-0.572**	-0.578**	-0.615**	-0.589**	-0.585**
	Fallow area	NS	-0.565**	-0.578**	-0.757**	-0.562**	NS

Fig. 1b. Weather v/s *A.craccivora* (fallow) in Cylindrical trap

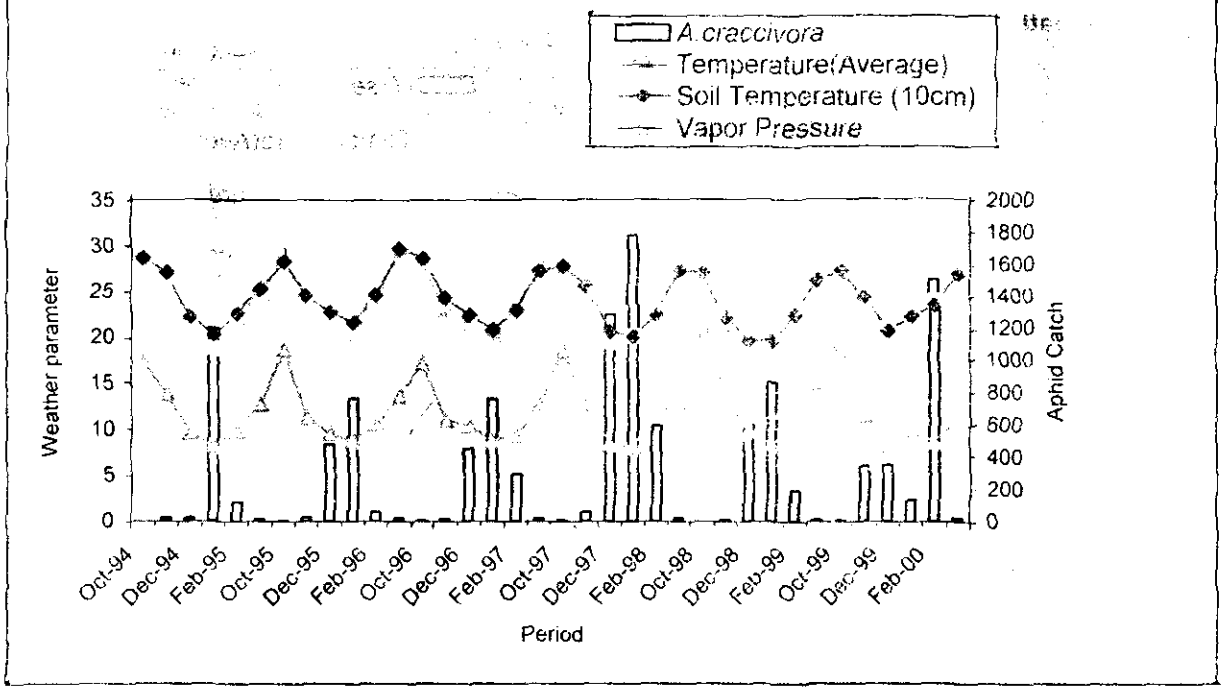

Fig 1b

Fig 1c. Weather v/s *H.setatriae* (crop) in Cylindrical trap

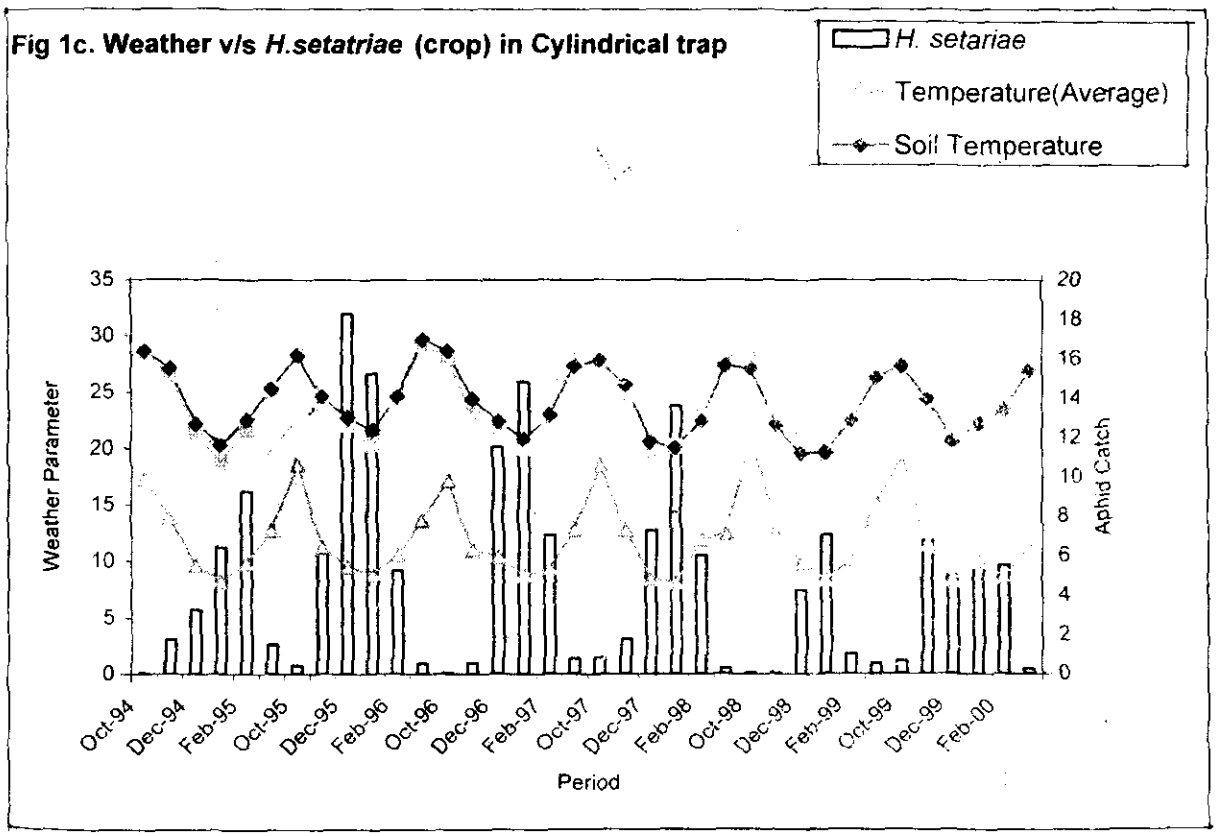

Fig 1c

Fig 1d. Weather v/s *H.setariae* (fallow) in Cylindrical trap

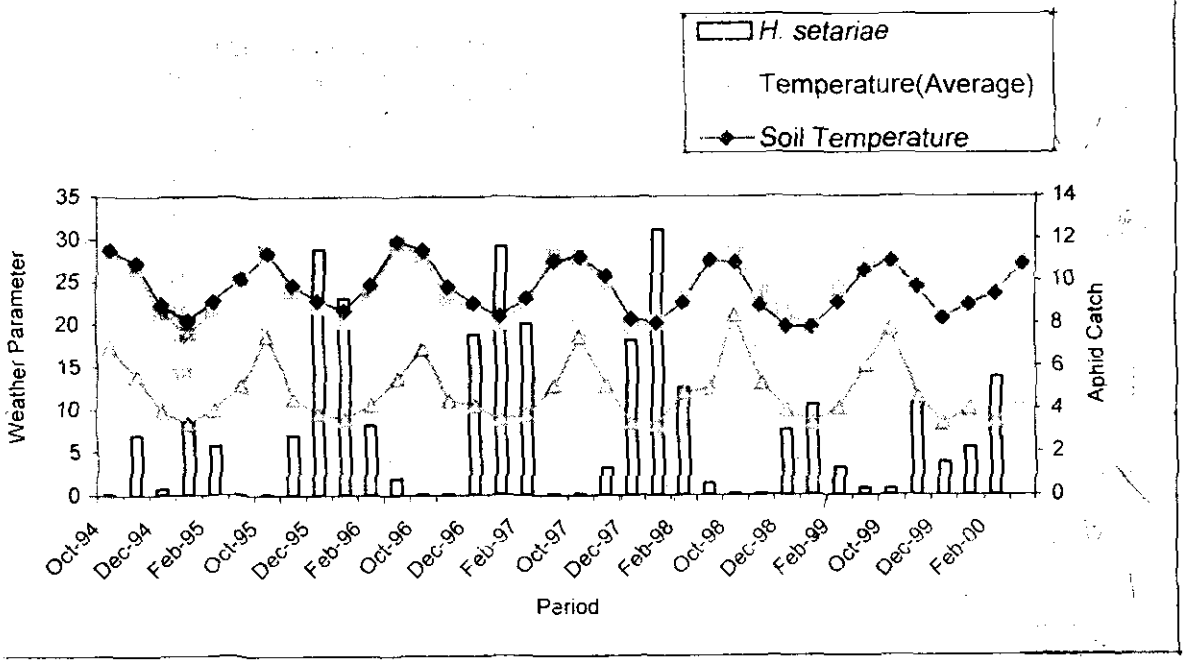

Fig.1d

During the studies, population of *H. setariae* was less in numbers (maximum 16/week/trap) which suggested that the weather factors are not that much conducive for multiplication compared to *A. craccivora*, which appeared in thousands. As a result, postnatal development periods and generation times are short and reproduction rates, are potentially very high (Dixon, 1987).

For multiple regressions, the best variables were the vapour pressure and soil temperature at 10 cm depth which were the results of low temperature prevailed from the period SW 45 to 52 and SW 1 to 12.

This is in confirmation with Roychoudhury and Jain (1993) who showed a negative correlation of aphids with mean, maximum and minimum temperature. Similarly, Sheikh *et al.* (1999) predicted the population of aphids in groundnut using a limited period data, which also included minimum temperature as contributing factors.

All through the years of observations, the populations of aphids, *A. craccivora* was abundant (maximum of 3542/trap/week) and the species, *H. setariae* recorded maximum of 32 aphids/week/trap. The SW 45 to 15 was peak period of activity for both the species. February 1st to 2nd week is the sowing period for summer groundnut through well irrigation. After germination, by the time the crop produced sufficient leaves, it would be SW 9-10. Probably because of these reasons, only the peanut strip virus (PStV) has been consistently recorded higher and in most of the field 50% plants were removed and destroyed during summer season of 1993 to 1995 (our unpublished work). These two aphids have been well documented as vector for PStV virus (Singh *et al.*, 1993).

Low temperature favoured the population of aphids. The other important weather parameters such as soil temperature at 10 cm depth and vapour pressure were also responsible for multiplication of alate forms of aphids. The aphids are being vector of many viral diseases of food and fiber crops, it would be easy to initiate the management of the aphids, to avoid the spread of viral diseases such as Peanut Stripe Virus diseases and to reduce loss (Singh *et al.*, 1993). Cylindrical trap was found to be superior in trapping the aphids, which are carried by wind being passive flier, could be used effectively to monitor these two species of aphids as well as other aphids in different crops and cropping systems.

It is now possible to forecast the population occurrence of *A. craccivora* and *H. setariae* based on the weather parameter prevailing over a short period. The cost of making a forecast using locally made gadgets is relatively small. Forecasting and early warning are both meant for warning of environmental conditions that are suitable for the occurrence of an epidemic. Presumably factors such as temperature, vapour pressure and soil temperatures

are likely to be important, while other factors such as migration may also be involved and precise information are likely to vary from place to place. In our situations, early detection is also possible after collection of epidemiological data and detecting the actual occurrence of an epidemic as soon as it begins.

The prediction of population can be made using average temperature, soil temperature at 10 cm depth and the vapour pressure in this area. This can be ensured taking these parameters for the period SW 43 to 45. Based on the prediction formula, the calculations for actual and predicted are coming closer. For the post-rainy sowing i.e., by the second or third week of February every year, the weather data of the above three independent factors can be taken into account and the population can be predicted. When the population is predicted, accordingly, the management/control options can be finalized in advance.

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Systemic induced resistance in sunflower to *Alternaria* leaf blight by foliar application of SA and Bion

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Abstract

Foliar application of Salicylic acid (SA) and Bion solutions to Sunflower induced systemic resistance to *Alternaria helianthii* (Hansf.) Tubaki and Nishihara. SA at 15 mM were effective in inducing resistance, however SA at 20 mM had phytotoxic effect. Studies indicated that lag period of 3-7 days is required for induction of systemic resistance.

Key words: Systemic acquired resistance (SAR), induced systemic resistance (ISR), Salicylic acid (SA), Bion, *Alternaria helianthii*

Introduction

Sunflower (*Helianthus annuus* L.) is one of the important oilseed crops grown in the world. It is cultivated in an area of 183.98 lakh ha with a production of 209.03 lakh tonnes and a productivity of 1136 kg/ha (Damodaram and Hegde, 2002). Although, India stands third in sunflower cultivation (21.0 lakh ha) but sixth in production (15.0 lakh ha) with a productivity of 714 kg/ha (Anonymous, 1999). There are several limitations for increasing production of sunflower, one of them being diseases. Alternaria leaf blight constitutes a potential threat to all sunflower growing regions of the wold (Yang, 1988). Although, several fungicides are available to manage this disease, development of resistance to fungicides by plant pathogens is a major limiting factor. Further, in the development and use of chemical agents for crop disease management, considerable attention must be given to the preservation of the global environment. By keeping all these points in view, investigation was carried out for utilization of induced systemic resistance in managing Alternaria leaf blight in sunflower.

Materials and methods

Sunflower leaves infected with *A. helianthii* were collected from Directorate of Oilseeds Research, Rajendranagar, the pathogen was isolated by tissue segment method and further purified by single spore isolations. For pathogenicity studies, Alternaria susceptible open pollinated variety 'Morden' was planted in 18 cm diameter pots (three plants/pot). With a mixture of soil and farm yard manure (FYM) in 4:1 ratio and maintained on glass house benches. The inoculum was prepared by washing the conidia of *A. helianthii* from 15 days old culture grown on sunflower leaf extract medium in petriplates. Five ml of sterile distilled water was added to each plate and the conidia were scraped with the help of camel hair brush. The spore suspension was filtered through three layers of cheese cloth. Tween 20 @ 0.1% (Polyoxyethylene Sorbiten monoleate), surfactant was added to the suspension to enable uniform spread of inoculum on the leaves. The conidial concentration was monitored using haemocytometer.

Thirty days old plants were inoculated in the glass house by spraying conidial suspension (10,000 conidia/ml) of Alternaria on leaves with a hand sprayer. Control was maintained by spraying with sterile distilled water only. Inoculated plants were kept in the incubation chamber made up of polythene sheets in the glasshouse for 48 h colane at R.H. 95%.

Salicylic Acid (SA; 2-hydroxy benzoic acid MS ICN biochemicals Inc; Thame U.K.) was dissolved in sterile distilled water containing 0.1% tween 20 as a wetting agent, to produce 15 mM, 1.5 mM and 0.15 mM S.A solutions. Bion (acibenzolar-s-methyl; benzothiodiazole, CGA 245704; benzo (1,2,3) thiadiazole-7-carbothioicacids-methylester (MS Novartis India Ltd, Mumbai) as water dispensable granule (WG 50%) was dissolved in sterile distilled water to produce 5mM, 0.5mM and 0.05mM Bion solutions.

The effect of SA and Bion in inducing disease resistance was observed after one day, replicate plants from each treatment were taken and their second formed leaves were inoculated with *A. helianthii*. Similarly other plants were inoculated at 3,5,7 and 9 DAT and disease reduction over control was calculated (Ishii *et al.*, 1999).

Slide germination technique (Montgomery and Moore, 1938) and poisoned food technique (Nene and Thapliyal, 1979) were employed to test the efficacy of salicylic acid and Bion against *A., helianthii in vitro*.

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Slide germination technique: Four concentrations (1000, 100, 10, 1 mg/ ml each) of SA and bion were prepared. Two drops of each concentration were pipetted into the cavity slide and allowed to dry. Equal quantity of spore-suspension was placed over the dried inducer chemical solution and incubated at 27±1°C for 5 h. The trial was replicated five times. Suitable control was maintained with distilled water. After 5 h of incubation, spore-germination counts were recorded and germination % was calculated.

Poisoned food technique: Different concentrations (1000, 100, 10, 1 μg/ml) of AS and Bion were prepared and poured into sterilized petriplates. Small disc (0.8 cm diameter) of *A. helianthii* culture was placed at the centre of each poisoned plate. These radial growths of the fungal mycelium was recorded at 7, 14 and 21 days after inoculation.

Estimation of total phenols: Plants were treated with salicylic acid and Bion. Later the phenolic content of treated plants was estimated at different intervals as per Mahadevan and Sridhar, 1996.

Results and discussion

Inoculation of the second formed leaf with *A. helianthii* 24h before the application of SA and Bion on first formed leaf had no influence on the infectivity of the pathogen (Table 1). Bion 5 mM had significantly higher disease control (22.43%) at 1 DAT. Similar trend was observed with 5 DAT, 7 DAT and 9 DAT. However, the differences observed between 7 DAT and 9 DAT were not significant. The results revealed that treating first formed leaves with SA 15 mM and Bion 5 mM can induce resistance to *A. helianthii* in the second formed leaves and the induced resistance persisted for atleast 9 days after treatment. Similar results were also reported by Weete (1992) and Frey and Carver (1998).

Studies on spore germination of *A. helianthii* showed (Table 2) that less spore-germination was observed at SA 1000/μg ml. Similar results on damping off seedlings disease reported by Chen-Chunquan *et al.* (1999) indicated that, zoospore germination of *Pythium aphanidermatum* was reduced on application of SA at 1000 μg/ml. SA and Bion foliar application inhibited the radial growth of *A. helianthii* at 1-100 μg ml (Table 3). At higher concentration (1000 μg ml) complete inhibition of mycelial growth was observed with SA. The reduction in spore germination and mycelial growth of *A. helianthii* not only resulted a direct effect as inducers on the pathogen, but also protection was achieved in *in vivo*. This might be due to the results of induced resistance and also the direct effects of the inducer chemical on the pathogen.

Table 1 Effect of application SA and Bion to first formed leaves on resistance of second formed sunflower leaves to *Alternaria helianthii*

Treatment	Disease reduction (%) over control						Mean
	1 DBT	1 DAT	3 DAT	5 DAT	7 DAT	9 DAT	
SA 15 mM	0.93 (5.13)	9.77 (17.72)	19.92 (26.50)	51.77 (46.01)	63.89 (53.10)	63.62 (52.94)	34.98 (33.57)
SA 1.5 mM	0.13 (1.21)	6.81 (15.12)	15.90 (23.20)	33.77 (35.40)	34.53 (35.92)	34.90 (36.19)	21.01 (24.51)
SA 0.15 mM	0.13 (1.21)	4.99 (10.57)	9.87 (17.66)	7.79 (14.59)	14.95 (22.40)	15.00 (22.73)	8.79 (14.86)
Bion 5 mM	1.20 (6.24)	22.43 (20.54)	25.79 (30.47)	57.45 (49.30)	68.03 (55.57)	68.79 (56.04)	40.22 (37.36)
Bion 0.5 mM	0.13 (1.21)	6.17 (10.37)	15.09 (22.63)	26.50 (30.35)	41.24 (39.93)	41.80 (40.25)	21.82 (24.12)
Bion 0.05 mM	0.13 (1.21)	6.25 (14.47)	10.26 (16.88)	13.53 (17.78)	33.38 (35.28)	36.21 (36.97)	16.63 (20.43)
Mean	0.44 (2.70)	10.44 (14.80)	16.13 (22.89)	31.80 (32.23)	42.67 (40.36)	43.38 (40.85)	23.90 (25.80)

Figures in parenthesis are arc sine transformed values

	SEd±	CD (P=0.05)
Periods	1.58	3.15
Treatments	1.71	3.40
Interaction	4.19	8.33

Table 2 **Effect of SA and Bion on spore germination of *Alternaria helianthii in vitro***

Treatments	Spore germination (%) at different concentrations (µg/ml)					Mean
	1000	100	10	1	0	
SA	66.20 (54.45)**	78.43 (62.32)	91.45 (73.01)	91.59 (73.15)	95.34 (77.59)	84.60 (68.10)
Bion	76.75 (61.17)	80.88 (64.07)	93.03 (74.71)	91.83 (73.41)	95.34 (77.49)	87.56 (70.19)
Mean	71.47 (57.81)	79.65 (63.20)	92.24 (73.86)	91.71 (73.28)	95.34 (77.59)	86.08 (69.15)

Data in parenthesis are arc sine transformed values

	SEd±	CD (P=0.05)
Concentrations	0.36	0.73
Treatments	0.23	0.46
Interaction	0.51	1.03

Table 3 **Efficacy of SA and Bion on radial growth of *Alternaria helianthii* at four concentrations (µg/ml)**

Treatment	Growth reduction (%) over control			Mean
	7 DAI	14 DAI	21 DAI	
SA 1000	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
SA 100	8.12 (12.50)	35.88 (36.20)	32.38 (34.00)	25.47 (27.57)
SA 10	12.00 (15.69)	16.81 (20.94)	10.48 (18.38)	13.10 (18.33)
SA 1	4.67 (7.81)	36.37 (36.64)	7.01 (15.01)	16.02 (19.82)
Bion 1000	66.73 (54.85)	65.94 (54.76)	71.57 (58.15)	68.08 (55.92)
Bion 100	64.76 (53.85)	53.39 (46.99)	57.33 (49.52)	58.49 (50.12)
Bion 10	39.48 (38.14)	46.25 (42.79)	45.81 (42.56)	43.85 (41.16)
Bion 1	25.24 (26.56)	22.77 (28.26)	21.85 (27.44)	23.29 (27.42)
Mean	40.12 (37.42)	47.17 (44.57)	43.30 (41.88)	43.53 (41.29)

Data in parenthesis are arc sine transformed values

	SEd±	CD (P=0.05)
DAI	2.06	3.99
Treatments	3.40	6.73
Interaction	5.89	11.69

Table 4 **Effect of SA and Bion application on the phenolic content of sunflower leaves at different time intervals**

Treatment		Total phenols expressed as catechol equivalents (mg/g)					Mean
		1 DAT	3 DAT	5 DAT	7 DAT	9 DAT	
SA 15 mM							
	First leaf	0.51	0.58	1.07	1.47	1.47	1.01
	Second leaf	0.51	0.57	0.88	1.23	1.23	0.88
	Third leaf	0.51	0.57	0.88	1.18	1.20	0.86
Bion 5 mM							
	First leaf	0.51	0.63	1.21	1.51	1.51	1.06
	Second leaf	0.51	0.59	0.98	1.25	1.25	0.90
	Third leaf	0.51	0.59	0.98	1.25	1.25	0.90
Mean		0.51	0.59	1.00	1.32	1.32	0.93

	SEd±	CD (P=0.05)
DAT	0.01	0.02
Treatments	0.01	0.02
Interaction	0.03	0.05

There was no significant difference between the treatments at one day after the application of chemicals on phenolic content of leaves. However, changes observed from 3 DAT to 9 DAT were significant both with SA and Bion. The total phenols were maximum with Bion after 7 DAT (1.52 mg/g) followed by SA (1.47 mg/g) in first leaf. In all the cases, differences observed in Phenolic content of second and third formed leaves were not significant (Table 4). Generally 3 to 7 days are required for the induction of defense mechanism (Frey and Carver, 1998; Jeum *et al.*, 2000). The study indicates, resistance in sunflower to *A. helianthii* can be enhanced systematically through foliar application of SA and Bion.

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Field screening of linseed, *Linum usitatissimum* Linn. genotypes against the incidence of budfly, *Dasyneura lini* Barnes and blight, *Alternaria lini* Dey

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Abstract

Forty nine genotypes of linseed (*Linum usitatissimum* Linn.) were screened under natural infestation conditions against the incidence of budfly (*Dasyneura lini* Barnes) and Alternaria blight (*Alternaria lini* Dey) during five consecutive *rabi* seasons of 1997-98 to 2001-02 at JNKVV, Zonal Agricultural Research Station, Tikamgarh (M.P.). Entries, JLT-84-5-1, JLT-84-12-1, JLT-24, JLT-26, LMH-91-24 and LMH-16-5 (6.2-10%) reacted as resistant against the incidence of budfly on the basis of five years pooled mean, whereas, genotypes, 5610, EC-1392, RLC-29, JLT-84-12-1, LMH-43 and LCK-93-24 (4.2-4.9%) were highly resistant against the infestation of Alternaria blight. Grain yield was highest in genotypes, LMH-16-5 (2120 kg/ha) followed by LMS-5-38 (2116 kg/ha), JLT-90 (2092 kg/ha), JLT-24, JLT-84-5-1 (2056 kg/ha), Kangra local (2037 kg/ha), NL-97 (2032 kg/ha), LCK-9211 (2019 kg/ha) and JLT-26 (2005 kg/ha). Thus, four genotypes, LMH-16-5, JLT-24, JLT-84-5-1 and JLT-26 were resistant to both the pests as well as high yielding. Budfly susceptible genotype, LC-54 had longer blooming period (38 days) and budfly resistant genotypes, LMH-16-5 and JLT-26 had lesser blooming period (27-30 days). However, this behaviour did not correlate with all the genotypes.

Key words: Budfly, Alternaria blight, linseed, resistance

Introduction

Linseed, *Linum usitatissimum* Linn. is affected by a number of insect pests and diseases, although only few of them are of economic importance. Budfly. *Dasyneura lini* Barnes among the insect pests and Alternaria blight (*Alternaria lini* Dey) among the diseases are the most devastating pests causing yield losses to the extent of 88% (Pal *et al.,* 1978; Jakhmola and Yadav, 1983) due to budfly and 60 % due to Alternaria blight (Chauhan and Shrivastava, 1975). Use of resistant/tolerant varieties is the most effective and economic way to manage these pests. But, no high yielding varieties could be evolved so far with multiple resistance to both the pests (Lingappa *et al.,* 2003). Keeping these facts in view, present investigations on the field screening of linseed genotypes against the incidence of budfly and Alternaria blight were carried out to identify the high yielding pest resistant genotypes.

Materials and methods

Thirty four genotypes during 1997-98 and forty nine genotypes of linseed during 1998-99 to 2001-02 were sown during the end of November in all the five *rabi* seasons. Two rows of 4 m length of each genotype were sown at 30 cm row spacing in Randomised Block Design and three replications during each season. Infester row of budfly susceptible variety, Neelum was raised around the crop to serve the inoculum. The crop was grown on recommended agronomic practices under natural infestation conditions.

Observations on the incidence of budfly and Alternaria blight were recorded at the dough stage following the guidelines of AICRP (Anonymous, 1985). Grain yield was also recorded and observations of all five years were pooled.

Results and discussion

Reaction against the incidence of budfly : Budfly damage varied significantly among the genotypes during all the five seasons of study being highest during 1998-99 (11.9 to 63.9%) followed by 1997-98 (4.0. to 50.9%) capsule damage. However, in rest of the years, incidence of budfly was mild (Table 1). Mean incidence of budfly (5 years) also varied significantly with 6.6-26.4% capsule damage. Genotypes, JLT-84-5-1 (6.2%), JLT-84-12-1 (6.6%), JLT-24 (7%), JLT-26 (8.1%), LMH-91-24 (9.6%) and LMH-16-5 (10%) reacted as resistant on the basis of pooled mean incidence. Whereas, Neelum (26.4%), Kiran (25.4%) and LC-54 (25.2%) were susceptible in reaction. Rest of the 40 entries were moderately resistant against the incidence of budfly. Malik (1999) has also reported LC-54 and Neelum as susceptible to budfly.

Table 1 Mean % capsule damage due to budfly in linseed genotypes and mean blooming period

Entries	% capsule damage due to budfly						Mean blooming period (days)
	1997-98	1998-99	1999-2000	2000-01	2001-02	Mean	
IC-16392	25.0 (29.9)	30.4 (33.5)	7.2 (15.5)	11.3 (19.6)	2.4 (8.9)	15.3 (22.7)	28
J-23	26.8 (31.2)	27.7 (31.8)	16.4 (23.8)	22.5 (28.3)	9.3 (17.9)	20.5 (26.6)	37
JLT-24	4.0 (11.5)	8.3 (16.4)	8.8 (17.2)	10.7 (19.1)	3.9 (11.2)	7.0 (15.1)	32
JLT-26	6.5 (14.7)	23.0 (28.5)	4.8 (12.5)	5.3 (13.3)	1.1 (6.0)	8.1 (15.0)	30
JLT-46	8.1 (16.5)	23.1 (28.6)	7.3 (15.6)	15.9 (23.3)	2.9 (9.8)	11.5 (18.8)	39
JLT-83	21.3 (27.4)	39.8 (39.1)	8.1 (16.4)	17.8 (24.9)	5.1 (13.1)	18.4 (24.2)	37
JLT-84-5-1	4.3 (11.9)	9.9 (18.4)	6.0 (14.1)	7.8 (16.2)	2.8 (9.6)	6.2 (14.0)	35
JLT-84-12-1	5.3 (10.8)	15.3 (23.0)	4.7 (12.4)	4.8 (12.6)	2.9 (9.8)	6.6 (13.7)	35
JLT-90	9.6 (18.1)	22.0 (27.9)	7.6 (15.9)	6.5 (13.5)	6.1 (14.3)	10.4 (17.9)	34
JLT-93	12.2 (20.4)	15.4 (23.0)	6.5 (14.7)	11.9 (20.2)	5.2 (13.2)	10.2 (18.3)	38
Kiran	33.1 (35.0)	63.9 (53.2)	6.8 (15.0)	13.6 (21.7)	9.5 (18.0)	25.4 (28.6)	34
LC-54	19.9 (26.5)	44.0 (41.6)	25.1 (30.0)	18.5 (25.5)	18.6 (25.5)	25.2 (29.8)	38
LMH-6-5	5.0 (12.9)	42.0 (40.4)	7.7 (16.1)	14.2 (22.0)	4.0 (11.5)	14.6 (20.6)	30
LMH-43	12.8 (20.9)	23.2 (28.8)	3.0 (13.2)	11.2 (19.6)	4.8 (12.7)	11.0 (19.0)	35
LMH-91-24	4.5 (12.2)	22.6 (28.4)	4.7 (12.3)	9.7 (18.1)	6.3 (14.5)	9.6 (17.1)	33
LMH-90	6.8 (15.1)	53.7 (47.2)	12.7 (20.8)	9.6 (18.1)	4.1 (11.7)	17.4 (22.6)	33
LCK-85-28	23.8 (29.1)	29.0 (32.6)	11.6 (19.8)	19.4 (26.2)	5.0 (12.9)	17.8 (23.1)	37
LCK-92-11	34.0 (35.5)	22.3 (28.0)	15.3 (22.9)	15.8 (23.4)	6.2 (14.4)	18.7 (24.8)	39
LCK-93-03	30.1 (33.1)	19.3 (25.9)	15.4 (22.8)	14.4 (22.3)	10.4 (18.8)	17.9 (24.6)	24
LCK-93-24	22.4 (28.1)	18.5 (25.4)	7.7 (16.0)	8.0 (16.3)	7.8 (16.2)	12.9 (20.4)	35
LCK-94-36	15.1 (22.8)	40.9 (39.7)	8.6 (17.0)	14.3 (21.9)	5.7 (13.8)	16.9 (23.0)	31
Neela	16.0 (23.5)	32.9 (34.9)	8.9 (16.7)	16.0 (23.6)	5.9 (14.1)	13.9 (22.6)	31
Neelam	50.9 (45.5)	34.3 (35.8)	14.7 (22.4)	16.5 (24.0)	15.7 (23.3)	26.4 (30.2)	30
NL-97	20.3 (26.8)	40.7 (39.6)	3.2 (10.1)	7.3 (15.6)	6.5 (14.8)	15.6 (21.4)	37
NL-8804	19.2 (25.9)	38.1 (38.1)	3.2 (10.2)	13.8 (21.8)	6.1 (14.3)	16.1 (22.1)	33
RL-1011	16.5 (24.0)	18.0 (25.1)	13.3 (21.3)	15.4 (22.9)	5.2 (13.2)	13.7 (21.3)	36
RLC-29	15.4 (23.1)	44.0 (41.5)	8.3 (16.5)	8.1 (16.5)	4.4 (12.1)	16.0 (21.9)	37
RLC-40	26.5 (30.9)	40.6 (39.6)	8.7 (17.1)	13.6 (21.6)	4.9 (12.8)	18.9 (24.4)	37
T-397	20.1 (26.5)	33.3 (35.2)	13.0 (21.0)	19.7 (26.3)	5.0 (12.9)	18.2 (24.4)	32
672 EC-1427	20.1 (26.5)	35.3 (36.4)	8.4 (16.8)	12.9 (21.1)	3.0 (10.0)	15.9 (22.2)	37
692	26.2 (30.7)	47.2 (43.4)	8.9 (16.9)	9.3 (17.7)	5.2 (13.2)	19.4 (24.4)	30
1189	7.0 (15.3)	25.0 (30.0)	11.3 (19.3)	13.4 (21.5)	7.0 (15.3)	12.7 (20.3)	38
1216 JRF-1	10.7 (17.8)	29.7 (33.1)	6.7 (15.3)	6.3 (14.5)	8.6 (17.1)	11.0 (19.6)	39
1341 LC-1	19.7 (26.3)	33.8 (35.5)	15.7 (23.4)	14.2 (22.1)	6.3 (14.5)	17.9 (24.4)	32
5610	—	32.6 (34.8)	11.0 (19.6)	12.3 (20.4)	8.0 (16.4)	16.0 (22.8)	25
ACCNo.-442	—	39.9 (39.1)	14.7 (22.4)	20.6 (27.0)	4.5 (12.2)	19.9 (25.2)	32
ACCNo.-1396	—	47.2 (43.4)	8.0 (16.4)	17.8 (24.9)	12.8 (21.0)	21.4 (26.4)	31
A-958	—	37.5 (37.8)	12.4 (20.6)	12.1 (20.4)	7.2 (15.6)	17.3 (23.6)	28
CI-1466	—	39.4 (38.9)	11.9 (20.0)	15.1 (22.8)	14.4 (22.3)	20.2 (26.0)	25
CI-1956	—	35.3 (36.4)	17.6 (24.7)	15.8 (23.3)	18.4 (25.4)	21.8 (27.4)	33
EC-1392	—	32.0 (34.4)	1.5 (5.7)	7.0 (15.3)	13.6 (21.6)	13.5 (19.2)	27
EC-1424	—	21.9 (27.9)	5.7 (13.7)	10.2 (18.7)	7.8 (16.2)	11.4 (21.8)	25
JRF-3	—	23.8 (29.2)	19.0 (25.9)	7.9 (16.2)	3.6 (10.9)	13.6 (20.5)	31
JRF-4	—	22.5 (28.3)	5.0 (12.8)	9.2 (17.6)	6.0 (14.2)	10.7 (18.2)	29
JRF-5	—	23.9 (29.2)	14.8 (22.5)	17.4 (24.6)	7.9 (16.3)	16.0 (23.1)	26
Kangra Local	—	23.2 (28.7)	11.8 (20.0)	11.3 (19.6)	5.1 (13.0)	12.8 (20.3)	30
LCK-88062	—	42.3 (40.5)	11.6 (19.9)	17.6 (24.6)	6.1 (14.3)	19.4 (24.8)	25
LMH-16-5	—	22.4 (28.1)	4.3 (11.7)	7.6 (15.9)	5.9 (14.1)	10.0 (17.4)	27
LMS-5-38	—	29.8 (33.0)	8.0 (16.4)	16.6 (23.9)	7.8 (16.2)	15.5 (22.4)	26
S Em ±	(1.97)	(2.00)	(1.45)	(1.35)	(1.38)	(1.10)	
CD (P=0.05)	(5.58)	(5.67)	(4.10)	(3.82)	(3.90)	(3.11)	

Figures in parenthesis are angular transformed values.

Table 2 Mean % bud damage due to Alternaria blight and grain yield

Entries	% bud damage due to Alternaria blight						Grain yield (kg/ha)
	1997-98	1998-99	1999-2000	2000-01	2001-02	Mean	
IC-16392	23.0 (28.7)	7.0 (15.3)	2.6 (9.3)	2.9 (9.7)	3.1 (9.7)	7.7 (14.5)	1852
J-23	15.6 (23.2)	7.9 (16.3)	3.7 (11.0)	2.6 (9.1)	1.5 (7.0)	6.3 (13.3)	1972
JLT-24	9.2 (17.7)	14.3 (22.1)	4.2 (11.7)	3.0 (9.9)	5.2 (13.0)	7.2 (14.9)	2056
JLT-26	9.3 (17.7)	10.6 (18.6)	4.8 (12.5)	0.4 (2.6)	3.1 (10.1)	5.7 (12.3)	2005
JLT-46	16.7 (24.1)	7.5 (15.8)	6.4 (14.8)	5.2 (13.1)	2.9 (9.7)	7.7 (15.5)	1866
JLT-83	16.2 (23.7)	9.7 (18.0)	2.1 (8.2)	6.7 (15.0)	2.8 (9.6)	7.5 (14.9)	1778
JLT-84-5-1	12.8 (20.9)	11.2 (19.5)	3.3 (10.1)	3.1 (10.2)	3.2 (10.1)	6.8 (14.2)	2056
JLT-84-12-1	10.2 (18.6)	4.5 (12.2)	2.4 (7.3)	3.4 (10.5)	2.5 (9.1)	4.6 (11.5)	1843
JLT-90	20.1 (26.6)	15.9 (23.4)	3.2 (9.9)	5.0 (12.9)	2.7 (9.4)	9.4 (16.4)	2092
JLT-93	20.3 (26.7)	17.8 (24.9)	3.0 (9.9)	4.7 (12.5)	2.1 (8.2)	9.6 (16.4)	1931
Kiran	16.8 (24.2)	6.4 (14.7)	3.5 (10.8)	3.6 (10.7)	4.4 (12.1)	6.9 (14.5)	1574
LC-54	21.2 (27.4)	7.8 (16.2)	10.5 (18.9)	2.8 (9.2)	5.7 (13.6)	9.6 (17.1)	1685
LMH-6-5	34.4 (35.9)	15.9 (23.5)	4.8 (12.5)	6.7 (14.9)	2.7 (9.0)	12.9 (19.2)	1583
LMH-43	10.0 (18.4)	5.5 (13.5)	1.6 (5.6)	1.7 (7.1)	4.8 (12.6)	4.7 (11.4)	1449
LMH-91-24	10.0 (18.4)	10.8 (19.1)	8.2 (16.6)	5.9 (14.0)	6.9 (15.0)	8.4 (16.6)	1867
LMH-90	25.9 (30.6)	12.1 (20.2)	2.9 (9.7)	3.3 (10.5)	7.3 (16.0)	10.3 (17.4)	1889
LCK-85-28	13.0 (21.1)	7.3 (15.5)	2.1 (8.0)	4.3 (11.9)	4.4 (12.5)	6.2 (13.8)	1704
LCK-92-11	11.3 (19.6)	8.9 (17.3)	4.0 (11.3)	3.2 (9.9)	4.2 (12.0)	6.3 (14.0)	2019
LCK-93-03	15.5 (23.2)	7.6 (15.9)	5.6 (14.1)	2.6 (9.3)	4.0 (11.5)	7.1 (14.8)	1560
LCK-93-24	8.2 (16.6)	7.6 (15.9)	2.6 (9.0)	2.7 (9.4)	3.2 (10.5)	4.9 (12.3)	1685
LCK-94-36	9.6 (17.9)	10.5 (18.0)	13.1 (21.1)	6.3 (14.5)	6.1 (14.3)	9.1 (17.2)	1769
Neela	20.0 (26.5)	10.5 (18.7)	3.6 (10.8)	4.1 (11.7)	4.3 (12.0)	8.5 (15.9)	1810
Neelam	13.3 (21.2)	10.5 (18.9)	4.8 (12.6)	2.9 (9.7)	3.5 (10.9)	7.0 (14.7)	1847
NL-97	13.7 (21.7)	9.4 (17.8)	2.3 (8.7)	1.7 (7.4)	4.7 (12.4)	6.4 (13.6)	2032
NL-8804	15.5 (23.2)	9.1 (17.6)	7.4 (15.6)	5.3 (13.3)	4.2 (12.0)	8.3 (16.3)	1592
RL-1011	26.8 (31.1)	10.6 (18.9)	4.4 (12.1)	2.8 (9.5)	3.7 (11.1)	9.7 (16.5)	1810
RLC-29	6.8 (14.8)	6.3 (14.6)	3.6 (12.2)	2.4 (8.8)	3.4 (10.6)	4.5 (12.2)	1787
RLC-40	16.1 (23.6)	11.6 (19.8)	3.5 (10.4)	5.4 (13.4)	5.7 (14.0)	8.5 (16.2)	1945
T-397	11.3 (19.6)	10.4 (18.8)	7.1 (15.4)	3.6 (10.7)	2.5 (8.9)	7.0 (14.7)	1652
672 EC-1427	13.5 (21.5)	12.7 (20.8)	2.8 (9.0)	3.7 (11.1)	3.0 (10.0)	7.1 (14.5)	1866
692	26.3 (30.8)	7.2 (15.5)	4.7 (12.2)	3.2 (10.2)	3.5 (10.8)	9.0 (15.9)	1880
1189	28.7 (32.2)	7.8 (16.2)	8.9 (17.3)	8.1 (16.5)	4.8 (12.3)	11.7 (18.9)	1523
1216 JRF-1	37.4 (37.7)	28.4 (32.2)	20.3 (26.7)	9.2 (17.6)	7.8 (16.6)	20.6 (26.2)	1731
1341 LC-1	25.1 (30.1)	7.9 (16.3)	3.0 (9.6)	2.2 (8.4)	5.8 (14.4)	8.8 (15.8)	1855
5610	---	8.8 (17.3)	2.0 (8.1)	3.2 (10.0)	3.0 (10.0)	4.2 (11.4)	1592
ACC No.-442	---	13.9 (21.9)	4.2 (11.8)	5.2 (13.0)	4.5 (12.2)	6.9 (14.7)	1509
ACC No.-1396	---	12.5 (20.9)	3.3 (10.4)	2.8 (9.4)	8.7 (17.2)	6.8 (14.5)	1528
A-958	---	17.9 (24.7)	7.6 (16.0)	1.9 (7.9)	7.6 (15.4)	8.7 (16.0)	1899
CI-1466	---	9.0 (17.7)	5.2 (13.2)	2.5 (8.8)	7.2 (15.4)	6.0 (13.8)	1344
CI-1956	---	10.5 (19.4)	6.8 (15.1)	3.9 (11.2)	8.8 (17.2)	7.5 (15.7)	1369
EC-1392	---	8.4 (16.9)	1.8 (7.6)	0.8 (5.1)	6.6 (15.0)	4.4 (11.1)	1945
EC-1424	---	10.3 (19.0)	5.3 (13.3)	4.5 (12.2)	10.0 (18.2)	7.5 (15.7)	1346
JRF-3	---	42.8 (41.6)	19.1 (25.9)	21.9 (27.8)	21.1 (27.9)	26.2 (30.8)	954
JRF-4	---	35.6 (36.9)	40.4 (39.5)	14.4 (22.3)	21.7 (28.1)	28.0 (31.7)	1282
JRF-5	---	24.9 (30.2)	13.9 (21.9)	9.6 (18.0)	5.6 (13.8)	13.5 (21.0)	1324
Kangra Local	---	13.0 (21.1)	4.5 (12.2)	2.4 (8.8)	4.5 (12.2)	6.1 (13.6)	2037
LCK-88062	---	14.2 (22.7)	6.2 (14.4)	3.4 (10.5)	4.2 (11.5)	7.0 (14.8)	1685
LMH-16-5	---	17.9 (24.7)	6.0 (14.2)	4.0 (11.4)	5.0 (12.9)	8.2 (15.8)	2120
LMS-5-38	---	11.3 (19.4)	3.2 (10.3)	2.7 (9.5)	3.6 (10.7)	5.2 (12.5)	2116
S Em ±	(2.50)	(2.70)	(1.95)	(1.83)	(1.79)	(2.45)	133.5
CD (P=0.05)	(7.07)	(7.63)	(5.51)	(5.18)	(5.06)	(6.80)	377.5

Figures in parenthesis are angular transformed values.

However, during 1998-99 with high incidence of bud fly 1998-99, only two entries i.e., JLT-24 (8.3%) and JLT-84-5-1 (9.9%) reacted as resistant. Whereas, entries, JLT-84-12-1, JLT-26, LMH-91-24 and LMH-16-5 resistant on mean incidence basis behaved as moderately resistant. Genotypes, Kiran and LMH-90 were highly susceptible, 27 entries were susceptible and only 18 entries reacted as moderately resistant during this season.

Correlation coefficient between mean blooming period (24-39 days) and % capsule damage was computed and found to be non significant (0.047). Thus these findings differ with the findings of Malik *et al.*(1991) and Rai *et al.* (2000) that varieties having longer blooming period were severely infested by the budfly as compared to those with shorter blooming period. However, budfly susceptible genotype, LC-54 had longer blooming period (38 days) and resistant genotypes, LMH-16-5 and JLT-26 had shorter blooming period (27-30 days). But, this behavior was not exhibited in all genotypes.

Reaction against the incidence of Alternaria blight : Alternaria bud blight incidence varied significantly among the genotypes being 8.2-37.4, 4.5-42.8, 2.0-40.4, 1.7-21.9 and 1.5-21.7% respectively during 1997-98 to 2001-02. Pooled mean incidence also varied significantly (4.2-38%) among the genotypes. Six genotypes *viz.*, 5610, EC-1392, RLC-29, JLT-84-12-1, LMH-43 and LCK-93-24 (4.2-4.9% bud damage) reacted as highly resistant, 36 (5.1-10% bud damage) reacted as resistant and five, LMH-90 (10.3%), 1189 (11.7%), LMH-6-5 (12.9%), JRF-5 (13.5%) and JRF-1(20.6%) reacted as susceptible and two, JRF-3 (26.2%) and JRF-4 (28%) reacted as highly susceptible to Alternaria blight (Table 2).

However, during the year of high incidence of Alternaria blight (1997-98 and 1998-99), no genotype behaved as highly resistant. Genotypes reacted as highly resistant on pooled mean basis reacted only as resistant during the years of higher incidence. Thus, eight genotypes, *viz.*, RLC-29 (6.8 and 6.3%), JLT-84-12-1 (10.2 and 4.5%), LMH-43 (10 and 5.5%), LCK-93-24 (8.2 and 7.6%), JLT-26 (9.3 and 10.6 %), EC-1392 (8.4%), 5610 (8.8%) and CI-1466 (9%) behaved as resistant. Thirty six genotypes were moderately resistant. Genotypes, JRF-1, JRF-3 and JRF-4 were found highly susceptible to Alternaria blight.

Multiple resistance : Genotypes, JLT-84-5-1, JLT-84-12-1, JLT-24, JLT-26, LMH-91-24 and LMH-16-5 were found resistant to budfly as well as Alternaria blight.

Grain Yield : Grain yield was recorded only during *rabi* seasons of 1999-2000, 2000-01 and 2001-02 and varied significantly among the genotypes during all three seasons. Correlation coefficient between mean capsule damage caused by budfly and grain yield and between incidence of Alternaria blight and grain yield were also computed being r=0.?27 and –0.480 respectively which indicated that with the increase in susceptibility to each of the pest the grain yield was reduced. However, mean grain yield was maximum in genotypes, LMH-16-5 (2120 kg/ha), LMS-5-38 (2116 kg/ha), JLT-90 (2092 kg/ha), JLT-24 (2056 kg/ha), JLT-84-5-1 (2056 kg/ha), Kangra local (2037 kg/ha), NL-97 (2032 kg/ha), LCK-9211 (2019 kg/ha) and JLT-26 (2005 kg/ha) (Table 2).

Among these high yielding genotypes , LMH-16-5, JLT-24, JLT-26 and JLT-84-5-1 were also resistant to both the pests. Thus, these four multi-resistant genotypes with high yields may be further evaluated/improved for the development of high yielding multi-resistant varieties of linseed.

Similar efforts have been also made by Malik and Singh (1997) against the incidence of budfly and Alternaria blight and identified Neela as resistant to both the pests but with poor yields. However, in present studies, Neela reacted as moderately resistant to budfly and resistant to Alternaria blight with average yield of 1810 kg per ha.

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Forecasting of sesame, *Sesamum indicum* L. production in India

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Abstract

The paper analyzes the future production scenario of sesame in India and suggests strategies to enhance its production. The forecasting is carried out on secondary data and is supplemented with qualitative assessment based on experts opinions. The forecast indicates that average production of sesame will increase from the present about 0.55 mt to about 0.8 mt by 2010 AD. Low yields, lack of standardized techniques for hybrid seed production and a lack of basic research were some major deterrents identified. Breakthrough in sesame research for development of hybrids and positive market is predicted to offset the constraints and ensure a modest future to sesame. Strategies focusing research along with hastening technology transfer policy is considered critical to sustain the growth of sesame production in India.

Key words: Forecasting, sesame

Introduction

India became near self-sufficient in edible oils by 1991 as a result of launching of technology mission on oilseeds in 1986 by the Government of India (Prasad *et al.*, 1994). The enhanced oilseed production came largely from rapeseed and mustard, soybean and sunflower (Virupakshappa and Kiresur, 1997; Rama Rao *et al.*, 2000). However, sesame though being the oldest traditional crop, could not register significant gains. In reality, the area and production under this crop has not shown adequate growth rate with the yield levels lowering especially during last five years (Singh *et al.*, 1997; Paroda, 2000). Our studies based on simple statistical analysis of secondary data could not provide adequate answers to understand this situation. In an effort to provide plausible answers to this, it was found necessary to analyze the sesame system in a holistic manner.

The future of a commodity not only depends on the need for the commodity but also on other competing crops or choices available to farmers, socio-economic factors, consumer habits, state policies, trade and private sector role. In-depth analysis of such a system would have to integrate quantitative with qualitative information. In such a scenario, the future projections need to integrate statistical (historic) data with qualitative information. Systems approach coupled with technological forecasting provides a means to achieve this. This study is aimed to fulfill this felt need so as to identify the constraints and potentials of sesame crop in the future, i.e., by 2010 AD.

Materials and methods

A blend of forecasting techniques was used to integrate qualitative and quantitative information in making the forecasts. The quantitative forecasts were made based on statistical analysis of secondary data for trend and growth in conjunction with brainstorming and Delphi methods for qualitative issues (Rohtagi *et al*, 1979; Martino, 1983; Makridakis, 1998).

The data were collected from a range of primary and secondary sources. The primary data was collected with the help of oilseed experts across the country. Secondary data was collected from various publications on oilseeds (GOI, 2001; CMIE, 2001; Damodaram and Hegde, 2001; Ramanjaneyulu *et al.*, 2001; FAO, 2002).

The key quantitative and qualitative issues were identified through brain storming session and discussions with experts (Rama Rao *et al.*, 2000). The issues comprised of various aspects of oilseeds such as cultivation, research and development, seeds, marketing, consumption, alternate uses, processing and state policies.

Results and discussion

Growth : The average yield of sesame during 1979-2001 was about 300 kg/ha, as the crop was grown under sub-optimal conditions in India. The oilseeds in India showed changes in the area, production and yield after 1986. This corresponds to initiation of mission-mode program to accelerate the oilseed sector embarked by the national government. While the program continues even today, the initial gains seem to be offset by early 1990s. Hence, the sesame data was analyzed for growth for the three periods, namely 1979-85, 1986-93 and 1994-2001. The

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compound annual growth rates of area, production and productivity of sesame (Table 1) show that there is rise in the growth rate in the period, 1986-93. Compound growth rates in 1979-85 for both area (-1.6%) and production (4.3%) went up to 1.4% and 7.8%, respectively, in the period 1986-93. Growth rate for yield too increased from 2.5% in 1979-85 to 6.4 % in 1986-93.Period 1986-93 assumed significance as the gains were not sustained in the next period i.e., 1994-2001, when rates for area, production and yield decreased.

Table 1 Compound annual growth rates of area, production and yield of sesame

Period	Compound annual growth rate (%)		
	Area	Production	Yield
1979-85	-1.6	2.5	4.3
1986-93	1.4	7.8	6.4
1994-01	- 4.0	-1.5	2.6

Source: *Oilseeds Situation-A Statistical Compendium*, Damodaram and Hegde, 2001.

Statistical forecast: A simple forecast based on trend extrapolation of historic data projects a shockingly low area of 1.5 m. ha and 0.4 m. tonnes for sesame area and production. But most experts on sesame differed with this and there was a broad consensus predicting sesame to show modest gain and sustain its area and production in the coming decade.

Cybernetic diagram for sesame: To provide a more realistic forecast a systemic view is attempted by incorporating qualitative and quantitative factors in cybernetic diagram illustrated in Fig. 1.

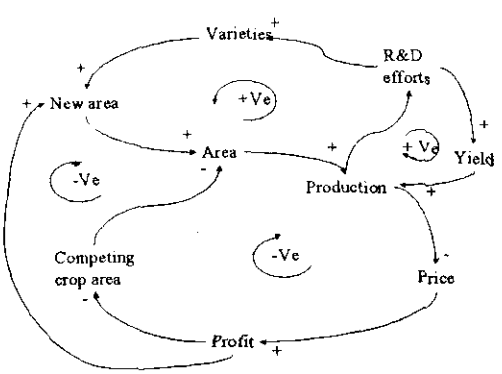


Fig 1 Cybernetic diagram for sesame

The cybernetic diagram showed the cause and effect relationship among the identified variables of the system (Mohapatra *et al.*, 1994). It is characterized with feedback loops having positive and negative polarities. This polarity in turn reflects whether the flow is reinforcing or inhibiting over time. In case of sesame, the important variables were identified in a brainstorming workshop involving experts from research, development, academic, trade and processing sectors. Results of the model simulation indicate a balanced outlook, i.e., –ve and +ve factors balance each other. Concerted efforts in research and development would lead to higher yields, production and area even with available varieties. Factors like low prices and competing crops would negate these effects. Strategic planning to thwart this threat, perhaps can sustain the crop. Keeping this model in view, details on contributing factors are discussed below.

Exploitable yield and technology time gap: The national average annual yield of sesame during 1979-2001, is 300 kg/ha while the realizable yield with improved technology is twice this; thus the realizable yield gap in sesame accounts for nearly 50 % of the actual yield. Time to achieve the realizable yield (i.e. yield of improved varieties / hybrids) was forecasted by fitting yield data (1979-2001) to the growth model using the formula (Martino, 1983).

$$y = L / (1+a\, e^{-bt})$$

where, L is upper limit to growth of the variable y, t is time and a and b are the coefficients evaluated by fitting the data.

The model depicted in Fig. 2 gives the time required for achieving the desired yield by using improved technologies as about 22 years. Even though sesame is oldest oilseed crop, the time lag to achieve the realizable yield is large as the crop is largely grown under dry land farming. It is thus, a challenge to look and frame the ways and means to exploit the realizable yield potential in this crop.

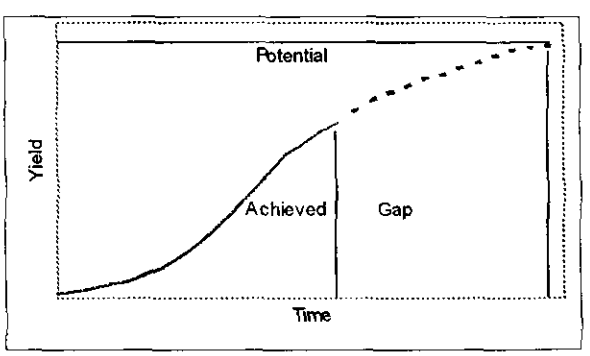


Fig 2 Growth model for depicting time for realizing yield

Major technological advances like that in castor (Rama Rao *et al.*, 2000) and better dissemination techniques for the improved methods can reduce this gap. The technology transfer through public system for sesame is forecasted to remain low as at present. However, some positive changes are expected through the entry of private sector entry in seed marketing.

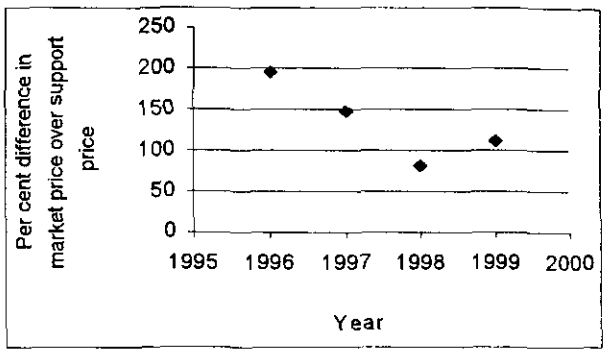
Quality seed: Production and distribution of certified seed to farmers is one of the major developmental tools in promotion of a crop vis-à-vis area under cultivation. The quantity of seed required is about 13800 tonnes (@ 6 Kg/ha) and the actual production is about 7 % of this. As there are no hybrids of this crop, experts opine that, seed replacement of 15 to 20 % is sufficient as farmers can use the home grown seed for about five to six years. In other words, though seed multiplication is not commensurate with required quantity for this crop, it cannot be considered major constraint in the absence of hybrids. However, there is need to coordinate quality seed multiplication to introduce hybrids in this crop.

Competing crops: One of the major reasons for shift in area under oilseed crops in the past has been due to competition from other profitable crops. During the last decade, there have been remarkable changes in the area under oilseed crops. Based on the data available though primary and secondary sources and opinions of experts, the major competing crops identified for sesame are groundnut, millets and pulses. Delphi forecast indicated that these crops may indent into the sesame area based on market prices and their relative profitability. On the other hand, sesame is likely to spread into non-traditional areas by 2010 AD and they are:

* Hilly areas of Uttar Pradesh, Madhya Pradesh, Himachal Pradesh and Maharashtra,
* Rice fallows in new project areas,
* Rainfed areas in Rajasthan, Madhya Pradesh, Uttar Pradesh, Karnataka and Andhra Pradesh.

The crops likely to be replaced by sesame are niger, minor millets, *Pennisetum* and sorghum. Thus, rice fallow situation, change over to multiple cropping from single/two crops, inter cropping and catch crop would be the major contributors for growth of sesame in India.

Price : Government support price provides assurance from market risk. The government is supporting sesame through minimum support price scheme from 1995-96 onwards. The difference in average price of sesame seed in market with the prevailing government support price is shown in Fig. 3. It is evident that market prices are always higher than the government support price.

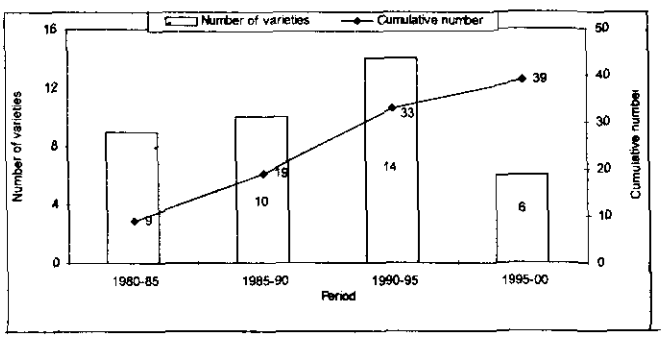


Source : Agricultural Statistics at a Glance, 2001.

Fig 3 Comparative market price over support price of sesame seed

Though government support price assures minimum returns and is a tool to avoid distress sales. In international market, the average world export price of sesame is in the range of Rs 3500 to Rs 4500/tonne during 1997-2000 (FAO, 2002), which is much higher than the open market price in India during the same period. Thus, Indian sesame has no threat from international markets. Marketing sesame is not a serious constraint but growers feel that the support price need to be more realistic as it would further push up and stabilise the open market price.

High yielding varieties / hybrids: Sesame is a seasonal and location bound crop. A particular variety does not perform uniformly in all locations and in all seasons. A number of varieties and hybrids have been released for various sesame growing locations in the country. The number of sesame varieties released during1980-2000, is depicted in Fig. 4.



Source : Oilseeds Situation-A Statistical Compendium, Damodaram and Hegde, 2001.

Fig. 4 Varieties and hybrids released in sesame (1980-2000)

About 39 improved varieties of sesame were developed during 1980- 2000. Up to 1995 there has been a steady increase in the number of varieties with a maximum of 14 varieties during 1990-95. However, only five cultivars were developed during the last five years. This reflects the early gains of technology mission program initiated in 1986. It is matter of concern that there has been a sudden decline during the past five years and the pace of development has not been on a sustainable mode. The possible causes leading to this and its future are discussed below.

The performance of varieties released is not uniform and yield of a new variety represents a measure of research in developing it. It is interesting to note that, 75 % of the varieties released in sesame were having yield above the threshold (yield with improved technology). The decline in release of newer varieties in the recent past is an indication that it would be difficult to look for more conventional varieties and the newer varieties have to come from hybrids and biotechnology, which can promise varieties with yield greater than the present threshold level. In other words, some major research breakthroughs are key to new varieties / hybrids and hence to the future of this crop.

Research breakthroughs : Based on Delphic survey some major research breakthroughs that are considered possible by experts in the next ten years in sesame are:

* Development of photo insensitive varieties with low senescence,
* Exploitation of germplasm for HYVs.
* Varieties for specific end uses like bold white seed
* Commercialization of newer end-use varieties
* Biofertilizer and biocontrol agents
* Value-added food products like sweetened candies, perfumes and sesame meal

The yield levels for new varieties/hybrids evolved by 2010 AD will be about 1000 kg/ha for varieties and 2000 kg/ha for hybrids. At present private sector share in sesame seed business is insignificant and by 2010 AD it would have market share of 20% for improved varieties and 75% for hybrids. This is critical to arrest declining trend in area under this crop.

There is a need to develop sustainable hybrid seed production techniques under farmer's field conditions as the cross-pollination is mostly by insects. The potential of enhancing crop productivity to a certain level being inherent, these have to be proved in field in order to sustain farmers interest in the crop.

Publications: Research results are generally disseminated through publications, which are good measure of research effort. Like improved varieties, number of publications is another means to reflect the research output. Manpower being a key resource in research, publications per scientist provides a measure of the effort. The average number of papers per scientist per year was calculated from the publications data during 1989-91 and 1997-99. It is of concern to note that the number of papers per scientist per year of 0.15 low. Further, publication data also indicated that basic research on sesame is at low key and experts also concurred on this. Basic research is low, as bulk of the scientists are in experimental research. Further, drop in number of new varieties emanated from this constraint. Thus a shift in research focus to basic area is pre requisite for contemplated research breakthroughs as discussed above. The forecast indicates a small shift to basic research which is critical to development of knowledge leading to development of new improved varieties and hybrids in this crop.

Consumer preferences to oils :Survey on consumer choices of edible oils show (Table 2) that the sesame oil is least preferred by all income categories. The results do not show any changes in consumption of sesame oil in future either on health or on economic grounds. In other words, sesame oil continues to be used for specific purposes as is being used at present.

Table 2 Consumer preferences for edible oils

Preference	Preferences of consumption
1	Rapeseed-mustard, Palm oil, Groundnut, Safflower
2	Groundnut, Rapeseed-mustard
3	Soybean, Safflower, Rapeseed-mustard
4	Sesame, Others*

* Other oils like vanaspati / ricebran oil / cotton seed oil

Production forecast: Forecasts for sesame area and production by 2010 AD are given in Table-3. The forecasts were made by the trend based on past two decade data, delphi and consultation with oilseed experts. As indicated earlier, the projections for area and production by trend forecasting are 1.6 m.ha and 0.4 m. tonnes, respectively. The corresponding forecast by Delphi was 2.3 million ha and 1.0 million tonnes, respectively. A combined forecast was prepared in consultation with oilseed experts with due consideration to the above factors and the final forecasts are 2 m. ha for area and 0.8 million tonnes for production. The production of sesame in 2010 AD will be 0.27 m.tonnes higher than the average production of 0.53 m. tonnes during 1997-00. The contributions of area and productivity to the growth in sesame production will be 6

% and 94 % respectively, i.e., the additional production would largely come from yield enhancement.

Table 3 Forecasts for sesame area, production and yield by 2010 AD

	Area (million hectares)	Production (million tonnes)
Trend	1.6	0.4
Delphi	2.3	1.0
Combined forecast	2.0	0.8

Assuming the present use of sesame continues in the next decade, sesame oil production would be around 320 thousand tonnes by 2010 AD, which is higher by about 80,000 tonnes than the present. As India continues to import edible oil to meet domestic demand, this additional quantity will be used in the domestic sector.

Conclusions

This paper attempts to project the future situation for sesame crop in India. This would be necessary to prioritize the already dwindling status of sesame research and production in this country. Even though this is a traditional crop for centuries, the recent past indicates decline in its area. However, present usage patterns in conjunction with the research/developmental efforts for the crop show a modest future for it. Possible research achievements in evolving HYV/ hybrid coupled with limited entry of private sector in seed marketing is likely to offset this downward trend. Our study shows that basic research in this oilseed needs to be strengthened. It was seen that very slow technology transfer process is the main reason for high realizable yield gap in sesame. Development of improved varieties / hybrids is critical to the research and extension systems in both public and private sectors to speed up transfer of technologies. The potentialities being limited for the crop in terms of diversification or very high productivity levels, price competitiveness would be a major force for the growers in the present day product-driven agricultural trade. In such a scenario, sesame crop sustains and its production is forecasted to increase from present 0.5 mt to about 0.8 mt by 2010 AD.

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Seed composition and fatty acid profile of some tree borne oilseeds

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Abstract

The oil and protein contents with their fatty acid profiles of 15 tree oilseeds were analysed. The oil content of seeds ranged from 4.6% in *Parkinsonia aculeata* to 37.4% in *Pongamia pinnata*. Protein content was the lowest in *Melia azedarach* (7.9%) and highest in *Albizzia lebbek* (30.9%). Oleic and linoleic acid were the major fatty acids in seven species each while *Jatropha curcas* had an equal proportion of both the fatty acids.

Key words: Tree borne oilseeds, phenology, oil content, fatty acid profile, protein content

Introduction

India has made tremendous progress in the production of annual oilseeds as a result of the technological advances and area expansion (Rai *et al.*, 2002). However, the wide demand supply gap still exists and the bridging of this gap needs immediate attention. At this juncture, when further area expansion is not feasible, the need to tap the perennial sources of oil gains importance. India has a vast array of non-traditional oilseeds, particularly the forest and tree oilseeds. Many of the species have been in use by ethnic communities since time immemorial, as they provide edible grade oil and possess medicinal and pesticidal properties. Besides, the oils find use in a wide range of industrial applications and also have export potential. Exploitation of the same has become essential for their utilization in the edible and non-edible oil industry to reduce the pressure on the annual oilseeds (Bhattacharya, 2002).

Among the many factors affecting the utilization of the oil and protein from seeds, the major one is the source of availability of seeds. In order to develop the system on a sustainable basis, in addition to collection of seeds from existing trees, the setting up of plantations may form a viable alternative. Presently large quantities of the minor forest products including tree borne oilseeds are consumed locally. The exploitation of these products should therefore, be preceded by the efforts for their renewal on a sustainable basis (Mukta, 2002). In this context, at the Directorate of Oilseeds Research, Hyderabad, a plantation of various tree species was established on shallow marginal soils under rainfed conditions. The flowering and fruiting phenology of the trees, oil and protein contents of the seeds along with the fatty acid profile of 15 tree oilseeds have been studied. Their importance and scope for their utilization are discussed.

Materials and methods

Trees of 15 species were planted at the Research farm of the Directorate of Oilseeds Research, Hyderabad on erosion prone Alfisols with poor soil fertility under rainfed conditions. The site receives an annual rainfall of 700 mm and air temperature during the months of May-June reaches upto 43^{0}C. The trees were planted during 1988-89 and observations on flowering and fruiting phenology were recorded at regular intervals. Seeds of these plant species were collected during 1997-98 and 1998-99 seasons after proper maturity. These were studied and analysed for oil (soxhlet extraction) and protein (Kjeldahl N x 6.25) contents. The oil was extracted with petroleum ether which was interesterified with methanolic KOH (Paquot, 1979). The methyl esters of fatty acids were separated on a DEGS column at 180^{0}C in an AIMIL gas chromatograph. Nitrogen (40 ml/min) was the carrier gas. The detector and oven temperatures were maintained at 250^{0}C. The identification of the fatty acids was based on comparison of RT values of standards.

Results and discussion

The juvenile period for all the species studied ranged from 0.5 to 4 years (Table 1). Species like *Jatropha curcas* flowered early while *Pongamia pinnata* took 4 years for the initiation of flowering. The seed maturity of 10 species occurred in the first half of the year while three species i.e., *Anonna, Leucaena* and *Jatropha* matured in the latter half. Seed maturity during the monsoon has been the major hindrance in collection programmes of tree borne oilseeds. In the present study, majority of the species matured before or after the monsoon so collection programmes could be successfully organised.

Ease of seed removal is another factor which will affect the extraction and utilization of oil. Among the species studied, the seed separation from fruit was found to be difficult for only three species *Melia, Anonna* and marking nut. However, most of the leguminous tree species have hard seed coats and need special processing techniques for oil extraction.

Oil and protein content: The oil content of the seeds ranged from 5-10% in *Albizzia, Acacia, Leucaena, Melia* and *Parkinsonia*. Marking nut seeds contained around 17% oil. *Pithecellobium* seeds contained 18% oil while Garg (1996) reported an oil content of 16%. *Anonna, Bauhinia, Ceiba, Simarouba* and *Moringa* contained 20-30% oil while the seeds of *J. curcas* and *Pongamia pinnata* contained 30-40% oil.

The protein content on whole seed basis ranged from 8-28%. Lower level of protein was observed in *Melia* (7.9%), *Anonna* (13.6%), *Bauhinia* (13.9%), *Parkinsonia* (15.6%) *Simarouba* (16.5%) and *Acacia* (17.6%). In the case of *Acacia*, Sita Devi *et al.* (1979) have reported total protein content of 19.6%. *Albizzia, Leuceana, Ceiba* and *Moringa* seeds contained higher level of protein (25-30%) while seeds of the remaining five species viz., Semecarpus, *J. curcas, Erythrina indica, Pongamia* and *Pithecellobium* seeds had protein in the range of 20-25%. Ambasta (1986) has reported higher value of protein in seeds of *Pithecellobium* (30%) and edibility of seeds of *Parkinsonia* with glutelin and albumin being the primary proteins.

Fatty acid profile: *Fatty acid composition of the oils* derived from the tree borne oilseeds showed wide variations (Table 2). Palmitic, palmitoleic, stearic, linoleic, linolenic, arachidic and behenic acids were the fatty acids identified in one or the other of these vegetable oils. Except for lower values for *Moringa* and *Melia*, all other species contained palmitic acid ranging from 10-21%. However, higher values of palmitic acid were reported by Garg (1996) in case of *Melia* (9.7%) and Raval and Toliwal (1996) for *Moringa* (12.3%). In the present study, the highest value was recorded in the case of *Ceiba pentandra* (20.6%). *Simarouba* (23%) was the richest in stearic acid followed by *Albizzia* (15%) while the other species exhibited the normal range of 3-12%. Variable values of stearic acid have been reported in mature seeds of *Jatropha curcas* ranging from 3.9% in the present study to 5.25 % reported by Raina and Gaikwad (1987). However, Datta and Pandey (1996) could not detect the presence of stearic acid during GLC analysis of mature seed.

Table 1 Flowering and fruiting phenology of some tree borne oilseeds

Species	*Family*	*Common name*	Number of years to first flowering	*Time of flowering*	Period of harvesting	Ease of threshing*
Acacia nilotica	Mimosaceae	Babul	3-4	July	March-April	++
Albizzia lebbek	Mimosaceae	Siris	2	Feb-March	June-Aug	+++
Anonna squamosa	Annonaceae	Sitaphal	3	July-Aug	Nov	+
Bauhinia spp	Caesalpiniaceae	Kachnar	3	Sept-Oct	March	+++
Ceiba pentandra	Bombacaceae	Kapok	2-3	Nov-Dec	May	++
Erythrina indica	Fabaceae	Dadhap	2-3	Dec-Feb	April	+++
Jatropha curcas	Euphorbiaceae	Ratanjyot	0.5	July-Aug	Aug-Oct	+++
Leucaena leucocephala	Mimosaceae	Subabul	1.5-2	April, July	Nov-Dec	+++
Melia azedarach	Meliaceae	Persian lilac	1.5-3	July	April – June	+
Moringa oleifera	Moringaceae	Saijan	1.5-2	Feb	May – Aug	+++
Parkinsonia aculeata	Caesalpiniaceae	Vilayati babul	2.5-3	Jan, Aug	April-May	++
Pithecellobium dulce	Mimosaceae	Jangli jalebi	2.5-3	Jan-Feb	May-June	++
Pongamia pinnata	Fabaceae	Karanj	4	March, July	Feb-March	+++
Semecarpus anacardium	Anacardiaceae	Marking nut	3-5	July-Aug	Jan- March	+
Simarouba glauca	Simaroubaceae	Aceitino	3	Dec	April	++

* Ease of threshing + = very difficult, ++ = medium, +++ = easy seed removal

Table 2 Seed composition and fatty acid profile of some tree borne oilseeds

Genera	Total oil content (%)	Seed Protein (%)	Palmitic acid 16:0	Stearic acid 18:0	Oleic acid 18:1	Linoleic acid 18:2	*Other fatty acids
Acacia nilotica	7.4	17.6	12.5	11.5	28.3	44.5	-
Albizzia lebbek	5.3	30.9	17.1	14.7	23.4	54.9	-
Anonna squamosa	25.9	13.6	15.0	10.6	48.0	24.7	18:3 = 1.4
Bauhinia spp	20.4	13.9	10.0	11.9	20.4	47.5	20:0 = 1.7, 22:0 = 0.4
Ceiba pentandra	28.1	25.0	20.7	2.8	32.7	42.1	16:1=0.6
Erythrina indica	16.2	19.7	14.9	7.7	61.4	5.7	20:0=3.8, 22:0=4.3
Jatropha curcas	33.0	23.0	12.6	3.9	41.8	41.8	-
Leucaena leucocephala	7.9	27.8	17.9	8.4	18.7	55.0	-
Melia azedarach	7.5	7.9	8.4	4.0	23.7	62.9	20:0=0.5
Moringa oleifera	20.5	24.5	7.3	6.0	77.0	0.6	20:0=3.9, 22:0=2.8, 16:1=2.0
Parkinsonia aculeata	4.6	15.6	16.5	7.2	31.6	44.0	-
Pithecellobium dulce	17.9	21.4	20.1	4.6	43.2	29.8	18:3=2.8 20:0=2.3
Pongamia pinnata	37.4	20.2	11.3	6.4	54.5	17.0	18:3=4.5, 20:0=5.2
Semecarpus anacardium	16.8	23.2	14.4	6.8	60.0	7.7	20:0=4.8, 22:0 6.3
Simarouba glauca	27	16.5	11.3	23.0	64.9	1.6	-

* 16:1=Palmitoleic acid; 18:3= Linolenic acid; 20:0=Arachidic acid; 22:0=Behenic acid

Oleic acid was the major fatty acid in *Moringa* (77%), *Simarouba* (65%), *Erythrina* (61%), *Semecarpus* (60%), *Pongamia* (55%), *Anonna* (48%), and *Pithecellobium* (43%). Linoleic acid was the predominant fatty acid in the case of *Melia* (63%), *Albizzia* (55%), *Leucaena* (55%), *Bauhinia* (48%), *Parkinsonia* (44%), *Acacia* (44%) and *Ceiba* (42%). The lowest level of linoleic acid was observed in *Moringa* (0.6%).

Among the minor fatty acids, palmitoleic acid was observed in *Moringa* (2%) and *Ceiba* (0.6%) only. However, it has been reported by Garg (1996) in case of *Pithecellobium* (3.1%) also. Linolenic acid was observed in four species *viz.*, *Pongamia* (4.5%), *Pithecellobium* (3%), *Anonna* (1.4%) and *Ceiba* (1.1%). Arachidic acid was little more widespread and was present in *Semecarpus* (5%), *Erythrina* (4%), *Moringa* (4%), *Bauhinia* (2%), *Pithecellobium* (2%) and *Melia* (0.5%). Behenic acid (22:0) was observed in *Semecarpus* (6%), *Erythrina* (4%), *Moringa* (3%) and *Bauhinia* (0.4%).

Raina and Gaikwad (1987) reported that the fatty acid composition of 'Curcas oil' was found to be affected by stage of maturity and season of harvest. The variable values obtained in the other species as discussed above may also be dependant on these factors. The variations can also be attributed to the regional difference in seed sources and variations in the analytical techniques adopted.

Utilization: From the point of view of utilization, palmitic, stearic and oleic acids find uses in soaps, detergents, plastics, coated papers, rubber coatings, candles, crayons, waxes, lubricating greases, polishes, buffing agents and cosmetics. Linoleic acid and linolenic acid though categorized as essential fatty acids, for human nutrition, have uses in the paint and varnish industry, because of their higher unsaturation. Most of the tree borne oilseeds depending on the oil content and availability can easily be utilized for the above purposes depending upon their fatty acid composition. *Moringa* seeds are edible, and hence its oil can easily be utilised as edible oil when available in sufficient quantities. Raval and Toliwal (1996) have found no harmful effects of this oil in a feeding study conducted on rats. This oil was low in 16:0 which is considered problematic to cardiac patients. Further, the oil being rich in oleic acid (18:1) and very low in linoleic acid is very stable and should serve as very good frying oil. Higher levels of stearic acid in *Simarouba* would be useful in avoiding hydrogenation and also serve as cocoa butter substitute. The unsaponifiable matters of some of the vegetable oils may find uses as pesticides, medicines etc.

In recent years, efforts for the use of vegetable oils and their methyl esters as potential alternative fuels for diesel engines have increased. Out of the species included in this study, seed oils *of Anonna, Jatropha curcas, Moringa* and *Pithecellobium* have been reported to possess high cetane index of methyl esters and have potential for use as diesel substitutes (Kalayasiri *et al.*, 1996). In India, oils from species like *Pongamia pinnata* (karanj) (Shrivastava, 2001) and *J. curcas* (Patil and Singh, 1991) are already undergoing trials for use as biofuel.

Most of the species described above are found abundantly in India and the oilseeds and oils can be easily exploited, after survey regarding seed availability and the scope for its collection. These species can also fit into different systems and problem areas (Hocking, 1993) giving the dual benefit of rehabilitation as well as the production of useful products. Systematic efforts for collection, plantation and utilization, along with policies for marketing and pricing need to be made immediately to prevent further wastage of the already available resources and promote continued production in a sustainable manner.

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Production and economic factors growth in cultivation of groundnut, *Arachis hypogaea* L. crop in India

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Abstract

The average cost of cultivation of the groundnut at All India level in 1997-98 was computed Rs.1094/q. Against that minimum support price was fixed at Rs.980/q, leaving a negative remuneration of Rs.113.95/q. Self labour and fixed cost components included in the analysis of cost of cultivation were the major incentives to the farmers to grow this crop. However, a negative growth rate of 3% per annum in the area during 1990-91 to 1997-98 is an indication that the farmers have shifted to other crops. A modest growth rate of 1.79% per annum was achieved in the production of the groundnut during 1975-76 to 1997-98, largely due to the increased yield of 1.2% per annum, as growth rate in the area has been low (0.58 % per annum).To make the crop more remunerative, yields have to be increased further at reduced cost of cultivation. The share of cost of labour in the total cost of cultivation has been comparatively high (29.3% in 1997-98) that needs to be reduced through use of appropriate technology.

Key words: Growth trend in production factors, fixed and operational cost, support price, economic return, groundnut

Introduction

The groundnut is an important oilseed crop. It accounts for 34% of the world area under cultivation, and contributes 26.8% of the total groundnut production. Its share in the total oilseeds production of 20.87 m.t. was 25.44% in 1999 -2000. Its yield has been fluctuating in the country due to weather aberration as area under irrigation is limited to less than 20%. The major states that grow the crop are Gujarat (26.64%), Andhra Pradesh (26.06%), Karnataka (16.16%), Tamil Nadu (12.08%), Maharashtra (7.57%), Rajasthan (3.93%), Madhya Pradesh (3.78%), Uttar Pradesh (1.5%) and Orissa. These states together cover more than 98.5% area. The average yield of the crop was recorded 1210 kg/ha in 1998-99 and it reduced to 774kg/ha in 1999-2000. Low return in cultivation of groundnut due to higher cost of production and inadequate marketing support, encouraged farmers to shift to other crops as revealed from the reduction in area under cultivation. Analysis was therefore made in production factors (area, yield and total production), and economic factors (cost of cultivation, minimum support price and margin of profit) to study the inputs contributing to lower return.

The data for the analysis of the production and economic factors for the year of 1975-76 to 1997-98 were obtained from the various issues of Agricultural Statistics at a Glance, and Cost of Cultivation of Principal Crops in India, published by the Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India. The analysis of the cost of cultivation includes paid out and imputed costs as (Singh and Chandra, 2002),

Operational cost including inputs:

- Human labour, bullock labour, and machine hour
- Seed, fertilizer & manure, insecticides, irrigation charge, and
- Interest on working capital.

Fixed cost:

- Rental value of owned land, rent paid for leased-in land, land revenue, cess and taxes,
- Depreciation on implements and farm buildings, and
- Interest on fixed capital.

The weighted average cost of cultivation/hectare and components of cost of cultivation at All India level was computed by taking into account cost of cultivation (or cost of input components), and area under the groundnut grown in different states. Like wise the cost of cultivation per quintal was computed by taking into account cost of cultivation per quintal and the total production of the groundnut from the different States. These are expressed as:

Cost of cultivation per hectare,

$$C_{ha} = \frac{\sum_{i=1}^{n} C_{hai}A_i}{\sum_{i=1}^{n} A_i} \quad (1)$$

Cost of cultivation per quintal,

$$C_q = \frac{\sum_{i=1}^{n} C_{qi}P_i}{\sum_{i=1}^{n} P_i} \quad (2)$$

Where,

C_{ha} = Weighted average cost of cultivation/ha at All India level, Rs/ha

C_q = Weighted average cost of cultivation/q at All India level, Rs/q

n = Number of states from where cost of cultivation data collected

C_{hai} = Average cost of cultivation/ha for i^{th} states in a given year, Rs/ha

C_{qi} = Cost of cultivation/q for i^{th} states in a given year, Rs/q

A_i = Area under cultivation in i^{th} states in a given year, thousand ha

P_i = Total production of the crop in i^{th} states in a given year, million tonnes.

Growth in area, yield and production of groundnuts

There has been wide fluctuation in the yield and area under cultivation of the groundnut as the crop is largely grown in arid regions of the country, and the area under irrigation is less than 20%. The area under cultivation of groundnut crop was 7.22 m.ha in 1975-76, which increased to 8.67 m.ha in the year 1991-92. Since then, it has gradually reduced to 7.09 m.ha in 1997-98 with a negative growth rate of 3% per annum. The crop however, has recorded an increase in the yield from 935 kg/ha to 1040 kg/ha during this period, recording a growth rate of 1.2 % per annum. As a result the total groundnut production has increased from 6.76 m.t. in 1975-76 to 7.37 m.t in 1978-79, recording a growth rate of 1.79 % per annum (Fig. 1). The highest production of the groundnut was achieved 9.66 million tonnes in 1988-89, recording an average yield of 1132 kg/ha. The All India average growth in the production factors of the groundnut can be expressed as:

Area under cultivation, m.ha $A = 6.58 + 0.157x - 0.005x^2$, ($R^2$=0.29) (1)

Production, m.t. $P = 5.35 + 0.156x - 0.002x^2$, ($R^2$ = 0.34) (2)

Yield kg/ha, $Y = 822.39 + 1.17x + 0.357x^2$, ($R^2$ = 0.35) (3)

Growth in fixed, and operational cost of cultivation

The total cost of cultivation of the groundnut was Rs.1584/ha (or Rs.235.71/q) in 1975-76, which has increased to Rs.13,977/ha (or Rs.922/q) in 1997-98. This recorded a growth rate of 11.21% per annum. The operational cost increased from Rs.1084/ha to Rs.10061/ha (10.94 % per annum), and fixed cost from Rs.504/ha to Rs. 3916/ha (11.68% per annum), during this period (Figs. 2 & 3). The share of cost of different components in the total cost of cultivation for the year 1997-98, revealed that human labour cost has been the highest with 29.3% share. Besides fixed cost (28% of the total cost), the share of the cost of seed was 16.1%, followed by fertilizer, 10.2%, and bullock labour, 7.2%. The share of cost of other components was small (Fig. 4). The cost of cultivation per quintal in Maharashtra was highest with Rs.1418/q, and lowest in Gujarat with Rs.933/q (Fig 5a and 5b). The growth in the average cost of cultivation at all India level could be expressed as,

Cost of cultivation Rs./ha, $C_{ha} = 2048.2 - 196.6x + 30.53x^2$, ($R^2$= 0.98) (4)

Cost of cultivation Rs./q, $C_q = 161.64 + 6.26x + 1.62x^2$, ($R^2$ = 0.96) (5)

Cost of inputs affecting cost of cultivation

Human labour: The human labour requirement in cultivation of a groundnut crop is excessively high. Decortication, planting, weeding, harvesting, and stripping of pods are largely performed by human power as these operations have hardly been mechanized. It was estimated that the use of human energy per hectare has increased from 574 human-hours in 1975-76 to 689 human-hours in 1997-98, recording a growth rate of 0.38 % per annum (Singh, 1997). The share of cost of human labour was Rs.339.46/ha in 1975-76, and that has increased to Rs.4099/ha in 1997-98, recording a growth rate of 12.3% per annum (Fig. 6). The share of cost of human labour for the states of Maharashtra and Gujarat, that recorded the highest and the lowest cost of cultivation per quintal, respectively, are given in Fig. 5a and 5b. The growth in cost of human labour at All India level could be expressed as,

Cost of human labour/ha $H_c = 683.45 - 133.06x + 11.51x^2$, ($R^2$ = 0.95). (6)

Bullock labour: Draught animals are still used for variety of farm operations like seed bed preparation, ridge and furrow making, sowing/planting, and digging operations The share of cost of animal energy in total cost of cultivation at All India level in 1997-98 was 7.19 %. It was12.6% in Maharashtra and 7.9% in Gujarat. Tractors are also used for some these operations, as a result, use of animal energy per hectare at All India basis has

reduced considerably from 127 pairs-hour/ha in 1975-76 to 81 pairs-hour/ha in 1997-98, recording a negative growth rate of 1.38% per annum (Singh, 1997). But the cost of bullock labour during this period has recorded a modest increase of 0.62% per annum (Rs.227/ha to Rs.1009.51/ha (Fig. 6). This is due to higher maintenance cost of animals, and increased wages of the operator. The growth in use of animal power could be expressed as,

Cost of animal labour, $B_c = 245.02 - 4.24x + 1.6X^2$, ($R^2 = 90$) (7)

Machine hour cost: Mechanization of groundnut cultivation is constrained due to limited availability of improved farm machinery. In 1997-98, the share of cost of use of machines was 3.2%, as most of the farm operations are done by human and animal power (Fig. 4). The average cost of use of machines was Rs.11/ha in 1975-76, and that has increased to Rs.446.37/ha in 1997-98 (Fig. 6), recording a significant growth rate of 17.3% per annum. This could be expressed as,

Machine hour cost, $M_c = 78.98 - 21.22x + 1.49x^2$, ($R^2 = 0.85$) (8)

Seed cost: Seed is one of the major inputs that influences the yield. Its share in the total cost of cultivation of the groundnut was 16% as seen from the Figs. 4 and 5. The seed cost was Rs.375.56/ha in 1975-76, and that has increased to Rs.2251/ha in 1997-98, recording a growth rate of 10.4% per annum. The growth could be expressed as (Fig. 7),

Seed cost, $S_c = 781.52 + 9.02x + 3.64x^2$, ($R^2 = 0.98$) (9)

Fertilizer cost: Fertilizer is another input essential to increase the yield. Its share was 10.2% of the total cost of cultivation in 1997-98. In 1975-76, it was Rs.71.83/ha, and has increased to Rs.1419.48/ha in 1997-98, recording a growth rate of 11.12% per annum. The growth could be expressed as (Fig. 7),

Fertilizer cost per hectare, $F_c = 204.78 - 20.90x + 2.80x^2$, ($R^2 = 0.95$) (10)

Cost of irrigation: The All India average irrigated area under groundnut crop was only 19.6% in the year 1997-98, compared with the total oilseed crops of 24.4%. The states of Rajasthan (35.9%), Maharashtra (35%), and Tamil Nadu (31.2%) have higher irrigated area under the groundnut compared to other states. These states have also recorded higher yields (Govt. of India, 2001). The share of average cost of irrigation was Rs.23.22/ha in 1975-76, and that has increased to Rs.356.38/ha in 1997-98, recording a growth rate of 15.68% per annum (Fig. 7). This cost could be expressed as,

Irrigation cost per hectare, $Irri_c = 22.68 + 0.25x + 0.47x^2$, ($R^2 = 0.75$) (11)

Cost of plant protection: The yield of the groundnut is affected by the diseases and pests, and therefore, precautions are necessary for proper protection. However, average investment in plant protection measures by the farmers at All India level in 1997-98 was only 1.7% of the total cost of cultivation. It was only Rs.7.86/ha in 1975-76 , and has increased to Rs.232.50/ha 1997-98 (Fig. 7). The increase in cost could be expressed as,

Cost of plant protection, $PP_c = 30.55 - 6.41x + 0.51x^2$, ($R^2 = 0.78$) (12)

Minimum support price, and profit

Importation of oil is a regular feature to meet the consumers' demand due to lower oilseeds' production in the country. The market price of oilseeds therefore, fluctuates as per season, and availability of imported oil in the market. Traders, and oil crushers make the marketing of oilseeds complex. The Government provides minimum support price (MSP) to the farmers to ensure economic returns. The MSP for the groundnut in the year 1975-76 was fixed at Rs.135/q, compared with the All India average cost of cultivation of Rs.104.71/q. This enabled the farmers to get a remuneration of Rs.30.30/q. The average cost of cultivation has increased to Rs.1094/q, and the MSP to Rs. 980/q, in the year 1997-98. This yielded a negative margin of Rs.114/q. The trends in the profit as computed by subtracting Eq. 5 of the cost of cultivation from the Eq. 13 of MSP could be given by the expression Eq. 14 as (Fig. 2),

Support price, Rs/q, $S_p = 133.04 + 4.25x + 1.49x^2$, ($R^2 = 0.99$) (13)

Profit Rs/q, $P_r = -(28.6 + 2.01x + 0.126x^2)$ (14)

The projected margin of profit for the year 2006-07 based on the above analysis of cost of cultivation, and the minimum support price is given in Table 1. It may be seen that against the estimated cost of production of Rs.2105/q (or Rs.25,293/ha and yield 1201.74 kg/ha), the minimum support price is estimated Rs.1700/q, which may yield a negative return of Rs.405/q. The above analysis has revealed that the growth in cost of cultivation of the groundnut has been very high, and the minimum support price fixed by the Government has not been adequate to compensate the cost of production. Self labour and fixed cost components included in the analysis of cost of cultivation are the major incentives to the farmers to grow the crop. Farmers in future may be discouraged to grow this crop if adequate incentive is not given. A negative growth rate of 3% per annum since 1991 to 1997-98 in area under cultivation is an indication of the trend. Measures may also have to be taken to reduce the cost per quintal by increasing the yield. Since, the cost of human and animal components are very high as seen from the Table 1 (36.6%), this need to be reduced by using improved machinery.

Table 1 Estimated cost of share of cost of inputs in total cost of cultivation of groundnut at all India level

Cost component	Computed cost 1997-98		Projected cost 2006-07	
	Rs./ha	Share, %	Rs./ha	Share, %
Human labour	4099.09	29.3	7619.70	30.1
Draught labour	1009.00	7.2	1651.18	6.5
Machine labour	446.37	3.2	853.05	3.4
Seeds	2251.00	16.1	4559.18	18.0
Fertilizer	1419.48	10.1	2247.68	8.9
Irrigation	356.38	2.5	482.10	1.9
Plant protection	232.50	1.7	321.95	1.3
Total cost of cultivation including fixed cost	13977	100	25293	100

Based on Cost of Cultivation of Principle Crops in India, 1991,1996 and 2000.

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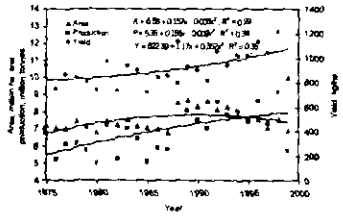

Fig. 1: Growth in area, production and yield of groundnut in India

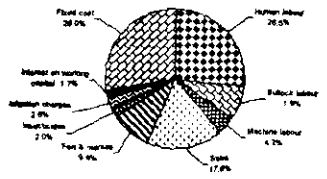

Fig. 6a: Share of cost of different inputs in lowest cost for cultivation of groundnut (Rs./ha) in 1997-98

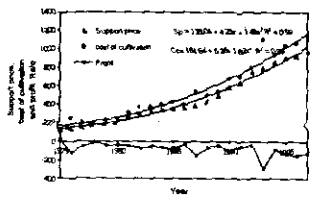

Fig. 2: All India growth in cost of cultivation, minimum support price and profit in cultivation of groundnut

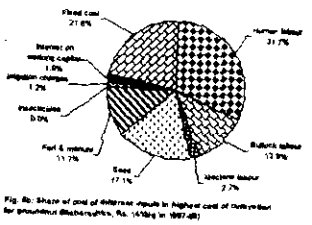

Fig. 6b: Share of cost of different inputs in highest cost of cultivation for groundnut (Rs./ha) in 1997-98

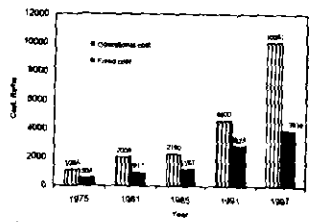

Fig 3: Growth in operational and fixed cost for groundnut production in India

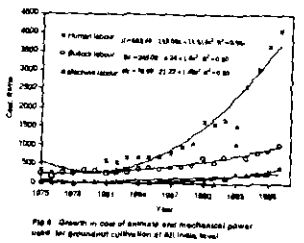

Fig 4: Growth in cost of animate and mechanical power use for groundnut cultivation at all India level

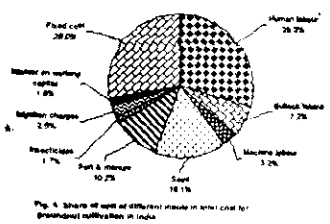

Fig. 5: Share of cost of different inputs in total cost for groundnut cultivation in India

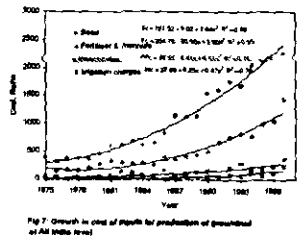

Fig 7: Growth in cost of inputs for production of groundnut at All India level

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Growth analysis of production and economic factors in rapeseed-mustard cultivation in India

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Abstract

The economic analysis of rapeseed-mustard crops has revealed that the minimum support price (MSP) (Rs.300/q) fixed by the Government was higher than the cost of cultivation (Rs.235.71/q) that yielded a margin of profit of Rs.64.29/q in the year 1980-81. The cost of cultivation recorded a higher growth rate of 8.46 % per annum compared to 7.47% of MSP during 1980-81 to 1997-98. Compared with the cost of cultivation of Rs.922/q, the MSP was fixed at Rs.940/q in 1997-98. As a result, the margin of profit has reduced to Rs 18/q. Besides, the farmers get the advantage of the cost of self labour, and value of the assets included in the fixed cost. Nevertheless, the lower margin of profit might have affected the capacity of the farmers to adopt better inputs, as evident from the negative growth rate in the yield of 1.03 % per annum, and a lower growth rate of 0.13% per annum in area, since 1990-91. Over all, during 1980-81 to 1997-98 the rapeseed-mustard crops have recorded a growth rate of 6.7 % per annum in production. This was achieved as a result of a higher growth rate of 4.18 % per annum in the area under cultivation, and 2.41% per annum in yields.

Key words: Growth in production factors, cost of cultivation, economic return, rapeseed-mustard

Introduction

The rapeseed-mustard are important oilseed crops in the country. The area under these crops was 6.07 m.ha that produced 5.96 m.t of oilseeds in 1999-2000. The major states growing rapeseed-mustard are Rajasthan (2.57m ha), Uttar Pradesh (1.07m ha), Madhya Pradesh (0.70 m ha), Haryana (0.45 m ha), West Bengal (0.34 m ha), Gujarat (0.32 m ha) and Assam (0.29 m ha), and contributed 95.3% of the total area under cultivation (Govt of India, 2001). The cost of cultivation of rapeseed-mustard is comparatively low, and the farmers find these crops very remunerative. The Government of India facilitates economic returns by fixing Minimum Support Price (MSP). The Government also helps the farmers to increase the yield of the oilseeds by providing incentives under Technology Mission on Oilseeds. These measures have helped the farmers to increase the All India average yield to about 982 kg/ha in 1999-2000. The average yields in the states of Haryana (1324 kg/ha), Rajasthan (1033 kg/ha), Uttar Pradesh (1020 kg/ha), Madhya Pradesh (949 kg/ha), and Gujarat (941 kg/ha) was found higher than others. An analysis has been made to study the growth in production (area, yield and total production) and economic factors (cost of cultivation, minimum support price and profit) that will help in identifying the inputs contributing to increased growth in productivity of rapeseed-mustard crops.

The growth trends in area, yield, production, cost of cultivation, and net income in cultivation of rapeseed-mustard crops have been analyzed on All India basis from the secondary data collected from the Agricultural Statistics at a Glance (2001), and the Cost of Cultivation of Principal Crops in India (1991, 1996, and 2000), published by the Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi for the periods of 1980-81 to 1997-98. The weighted averages of cost of cultivation per hectare and components of cost of cultivation at All India level were computed by taking into account cost of cultivation (or cost of inputs component), and area under the crops grown in different states. Like wise the cost of cultivation per quintal at All India was computed by taking into account the cost of cultivation per quintal and the total production of the crops from the different states. The items of cost of production that were included in the analysis were paid out and imputed costs (Singh and Chandra, 2002) as;

Operational cost including inputs:

- Human labor, bullock labor, and machine hour
- Seed, fertilizer & manure, insecticides, irrigation charge, and
- Interest on working capital

Fixed cost:

- Rental value of owned land, rent paid for leased-in land, land revenue, cess and taxes,
- Depreciation on implements and farm buildings, and
- Interest on fixed capital

The cost of cultivation are given as :

Cost of cultivation/hectare:

$$C_{ha} = \frac{\sum_{i=1}^{n} C_{hai} A_i}{\sum_{i=1}^{n} A_i} \quad (1)$$

Cost of cultivation/quintal:

$$C_q = \frac{\sum_{i=1}^{n} C_{qi} P_i}{\sum_{i=1}^{n} P_i} \quad (2)$$

Average net income/quintal:
Minimum support price - Cost of cultivation (3)

For the estimation of the growth trends, different regression equations were fitted, and the best expressions were identified based on highest coefficients of determination (R^2), and minimum value of standard error. In the prediction equation, 1980-81 has been taken as base year =1. The compound growth rate (r, %) for different growth periods was calculated as, $y = a (1+ r/100)^x$, where, y is depended function (yield, area, *production, cost of cultivation*), and x elapsed time period in years. The significance of growth rates was tested by using t statistics as: t = r/SE (r), where SE is standard error(Subramaniyam and Vasanthi, 1988).

Growth trends in area, crops yield and total production

The total production of rapeseed-mustard has increased from 2.30 m.t. to 4.70 m.t. during 1980-81 to 1997-98, recording a significant growth rate of 6.7 % per annum (Fig. 1). This was achieved due to increased growth in area under cultivation (4.18% per annum) and yields of the crops (2.41 % per annum) during this period. The area under cultivation has increased from 4.11 million hectares to 7.04 million hectares, and yields from 560 kg/ha to 668 kg/ha. Maximum growth in area of 10% per annum, and in yield 6.43 % per annum was recorded during 1986-87 to 1990-91. This was the period when promotional measures were undertaken by the Government of India to increase the oilseeds' production under Technology Mission on Oilseeds. However, since 1991-92 onwards, a lower growth of 0.24% per annum in production of rapeseed-mustard was recorded as growth in area was reduced to 0.13 % per annum, and yield recorded a negative growth rate of 1.03 % per annum. The growth in production factors could be best estimated by,

Area under cultivation million ha, $A=3.73+0.065x+0.007x^2$, $R^2=0.86$ (4)

Yield kg/ha, $Y = 446.55+ 61.83x - 2.188x^2$, $R^2 =0.69$ (5)

Production, million tonnes, $P = 1.30 + 0.384x - 0.0072x^2$, $R^2 =0.82$ (6)

Growth trends in cost of cultivation

The analysis of data of cost of cultivation of rapeseed-mustard at All India level for the period 1980-8 -1997-98 revealed that it has recorded a growth rate of 11.57 % per annum on hectare basis or 8.46% per annum on quintal basis (Rs.1617/ha to Rs.9019/ha or Rs.231.71/q to Rs.922/q, respectively). The fixed cost component increased from Rs.738/ha to Rs.4183/ha (5.67 times), and operational cost from Rs.879/ha to Rs.4836/ha (5.5 times) (Figs. 2 and 3). The average growth in cost of cultivation could be expressed by,

Cost of cultivation, $Rs./_q = (276.86 - 17.45x + 2.622x^2)$, ($R^2= 0.98$) (7)

The detailed share of cost of different inputs contributing to the total cost was also analyzed for the year 1997-98 (Fig. 4). It revealed that share of fixed cost component was 46.4%, human labour, 24.7%, bullock labour, 38%, and machinery use cost, 10.6%.. The share of cost of other inputs was; seed, 12%, fertilizer and manure, 9.5%, *irrigation charges*, 2.5%, *insecticides*, *0.4%, and interest* on capital, 0.9%. The share of cost of different inputs for the highest and lowest cost of cultivation was also analysed for the year 1997-98 (Haryana, Rs.1381/q, and Assam, Rs.955/q). These are shown in Figs. 5a and 5b.

Growth trends in cost of inputs influencing cost of cultivation

Human labour cost: The cost of cultivation data of rapeseed-mustard at All India level revealed that the share of cost of human labour in total cost of cultivation was 24.7% in 1997-98 (Fig. 4). This indicated that human energy is still very extensively used, besides mechanical energy. Sowing, thinning, harvesting, and threshing are the major operations where human power is employed in cultivation of these crops. The average All India human energy input in cultivation of rapeseed-mustard was 367 hours/ha in1980-81, which reduced to 339 human-hours/ha in1997-98, recording a negative growth of 0.97% per annum (Singh, 1997). Increased human energy inputs and higher wages have increased the human labour cost from Rs.461/ha in 1980-81 to Rs.2226/ha in 1997-98, with a growth rate of 11.50% per annum (Fig. 6). This could be expressed as,

H_c Rs/ha= $624.66 - 103.82x + 11.11x^2$, $R^2 = 0.96$ (8)

Drought animal labour cost: The rapeseed-mustard crops do not require fine tilth. Animal drawn ploughs and Bakhars are the most popular tillage implements used by the farmers. Sowing is done by broadcasting or using animal drawn sowing devices like *Dufan/Tifan*. These operations are gradually being replaced by tractor drawn

machinery in some of the mechanized states. As a result, average use of animal energy in the country has reduced from 105 animal-pairs/ha in 1980-81 to 37 animal-pairs/ha in 1997-98, with a negative growth rate of 5.56% per annum (Singh and Chandra, 2002). The share of cost of use of animal labour in total cost of cultivation at All India level is given in Fig. 4 and 5. It was Rs.209/ha in 1980-81, and that has increased to Rs.344/ha in 1997-98 recording a growth rate of 1.55 per annum (Fig 6). The increase in cost was mainly due to increased cost of maintenance of the animals. The growth in animal labor cost could be expressed as,

$$B_c = 176.13 + 46.74x - 4.76x^2 + 0.154x^3,\ R^2 = 0.25 \quad (9)$$

Machine hour cost: Besides human and animal power, use of tractors for tillage, and electric motors and engines for irrigation and threshing has increased. On All India basis the share of cost of use of machine hour in the total cost was 10.6% in the year 1997-98 (Fig 4). This has increased from a meager Rs.57/ha in 1980-81 to Rs.954/ha in 1997-98, recording a significant growth rate of 19.6 % per annum (P <0.01)(Fig 6). In the state of Haryana which has recorded the highest cost of cultivation, the share of machine use cost was 12.3% of the total cost, but it was only 0.1% in Assam that recorded lowest cost of cultivation (Figs. 5a and 5b). The growth rate in cost of machine hour could be expressed by:

$$M_c = 58.80 - 10.76x + 3.31x^2,\ R^2 = 0.97 \quad (10)$$

Fertilizer: Oilseeds responds well to the use of balanced doses of fertilizers. The average cost of use of fertilizer in total cost of cultivation at All India level in 1997-98 was computed 9.5 % (Fig. 4), and it was 10.1% in Haryana and 7.6% in Assam (Figs. 5a and 5b). The cost was Rs.24/ha in 1980-81, and that has increased to Rs.858/ha in 1997-98, recording a growth rate of 20.77% per annum (Fig. 7). The highest growth rate in use of cost of fertilizer was recorded 40.85 % per annum during 1986-87 to 1990-91, possibly due to promotion of cultivation of oilseeds initiated under Technology Mission on Oilseeds. The growth in use of cost of fertilizer could be expressed as:

$$F_c = 32.17 - 1.82x + 2.70x^2,\ R^2 = 0.94 \quad (11)$$

Seed: The high yielding varieties are one of the major inputs for increasing the crop yield. The OILFED, State Seeds corporations, National Seed Corporations, State Agricultural Universities, and private seeds companies supply certified seeds of rapeseed-mustard to the farmers. The average investment in seed was Rs.38/ha in 1980-81, and that has increased to Rs.109/ha in 1997-98, recording a growth rate of 7.8% per annum (Fig 7). This could be expressed as.

$$S_c = 33.47 + 1.256x + 0.201x^2,\ R^2 = 0.87 \quad (12)$$

Plant protection: Diseases, and pests' management is the major problem in production of rapeseed-mustard. However, the farmers do not take adequate precautions as evident from the investment in plant protection that was only 0.4% of the total cost of cultivation in 1997-98. On an average, about Rs.13/ha was spent for the plant protection in 1980-81, and that has increased to only Rs.34/ha in 1997-98, recording a growth rate of 9.6% per annum (Fig 7). This could be expressed as;

$$PP_c = 7.75 - 1.5x + 0.123x^2,\ R^2 = 0.46 \quad (13)$$

Irrigation: The rapeseed-mustard crops do not require much water but some of the varieties response well to the irrigation. The All India average area under irrigation of rapeseed-mustard crops was 57.6% in 1997-98. The states of West Bengal (98.5%), Gujarat (92.8%), Punjab (87.4%), Haryana (67.3%), and Rajasthan (62%) have higher irrigated area under the crops, and Madhya Pradesh (34.9%) and Bihar (37.6%), the lowest. The share of average cost of irrigation at All India level was Rs.74/ha in 1980-81, and that has increased to Rs.227/ha in 1997-98), recording a growth rate of 10.92% per annum (Fig. 7). This could be expressed as;

$$\text{Cost of irrigation Rs/ha} = 34.03 + 23.16x,\ (R^2 = 0.73) \quad (14)$$

Support price and profit in cultivation of rapeseed-mustard

The demand of vegetable oils in the country is increasing for cooking as well as for industrial applications. Domestic production is inadequate to meet the demand, and therefore, the country imports edible oil every year. The oilseeds processing has become one of the major agro-industries in India, and the estimated population of processing units are; *Kolhus* ,250,000, mechanical expellers, 50,000, oil mills, 15,500, and solvent extraction plants, 725. The oil millers are not able to utilize full installed capacity of oilseed processing units as domestic oilseeds production is inadequate. Only about 30 % of the installed capacity of these units is being utilized, and therefore, oilseeds are always in demand by the millers.

Marketing of agricultural crops in general and commercial crops like oilseeds in India is complex. The farmers have choice to sell the oilseeds in open markets or to the oil millers. In this analysis only minimum support price (MSP) fixed by the Government has been considered for the computation of profit. The MSP for the rapeseed-mustard was fixed at Rs.300/q in 1980-81 compared with the cost of cultivation of Rs.235.71/q. This enabled the farmers to get a profit of Rs.64.29/q. Since then, the cost of cultivation has increased to Rs.922/q (growth rate 9.55% per annum), and the MSP to Rs.940/q (growth rate 5.27% per annum), in 1997-98. This has reduced the margin of profit to Rs.18 only.The expression for the growth in the margin of profit (Fig 3) could be given by

subtracting Eq. 15 of minimum support price from Eq. 7 of cost of cultivation.

Support price, Rs/q, S_p = 271.56 +15.09 x +1.33 x^2, (R^2 = 0.98) (15)

Profit, Rs/q, P_r = - 4.3 + 32.54x - 1.492x^2 (16)

Based on the above costs projection, the margin of profit has been computed for the year 2006-07 (Table 1). It may be seen that the production cost may increase to Rs.10376/ha or Rs.1596/q, and the minimum support price to Rs.1560/q, and that may yield a negative return of Rs.36/q. Since the cost of animate components (human and animal) are very high as seen from the Table 1 (62.9%), these need to be reduced by the use of appropriate technology to make the cultivation of rapeseed-mustard profitable.

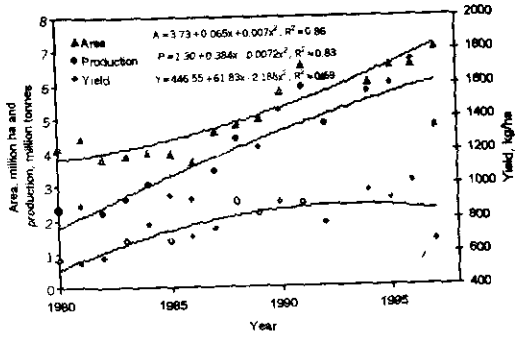

Fig. 1: Growth in area, production and yield of rapeseed-mustard in India

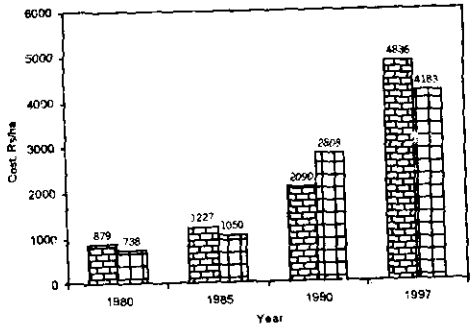

Fig. 2: Operational and fixed costs for rapeseed-mustard production in India

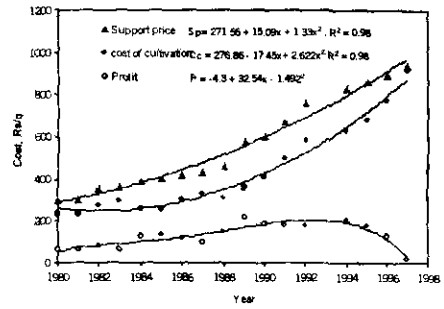

Fig. 3: Growth in cost of cultivation, support price and profit in cultivation of rapeseed-mustard in India

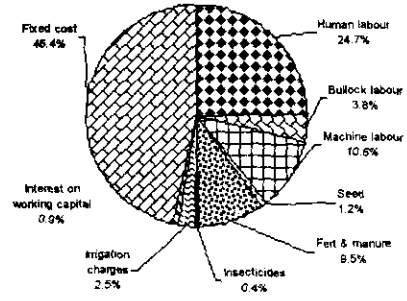

Fig 4. Share of cost of different inputs in cultivation of rapeseed-mustard at All India level (Rs.8019/ha in 1997-98)

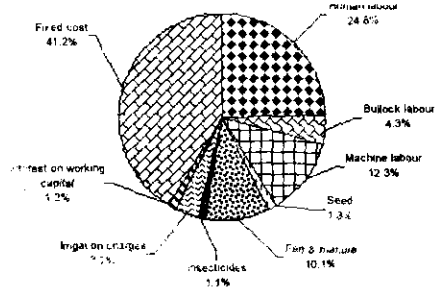

Fig 5a. Share of cost of different inputs in highest cost of cultivation of rapeseed-mustard (Haryana, Rs.1381/q in 1997-98)

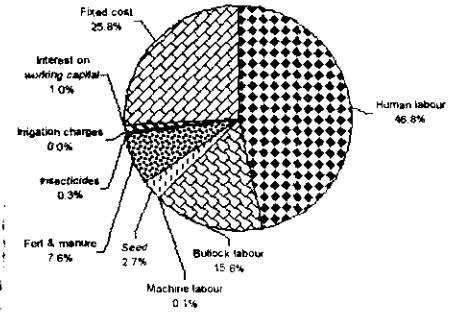

Fig 5b. Share of cost of different inputs in lowest cost of cultivation of rapeseed mustard (Assam, Rs.955/q in 1997-98)

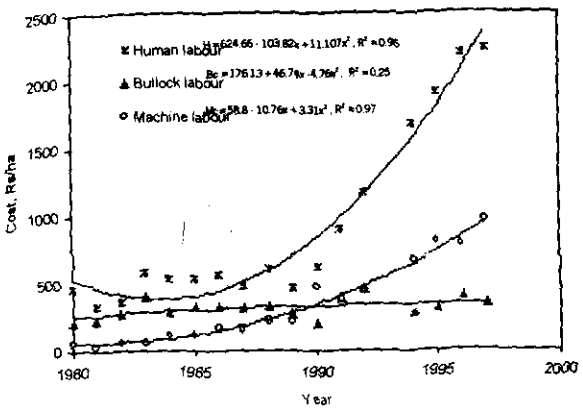

Fig. 6: Growth in cost of animate and mechanical power input for cultivation of rapeseed-mustard in India

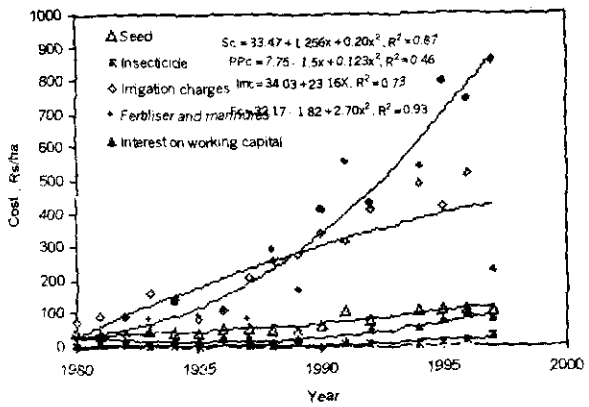

Fig. 7: Growth in cost of inputs for cultivation of rapeseed-mustard in India

Table 1 **Estimated cost of the share of cost of *inputs in total cost of cultivation of rapeseed-mustard at All India level***

Component	Computed cost 1997-98		Projected cost 2006-07	
	Rs/ha	Share%	Rs/ha	Share, %
Human labour	2226	24.7	5436	52.4
Drought animal	344	3.8	880	8.5
Machine hours	954	10.6	2017	19.4
Seeds	109	1.2	202	1.9
Fertilizer	858	9.5	1810	17.4
Irrigation	227	2.5	637	6.1
Plant protection	34	0.4	52	0.5
Total cost of cultivation including fixed cost	9019*	100	10376	100

Projection based on the Cost of Cultivation of Principal Crops in India, 1991, 1996 and 2000.

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An expert tool for fertilizer management of rapeseed-mustard

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Abstract

Fertilizer requirement for crop production is influenced by many factors including soil and climatic conditions. A computer based expert tool named as FARM (RM) i.e. Fertilizer Application Recommendation Manager (Rapeseed-Mustard) has been developed for efficient utilization of fertilizer for production of rapeseed-mustard in India. The FARM (RM) provides fertilizer information, options and suggestions for making decisions regarding economic application of fertilizer based on recommended doses of fertilizer for different states of India. This program has incorporated the database, knowledge and experience of experts in the field of rapeseed-mustard production. The system recommendation of fertilizers includes several aspects such as the fertilizer types, quantity and the interval between applications. The system is developed Graphical User Interface (GUI) based, and thus allows user to interact with the system through graphical screens and icons. The variables that need to be used to build fertilizer recommendation scenario are accessible through menus, control buttons, command buttons, and input boxes. Thus the system is very useful to farmers and the extension workers who are less educated and are not in position to advice the farmers according to their needs and available resources for maximum profit.

Key words: Expert system, knowledge base, fertilizer, rapeseed-mustard

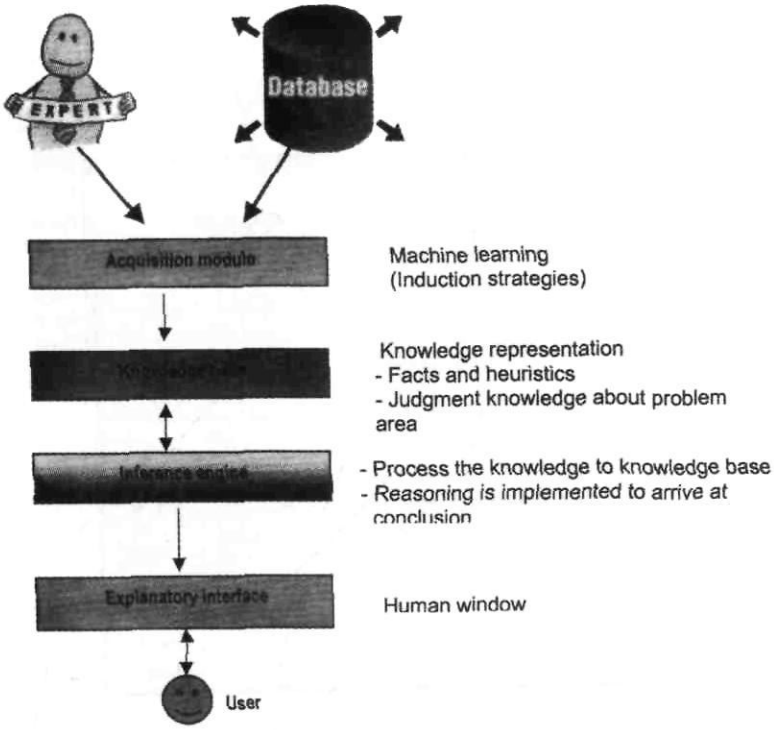
Introduction

The effect of research in agriculture production process depends on how effectively the resulting scientific information can be transformed into increased knowledge held by farmers. This raises the need for effective way to transfer technology, scientific information from research institutes to farmers. The information transfer between researches and farmers must be need based, timely, and complete to fulfill the farmers' need. Science's solution to this problem is to use computer; the computer technology can provide innovative services in almost every human activity provided one has the capability to use them properly according to their need (Chai *et al.*, 1994; Allan Leak Jensen *et al.*, 2000).

The development of FARM (RM) is a step in this direction to facilitate decision making of application of fertilizer for rapeseed-mustard production. The overall broad objective of this work was to develop a computer-based expert tool, which provides information and recommendations on efficient utilization of fertilizer for rapeseed-mustard production. FARM (RM) incorporated the database, experience and knowledge of human experts in the field of rapeseed-mustard production and processes the knowledge for the purpose of making expert's knowledge available to users. The system recommends the economic quantity and application of fertilizer on the basis of recommendation of experts for different locations (16 states) and different rapeseed-mustard crops (mustard, *toria*, brown *sarson*, yellow *sarson*, gobhi *sarson*) in India (Kumar *et al.*,1999). Thus FARM (RM) can perform an important role to help the farmer and extension personnel in fertilizer recommendation for achieving economic and sustainable rapeseed mustard production. The program has been developed specifically for rapeseed-mustard but the concept should also apply to develop fertilizer recommendation manager for other crops, and the program should serve as prototype in developing a total crop managerial program for rapeseed-mustard.

Materials and methods

What was required, was to build an expert tool that is capable of recommending fertilizer quantity, doses, time of applications and that has the ability to employing GUI to enhance the performance and interface with the ordinary user. The FARM (RM) is computer program that uses knowledge and inference procedure to solve problems that are difficult enough to require human expertise for their solution. The following design techniques have been used in developing the system. (Fig.1).



Design of expert system

Fig1.

The feasibility study was conducted for the development of expert system to identify the problems and the factors that influence the fertilizer application decision making of farmers and extension personnel. The technical and economic feasibility study has also been done, regarding hardware, software, people skill that are needed for implementation of the system.

A panel of experts in the field of fertilizer application for *rapeseed-mustard crop production was consulted.* Information about the application of fertilizer for different rapeseed-mustard crops (mustard, *toria*, brown *sarson*, *taramira*, yellow *sarson*, gobhi *sarson*) for different states of India was collected.

For user-friendly interface with the system, the programs have been written in **object oriented programming language Visual Basic 6.0** to develop interactive forms and reports, and **MS-Access 2000** has been used as back end to manage the fertilizer application database. The database of FARM (RM) contains the different tables of data on fertilizer for locations (sixteen mustard growing states of India), and fertilizer requirement data for different rapeseed-mustard crops (mustard, toria, taramira, brown sarson, yellow sarson, etc.) in term of N, P, K, S for both conditions *irrigated and rainfed.*

The system requirements for FARM(RM) are:

P.C. with windows 98/2000
16 MB RAM
2.5 MB disc space on hard disk
Mouse & Keyboard

Results and discussion

FARM (RM) is an interactive computer based system that allows user to input information such as: rapeseed-mustard crop to be grown (mustard, toria, brown sarson, yellow sarson, gobhi sarson), the field's agro climatic regions (rapeseed-mustard growing states of India) and the condition irrigated or rainfed by clicking appropriate options (Fig.2).

In addition the system provides the facilities to select the source of fertilizer such as: Straight fertilizer, Complex chemical, FYM+Chemical, Vermi+ chemical. Further it provides the options to select the different chemical fertilizer as the source of P (DAP, SSP, APS etc),source of N (UREA, CAN, etc), sources of K (MOP, SOP etc) source of S (gypsum, elemental sulphur) (Fig.3).

On the basis of above input information system recommends the requirement of fertilizer for total area (Hectare, Bigha, Acre, M.sq. etc) input by user for specific agro climatic location and specific mustard crop (Fig.4). The system also calculates the total cost of recommended fertilizer for that area (Fig.5).

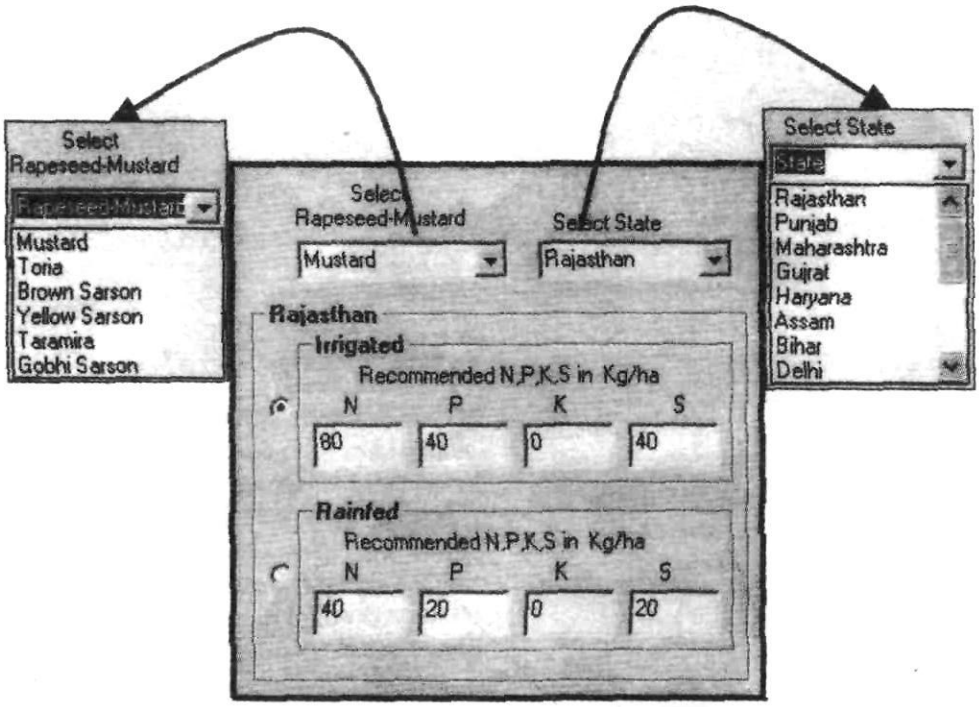

Select
Rapeseed-Mustard
Mustard
Toria
Brown Sarson
Yellow Sarson
Taramira
Gobhi Sarson
Select State
State
Rajasthan
Punjab
Maharashtra
Gujrat
Haryana
Assam
Bihar
Delhi
Rapeseed-Mustard
Mustard
Select State
Rajasthan
Rajasthan
Irrigated
Recommended N,P,K,S in Kg/ha
N P K S
80 40 0 40
Rainfed
Recommended N,P,K,S in Kg/ha
N P K S
40 20 0 20

Fig2

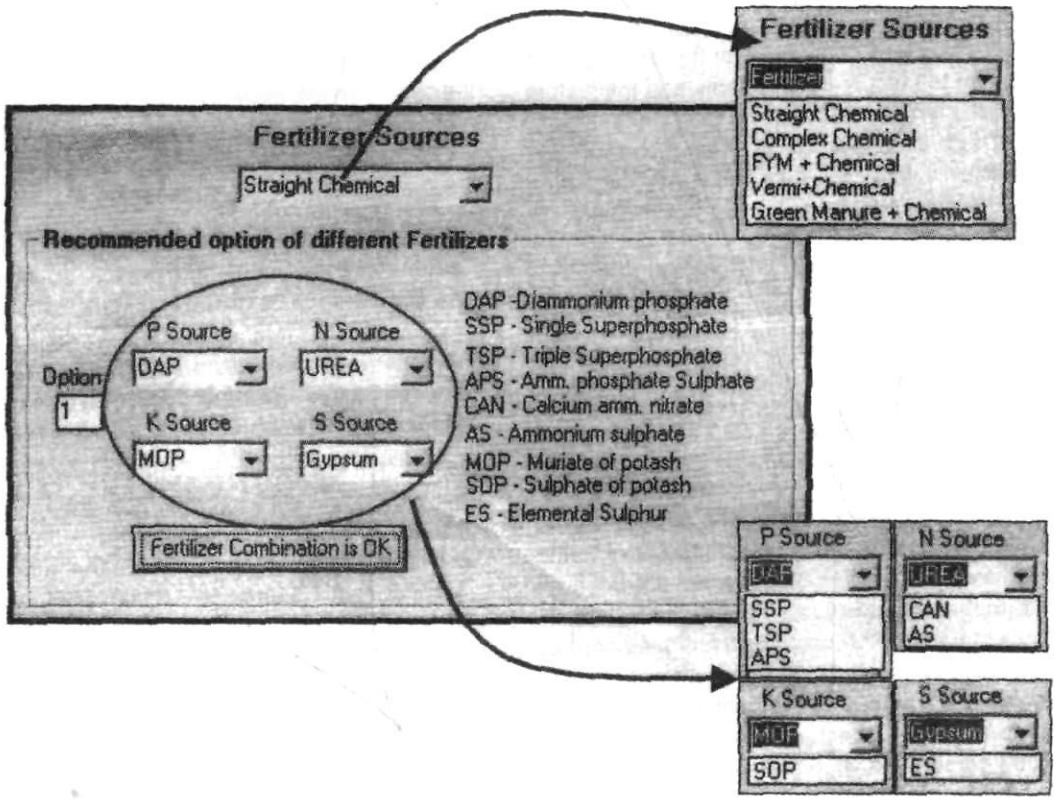

Fertilizer Sources
Straight Chemical
Complex Chemical
FYM + Chemical
Vermi+Chemical
Green Manure + Chemical
Fertilizer Sources
Straight Chemical
Recommended option of different Fertilizers
Option
1
P Source
DAP
N Source
UREA
K Source
MOP
S Source
Gypsum
Fertilizer Combination is OK
DAP -Diammonium phosphate
SSP - Single Superphosphate
TSP - Triple Superphosphate
APS - Amm. phosphate Sulphate
CAN - Calcium amm. nitrate
AS - Ammonium sulphate
MOP - Muriate of potash
SOP - Sulphate of potash
ES - Elemental Sulphur
P Source
DAP
SSP
TSP
APS
N Source
UREA
CAN
AS
K Source
MOP
SOP
S Source
Gypsum
ES

Fig.3

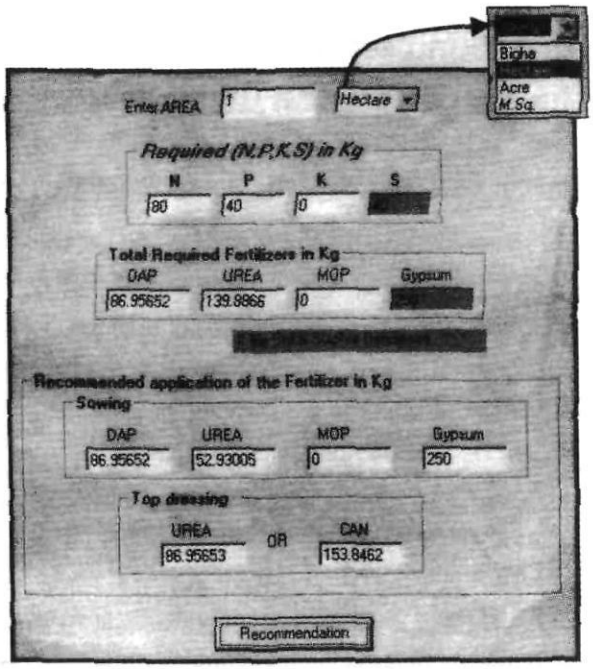


Fig.4

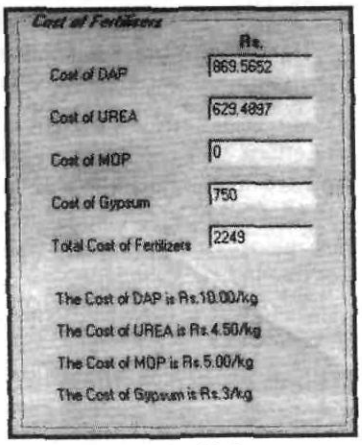


Fig5.

Thus, the system developed for mustard-growing area of India is simple to operate and provides sufficient information to farmer, extension people on application of fertilizer for their field. The benefit of using FARM (RM) is to encourage producer of rapeseed-mustard for sustainable production by helping them in decision-making of fertilizer application. The system can be installed on PC and is easy to operate. The demonstration copies of program have been provided to extension specialists and researchers for testing purpose.

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Short communication

Differential response of groundnut, *Arachis hypogaea* L. genotypes for *in vitro* callus induction and regeneration using mature embryo explants

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Groundnut, *Arachis hypogaea* L. is an important oilseed crop in both developed and developing countries for the production of oil and protein from the seed. Owing to its severe self-pollinated nature, biotechnological approaches would greatly aid in creation of favorable variability and its wide application in crop improvement programmes. An efficient plant regeneration system is a pre-requisite for *in vitro* mutation breeding, genetic transformation, cell line selection and germplasm storage (Horsch *et al.*, 1985). *In vitro* cell line selection for major fungal diseases and genetic transformation using appropriate gene/s for diseases, pests and other quality parameters in groundnut holds a greater potential, which requires an efficient *in vitro* regeneration protocol. In view of genotypic specificity of *in vitro* culture conditions and non-reproducibility of protocols reported from other laboratories, it is important to study the genotypic response and optimize the culture conditions for genotypes of the interest (Lazer *et al.*, 1984). Several reports have described *in vitro* plant regeneration of groundnut from various explants including embryo axes (Venkatachalam *et al.*, 1996). Baker and Wetzstein (1994) reported development of plants from dembryonated cotyledons. Studies by Atreya *et al.* (1984) indicated the severe genotypic differences for external requirement of cytokinins. We report the response of different agronomically superior groundnut genotypes and an efficient *in vitro* regeneration protocol from mature embryo axes explants.

The experiment was conducted under well defined conditions of the culture room maintained at 25±2° C. Uniform light (ca 1000 lux) provided by fluorescent tubes (7200°K) over a light or dark cycles of 14/10 hrs. The explants and calli were cultured on culture tubes (150 X 25 cms) containing 12.5 ml of appropriate medium. In the present study five genotypes, KRG 1, R 8808, JL 24, S 206 and TMV 2 were used.

The mature embryo axes were excised from the one-year-old pods by cut opening the dry seeds. The embryos were surface sterilized by soaking in 0.1% $HgCl_2$ for 4 to 5 minutes followed by 4 times wash using sterile distilled water to remove the traces of mercuric chloride and then they were transferred on to the MS basal medium supplemented with different concentrations of 2,4-D for callus induction. Callus formed on 2,4-D media was subcultured 2-3 times on MS basal supplemented with 0.5mg/l Kinetin. Observations on percent callus induction and other calli parameters were recorded across treatments and genotypes. Subcultured callus from each genotypes was transferred on to MS basal supplemented with different concentrations of kinetin for morphogenesis. Regenerated plantlets were transferred on to MS basal with 1 mg/l of NAA for root induction and then they were hardened to transfer in to the field.

The response of selected genotypes for callus induction was tried on MS basal medium supplemented with different concentrations of 2,4-D in order to understand the genotypic response. Highly significant differences among the genotypes and 2,4-D concentrations were evident for per cent callus formation (Table 1). Interaction between genotype and 2,4-D concentrations was highly significant for callus induction frequency. A *2,4-D* concentration of 3 mg/l induced the highest response of 81.20% followed by 2.5 mg/l (74.40%) and 2 mg/1 (74.16%). With increase in 2,4-D concentration there was a decline in response. Among the genotypes, TMV 2 gave a mean highest response of 72.64% across concentrations of 2,4-D, followed by KRG 1 (67.06%) indicating the differential response of genotypes for callus formation. Irrespective of the genotypes, the frequency of response for callus formation was more than 60%. It was found that a specific concentration of 2,4-D had a significant interaction with the genotype to induce callus. KRG 1 responded to an extent of 82.60% at 3 mg/l of 2,4-D, while a significant reduction (38.00%) at 4 mg/l of 2,4-D. This trend was found in all genotypes indicating genotypic differences to interact with 2,4-D concentrations in inducing callus (Table 1). It is clear from the data that with an increase in 2,4-D concentration there is a

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concurrent increase in the callus induction frequency only up to 3 mg/l. The genotype has been a crucial factor in influencing successful callus induction among groundnut genotypes (Lazer *et al.*, 1984; Bregitzer, 1992; Me Kently, 1995). The basis for such genotypic differences seems to lie in the endogenous hormone concentrations in the same explant tissues of different genotypes (Fitch and Moore, 1990).

The quality of the callus was judged usually on 0 to 4 scales considering variety quality parameters of callus influencing regenerability (colour, texture, growth rate, embryonic nature, compactness, nodular nature, nodular compact etc.). Only 2,4-D concentrations influenced significantly towards callus quality, while, genotype exhibited statistically on-par mean values. At a 2,4-D concentration of 2.5 mg/l, all genotypes induced best possible quality callus with a mean score for callus quality. Differences in the type of callus in terms of texture, colour and growth rate have been the intrinsic property of groundnut genotypes, which is primarily due to the severe interaction between the level of endogenous hormones and the exogenous application (Nidagundi, 1996).

Plantlet regeneration was attempted from mature embryo derived callus. The callus (about 250-350 mg) was transferred on to MS basal supplemented with 0, 0.5, 1, 2 and 3 mg/l of kinetin to induce plantlets. The callus started turning into green and nodular with varied degree of growth rate across treatments in all genotypes. About 15-20 days after inoculations, plantlets were induced from the callus in all the genotypes, in varied number. The highest percent of regeneration was at 3 mg/l (24%) followed by 2 mg/1 (10%) kinetin. At lower concentrations of kinetin there was no response for any morphogenesis in any of the genotypes. Among the genotypes KRG 1 gave a highest percent of regeneration (40% at 3 mg/l of kinetin followed by TMV 2 (20%) (Table 2). The genotype and growth regulators are the critical factors for shoot organogenesis and regeneration (Venkatachalam *et al.*, 1999). Opseitz *et al* (1987) reported significant genotypic differences for regeneration among different varieties and groups of groundnut with a greater potential for complete plantlet regeneration in Virginia types. In the present study, though the overall response of the selected genotypes for *in vitro* regeneration was poor, at specific concentrations of growth regulators against each genotype, the response was good. Hence, along with genotype the growth regulators also play an important role in morphogenesis (Maddock, 1985). Generally higher levels of cytokinins and the absence of auxins trigger organogenesis (Maddock, 1985). It is possible to induce regeneration from callus with cytokinins alone or higher concentration of cytokinins and lower concentration of auxins (Venkatachalam and Jayabalan, 1997). In the present study kinetin at 3 mg/l induced higher frequency of regeneration, whereas lower concentrations did not induce organogenesis, Cytokinins are known to induce better regeneration (Atreya *et al.*, 1984). The results obtained are in agreement with the statement that genotype and growth regulators have considerable effect on organogenesis and complete regeneration.

Table 1 Callus induction frequency (per cent) from matured embryo on MS medium for different genotypes and 2,4-D concentrations

Genotype	2,4-D concentrations (mg/l)					Mean
	1	2	2.5	3	4	
KRG 1	60.80 (51.25)^{bc}	81.60 (64.64)^{a}	80.00 (63.09)^{a}	82.60 (65.38)^{a}	38.00 (37.93)	68.06 (56.46)
R 8808	41.80 (40.27)^{d}	58.40 (49.85)^{c}	81.40 (64.50)^{a}	79.60 (63.20)^{a}	40.00 (39.11)	60.24 (51.39)
JL 24	39.80 (38.88)^{d}	66.00 (54.35)^{b}	79.00 (62.78)^{a}	81.00 (64.22)^{a}	38.60 (38.39)	60.88 (51.72)
S 206	39.00 (38.63)^{d}	83.80 (66.31)^{a}	64.00 (53.18)^{bc}	79.00 (62.78)^{a}	60.00 (50.78)	65.16 (54.33)
TMV 2	58.40 (49.85)^{c}	81.00 (64.22)^{a}	81.00 (64.22)^{a}	83.80 (66.31)^{a}	58.80 (50.07)	72.60 (58.93)
Mean	47.96 (43.78)^{c}	74.16 (59.87)^{b}	74.40 (61.54)^{ab}	81.20 (64.38)^{a}	47.08 (43.26)	

Arcsine transformed values are given in parenthesis. Means followed by same letter fall in the studentrised 't' range.
F-test
2,4-D levels - 683.499**
Genotypes - 67.006**
Interaction - 35.714**

Table 2 Regeneration response (%) of callus induced from mature embryo across different concentrations of Kinetin on MS medium

Genotype	Kinetin concentrations (mg/l)					Mean
	0	0.5	1.0	2.0	3.0	
KRG 1	0.0	0.5	10.0	10.0	40.0	12.0
R 8808	0.0	0.0	0.0	0.0	20.0	4.0
JL 24	0.0	0.0	0.0	0.0	10.0	6.0
S 206	0.0	0.0	2.0	10.0	20.0	10.0
TMV 2	0.0	0.0	0.0	2.0	30.0	10.0
Mean	0.0	0.0	10.0	8.0	24.0	

All the values are expressed in per cent

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Short communication

Combining ability analysis in Indian mustard, *Brassica juncea* (L.) Czern and Coss.

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A critical analysis of yield potential in Indian mustard of *Brassica juncea* (L.) Czern and Coss., revealed a picture of yield stagnation without much breakthrough. Therefore, the present investigation was carried out to study the genetic make-up of seed yield and its important contributing characters for formulating an efficient breeding methodology in this crop.

The present study was carried out at the experimental field of Rajasthan College of Agriculture, Udaipur during *rabi* 1998-99. The six parents *viz.*, culture 1, RC 781, T 59, Pusa bold, PHR 1 and RH 781 were selected on the basis of differences in the yield, yield components and disease resistance characters. Crosses were attempted for diallel mating design (excluding reciprocals). The total experimental material comprising six parents and their 15 crosses were planted in Randomised Block Design with three replications under two environments *viz.*, moisture stress (E_1) and irrigated (E_2). Material was raised in 3 m long rows. Row to row and plant to plant distances were maintained at 30 and 15 cm, respectively. Non-experimental rows were planted around the experiment to eliminate border effects. Observations were recorded on days to maturity, plant height, primary branches/plant, biological yield/plant, harvest index and seed yield/plant. Combining ability was analysed in environments according to method 2 Model 1 of Griffing (1956).

Analysis of variance for combining ability revealed that mean squares due to *gca* and *sca* were significant for all the characters under both the environments (E_1 and E_2) as well as over the environment except *sca* for days to maturity and *gca* for plant height in E_2 (Table 1). This indicated that both additive and non-additive gene effects played significant role in inheritance of these characters. The σ^2 *sca*/σ^2 *gca* was greater than one for all the traits suggesting predominance of non-additive gene effects. Kumar *et al.* (1994), Bhateria *et al.* (1995) and Singh *et al.* (1996) reported that both *gca* and *sca* variances were significant with preponderance of non-additive components. The present study is also in agreement with the above reports. Significance of environmental mean squares revealed differences between the environments. Mean squares due to interaction of *gca* and *sca* with environments (i.e., *gca* x E and *sca* x E) were significant for all the traits except days to maturity where *sca* x E was non-significant and primary branches/plant where both interactions were non-significant. This indicated that both *gca* and *sca* of different parents and their crosses were highly influenced by the environments. The higher magnitude of *sca* x E than *gca* x E variance indicated that non-additive components were affected largely by the environment.

Significant and positive *gca* effects revealed that cultivars T 59, Pusa bold and Culture 1 under E_1, cultivars PHR 1, RH 781 and T 59 under E_2 and cultivars T 59 and PHR 1 under pooled analysis were found good general combiner for seed yield/plant. Out of these, cultivars T 59 and Culture 1 were also good general combiner for earliness in all the three analysis. Similar results for earliness were also reported by Thakur *et al.* (1989). In addition to this T 59 was also good general combiner for biological yield/plant and harvest index under E_1 and pooled analysis. While, PHR 1 in E_2 and over the environments. Further, pusa bold and Culture 1 were good general combiner for plant height under moisture stress environment. Whereas, RC 781 performed better under E_2 and pooled analysis (Table 2).

Three crosses *viz.*, RC 781 x PHR 1, T 59 x PHR 1 and Culture 1 x Pusa bold were good specific combiners for earliness under moisture stress (E_1) and over the environments. Similarly, for plant height, the cross RC 781 x Pusa bold, for primary branches/plant the cross RC 781 x T 59 was the best specific combiner in all the environments. In addition to these, RC 781 x T 59, RC 781 x RH 781 (under E_2 and over the environments) and Culture 1 x PHR 1 (E_1 and over the environments) were good specific combiner for plant height. Cross PH 1 x RH 781 was the best specific combiner for biological yield/plant. It was followed by Pusa bold x PHR 1, RC 781 x T 59, RC 781 x RH 781 and Culture 1 x T 59. All these crosses were also good specific combiner in other environments except the cross RC 781 x T 59 in E_1. Similarly, for harvest index Culture 1 x RH 781,

Table 1 Mean squares of combining ability for different characters in Indian mustard

Source of variation	Env.	d.f.	Days to maturity	Plant height	Primary branches/plant	Biological yield/plant	Harvest index	Seed yield/plant
GCA	E_1	5	14.45**	138.41**	0.60**	68.17**	5.99**	2.83**
	E_2	5	10.51**	91.98	1.11**	32.97**	4.93**	3.09**
	E_3	5	19.55**	77.05*	1.47**	39.05**	6.86**	3.33**
SCA	E_1	15	3.17**	77.57**	0.36**	32.82**	4.38**	1.44**
	E_2	15	2.21	240.51**	0.42*	72.45**	3.74**	1.81**
	E_3	15	3.39*	190.42**	0.51**	58.80**	3.02**	1.38**
Environment		1	136.32**	2049.14**	1.19**	210.98**	281.72**	72.98**
GCA x Env.		5	5.41*	153.34**	0.24	62.10**	4.06**	2.59**
SCA x Env.		15	1.98	127.66**	0.27	46.47**	5.11**	1.87**
Error	E_1	40	1.38	24.31	0.11	1.87	0.35	0.02
	E_2	40	2.00	40.44	0.22	2.63	0.63	0.09
	E_3	80	1.69	32.37	0.16	2.25	0.49	0.06
σ^2SCA	E_1		26.82	798.97	3.74	464.31	60.50	21.20
	E_2		-	3001.09	3.01	1047.42	46.69	25.83
	E_3		12.77	1185.36	2.57	424.15	18.96	9.92
σ^2GCA	E_1		8.17	71.32	0.31	41.44	3.53	1.75
	E_2		5.32	-	0.55	18.97	2.69	1.87
	E_3		5.55	13.96	0.40	11.50	1.99	1.02
σ^2SCA/σ^2GCA	E_1		3.28	11.20	12.06	11.20	17.14	12.11
	E_2		-	-	5.47	55.21	17.36	13.81
	E_3		2.29	84.91	6.42	38.04	9.53	9.72
σ^2 (SCA x E)	P		-	1429.34	-	663.42	69.26	27.19
σ^2 (GCA x E)	P		2.33	75.61	-	37.41	2.33	1.58
σ^2 (SCA x E)/σ^2 (GCA x E)	P		-	18.90	-	17.73	29.72	17.21

*, ** Significant at 5% and 1% level, respectively.
+, ++ Significant against respective environmental interaction at 5% and 1% level, respectively
- Indicate insignificant variance

Table 2 Estimates of general combining ability effects for different characters in Indian mustard

Character	Env.	Name of cultivars							
		Culture 1	RC 781	T 59	Pusa Bold	PHR 1	RH 781	SE± (g_i)	SED ± (g_i-g_j)
Days to maturity	E_1	-2.19**	1.10**	-0.99*	1.31**	0.26	0.51	0.38	0.59
	E_2	-0.93*	1.19*	-1.26**	-0.76	0.36	1.40**	0.46	0.71
	P	-1.56*	1.15**	-1.12*	0.27	0.31	0.96**	0.30	0.46
Plant height	E_1	3.91*	0.99	-1.63	4.99**	-2.06	-6.20**	1.59	2.47
	E_2	-5.74**	4.85*	-0.16	-0.28	0.76	0.56	2.05	3.18
	P	-0.91	2.92*	-0.90	2.36	-0.65	-2.82*	1.30	2.01
Primary branches/plant	E_1	-0.47**	0.10	-0.10	0.35**	0.11	0.00	0.11	0.16
	E_2	-0.63**	0.18	-0.23	0.09	0.16	0.42**	0.15	0.24
	P	-0.55*	0.14	-0.16	0.22*	0.14	0.21*	0.09	0.14
Biological yield/plant	E_1	0.61	-2.76**	4.31**	1.06*	0.59	-3.81**	0.44	0.68
	E_2	-3.40**	-0.11	0.98	-1.01	1.11*	2.42**	0.52	0.81
	P	-1.39*	-1.43*	2.65**	0.03	0.85*	-0.70*	0.34	0.53
Harvest index	E_1	0.08	-1.58**	0.89**	0.61**	-0.18	0.18	0.19	0.30
	E_2	-0.55*	-0.67*	0.17	0.05	1.45**	-0.44	0.26	0.40
	P	-0.24	-1.13*	0.53**	0.33*	0.64**	-0.13	0.16	0.25
Seed yield/plant	E_1	0.16**	-0.85**	0.89**	0.25**	-0.03	-0.42**	0.05	0.08
	E_2	-0.90**	-0.41**	0.22*	-0.11	0.91**	0.28	0.10	0.15
	P	-0.37*	-0.63*	0.55**	0.07	0.44**	0.07	0.06	0.09

*, ** Significant at 5% and 1% level, respectively.

Culture 1 x PHR 1 and T 59 x Pusa bold were good specific combiner over the environments. Culture 1 x RH 781 was also good specific combiner in E_1 and E_2. Whereas, Culture 1 x PHR 1 and T 59 x Pusa bold were good specific combiner in E_1 and E_2, respectively. For seed yield/plant, crosses PHR 1 x RH 781, RC 781 x RH 781, T 59 x Pusa bold and Culture 1 x RC 781 were the best specific combiners in all the environments. In addition to these Culture 1 x PHR 1, Culture 1 x RH 781 (under E_1 and over the environments) RC 781 x T 59 and Pusa bold x PHR 1 (under E_2 and over the environments) were also good specific combiners for seed yield/plant.

On the basis of above study, it was observed that T 59 was good general combiner parent for almost all the characters in all the environments. Similar results for T 59 was also reported by Yadav *et al.* (1992) for one or other characters. PHR 1 was also good general combiner in E_2 and over the environments. Thus, crosses from these parents could throw superior transgressive segregants for future breeding programmes in Indian mustard.

Large number of crosses having atleast one good general combiner under one or other environments were spotted for different characters as also reported by Thakur *et al.* (1989) and Yadav *et al.* (1992). T 59 x Pusa bold (E_1, E_2 and over the environments), Culture 1 x PHR 1 (E_1 and over the environment) and RC 781 x T 59 (E_2 and over the environment) were superior for seed yield/plant. For biological yield/plant, Pusa bold x PHR 1, for plant height RC 781 x Pusa bold while for days to maturity T 59 x PHR 1 (except E_2) were good specific combiner in all the environments. Further, it was also observed that these crosses exhibited significant heterobeltiosis. Hence, these appeared useful in exploiting the non-additive gene action through heterosis breeding. However, to select desirable segregants from segregating generation crosses having significant heterobeltiosis non-significant sca effects and at least involving one good general combiner parent are desirable. Cross T 59 x RH 781 was identified for seed yield. For other characters like plant height, Culture 1 x RC 781 (E_2), biological yield/plant T 59 x PHR 1 (E_2) can throw transgressive segregants.

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Short communication

Heterosis in relation to combining ability for seed yield and its contributing traits in Indian mustard, *Brassica juncea* (L.) Czern and Coss.

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Rapeseed-mustard group of crops plays a very important role in the oilseeds economy of our country. The state of Uttar Pradesh is the major producer of rapeseed-mustard covering an area of 9.085 lakh ha, with the production of 8.965 lakh m.t. (2000-01) (Damodaram and Hegde, 2002). India is the largest producer of rapeseed-mustard but its productivity is much lower (941 kg/ha) than the world's average (1511 kg/ha), which received great attention of breeders for its genetic improvements as it has exhibited greater production potential under varying environment. To enhance the present yield level and overcome yield stagnation, it is essential to reshuffle the genes through hybridization in suitable parents. For this, it is necessary to identify the gene action involved in the expression of various yield contributing characters and also the combining ability of the parents and the resulting crosses. The present study was, therefore, undertaken to estimate heterosis in relation to combining ability effects for seed yield and its related traits. Oil and protein content in 9 x 9 diallel mating design of Indian mustard.

Nine strains/varieties of Indian mustard *Brassica juncea* (L.) Czern and Coss., *viz.*, Varuna, Shekhar, Vardan, Laha 101, Pusa Bold, RH-30, Pusa Basant, NDR-8501 and Kranti were crossed in diallel mating design excluding reciprocal. Nine parents along with 36 F_1, 36 F_2 were grown in randomized complete block design with three replications during *rabi*, 1999-2000 at Oilseeds Research Farm, Kalyanpur, C.S. Azad University of Agriculture and Technology, Kanpur. Recommended agronomic practices were followed for raising good crop. Ata were recorded on 5 competitive plants randomly taken in each parents in F_1 and 20 plants from F_2 in each treatment in all the three replications for recording data on plant height, branches/plant, siliquae on main raceme, seed yield/plant and 1000-seed weight. Oil content in seeds was estimated by NMR (New Port Analyzer MK 111A) and protein content in de-fatted seed cake was determined by Biuret method of Williams (1961). Data were analysed for combining ability as suggested by Griffings (1956) method II, Model I. Heterosis over mid parent and better parent and inbreeding depression were estimated as per the standard procedures and their significance were tested using 't' test.

Analysis of variance for general and specific combining ability was found significant for all the characters in both the generations except for 1000-seed weight in F_2 generation. Good general combiners on the basis of *gca* effects for seed yield and its contributing traits were Varuna, Kranti, Laha 101 and RH-30 (Table 1).These parents can be successfully utilized for improving seed yield and its contributing traits because of high general combining ability effects, additive effects and additive x additive epistasis. Dixit *et al.* (1983) and Thakral and Singh (1995) also reported similar result in Indian mustard.

In general, crosses with significant *sca* effects exhibited highly significant heterosis for most of the characters studied indicating that *sca* of crosses can be a suitable index to determine the performance of a crosses in the exploitation of heterosis. Of the 36 crosses, eight crosses *viz.*, Shekhar x Kranti, Pusa Basant x Kranti, Vardan x Pusa Bold, Varuna x Pusa Basant, Laha 101 x Pusa Bold, RH-30 x Pusa Basant, Varuna x RH-30 and Shekhar x Laha 101 showed desirable specific combining ability effects in F_1 and F_2 generations (Table 2). The economic heterosis, inbreeding depression and *gca* effects of P_1 and P_2 were found significant for most of the characters studied. These eight crosses also had high economic heterosis and comparatively low inbreeding depression for seed yield. The findings are in conformity with the findings of Kumar *et al.* (1990), Gupta and Sharma (1999) and Chauhan *et al.* (2000).

From the practical point of view, the above eight crosses showing high heterosis over the best cultivar with low inbreeding depression can be successfully utilized for the development of high yielding varieties of Indian mustard.

Table 1 General combining ability effect of parents in Indian mustard

Source of variation	Generation	Plant height	Branches/ plant	Siliqua on main raceme	Seed yield/plant	1000-seed weight	Protein content	Oil content
Varuna	F_1	-1.79**	0.33**	0.95**	-0.62**	0.32**	0.39**	0.26**
	F_2	-2.60**	0.69**	-1.12**	-0.16	0.32**	0.12	0.76**
Shekhar	F_1	1.20**	0.65**	1.22**	-0.33**	0.15**	0.10	0.12
	F_2	-0.17	0.74**	1.64**	-0.34**	-0.18**	0.17	0.35**
Varadam	F_1	1.18**	1.98**	1.26**	1.57**	0.02	-0.16	-1.11**
	F_2	-0.67**	0.84**	0.51**	0.31**	0.11**	-0.28*	-0.03
Laha 101	F_1	-0.78**	-0.88**	0.85**	0.02	0.08**	-0.24	0.59**
	F_2	0.44**	-0.32**	-0.05	1.21**	0.29**	-0.71**	0.15
Pusa Bold	F_1	-1.18**	-0.62**	0.49**	-1.03**	-0.19**	0.28	0.38**
	F_2	2.21**	-0.72**	-0.32**	-1.17**	-0.14**	0.41**	0.15
RH 30	F_1	-0.88**	-0.03	-1.14**	-0.32**	-0.15**	-0.01	-0.03
	F_2	1.69*	-1.17**	-0.71**	0.02	0.19**	0.23	-0.36**
Pusa Basant	F_1	0.89**	-0.38**	-2.04**	-0.42**	-0.07**	-0.31*	-0.10
	F_2	0.26	-0.19**	-1.35**	-0.49**	-0.17**	-0.28*	-0.59**
NDR 8501	F_1	4.04**	0.75**	1.79**	1.07**	-0.18**	0.05	-0.27**
	F_2	2.99**	0.05	1.05**	0.82**	-0.21**	0.03	-0.46**
Kranti	F_1	-2.68**	-0.49**	-0.71**	0.06	0.01	-0.11	0.16
	F_2	-4.15**	0.07	0.36**	-0.19	-0.10**	0.28*	0.02
SE(gi)	F_1	0.16	0.05	0.11	0.10	0.02	0.15	0.07
	F_2	0.20	0.08	0.12	0.11	0.02	0.13	0.10
SE (gi-gi)	F_1	0.24	0.07	0.17	0.15	0.04	0.22	0.11
	F_2	0.30	0.12	0.19	0.17	0.04	0.20	0.16
CD (P=0.01)	F_1	0.41	0.12	0.28	0.25	0.05	0.38	0.18
	F_2	0.51	0.20	0.30	0.28	0.05	0.33	0.25
CD (P=0.05)	F_1	0.31	0.09	0.21	0.19	0.03	0.29	0.13
	F_2	0.39	0.15	0.23	0.21	0.03	0.25	0.19

*, ** = Significant at 5 and 1 per cent levels, respectively.

Table 2 Superior cross combination based on *gca, sca* effects and heterosis in Indian mustard

Crosses	*Per se* performance	*gca* effect		*sca* effect		Economic heterosis	Inbreeding depression	Traits for which crosses also exhibited desirable *sca* effect
		P_1	P_2	F_1	F_2			
Shekhar x Kranti	16.10	-0.33**	0.06	3.68**	2.14**	58.33**	10.35**	Plant height (13.29**) and protein content (-1.16**)
Pusa Basant x Kranti	18.63	-0.42	0.06	3.30	2.19**	54.33**	8.31**	Plant height (10.63**), branches/plant (1.06**), siliqua on main raceme (1.58**), 1000-seed weight (0.72**) and oil content (1.79**)
Vardani x Pusa Bold	15.43	1.57**	-1.03**	2.21**	1.90**	52.60**	10.15**	Plant height (9.45**), branches/plant (5.06**), siliqua on main raceme (9.39**) and oil content (0.23)
Varuna x Pusa Basant	13.50	-0.62	-0.42**	1.86**	3.57**	35.83**	-16.54**	Plant height (-5.75**), siliqua on main raceme (5.95**) and 1000-seed weight (0.21**)
Laha 101 x Pusa Bold	13.26	0.02	-1.05**	1.59**	1.36**	33.81**	-7.28	Plant height (9.46**)
RH030 x Pusa Basant	13.30	-0.32**	-0.42	1.36**	3.61**	34.10**	-20.25**	Branches/plant (0.37&&(and siliqua on main raceme (3.61**)
Varuna x RH-30	13.00	-0.62**	0.32**	1.26**	1.95**	31.50	-12.56**	Oil content (1.34**)
Shekhar x Laha 101	13.60	-0.33**	0.02	1.22**	1.00	36.70	-8.08**	Plant height (-2.90**), branches/plant (2.86**) and siliqua on main raceme (2.06**)

*, ** Significant at 5 and 1 per cent level, respectively.

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Short communication

Selection indices in Indian rapeseed, *Brassica campestris* L. and mustard, *Brassica juncea* (L.) Czern and Coss.

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Indian rapeseed and mustard are two important oilseed crops contributing about 33 % of the total 22.9 metric tonnes oilseeds produced in India (Reddy, 1996). In Assam, rapeseed and mustard are cultivated in 92% of the total oilseed area and also considered to be important components of rice based cropping system. Therefore, serious efforts are necessary to achieve major breakthrough in the production of oilseed crops including rapeseed and mustard. Selection for seed yield based on a single character may not be effective. On the other hand, it is a very cumbersome process for a breeder to involve a large number of component characters simultaneously in a selection programme. Hence, knowledge of major yield components is necessary for evolving effective selection criteria. Selection indices provide the means for making use of correlated traits for higher efficiency in selection for yield. In the present investigation different selection indices have been constructed on the basis of multiple regression analysis and discriminate function.

Fourteen rapeseed var. *toria* and seven mustard genotypes were sown on November 15, 1996 in a Randomized Block Design with three replications in the experimental field of the Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat. Each plot consisted of three rows of 4 m length and 30 cm apart. The crop was raised following recommended package of practices. A plant-to-plant spacing of about 10 cm was maintained by thinning the crop after 15-20 days of sowing. Observations were recorded on 10 randomly selected plants from each plot for 13 yield and yield attributing traits. Based on their genetic variance, heritability and direct effect on yield, five characters *viz.*, biological yield, plant height, length of main inflorescence, siliquae on main inflorescence and secondary branches/plant in *toria* and four characters *viz.*, biological yield, plant height, seeds/siliqua and 1000-seed weight in mustard were chosen to fit multiple regression equations. Multiple regression equations were constructed with the help of partial regression coefficients of yield on independent characters. Fifteen different selection indices were constructed in both *toria* and mustard in different combinations for the characters on which yield showed significant partial regression coefficients. The efficiencies of different indices were determsined by calculating genetic advance and comparing it with that for straight selection for yield taken as 100 %.

Multiple regression equation with all the five characters in *toria* and with all the four characters in mustard exhibited 84.1 % and 95.4 % respectively (Table 1). Partial regressions of yield on length of main inflorescence in *toria* and that on plant height in mustard were found to be non-significant. Therefore, two more multiple regression equations were constructed one in *toria* and another in mustard with the characters on which yield showed significant partial regression coefficients and their efficiencies were estimated to be 78.9 % in *toria* and 93.9 % in mustard (Table 1). The exclusion of length of main inflorescence in case of *toria* and plant height in case of mustard from the multiple regression equations resulted in the reduction in their efficiencies by only 5.2 % and 1.6 % respectively indicating that these were not important characters contributing to the total variation in seed yield in these two species.

Discriminant function analysis revealed that the efficiency of the indices increased at a declining rate with the inclusion of additional characters (Table 2). Similar results were also reported by Sandhu *et al.* (1995) in pigeonpea. In the present investigation, straight selection for seed yield in both *toria* and mustard was found to be more efficient as compared to indirect selection for seed yield based on any single character except biological yield/plant which was equally efficient with straight selection. Considering two traits at a time, the combination of seed yield and biological yield/plant exhibited the highest efficiencies in both *toria* (146.1 %) and mustard (154.4 %). Among the three-factor indices in *toria*, two indices, one with seed yield, biological yield and secondary branches/plant and another with seed yield, biological yield and siliquae on main inflorescence exhibited the maximum efficiencies of 160.8% and 160.3%, respectively (Table 2).

Table 1 Partial regression coefficients and corresponding standard errors (SE) for multiple regression equations along with their efficiencies in rapeseed (*toria*) and mustard

Toria				Mustard			
Partial regression of yield on:	Multiple regression equation	Efficiency (%)	Partial regression coefficient ± S.E.	Partial regression of yield on:	Multiple regression equation	Efficiency (%)	Partial regression coefficient ± S.E.
Biological yield/plant (b_1)	Y=7.132+0.1473X_1		0.1473**±0.047	Biological yield/plant(b_1)	Y=3.052+0.0955X_1		0.0955*±0.042
Plant height (b_2)	+0.0545X_2		0.0545*±0.025	Plant height (b_2)	+0.0129X_2		0.0129±0.015
Length of main inflorescence (b_3)	+ 0.0114X_3		0.0114±0.013	No. of seeds/siliqua(b_3)	+0.1381X_3		0.1381*±0.053
Siliquae on main inflorescence (b_4)	+ 0.0951X_4		0.0951*±0.051	1000-seed weight (b_4)	+0.8615X_4	95.42	0.8615*±0.289
Secondary branches/plant (b_5)	-0.0858X_5	84.17	-0.0858*±0.057				
Biological yield/plant (b_1)	Y=-6.2080.1384X_1		0.1384**±0.044	Biological yield/plant (b_1)	Y=-3.759+0.1195X_1		0.1195*±0.031
Plant height (b_2)	+0.0534X_2		0.0534*±0.018	No. of seeds/siliqua (b_3)	+0.1613X_3		0.1613±0.091
Siliquae on main inflorescence (b_4)	+0.0875X_4		0.0875*±0.039	1000-seed weight (b_4)	+0.9307X_4	93.86	0.9307*±0.268
Secondary branches/plant (b_5)	-0.0427X_5	78.97	-0.0427±0.036				

* Significant at P=0.05; ** Significant at P=0.01

Table 2 Discriminant functions, genetic advance and relative efficiency of different functions in rapeseed (*toria*) and mustard

Discriminant function in		Genetic advance in		Relative efficiency (%) in	
Toria	Mustard	*Toria*	Mustard	*Toria*	Mustard
0.1582 X_1	0.1151 X_1	0.90	0.572	100.00	100.00
0.0434 X_2	0.0258 X_2	0.90	0.604	99.85	105.67
0.0085 X_3	0.0608 X_3	0.35	0.431	39.09	75.35
0.0215 X_4	0.2208 X_4	0.53	0.454	58.51	79.37
0.1635 X_5	0.0858 X_1 + 0.0378 X_2	0.63	0.883	69.79	154.38
0.1492 X_1 + 0.0519 X_2	0.1104 X_1 + 0.0764 X_3	1.32	0.740	146.08	129.58
0.1538 X_1 + 0.0126 X_3	0.1023 X_1 + 0.2720 X_4	0.99	0.738	109.49	129.04
0.1623 X_1 + 0.0031 X_4	0.0265 X_2 + 0.0653 X_3	0.94	0.758	103.72	132.57
0.1503 X_1 + 0.1654 X_5	0.0262 X_2 + 0.2289 X_4	1.08	0.765	120.15	133.72
0.1471 X_1 + 0.0500 X_2 + 0.0140 X_3	0.0588 X_3 + 0.2131 X_4	1.38	0.615	152.60	107.57
0.1351 X_1 + 0.0561 X_2 + 0.0270 X_4	0.0821 X_1 + 0.0371 X_2 + 0.0760 X_3	1.45	0.996	160.32	174.08
0.1381 X_1 + 0.0531 X_2 + 0.1630 X_5	0.0421 X_1 + 0.0430 X_2 + 0.3179 X_4	1.45	1.013	160.55	177.08
0.1790 X_1 + 0.0384 X_2 + 0.0063 X_3 + 0.1544 X_5	0.0891 X_1 + 0.0831 X_3 + 0.2879 X_4	1.45	0.881	160.82	154.01
0.1238 X_1 + 0.0580 X_2 + 0.0273 X_4 + 0.1615 X_5	0.0274 X_2 + 0.0626 X_3 + 0.2214 X_4	1.57	0.887	174.04	155.03
0.1235 X_1+0.0570 X_2+0.0140 X_3+0.0253 X_4+0.1630 X_5	0.0229 X_1 + 0.0433 X_2 + 0.0875 X_3 + 0.3410 X_4	1.62	1.125	179.66	196.59

In *Toria*
X_1 = Seed yield/plant
X_2 = Biological yield/plant
X_3 = Plant height at maturity
X_4 = No. of siliquae on main inflorescence
X_5 = No. of secondary branches/plant

In mustard:
X_1 = Seed yield/plant
X_2 = Biological yield/plant
X_3 = No. of seeds/siliqua
X_4 = 1000-seed weight

Whereas, in case of mustard, the index involving seed yield, biological yield and 1000-seed weight exhibited the maximum efficiency of 177.1 % which was about 19% less as compared to the most efficient index involving all the four characters. The four-factor index constructed with seed yield, biological yield, siliquae on main inflorescence and secondary branches/plant in *toria* exhibited the highest relative efficiency of 174.1 % and it was at par with the index involving all the five characters. Thus, considering the difficulties in simultaneous selection for several characters, it can be concluded that the index involving four characters *viz.*, seed yield, biological yield, siliquae on main inflorescence and secondary branches/plant in *toria* and the index involving three characters *viz.*, seed yield, biological yield and 1000-seed weight in mustard were quite efficient. Choudhury *et al.* (1990) also reported that secondary branches and biological yield/plant are some of the important characters in different *Brassica* species.

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Short communication

Combining ability analysis for seed yield, growth and development traits and biomass partitioning in taramira, *Eruca sativa* L. under rainfed conditions

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Taramira, *Eruca sativa* L. a non- edible oilseed crop of Cruciferae is generally grown on marginal and sub –marginal lands in a scanty rainfall. Yield is a function of physiological and morphological parameters like leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), root, stem, leaves and reproductive parts i.e. mature siliquae containing seeds. Combining ability analysis provides a guideline for the assessment of relative breeding potential of material, which can be utilized in pursuing systematic breeding programme (Asthana and Pandey, 1977) .This information on physiological characters is lacking in taramira under rainfed conditions. Therefore, this possibility was explored in the present investigation and the combining ability of genotypes was studied.

The experiment was conducted during *rabi* season of 2001-02 at Regional Research Station, CCSHAU, Bawal. The present study is based on a diallel set of 7 genetically diverse inbreds *viz.*, RTM-314, TC-31, BTM-1, DITA-1, TC-15, TC-22 and BTM-2 developed by three subsequent selfings through bud pollination. The 21 F_1's along with seven parents were grown in a Randomized Complete Block Design with three replications. Each treatment was sown in a single row of 5m length. The rows and plants within rows were spaced at 45 cm and 15 cm apart, respectively. The recommended cultural practices were followed to raise a good crop. Observations for LAI, CGR were recorded at their peak values (75 DAS) where as RGR and NAR at 25 DAS (peak values) on five randomly selected plants and growth analysis was done. LAI was computed by Leaf area (cm^2) / Ground area (cm^2); CGR by $(w_2 - w_1 / t_2 - t_1) \times 1/s$ where w_2 = weight in g/plant at 100 DAS, w_1= weight in g/plant at 75 DAS , t_2= 100 DAS , t_1 = 75 DAS, s = spacing; RGR by $(\log w_2 - \log w_1) / (t_2 - t_1)$ and NAR by $(\log L_2 - \log L_1 / L_2 - L_1) \times (w_2 - w_1 / t_2 - t_1)$ where L_2 = leaf area at 100 DAS, L_1= leaf area at 75 DAS.

The biomass partitioning was done for root, stem, leaves and reproductive parts at harvesting stage (150 DAS). Combining ability analysis was carried out according to Method 2, Model 1 of Griffing (1956).

The Analysis of variance for seed yield, growth and development characters i.e. LAI, CGR, RGR and NAR and biomass partitioning to root, stem, leaves and reproductive parts was carried out for testing the significance of genotypic differences. There were highly significant genotypic differences for all the traits. Significant *gca* and *sca* variances for all the characters except of stem for *gca* and of LAI for *sca*, suggesting the importance of additive and non-additive gene actions in the expression of the traits (Table 1). Significant estimates of *gca* and *sca* variances for seed yield were also reported by Kumar and Yadav, (1986) in taramira. In this study, higher magnitude of *gca* variance than the *sca* variance was recorded for seed yield, LAI, root, leaves and reproductive parts which indicated predominant role of additive and additive x additive epistatic components of genetic variance. These findings are in agreement with those of Kumar and Yadav, (1986). Non-additive effects (dominance and epistatic components of variation) were important for CGR, RGR, NAR and stem.

The parent TC-22 is the best general combiner for seed yield/plant followed by TC-31 because of their significant and positive *gca* effects (Table 2). The estimates of *gca* effects showed that the parent BTM-1 was good general combiner for CGR, RGR, NAR and biomass partitioning traits. Parent RTM-314 was a good general combiner for LAI, NAR and biomass partitioning traits and TC-31 for seed yield, CGR, NAR, RGR, root, stem and reproductive parts.

The cross TC-31 x TC-15 for seed yield/plant and reproductive part; TC-31 x BTM-1 for CGR and RGR, RTM-314 x BTM-1 for root, stem and leaves showed high *sca* effect and involved high x high *gca* parents. Obviously, high *sca* effects in such a case can be attributed to additive type interaction between the parents. In view of the considerable importance of additive x additive effects and possibility of their fixation, simple selections may be practiced. On the other hand, the parents with high *gca* effects did not give equally high *sca*

effects. The crosses involving both parents with high *gca effects*, e.g. TC-31 x TC-22 and TC-15 x TC-22 for seed yield; TC-31 x DITA -1 for CGR, TC-31 x BTM-1 for NAR and stem; RTM-314 x TC-31 for root; BTM-1 x DITA-1 for leaves and RTM-314 x BTM-1 and BTM-1 x TC-15 for reproductive parts gave low *sca* estimates. This is probably due to mutual cancellation of gene effects for these characters in the parents. Due to epistatic interactions even poor combining parents in the cross TC-15 x BTM-2 for NAR and leaves and DITA-1 x BTM-2 for root showed high *sca* effects. Under the present situation where both additive and non- additive variances are present, it is suggested that reciprocal recurrent selection may be adopted for rapid improvement.

Table 1 Estimates of general combining ability effects for yield, growth, development traits and biomass partitioning

Parent	Seed yield/plant	Growth, development trait				Biomass partitioning			
		LAI	CGR	RGR	NAR	Root	Stem	Leaves	Rep. Part
RTM-314	0.639	0.500*	-2.164*	-3.022*	0.135*	0.651*	1.009*	0.495*	5.19*
TC-31	2.231*	-0.548*	1.184*	2.334*	0.930*	1.673*	2.998*	-0.083	3.20*
BTM-1	-2.984*	-0.145*	1.339*	2.856*	0.623*	0.629*	1.428*	1.251*	14.62*
DITA-1	-3.098*	-0.012	2.117*	0.719*	-0.354*	-0.871*	0.016	0.573*	0.423
TC-15	0.494*	0.208*	-1.830	-3.025	-0.298*	-0.349*	-4.613*	-1.283*	10.22*
TC-22	3.946*	-0.270*	0.958*	3.345*	-0.361*	-0.983*	0.309	-0.149*	-10.16*
BTM-2	-1.228*	0.267*	-2.235*	-3.208*	-0.675*	-0.949*	-1.147*	-0.805*	-23.49*
SE(gi)	0.6715	0.0653	0.5359	0.5080	0.1243	0.2604	0.8491	0.1401	1.0020
SE(gi-gj)	1.0257	0.0997	0.8186	0.7759	0.1898	0.3978	1.2970	0.2141	1.5306

(*P= 0.05); Rep. = reproductive

Table 2 Estimates of specific combining ability effects for yield, growth, development traits and biomass partitioning

Parent	Seed yield/plant	Growth, development trait				Biomass partitioning			
		LAI	CGR	RGR	NAR	Root	Stem	Leaves	Rep. Part
RTM-314 x TC-31	-8.064*	-0.256	-9.841*	-9.712*	-3.714*	-0.517	-11.26*	-2.281*	25.08*
RTM-314 x BTM-1	5.251*	-0.009	-6.396*	-8.334*	1.500*	1.528*	10.89*	1.186*	-22.03
RTM-314x DITA-1	0.166*	-0.102	7.196*	14.70*	1.441*	-0.972	12.60*	4.564*	36.96*
RTM-314 xTC-15	-2.327	0.158	-11.14*	-2.752*	4.425*	2.506	15.93*	-0.781	5.670
RTM-314 X TC-22	12.59*	-0.483*	30.28*	13.48*	-3.502*	1.139	-9.995*	-0.414	35.94*
RTM-314 x BTM-2	16.40*	0.939*	-4.792*	-4.470*	4.822*	1.106	20.66*	-0.558	-15.82*
TC-31 x BTM-1	-10.01*	-0.241	8.006*	13.91*	0.199	3.706*	1.297	2.836*	13.65*
TC-31 x DITA-1	-11.89*	0.036	-1.592	-10.15*	-2.535*	7.206*	-5.492*	1.042*	9.244*
TC-31 x TC-15	8.314*	0.656*	-6.205*	-1.108	0.880*	1.683*	-4.362	0.797	17.15*
TC-31 x TC-22	-2.938	-0.216	-5.623*	6.122*	2.112*	-2.683*	-7.384*	-1.336*	-24.04*
TC-31 x BTM-2	11.04*	-0.203	16.01*	9.074*	0.876*	-2.717*	-7.829*	0.219	4.829
BTM-1x DITA-1	-3.212	-0.388*	-6.537*	6.825*	1.343*	-1.750*	4.945*	-3.892*	-26.27*
BTM-1x TC-15	9.629*	-0.168	16.32*	-6.830*	-2.003*	-2.072*	-4.392	-2.836*	-3.063
BTM-1x TC-22	10.04*	0.221	-8.638*	-7.201*	-2.250*	0.361	-3.514	3.231*	-9.493*
BTM-1x BTM-2	-1.316	0.833*	-4.655*	15.45*	2.674*	-1.272	-4.958*	-1.514*	41.74*
DITA-1 x TC-15	-4.256	0.169	-0.498	-5.426*	-2.496*	-3.172*	-1.681	-0.758	-15.97*
DITA-1x TC-22	3.992*	-0.068	-12.30*	-5.764*	-0.224	-1.039	4.197	3.108*	17.20*
DITA-1 x BTM-2	-12.33*	-0.380*	-3.063*	-3.711*	0.391	1.828*	-3.147	-2.636*	39.97*
TC-15 x TC-22	-5.768*	-0.282	-1.249	-1.019	-0.799*	0.339	15.13*	-1.336*	9.611*
TC-15 x BTM-2	0.973	-0.570*	-1.166	5.034*	0.975*	1.306	-0.718	1.519*	10.18*
TC-22 x BTM-2	-6.345*	-0.741*	2.426	-9.237*	-1.202*	-0.061	-2.040	-0.114	1.819
SE (Sij)	1.919	0.1865	1.5314	1.4517	0.3551	0.7443	2.4264	0.4005	2.8636
SE (Sij-sik)	2.901	0.2820	2.3153	2.1947	0.5369	1.1252	3.6683	0.6055	4.3293

(*P= 0.05)

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Short communication

Studying changes in populations under going recurrent S_1 selection in sunflower, *Helianthus annuus* L.

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Selection brings about changes in the mean performance of a population. It does this through a change in the gene and genotype frequency (Falconer, 1960). This change in gene and genotype frequency can be studied through the use of statistics namely, mean, variance, skewness and kurtosis (Mather and Jinks, 1971; Roy, 2000). Recurrent S_1 selection is one of the intra-population improvement methods (Hallauer and Miranda, 1981) which has been applied to the present sunflower populations and changes occurred have been studied.

Recurrent S_1 selection scheme was started in September, 1996 in the base population supplied by the Project Co-ordinator, Sunflower, UAS, Bangalore. It was developed by crossing *inter se* six component lines namely, 234B, 207B, PCSP, Accession 456, Accession 1260 and one variety, Morden.

The base population was planted on 25th September, 1996 at Crop Research Centre, Pantnagar in seven blocks comprising 100 rows of 5 m length each. In this base population around 200 superior plants were selected at flowering and selfed. At the time of harvesting 180 heads were individually harvested and seeds collected separately and these 180 S_1 families were planted in January, 1997. The population of selected individual plants was designated as PSSI.

Three populations, namely, S_1-A, S_1-B and S_1-C were developed by intercrossing 18,34 and 36 plants, respectively which were selected from the S_1 progeny population and these three groups of selected plants differed in plant height (90-100, 110-150 and >200 cm) and maturity (80-90,90-100 and >100 days), respectively. The selected S_1 progeny population was called SSPP. Out of these three populations one population S_1-A was lost during development programme. From the rest two populations first cycle populations (C_1-B and C_1-C) were reconstituted after allowing one round of random mating by way of growing these populations in isolation and finally in these two populations in the subsequent season selection (mass selection) was applied by way of rejecting all the undesirable plants from the populations in the field and thus first cycle selected populations (SC_1-B and SC_1-C) were developed. The two populations, C_1-B and C_1-C were evaluated during Rabi 1998-99 whereas the two populations, SC_1-B and SC_1-C were evaluated during *Zaid* (April planting) 1999. Five traits were analysed for the genetical study (Table 1). The four statistics computed and compared were means, variances, skewnesses and kurtoses (Snedecor and Cochran, 1966; Roy, 2000).

Means, variances, skewnesses and kurtoses of PSSI, SSSP, C_1-B, SC_1-B and C_1-C and SC_1-C of the two populations S_1-B and S_1-C and their comparisons are presented in Tables 1,2,3 and 4, respectively. Table 1 showed that mean yield per plant increased as the population progressed from first cycle (C_1) to first selected cycle (SC_1) generation. The increase in mean yield was associated with the reduction in the variances in both S_1-B and C_1-C populations suggesting the accumulation of individuals with similar performance for the trait as a result of selection. However, two populations showed reduction in mean leaf length and leaf width. For plant height, C_1-B population showed a reduction when compared with SSPP, however, it showed an increase in the SC_1-B population. This can be attributed to differences in the environments in which these two generations populations were grown. In general, plant height was influenced considerably by the prevailing environmental conditions during the crop season. SSPP was raised in favorable environment whereas C_1-B was grown in off-season (*Rabi*) environment. The overall results indicated progressive increase in seed yield while decrease in mean values of various traits in advancing generations of populations. The increase in seed yield following selection has been reported by many workers i.e., Fick and Rehder (1977), Mamonov and Selektsiya (1991) in sunflower.

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Skewnesses for leaf length in both S_1-B and S_1-C populations for all three generations, for plant height and head diameter in all three generations of S_1-B population and for leaf width in S_1-C population in all three generations were not significant. This indicated the ineffectiveness of selection for these traits or the changes could be too small to be detected. However, skewnesses for seed yield in both populations for two generations were positive and significant which indicated the effect of selection on this trait. Positive and significant skewnesses in C_1 generation populations showed the accumulation of individuals of low values close to mean with fewer high values spread far above it. The skewness did not change significantly from C_1-B to SC_1-B generation population but it increased significantly in SC_1-C generation population in comparison to C_1-C in S_1- C population. It is not surprising as the selection (visual selection) practiced was for yield only.

Table 1 Means of S_1 populations for different traits

Populations		Characters				
		Plant height	Leaf length	Leaf width	Head diameter	Seed yield/plant
PSSI		158.1±1.8	-	-	20.7±0.4	-
S_1-A	SSPP	97.7 ± 4.1	20.6 ± 0.9	21.2 ± 0.8	16.1 ± 0.8	-
	C_1-A	-	-	-	-	-
	SC_1-A	-	-	-	-	-
S_1-B	SSPP	130.2 ± 1.6	22.5 ± 0.7	22.3 ± 0.5	18.0 ± 0.4	-
	C_1-B	124.1 ± 1.4	20.7 ± 0.4	18.0 ± 0.4	19.5 ± 0.4	18.0 ± 0.4
	SC_1-B	131.1 ± 1.6	16.8 ± 0.3	16.4 ± 0.4	16.2 ± 0.3	22.4 ± 0.7
S_1-C	SSPP	156.6 ± 2.3	24.8 ± 0.7	25.5 ± 0.7	19.7 ± o.5	-
	C_1-C	118.3 ± 1.4	20.3 ± 0.4	16.6 ± 0.4	18.5 ± 0.4	16.6 ± 0.4
	SC_1-C	129.0 ± 2.2	18.1 ± 0.4	16.7 ± 0.5	16.1 ± 0.4	22.4 ± 1.0

- indicates no observation taken for such trait in that population (in case of S_1- A population it is because of loss of C_1-A and SC_1-A generations populations)

Table 2 Variances for different traits in S_1 populations

Populations		Characters				
		Plant height	Leaf length	Leaf width	Head diameter	Seed yield/plant
PSSI		599.7	-	-	24.6	-
S_1-A	SSPP	299.7	15.0	12.4	11.3	-
	C_1-A	-	-	-	-	-
	SC_1-A	-	-	-	-	-
S_1-B	SSPP	86.4	14.2	8.9	7.5	-
	C_1-B	234.4	21.3	21.1	17.2	298.0
	SC_1-B	357.4	14.4	21.3	15.2	70.4
S_1-C	SSPP	180.4	16.4	16.5	9.4	-
	C_1-C	222.5	18.8	16.5	18.8	312.4
	SC_1-C	616.0	20.1	24.6	8.4	147.2

Table 3 Skewnesses for different traits in S_1 populations

Populations		Characters				
		Plant height	Leaf length	Leaf width	Head diameter	Seed yield/plant
PSSI		0.06	-	-	31.48**	-
S_1-A	SSPP	0.28	2.24**	2.01**	0.17	-
	C_1-A	-	-	-	-	-
	SC_1-A	-	-	-	-	-
S_1-B	SSPP	0.01	0.08	0.01	0.22	-
	C_1-B	0.06	0.31	0.20**	0.01	1.22**
	SC_1-B	0.04	0.03	0.64**	0.37	0.78**
S_1-C	SSPP	0.83*	0.63	0.03	0.37	-
	C_1-C	0.24	0.30	0.15	0.14	1.62**
	SC_1-C	0.29	0.06	0.04	0.72**	3.53**

*, ** Significant at 5 and 1% levels of probability, respectively.

Table 4 Kurtoses in S_1 populations for various traits

Populations		Characters				
		Plant height	Leaf length	Leaf width	Head diameter	Seed yield/plant
PSSI		0.70*	-	-	2.14**	-
S_1-A	SSPP	-0.39	0.81	0.80	-2.13	-
	C_1-A	-	-	-	-	-
	SC_1-A	-	-	-	-	-
S_1-B	SSPP	3.78**	-1.40	71.92**	2.04*	-
	C_1-B	0.70	1.23**	1.37**	7.70**	0.30
	SC_1-B	0.88*	3.29**	1.26**	1.77**	0.55
S_1-C	SSPP	0.28	0.93	-2.68**	-1.26	-
	C_1-C	0.38	1.16**	1.60**	1.60**	0.22
	SC_1-C	-0.28	2.51**	2.78**	1.26*	0.40

*, ** Significant at 5 and 1% levels of probability, respectively.

For seed yield the kurtoses were found not significant and positive in C_1 and SC_1 generations of both S_1–B and S_1-C populations whereas kurtoses were significant and positive for leaf length in C_1 and SC_1 generations of both populations and for head diameter in all three generations of S_1-B and C_1 and SC_1 generations of S_1-C population. In case of leaf width in both populations estimates of kurtosis were significant and positive except for SSPP generation of S_1-C population. Kurtosis for plant height was found to be significant and positive in case of SSPP and SC_1-B generations of S_1-B population. The positive kurtosis in C_1 and SC_1 generations of both populations for leaf length, leaf width and head diameter showed that many individuals are close to mean for these traits.

Considering means, variances, skewnesses and kurtoses of the base and advanced generation populations it can be concluded that the recurrent S_1 selection has brought about changes in the two populations. Further, it also showed presence of higher variability for seed yield in the populations and thus further cycle of recurrent S_1-selection can be practiced in order to improve yield further.

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Short communication

Evaluation of three-way hybrids in sunflower, *Helianthus annuus* L.

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Heterosis has been explored and utilized in the production of single cross hybrids, utilizing cytoplasmic male sterile lines derived from *Helianthus petiolaris* source. Three-way hybrids reduce the cost of seed production and at the same time provides broad genetic base to sustain climatic fluctuations. Open pollinated varieties and three-way hybrids as a group are slightly more stable than single cross hybrids (Fick *et al.*, 1974; Fick and Zimmer, 1976). Therefore efforts were made to synthesise three-way hybrids with the material available at All India Coordinated Research Project on Sunflower, Regional Agricultural Research Station, Nandyal, AP and to evaluate the performance of three-way hybrids.

Four CMS lines *viz.*, CMS 7-1A, CMS 234A, CMS 850A, CMS 852A, their maintainers and three restorer lines RHA 6D-1, RHA Single Head and RHA 274 were utilized for the production of three-way hybrids. Crossing between A and B lines (excluding crosses with respective maintainers i.e. CMS 7-1A with CMS 7-1B) was taken up during *rabi*, 1998-99. During *rabi* 1999-2000 twelve single cross hybrids were raised to synthesise three-way hybrids by crossing them with three 'R' lines *viz.*, RHA 6D-1, RHA Single Head and RHA 274. It was observed that 7-1B and 850B could not maintain the sterility of CMS 852A where as the reciprocal crosses i.e., CMS 7-1A X 852B and CMS 850A X 852B were sterile (Table 1). Therefore only 10 sterile single crosses were utilized for production of there way hybrids. Thirty, three-way hybrids were raised in a Randomised Block Design with two replications during *Kharif and rabi,* 2000-2001 for evaluating their performance in comparison with the popular single cross hybrids *viz.*, APSH 11 and MSFH 17. Each entry was grown in a single row of 4.5 m length by adopting a spacing of 60 x 30 cm. Observations on important attributes like head diameter (cm), seed yield (g/plant) and 100 seed weight (g) were recorded. It was found that the restorer lines could not restore the fertility of single crosses CMS 234A x 850B and CMS 850 x 7-1B (Table 2). Studies conducted by Fick and Zimmer (1974) revealed the presence of two independent complimentary dominant genes in the genetic control of fertility restoration in CMS lines. Fick (1978) indicated that the inheritance of fertility restoration is more complex and up to four non-allelic genes may be involved in this process.

Table 1 Sterility/ Fertility in single crosses of sunflower derived CMS lines and their maintainers

Maintainer CMS line	7-1B	234B	850B	852B
CMS 7-1A	-	Sterile	Sterile	Sterile
CMS 234A	Sterile	-	Sterile	Sterile
CMS 850A	Sterile	Sterile	-	Sterile
CMS 852A	Fertile	Sterile	Fertile	-

Table 2 Fertility restoration with R lines in single crosses of sunflower

R line Single cross hybrid	RHA 6D-1	RHA Single Head	RHA 274
CMS 7-1A X 234B	Fertile	Fertile	Fertile
CMS 7-1A X 850B	Fertile	Fertile	Fertile
CMS 7-1A X 852B	Fertile	Fertile	Fertile
CMS 234A X 7-1B	Fertile	Fertile	Fertile
CMS 234A X 850B	Sterile	Sterile	Sterile
CMS 234A X 852B	Fertile	Fertile	Fertile
CMS 850A X 7-1B	Sterile	Sterile	Sterile
CMS 850A X 234B	Fertile	Fertile	Fertile
CMS 850A X 852B	Fertile	Fertile	Fertile
CMS 852A X 234B	Fertile	Fertile	Fertile

The differences among the entries for head diameter, seed yield and 100 seed were highly significant. None of the three-way hybrids had significantly higher values of head diameter, seed yield and 100 seed weight than the superior check hybrids (Table 3). Sixteen three-way hybrids were on par with MSFI 17 in head diameter. Seven, three-way hybrids had seed yield on par with the highest yielding check MSFH 17 (22.4 g/plant). All these hybrids were on par with APSH 11 for 100-seed weight, the superior check for this attribute. These three-way hybrids may be tested extensively over different environments. Though these three-way hybrids had no yield advantage over popular two-way hybrids presently grown in the tract, they may be preferred for their advantage in reducing seed production cost (Virupakshappa, 1998). However more studies are required in this direction using sources like CMSPF, CMS I, CMS GIG 1and CMS PET-2 to further improve yield ceiling of three-way hybrids and also to avoid the potential risk of the cytoplasm becoming vulnerable to pests.

Table 3 Mean performance of three-way hybrids in sunflower

Entry	Head diameter (cm)	Seed yield (g/plant)	100 seed weight (g)
(CMS 7-1A X 234B) x RHA 6D-1	11.1	20.1	4.1
(CMS 7-1A X 234B) x RHA Single Head	11.3	18.7	4.6
(CMS 7-1A X 234B) x RHA 274	116	15.2	4.9
(CMS 7-1A X 85B)x RHA 6D-1	9.7	11.[illegible]	3.5
(CMS 7-1A X 850B) x RHA Single Head	11.1	12.3	4.7
(CMS 7-1A X 850B) x RHA 274	11.1	13.2	4.9
(CMS 7-1A X 852B) x RHA 6D-1	9.4	9.9	3.9
(CMS 7-1A X 852B) x RHA Single Head	11.4	22.5	4.6
(CMS 7-1A X 852B) x RHA 274	10.9	23.8	4.2
(CMS 234A X 7-1B) x RHA 6D-1	12.0	19.3	4.6
(CMS 234A X 7-1B) x RHA Single Head	11.0	13.9	4.0
(CMS 234A X 7-1B) x RHA 274	10.9	14.1	3.9
(CMS 234A X 852B) x RHA 6D-1	10.4	14.3	3.9
(CMS 234A X 852B) x RHA Single Head	9.5	14.9	4.1
(CMS 234A X 852B) x RHA 274	11.8	17.6	4.6
(CMS 850A X 234B) x RHA 6D-1	11.5	10.7	4.1
(CMS 850A X 234B) x RHA Single Head	11.0	20.4	4.5
(CMS 850 A X 234B) x RHA 274	11.0	14.0	4.2
(CMS 850A X 852B) x RHA 6D-1	10.5	19.2	4.5
(CMS 850A X 852B) x RHA Single Head	10.5	15.7	4.5
(CMS 850A X 852B) x RHA 274	11.1	17.1	4.9
(CMS 852A X 234B) x RHA 6D-1	10.7	18.1	4.4
(CMS 850A X 234B) x RHA Single Head	11.1	18.0	4.1
(CMS 850A X 234B) x RHA 274	10.7	14.3	4.6
APSH 11 (C)	11.8	21.7	4.4
MSFH 17 (C)	12.5	22.4	3.7
Grand Mean	11.0	16.7	3.7
SEm±	0.58	1.54	0.28
CD (P=0.05)	1.61	4.27	0.78
CV (%)	10.6	18.5	13.1

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Short communication

Genetic divergence in the inbred lines of sunflower, *Helianthus annuus* L.

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The development of new varieties is mainly dependent on the extent of genetic divergence present in the base material and the magnitude of genetic variability for the different characters. Studies on genetic divergence and variability revealed that they play an important role in framing a successful breeding programme. It is evident that, the genetically diverse parents are likely to produce high heterotic hybrids and desirable recombinants. The multivariate analysis (D^2) is the powerful biometrical tool to measure genetic divergence within a set of genotypes. The present study based on 101 genotypes is an attempt to ascertain the nature and magnitude of genetic diversity present in each trait to identify the donors with broad based genetic divergence.

The material comprising 101 genotypes including 98 inbred lines, two hybrids and one open pollinated variety were evaluated in randomized block design with two replications at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi*, 2000. The observations were recorded on seed yield and its component characters *viz.*, days to 50% flowering, days to maturity, plant height, number of leaves/plant, stem girth, head diameter, number of filled seeds, number of unfilled seeds, test weight and oil per cent. Multivariate analysis was done as per Mahalanobis's D^2 technique and clustering was done following the Tocher's method.

Genetic divergence in genotypes, especially in respect of the characters in which improvement is sought, is an indispensable prerequisite for successful crop improvement programme. The D^2 statistics was found to be most useful tool for estimating genetic divergence, which is the basis for choosing the parents in crossing programme. The progenies derived from diverse crosses are expected to show a broad spectrum of genetic divergence providing greater scope for isolating high yielding types in the succeeding generations.

The multivariate analysis giving the D^2 values among 101 genotypes revealed that all these genotypes can be grouped into ten clusters (Table 1).

Table 1 Distribution of 101 sunflower genotypes in different clusters

Cluster	No. of genotypes	Genotypes
I	6	GP-4, GP-1347, GP-926, GP-1625, GP-574, LIB-02M-12
II	10	GP-979, GP-954, GP-960, GP-814, GP-1107, GP-978, GP-657, GP-736, LIB-02M-14, GP-897
III	10	GP-879, GP-1129, GP-1770, GP-2154, GP-1029, GP-1478, GP-1545, GP-1806, GP-1148, GP-1251
IV	6	GP-798, VND-NB-5, VND-NB-2, Morden, VND-NB-7, DRM-57-1
V	7	GP-847, GP-737, GP-1303, APSH-11, GP-1431, KBSH-1, GP-1195
VI	12	GP-728, GP-302, GP-1272, GP-904, GP-347, GP-1260, GP-146, GP-899, GP-1890, GP-1461, GP-1550, GP-2235
VII	13	GP-528, GP-1592, GP-913, GP-953, GP-1993, GP-995, GP-1332, GP-484, GP-2043, GP-940, GP-805, GP-1348, GP-1114
VIII	14	GP-719, GP-1932, GP-209, GP-547, GP-2198, GP-1219, GP-1327, GP-2024, GP-1602, GP-2459, GP-917, GP-579, GP-1332, GP-1016
IX	14	GP-654, DRM-75-1, X-15-NB-9, LIB-02M-6, VND-NB-10, DRM-72-2, LIB-02M-3, DRM-29-2, DRM-49-4, GP-1529, X-15-NB-10, DRM-70-1, X-15-NB-5, DRM-29-1
X	9	DRM-10-2, DRM-34-2, DRM-65-4, DRM-12-2, DRM-24-1, DRM-60-4, DRM-30-2, DRM-24-3, DRM-71-2

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Among these, clusters VIII and IX consists of 14 genotypes each, followed by cluster VII (13), VI (12), II and III (10), X (9) V(7) and cluster I and IV with 6 genotypes each. The important inbred line GP-1431 with respect to maximum seed set per cent grouped in cluster V while, APSH-11 and KBSH-1 were also grouped in cluster V whereas, the open pollinated variety Modern was grouped in cluster IV. The pattern of distribution of genotypes into various clusters was at random showing that genetic diversity was not related. Similar results were also reported by Yadav *et al.* (1988).

Most of the intra clusters closely related and cluster D values (Table 2) ranged from 14.59 (cluster VII) to 24.18 (cluster IV). From the inter cluster D values of the ten clusters it was concluded that highest divergence was present between cluster V and X (63.50) followed by cluster V and VI (54.95) and cluster V and IX (54.13), while lowest divergence was noticed between cluster VII and VIII (20.60). The cluster means exhibited that minimum and maximum values, respectively were plant height 65.83 cm (cluster X) and 171.45 cm (cluster VIII), number of filled seeds 300.41 (VI) and 695.57 (V), test weight 2.78g (X) and 6.35g (VI) and seed yield 9.79 g (X) and 29.62 g (I).

Table 2 Average intra and inter cluster distance (D values)

	I	II	III	IV	V	VI	VII	VIII	IX	X
I	19.74 C	24.91 M	26.18 M	32.58 H	29.12 M	38.14 H	30.32 H	38.37 H	38.48 H	51.02 H
II		17.92 C	22.68 M	28.36 M	29.42 M	36.43 H	27.22 M	30.94 H	35.09 H	44.76 H
III			15.72 C	35.69 H	37.84 H	25.89 M	22.19 M	22.71 M	32.49 H	45.48 H
IV				24.18 M	36.87 H	47.23 H	34.83 H	40.29 H	34.84 H	38.14 H
V					18.81 C	54.95 H	46.40 H	51.61 H	54.13 H	63.50 H
VI						17.48 C	21.15 C	22.41 M	30.32 H	44.48 H
VII							14.59 C	20.60 C	21.60 C	34.72 H
VIII								15.02 C	26.69 M	36.82 H
IX									19.30 C	25.14 M
X										16.57 C

H = Highly divergent (above 30); M = Moderately divergent (23-40) and C = Closely related (below 22)

The analysis for the relative contribution of characters indicating that number of filled seeds (43.84 %), plant height (26.50 %) and test weight (18.42 %) contributed maximum towards genetic divergence. These findings were in consonance with the earlier results of Yadav *et al.* (1988) and Venkateswara Rao (1999). In the present study, highest divergence was observed between cluster V (GP-847, GP-1303, GP-1431, GP-1195 and GP-737) and cluster X (DRM-10-2, DRM-65-4, DRM-34-2, DRM-30-2 and DRM-71-2). Hence, crossing between genotypes belonging to these two clusters may exhibit high heterosis for further breeding programmes.

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Short communication

Identification of fertility restorers for CMS lines in sunflower, *Helianthus annuus* L.

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The only source of cytoplasmic-genetic male sterility in sunflower (*Helianthus annuus* L.) used extensively for the production of commercial hybrid seed is *H. petiolaris* cytoplasm (PET-1) (Leclercq, 1969). Other sources of cytoplasm for sterility are available, but these could not be used in commercial hybrid seed production because effective fertility restorer is not available for these new cytoplasmic sources (Vishnuvardhan Reddy *et al.*, 2002). So, till the effective fertility restorer lines on new cytoplasmic sources are not available, identification of fertility restorers for *H. petiolaris* cytoplasm based CMS lines and exploitation of heterosis will be the major aim for the sunflower breeders. In the present study, diverse inbred lines were selected to study their sterility maintenance or fertility restoring ability by crossing them to cytoplasmic male sterile lines.

In the present study, 50 diverse inbreds were crossed to three CMS lines (PET-1) to determine the fertility restoring ability of the inbreds. Total 150 crosses were obtained in *rabi*, 2001 and F_1s were tested in summer, 2002 in R & D farm of Nirmal Agricultural Research and Development Foundation, Pachora. Each F_1 was grown in 4 rows of 4 m length with a spacing of 60 x 30 cm. The fertility restoration was observed at the time of anthesis. Visual observations, as well as microscopic staining technique (1% acetocarmine) were used to observe the pollen fertility.

Out of 150 crosses, 74 F_1s (49.3 %) found to be fertile, 60 (40 %) were sterile and 16 crosses (10.67) were partial fertile (Table 1).

Out of 50 inbred lines crossed to CMS lines, 18 lines *viz.*, IBR-4, 7, 8, 12, 13, 14, 15, 19, 23, 24, 25, 30, 33, 37, 43, 45, 47 and 50 restored fertility in the F_1s in all the three CMS lines, while 20 lines *viz.*, IBR-2, 3, 6, 11, 18, 21, 22, 26, 27, 28, 29, 31, 32, 34, 35, 36, 38, 40, 41 and 46 acted as maintainers of sterility in F_1s of all the three CMS lines and inbreds IBR-1 and 17 provided partial restoration of fertility in all the three CMS lines indicating the presence of restorer gene in heterozygous condition in these lines. IBR-1 and IBR-17 lines should be selfed for few more generations so that homozygosity of restorer gene for fertility, can be achieved.

Table-1 Fertile/sterile behaviour of the inbreds/germplasm line on three different CMS lines

Female/Male	CMS-11	CMS-20	CMS-32
IBR-1	PF	PF	PF
IBR-2	S	S	S
IBR-3	S	S	S
IBR-4	F	F	F
IBR-5	F	F	PF
IBR-6	S	S	S
IBR-7	F	F	F
IBR-8	F	F	F
IBR-9	F	F	PF
IBR-10	F	F	PF
IBR-11	S	S	S
IBR-12	F	F	F
IBR-13	F	F	F
IBR-14	F	F	F
IBR-15	F	F	F
IBR-16	F	F	PF
IBR-17	PF	PF	PF
IBR-18	S	S	S
IBR-19	F	F	F
IBR-20	F	F	PF
IBR-21	S	S	S
IBR-22	S	S	S
IBR-23	F	F	F
IBR-24	F	F	F
IBR-25	F	F	F
IBR-26	S	S	S
IBR-27	S	S	S
IBR-28	S	S	S
IBR-29	S	S	S
IBR-30	F	F	F
IBR-31	S	S	S

Table-1 (Contd...)

Female/Male	CMS-11	CMS-20	CMS-32
IBR-32	S	S	S
IBR-33	F	F	F
IBR-34	S	S	S
IBR-35	S	S	S
IBR-36	S	S	S
IBR-37	F	F	F
IBR-38	S	S	S
IBR-39	F	F	PF
IBR-40	S	S	S
IBR-41	S	S	S
IBR-42	F	F	PF
IBR-43	F	F	F
IBR-44	F	F	PF
IBR-45	F	F	F
IBR-46	S	S	S
IBR-47	F	F	F
IBR-48	F	F	PF
IBR-49	F	F	PF
IBR-50	F	F	F

F=Fertile; S=Sterile; PF=Partial Fertile

The results revealed that, the 10 inbreds IBR-5, 9, 10, 16, 20, 39, 42, 44, 48 and 49 acted as fertility restorer for CMS-11 and CMS-20 but, partial restorers for CMS-32. This indicated that, though the CMS lines used in this study belonged to PET-1 cytoplasm, the cytoplasm of CMS-11 and CMS-20 may be same but different from CMS-32. Similar results, were also obtained by Serieys (1999). He obtained partial restoration of fertility and full fertility restoration by wild male parents on two different CMS lines having same cytoplasmic background i.e., PET-1. Manivannan *et al.* (2002) crossed a CMS line 207A (PET-1 cytoplasm and female of hybrid LDMRSH-3) with 234B (maintainer of CMS-234A - a CMS line with PET-1 cytoplasm and female of hybrid KBSH-1) and obtained fertile progeny. In the same experiment, germplasm lines GP-255 and GP-270 proved to be maintainers of 207A and restorers of 234A. On the basis of this, authors suggested the difference in the cytoplasm of 207A and 234A. This indicated that, even if the CMS lines belonged to PET-1 cytoplasm but, they may have variation or difference. A maintainer of one CMS sometimes could not maintain the sterility of other CMS line, having same cytoplasmic background. Further, Dominguez-Gimenez and Fick (1975) suggested, the presence of modifying genes, which influenced the fertility restoration, resulted in partial restoration of fertility. Authors further suggested that, the inheritance of partial restoration may be complex and highly dependent of environmental conditions. However, detailed investigations regarding the full and partial fertility restoration in same cytoplasmic background (PET-1) by 10 inbreds should be carried out.

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Short communication

Response to selection for seed yield and yield attributes in sunflower, *Helianthus annuus* L.

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Sunflower (*Helianthus annuus* L.) cultivation started in India from 1972 with the introduction of Russian populations. The crop has contributed significantly to the oilseed production because of the development of several high yielding open pollinated varieties and hybrids, suitable for cultivation in different agro-production situations of the country. In recent years, the seed yield levels of sunflower have reached a plateau. So, there is a need to develop superior inbreds and populations, so that they can be utilized for further breeding programmes. The development of superior inbreds from the population involves several cyclic selection processes of population improvement programme. It will help the breeders to generate superior populations with improved performance of the concerned characters by imposing directional selection. The genetic variability in the base population is essential to subject a population for effective selection and to achieve a better response to selection in a particular trait(s).

Population improvement results into improved gene pool, because of accumulation of more frequency of favourable alleles in favourable combinations. Miller *et al.* (1977) obtained an increment of 12.2% oil content after three cycles of simple recurrent selection. The system is dynamic as hybridization and selection are employed simultaneously, so as to create new genetic variability along with desired response. The process of selection depends mainly upon the nature of gene action operating in a particular population. Therefore, the present study was undertaken to improve the base population by simple recurrent selection for seed yield and yield components in sunflower.

The present study was undertaken to improve the sunflower population in third selection cycle at Directorate of Oilseeds Research, Hyderabad during summer and *kharif*, 2001. Using seeds of second selection cycle (C_2), a population of about 20,000 plants were grown in bulk, from this population about 2000 phenotypically superior plants were selected and selfed. Out of these 2000 individuals, based on high autogamy, high oil content higher number of filled seeds and high seed yield, the best performing 200 plants were selected for progeny test during *kharif*, 2001 along with two checks (Morden and KBSH-1) in Randomized Block Design, replicated twice. Observations were recorded on eight characters *viz.*, days to maturity, head diameter, number of filled seeds, number of unfilled seeds, seed yield, 100 seed weight and oil content.

The mean and range for seed yield and yield contributing characters of the original base population and the gain achieved after three cycles of selection were calculated and presented in Table 1 and Fig.1. Cyclic selection has resulted in increase of 849.1% for the character number of filled seeds/head. The response to selection was 111.2 filled seeds/head/ cycle. The genetic gain for number of unfilled seeds was 535 (-81.69%) seeds for three cycles with a response of -178.3 unfilled seeds/head/cycle. Whereas the genetic gain was five days (decrease of 10.53%) with a response of -3.33 days/cycle for days to maturity.

The character head diameter showed a genetic gain of -1.51 cm (-9.93%) showing a response of -0.5 cm/cycle. The genetic gain for plant height after three cycles of selection was 12.3 cm (increase of 8.93%) with an average response of 4.1 cm/cycle. Mean while the percentage increase due to cyclic selection for character test weight was 11.89%. The genetic gain was 0.46 g with a response of 0.15 g/100 seed weight/cycle. The genetic gain for oil content for three cycles of selection was 3.16% increase (10.96%) with a response of 1.05 oil % per cycle. Positive response for oil content was showed by Miller *et al.* (1977) and Harinarayana *et al.* (1980). Seed yield per plant recorded a genetic gain of 14.49 g (335.42%) with a selection response of 4.83 g/head/cycle.

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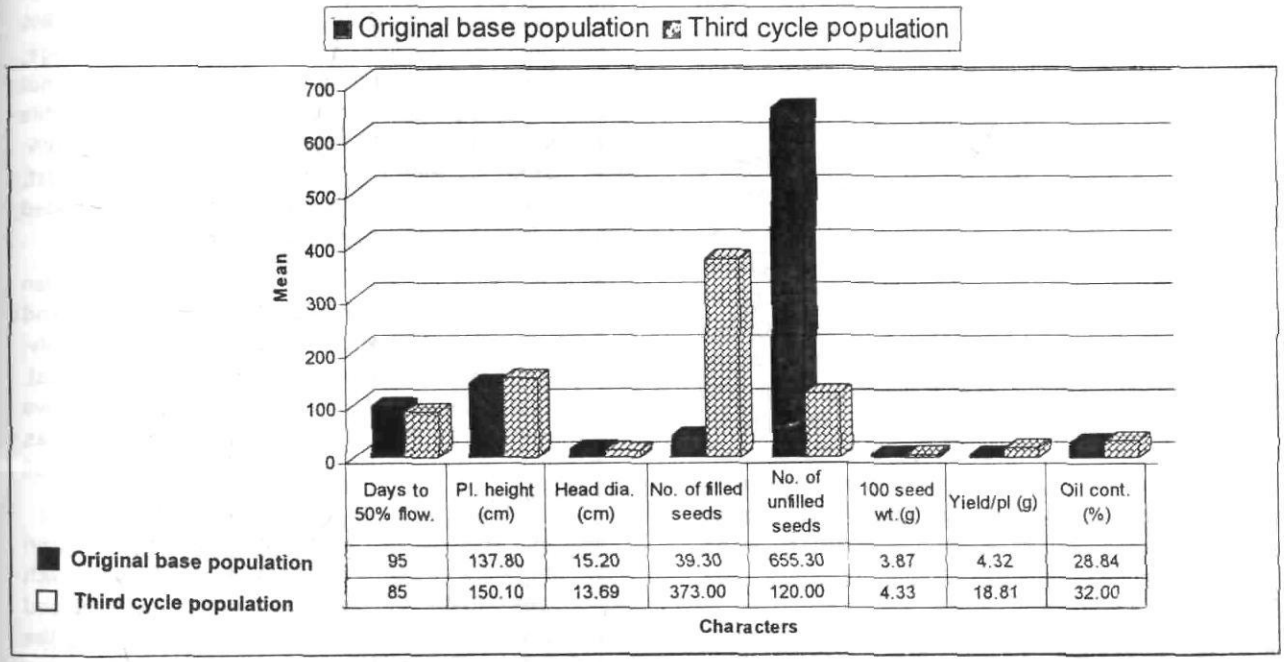
Table 1 Variability parameters for seed yield and yield attributes in original base population of sunflower and third cycle population *and response to selection*

Character	Range		Mean		Percentage increase or decrease	Response per cycle
	Original base population	Third cycle population	Original base population	Third cycle population		
Plant height (cm)	49-215	99.3-195-7	137.8	150.1	8.93	4.1
Head diameter (cm)	3-27	9.67-19.33	15.2	13.69	-9.93	-0.5
Days to maturity	74-111	76-97	95.0	85.0	-10.53	-3.33
Number of filled seeds/plant (g)	0-693	0-1545	39.3	373.0	849.1	111.2
Number of unfilled seeds/plant (g)	0-1715	0-1427	655.3	120.0	-81.69	-178.3
100 seed weight (g)	1.8-5.9	2.5-6.4	3.87	4.33	11.89	0.15
Seed yield/plant (g)	0-84.47	8.03-33.74	4.32	18.81	335.42	4.83
Oil content (%)	15.0-40.7	18.96-40.48	28.84	32.0	10.96	1.05

Fig-1 Response to selection for seed yield and yield attributes



Harinarayana et *al.* (1980); Miller and Hammond (1985); Pandey *et al.* (1988) and Mamonov (1991) also reported increase in seed yield due to cyclic selection.

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Short communication

Stability of cytoplasmic male sterility systems in sunflower, *Helianthus annuus* L.

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The discovery of cytoplasmic male sterility by Leclercq (1969) and the identification of fertility restorer genes by Kinman (1970) contributed to the commercial exploitation of heterosis on a large scale. All the hybrids so far developed possess only *Helianthus petiolaris* cytoplasm (PET-1) without exception, narrowing the cytoplasmic base. Genetic uniformity of this kind could result in genetic vulnerability of the hybrids if the cytoplasm becomes susceptible to any disease or pest. Though several new CMS sources have been developed, hybrids could not be developed due to lack of stability of male sterility in CMS sources and effective restorer lines. Hence an attempt has been made in the present study to identify most stable sources among the newly developed cytoplasmic sources.

Five CMS lines *viz.*, CMS 234A with PET-1 cytoplasm, DCMS 6 with PET-2 cytoplasm, DCMS 1 with GIG-1 cytoplasm, DCMS 4 with PEF-1 cytoplasm and DCMS 3 with ANL-2 cytoplasm were grown at an interval of two months by making six successive plantings from June 1999 to April 2000 at the Directorate of Oilseeds Research, Hyderabad representing the three major seasons. Plantings were done on the 1st of every month by growing each line in three rows of 5 m length with spacing of 60 cm between rows and 30 cm between plants within a row. The recommended cultivation practices were followed.

The pollen and seed fertility were assessed on 5 plants/row and each row formed one replication. Each plant was bagged to avoid contamination. Pollen fertility was studied by microscopic examination using 2% acetocaramine stain in the laboratory. Deeply stained and well filled pollen grains were taken as fertile while poorly stained and shrivelled pollen grains were counted as sterile. The number of fertile to sterile pollen grains observed were recorded from each line/sowing date and expressed as percentage. The seed set was assessed at harvest from bagged plants by taking actual counts of filled seeds to the total number of florets present and expressed in percentage.

The data on maximum and minimum temperatures, relative humidity and rainfall that prevailed during the growing period are given in Fig.1. The data on the percentage of pollen fertility and seed fertility are presented in Table 1. Of the lines studied the ANL-2 was unstable as it produced fertile pollen to a maximum of 9.7% during April followed by 9.2%, 8.8%, 6.2% and 5.8% during June, February, August and December plantings, respectively, whereas during October planting, it did not produce fertile pollen. Similarly, PEF-1 produced fertile pollen to the extent of 6.2% during April followed by 5.6%, 4% and 2.3% during February, June and August, respectively, while no fertile pollen (0.0%) was produced during October and December plantings.

The other CMS source *viz.*, GIG-1 produced fertile pollen to the extent of 0.8% during April followed by 0.6% and 0.3% during February and June plantings, respectively, whereas it does not produce fertile pollen during August, October and December plantings. The remaining two CMS sources *viz.*, PET-1 and PET-2 were regarded as stable sources as they did not produce fertile pollen in all the plantings.

Pollen and seed fertility was highest in the April sown crop. The data on weather parameters during crop growth period revealed that the high maximum temperature and marginally lower relative humidity prevailed during the months of March, April, May and June. Therefore the crop sown in February and April expressed maximum pollen and seed fertility. It clearly indicated that the influence of high temperature and lower relative humidity was the causes for break down of male sterility in sunflower. Similar kind of reports were given by Seetharam and Satyanarayana (1980) in sunflower, Pradhan and Jachuck (1991); Mishra and Pandey (1993) in rice; Brooking (1979) in sorghum. Reddy and Reddi (1972) suggested that the low relative humidity and high temperature were the causes for breakdown of male sterility in pearl millet.

Table 1 Pollen fertility (PF) and seed fertility (SF) expressed in percent in five diverse CMS sources of sunflower in different planting dates

Planting month	CMS sources									
	PET-1		PET-2		GIG-1		CMS-PF		CMS-1	
	PF	SF	PF	SF	PF	SF	PF	SF	PF	SF
June, 1999	0.0	0.0	0.0	0.0	0.3	2.0	4.0	3.1	9.2	7.3
August, 1999	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.8	6.2	4.3
October, 1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
December, 1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	4.3
February, 2000	0.0	0.0	0.0	0.0	0.6	0.5	5.6	4.8	8.8	6.4
April, 2000	0.0	0.0	0.0	0.0	0.8	0.6	6.2	4.2	9.7	8.7

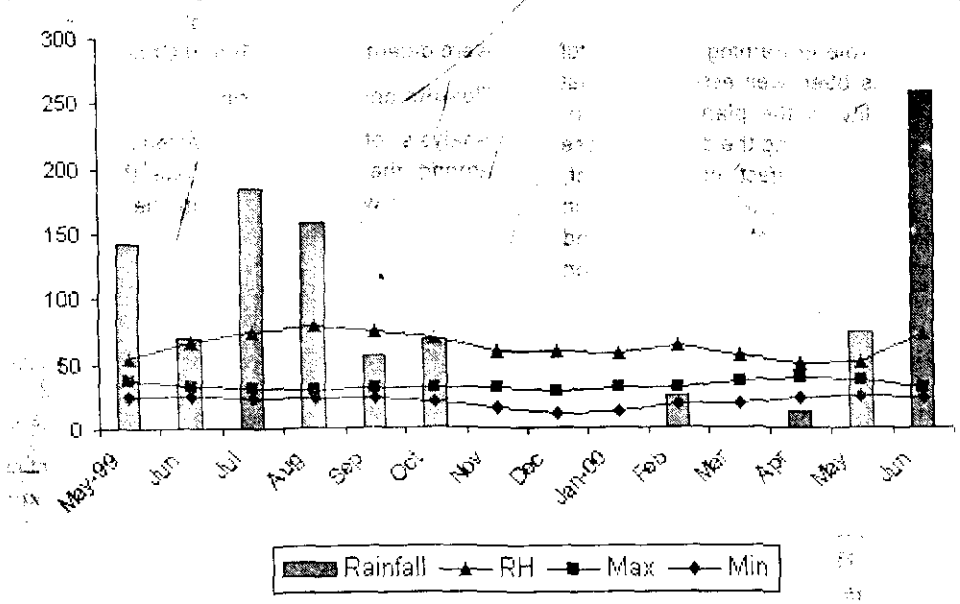

Fig.1 Weather during crop growth period

From the present study, it can be concluded that the CMS sources PET-1 and PET-2 can be extensively utilized in hybrid development followed by the CMS source GIG-1. High temperature and marginal relative humidity were the causes for breakdown of male sterility in PEF-1 and ANL-2 and to a limited extent in CMS GIG-1.

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Short communication

Genetic divergence analysis in sunflower, *Helianthus annuus* L.

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Sunflower, which is alien to Indian agriculture, holds great promise because of its short duration, wider adaptability, photo-insensitivity, drought tolerance and higher amount of superior quality oil (40-50%). The knowledge on the nature and extent of genetic variability present in any crop species plays an important role in framing a successful breeding programme. It has been well established that greater the genetic variability in the plant population, greater will be the chance of obtaining the desirable gene recombinants with high heterosis effect. In this content, Mahalonobis's D^2 statistics is an effective tool in quantifying the degree of divergence at genetic level and it also provides a quantitative measure of association between geographic and genetic diversity based on genotype distance (Mahalonobis, 1936). Keeping this in view, the present investigation was carried out to identify the divergent genotypes among the newly developed interspecific derivatives of sunflower.

The material for the present investigation comprised 80 sunflower germplasm accessions, which were in BC_4 F_5 generations obtained from the Directorate of Oilseeds Research, Rajendranagar, Hyderabad. The BC_4 F_5 generation genotypes were the interspecific derivatives of the following crosses:

1. *Helianthus argophyllus* x *Helianthus annuus*
2. *H. petiolaris* x *H. annuus*
3. *H. annuus* (wild) x *H. annuus*
4. [*H. argophyllus* x *H. annuus* (wild)] x [*H. annuus*]
5. *H. annuus* x *H. debilis*

The material was sown in randomised block design with two replications during *rabi*, 2000. Each genotype was sown in two rows of 5 m length with a spacing of 60 x 30 cm. Data were recorded on five randomly selected plants of each genotype in each/every replication for days to initiation of flowering, days to 50% flowering, days to maturity, plant height, head diameter, 100 seed weight, volume weight, oil content and seed yield per plant.

The data were subjected to statistical analysis. The genetic divergence existing between genotypes with respect to a set of nine characters was estimated using Mahalanobis D^2 statistics (Mahalanobis, 1936). Tracing D^2 as a generalised statistical distance, the criterion used by Tocher (Rao, 1952) was applied for determining the group crystallation. Average intra and inter cluster distances were determined (Singh and Chaudhary, 1977).

Results and discussion

Analysis of variance revealed significant differences among the genotypes for all the characters studied indicating wider variability in the experimental material. Through multivariate analysis, the 80 genotypes were grouped into 12 clusters (Table 1). The composition of different clusters varied from one to as much as sixty five. The cluster I comprised maximum number of genotypes (65) followed by cluster VII and VIII consisting three genotypes each, while remaining clusters, i.e., II, III, IV, V, VI, IX, X, XI and XII had only one genotype in each.

Most of the genotypes derived from different crosses were grouped in single cluster (cluster I), indicating the similarity for the characters studied in parent material. On contrary the genotypes having similar pedigree were grouped in different clusters. It clearly demonstrated the impact of selection pressure in increasing the genetic diversity. These results were in conformity with the findings of Teklewold *et al.* (2000).

The intra and inter cluster distances are presented in Table 2. The intra cluster distances was maximum in cluster VII (7.95) followed by cluster I (7.53) and cluster VIII (7.13). However, rest of the clusters had zero intra solitary entries each. Maximum inter cluster distance was observed between cluster VII and XII (25.68) followed by cluster VI and XII (25.49) and cluster V and XII (22.27) indicating maximum diversity between the genotypes of these clusters with respect to the traits considered. However, the lowest inter cluster distance was observed between cluster II and III (2.46), followed by cluster IV and IX (5.12) and cluster II and VIII (5.32) inferring the similarity for most of the characters among the genotypes of the respective clusters.

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The cluster means for each of nine characters are presented in Table 3. The cluster XII recorded highest mean values for seed yield per plant (70.62 g), 100 seed weight (8.15 g), head diameter (27.75 cm) and days to maturity (96 days), whereas the cluster VI and VII recorded lower mean values for seed yield per plant, 100 seed weight, head diameter and plant height. However, cluster II had higher mean values for both seed yield per plant and oil content.

Based on the inter cluster distances and cluster means, it can be concluded that the genotype of the cluster VII and XII cluster, VI and XII, cluster V and XII could be selected for hybridization programme as they are expected to produce high heterotic crosses.

Table 1 Distribution of 80 genotypes of sunflower in different clusters

Cluster No.	No. of genotypes	Genotypes
I	65	PS 4037, PS 1008, PS 1068, PS 2005, PS 1063, PS 4006, PS 4058, PS 2045, PS 2059, PS 4039, PS 4026, PS 3017, PS 2014, PS 1067, PS 2049, PS 4079, PS 1064, PS 1066, PS 1026, PS 2038, PS 5009, PS 2027, PS 5013, PS 5031, PS 1054, PS 2047, PS 1035, PS 5018, PS 1095, PS 1027, PS 2021, PS 1020, PS 1006, PS 5011, PS 4066, PS 4033, PS 2029, PS 1022, PS 2032, PS 2037, PS 2025, PS 2023, PS 4065, PS 5008, PS 5021, PS 3001, PS 1069, PS 4063, PS 4001, PS 1036, PS 1040, PS 4012, PS 4016, PS 4014, PS 4003, PS 4068, PS 4053, PS 1046, PS 1044, PS 1023, PS 1034, PS 1041, PS 1037, PS 1003, PS 2042
II	1	PS 3005
III	1	PS 4047
IV	1	PS 1042
V	1	PS 4057
VI	1	PS 2041
VII	3	PS 4021, PS 4069, PS 1060
VIII	3	PS 1085, PS 2008, PS 3014
IX	1	PS 2010
X	1	PS 3012
XI	1	PS 4029
XII	1	PS 4036

Table 2 Average intra and inter cluster distance (D values)

Cluster No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I		10.91	10.72	9.71	9.91	9.88	10.64	11.57	9.81	11.63	16.77	18.57
II		0.00	2.46	16.32	16.14	17.56	17.42	5.32	15.82	15.49	19.39	12.32
III			0.00	15.62	15.17	17.35	17.22	5.62	15.22	14.71	18.25	11.23
IV				0.00	8.10	7.84	10.80	16.56	5.12	6.56	13.65	20.61
V					0.00	7.49	9.43	16.45	8.42	11.18	16.22	22.27
VI						0.00	6.18	18.01	9.25	12.68	18.03	25.49
VII								17.84	10.74	14.53	18.17	25.68
VIII									16.18	16.36	20.39	12.66
IX									0.00	5.81	11.45	20.24
X										0.00	9.32	17.97
XI											0.00	19.96
XII												0.00

Table 3 Cluster means for nine characters in sunflower genotypes

Cluster No.	Days to initial flowering	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight. (g/100 ml)	oil content (%)	Seed yield per plant (g)
I	55	60	90	78	17.5	5.8	46.2	29.3	35.6
II	52	57	91	88	18.8	5.9	51.4	36.1	57.2
III	54	57	88	97	20.5	6.0	52.6	33.8	56.0
IV	68	70	92	94	18.8	5.3	38.3	21.5	25.6
V	64	66	83	67	19.7	5.6	57.0	28.8	22.5
VI	58	61	90	61	15.5	4.2	42.8	27.7	17.0
VII	49	55	86	68	13.0	5.1	49.0	28.9	17.5
VIII	51	58	91	80	19.8	6.7	50.0	30.2	56.5
IX	58	73	88	99	16.3	6.4	47.9	28.4	24.7
X	69	75	92	120	16.9	4.9	45.9	30.0	32.6
XI	58	68	93	170	14.7	4.5	58.5	35.4	28.9
XII	64	68	96	141	27.8	8.2	48.6	26.8	70.6

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Short communication

Components analysis in sunflower, *Helianthus annuus* L.

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Component analysis is the variance for a complex character via the variation of its component characters (Sparnaaji and Bos, 1993). For assessing the variation, the components are to be arranged in the ontogenetical order. This allows the determination of the mutually independent contribution of the individual components to the variation of complex character.

In the present study, the materials comprising of nine B lines *viz.*, WGB, 2B, 5B, 6B, SUF 11B, CO 4B, 234 B, 290 B and 822 B and restorer lines *viz.*, RHA 293, RHA 296, RHA 297, RHA 298, RHA 857, RHA 274, RHA 278, RHA 586 and RHA 6D-1 were raised in three rows of 3 m length with a spacing of 45 x 30 cm in a Randomized Block Design with three replications. Data on yield traits were recorded from ten randomly selected plants in each entry replication and the mean values used for analysis.

For the component analysis of seed yield:

X_1 = head diameter, $X_2 = \frac{\text{Percentage of filled seeds}}{\text{Head diameter}}$

$X_3 = \frac{\text{100 seed weight}}{\text{Percentage of filled seeds}}$ $X_4 = \frac{\text{Seed yield}}{\text{100 seed weight}}$

Component analysis was performed following Sparnaaij and Bos (1993). The contribution of successive primary characters to the variation of 'y' is measured by coefficient of determination (r^2). The difference between the r^2 values of two consecutive primary characters is taken to be the complementary determination (cd) of variation of 'y' by variation of the intervening component.

The component 'a' (head diameter) recorded the highest 'cd' value of 0.633 which indicated that the component is capable of explaining 63% of the variation of seed yield (Table 1). The other components showed relatively less influence on seed yield. Though a positive correlation of head diameter, 100 seed weight and filled seeds percentage has been reported by several workers (Naskar *et al.*, 1988; Dahiphale and Pawar, 1993), the fact that a trait is correlated with yield does not imply that it is a component of yield (Sparnaaij and Bos, 1993). This study has brought out that of the three traits *viz.*, head diameter, filed seeds percentage and 100 seed weight, head diameter is the key component of yield. Therefore, when the objective is to select parents/genotypes for breeding purposes, selection criteria must be chosen among the components of yield on the basis of their mutually independent effects on yield i.e., on the basis of their 'cd' values. Hence, a set of potential parents for the yield improvement programme would consists of genotypes of above average yield level with a high value for head diameter. This would enable the breeder to produce hybrids with maximum recombinative and stable heterosis.

Table 1 Coefficients of correlation (r) between the components of the complex character 'y' and the primary characters and complementary determination of (cd) values

Components	Head diameter (a)	Filled seeds (%) (b)	100 seed weight (c)	Seed yield (y)
x_1=a	1.000	0.308	0.663	0.749
x_2=b/a	-0.450	-0.107	-0.462	-0.262
x_3=c/b	0.560	-0.045	0.829	0.544
x_4=y/c	0.445	-0.017	-0.0075	0.723
y	0.749	0.333	0.680	1.000
r^2 (y, x_1, —, x_4)	0.633	0.090	0.409	1.00
CD (y, x_1, —, x_4)	0.633	-0.543	0.319	0.591

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Short communication

Genetic divergence in newly developed sunflower, *Helianthus annuus* L. genotypes

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Assessment of variability forms the basis for any crop improvement programme. To select most suitable and genetically divergent parents for crossing programme such studies are of immense importance. The multivariate analysis using Mahalanobis's D^2 statistic is a useful statistical method for measuring the amount of genetic diversity in a population. The usefulness of Mahalanobis analysis in quantifying genetic divergence has been emphasized by several workers (Yadav *et al.*, 1988; Rao *et al.*, 2000; Tecklewood *et al.*, 2000). Keeping this in view, the present investigation was carried out to ascertain the magnitude of genetic divergence in few sunflower genotypes.

Sixty nine newly developed sunflower genotypes and one open pollinated variety 'Morden' obtained from Directorate of Oilseeds Research, Hyderabad were studied in a Randomized Block Design with three replications. In each genotype, sown in three rows of 5 m length with a spacing of 60x30 cm, five plants were tagged to collect data on days to 50 % flowering, days to maturity, plant height, number of leaves/plant, head diameter, 100 seed weight, number of seeds/head, oil percent, seed filling percent and seed yield/plant. The genetic diversity was analyzed following Mahalanobis's D^2 statistic (Mahalanobis, 1936) and the genotypes were grouped into different clusters according to Tocher's method (Rao, 1952). The inter and intra clusters distances were calculated as per Singh and Chaudhary (1977).

The analysis of variance revealed wide range of variability and significant differences among all the genotypes for all the characters studied. The 70 genotypes were grouped into 12 clusters of which cluster I accommodated maximum of 59 genotypes, whereas, the remaining 11clusters had one genotype each (Table 1). The average intra and inter cluster D values among twelve clusters (Table 2) revealed that the maximum intra cluster D values were recorded by cluster I, while all other clusters had zero values as they were having single genotype in each. Inter cluster D value was minimum between cluster II and V (13.29) indicating close relationship and similarity for most of the characters of the genotypes of these clusters. The maximum inter cluster D value (108.91) found between cluster VII and XII was followed by cluster XI and XII (102.75), cluster III and XII (94.13), cluster VI and XII (92.53) and cluster II and XII (91.67) suggesting the existence of more diversity among the genotypes in respect of characters studied. Hence crossing between genotypes belonging to these clusters may result in high heterosis which could be exploited in crop improvement.

The cluster means of the characters indicated considerable differences among all the characters studied. The genotype of the cluster VI (N-NDOL-87) expressed superiority for plant height and number of seeds/head. The genotype of the cluster II (Acc-1439), IV (M-1005) and IX (Acc 1464) were early to reach 50 % following stage. The genotype of the cluster X (N-DOL-I) was late in maturity and had high oil percent, while the cluster VII (EC 376211) showed maximum mean value for 100 seed weight, head diameter and seed yield/plant. The cluster V (DSI-74) showed maximum mean value for number of leaves/plant, while the cluster VIII (DSI-23) had maximum mean value for seed filling percent. Intercrossing the genotypes from these clusters might result in generation of wide array of variability for exercising effective selection for the respective traits.

Table 1 Distribution of 70 genotypes of sunflower in different clusters

Cluster	No.	Genotypes
I	59	IB 44, RHA 341, HA 852, M 1001, HA 378, HAM 189, M 1013, HAM 188, R-348, PAR RVN 1329-1, ACC914, H-120, DSI-4, M-1018, EC 399418, M-1019, ACC 1223, M-307-3, ACC 1426, ACC 1174, ACC 1485 ACC 194-1, ACC 179, M-1031, HAM 11R, HAM 9R, M-120, DSI-11, RES 834-1, M-1007, M-1008, M-1017, HAM 161P3, M-19-5, Sungene-85, RHA 274, DSI-102, M-1032, M-80-1, DSI 63, ACC 1254, DSI 18, CMS 7-1B, DSI 27, HAM 180, N Dol-2, HA 380, ACC 916, M-1024, M-1026 Dwarf, DSI-61, EC 399453, DSI F2, DSI-35, M-1014 Dwarf, BCC-P6, HAM 174, ACC 1505, ACC 136.
II	1	ACC 1439
III.	1	EC 399464
IV	1	M-1005
V	1	DSI-74
VI	1	N-NDOL-87
VII	1	EC 376211
VIII	1	DSI-23
IX	1	ACC 1464
X	1	N-DOL-1
XI	1	Morden
XII	1	15 x NB-2

Table 2 Average intra and inter cluster distance (D) values

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	30.90	40.30	42.23	45.29	45.89	40.02	54.00	40.22	53.55	40.22	45.59	73.00
II		0.00	15.23	68.61	13.29	37.93	20.75	34.25	30.54	56.61	39.78	91.67
III			0.00	72.60	20.45	27.56	22.38	38.10	37.58	52.62	44.55	94.13
IV				0.00	71.05	69.66	86.01	48.78	69.16	43.16	71.28	38.38
V					0.00	43.64	29.15	30.50	26.37	58.57	50.83	89.56
VI						0.00	42.56	49.86	58.14	39.40	47.53	92.53
VII							0.00	50.95	40.88	69.44	44.00	108.91
VIII								0.00	24.48	42.33	61.69	60.78
IX									0.00	62.11	62.95	80.79
X										0.00	68.33	59.09
XI											0.00	102.75
XII												0.00

From this study highly diverse and superior genotypes *viz.*, EC 376211 (cluster VII), 15 x NB-2 (cluster XII), Morden (cluster XI), EC 399464 (cluster III) N-NDOL-87 (cluster VI), ACC 1439 (cluster II), and DSI-74 (cluster V) could be selected based on inter cluster distances. Since highly divergent genotypes would provide a wide spectrum of variability enabling further selection, these selected genotypes may be utilized in sunflower breeding programmes.

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Short communication

Genetic analysis of yield and important traits in sunflower, *Helianthus annuus* L. hybrids

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Sunflower *(Helianthus annuus* L.) is the third important edible oilseed crop in the world after soybean and groundnut. At present (2000-01) the sunflower area in the country is 2.1 m. ha with a production of 1.3 million tones of seed (Damodaram and Hegde, 2002). Though the progress achieved is quite high in terms of area and production, India's productivity of 566 kg/ha is one of the lowest in the world. This necessitates improvement of this crop by appropriate breeding strategies of various genetic approaches. Combining ability tests provide useful information fo' identifying desirable combinations of inbred lines to be utilized in hybridization programmes. In this study, an attempt was made to estimate the combining ability and heterosis for yield and related traits in sunflower.

The materials for the study consisted of nine lines *viz.,* CMS WGA, CMS 234 A, CMS 2 A, CMS 822 A, CMS 5 A, CMS 6 A, CMS 290 A, CMS SUF 11 A, CMS CO 4 A and nine testers *viz.,* RHA 297, RHA 857, RHA 298, RHA 293, RHA 296, RHA 586, RHA 6D-1, RHA 274 and RHA 278. Eighty -one hybrids were evolved by crossing the lines with testers in line x tester design and the 81 hybrids were raised along with their parents in Randomized Block Design with three replications during *kharif,* 1997 at Oilseeds farm, Tamil Nadu Agricultural University, Coimbatore. Each entry was raised in three rows of 3 m length adopting a spacing of 60 cm between the rows and 30 cm between the plants within each row. Five randomly chosen plants were tagged in each entry in all the three replications to record observations. Biometric observations were recorded for seven characters *viz.,* days to 50% flowering, plant height, head diameter, stem girth, 100-seed weight, oil content and seed yield / per plant. The data were analyzed as suggested by Kempthorne (1957).

Successful and sound breeding programme depends on the correct understanding of gene action involved in determining the different characters. With the knowledge of general and specific combining ability variances, the type of gene action can be assessed. It is claimed that if the GCA variance is greater, it implies preponderance of additive gene action for the trait and if SCA variance is grater, then the particular character is mostly under the control of non-additive gene action. In the present study, the ANOVA for combining ability showed lines and testers differed significantly for the traits, plant height and oil content (Table 1). The significant mean squares for line x tester interaction for all characters namely days to 50% flowering, plant height, head diameter, stem girth, 100-seed weight, oil content and seed yield / plant revealed that they interacted and produced markedly different combining ability effects and it might be due to wide genetic diversity of lines and testers. The ratio of GCA : SCA variances was less than unity for all these traits indicating the predominant role of non-additive gene action and stresses the need for exploiting non-additive variance through heterosis breeding. The present results are in agreement with the findings of Rao *et al,* (1992), Marinkovic (1993) and Limbore *et al,* (1997).

In any breeding programme, the choice of correct parents is the secret of success. Selection of parents for hybrid production should be based on *per se* performance, genetic diversity and combining ability effects.

The *per se* performance was considered as an important criterion for evaluation. The results indicated that none of the lines recorded superior values for yield. Among the lines and *cms* 6A for head diameter and *cms* 234 A and *cms* 290 A for plant height recorded desirable mean. Among the testers, RHA 857 recorded higher *per se* performance for yield, oil content, 100-seed weight, stem girth, head diameter and days to 50% flowering The tester RHA 857 and RHA 6D-1 for oil content and RHA 293 for plant height recorded desirable mean.

The second criterion for selection is by considering general combining ability effects *(gca)* of the parents.

Since the parents with high mean values may not necessarily be able to transmit their superior traits into their progenies, it becomes necessary to assess their compatibility to express their own high performance to the hybrids involving them. Two lines CMS 234 A and CO 4 A recorded positive *gca* for seed yield, oil content and 100-seed weight. In addition CMS 234 A recorded desirable *gca* for days to 50% flowering. None of the testers recorded good combining ability for seed yield. The tester RHA 857 that was found superior *per se* performance showed moderate or low *gca* for days to 50 % flowering, head diameter, stem girth, 100-seed weight, oil content and seed yield / plant. The testers RHA 298, RHA 293 and RHA 586 recorded positive *gca* for oil content. In general there was no correspondence between *per se* performance and combining ability effects as reported by Shekar *et al.* (1998).

The hybrids CMS CO 4 A x RHA 297 and CMS CO 4 A x RHA 586 resulted by crossing parents with high x low *gca* effects. High *sea* effects of high x low *gca* combinations might be due to complementary non-additive interallelic interactions and hence could be used in heterosis breeding. The hybrids CMS SUF 11A x RHA 274 and CMS WGA x RHA 857 resulted from low x low combining parents. Sugoor *et al.* (1996) also observed that hybrids with high *sca* effects were produced when poor general combiners were crossed. An appreciable portion of heterosis expressed by low *gca* x low *gca* crosses might be ascribed to dominance x dominance type of non allelic gene action-registering over dominance and were non-fixable. Thus it is clear that the superior performance of these hybrids was largely due to epistatic interaction. To harness this type of gene action in these cross combinations, selection has to be postponed to later generations for realization of superior segregants. In these crosses a suitable population improvement programme such as intermating of F_2 segregants followed by recurrent selection would be appropriate to exploit the non-additive gene action.

From the foregoing discussion, it can be concluded that, the parents CMS 234 A and CO 4 A are good combiners for seed yield / plant, oil content, plant height and days to 50 % flowering. However none of these parents recorded superior *per se*. Among the hybrids CMS SUF 11A x RHA 274, CMS 234 A x RHA 297, CMS CO 4 A x RHA 586, CMS WGA x RHA 857 and CMS CO 4 A x RHA 297 recorded superior *per se* for seed yield, *sca* and heterosis. All these hybrids recorded significant *sca* and heterosis for more than one yield components. Hence these hybrids could be recommended for large scale evaluation. Hybrids involving good combining parents namely CMS 234 A x RHA 297, CMS CO 4 A x RHA 297 and CMS CO 4 A x RHA 586 could be also used for pedigree breeding for the development of superior varieties.

Table 1 Analysis of variance for combining ability

Source of variance	df	Days to 50% flowering	Plant height (cm)	Head diameter (cm)	Stem girth (cm)	100-seed weight (g)	Oil content (%)	Seed yield/plant (g)
Lines	8	62.49	1185.25**	6.33	0.15	3.32	11.11*	421.61
Testers	8	81.33	971.70*	3.47	0.09	2.94	13.59**	64.73
Lines x Testers	64	42.28*	430.86**	7.64**	0.13*	2.18**	4.71**	461.49**
Error	196	2.11	140.58	3.39	0.06	0.51	1.55	55.13
σ^2 *gca*	-	0.07	1.50	-0.01	0.00	0.00	0.02	-0.51
σ^2 *sca*	-	19.56	231.68	0.85	0.02	0.76	2.65	89.97

*,** Significant at 5 and 1 % respectively.

Table 2 General combining ability of parents for various characters

Parent	Days to 50% flowering	Plant height (cm)	Head diameter (cm)	Stem girth (cm)	100-seed weight (g)	Oil content (%)	Seed yield/plant (g)
Lines							
CMS WGA	1.71**	0.19	0.56	0.05	-0.50**	-0.15	-2.05
CMS 234A	-1.51**	-5.59*	-0.10	-0.07	0.53**	0.69**	8.12
CMS 2A	-1.96**	-0.34	-0.45	-0.02	0.13	-0.36	-5.48**
CMS 822A	-0.99**	8.12**	-0.07	-0.04	-0.26	-0.13	-1.25
CMS 5A	0.56*	4.76*	-0.81*	-0.12*	-0.37*	-0.37	-2.89*
CMS 6A	2.74**	6.79**	-0.37	0.08	0.14	0.14	-0.32
CMS 290A	-0.51	-9.58**	0.34	0.01	-0.14	0.52**	-0.86
CMS SUF 11A	0.41	4.28	0.47	0.09*	0.07	-1.2**	1.24
CMS CO 4A	-0.44	-8.64**	0.43	-0.02	0.40**	0.87**	3.50*
Testers							
RHA 297	3.52**	0.36	0.06	-0.01	-0.44**	-0.32	2.64
RHA 857	1.63**	3.53	0.12	-0.02	-0.55**	-0.20	-1.71
RHA 298	0.93**	4.33	0.33	0.08	0.55	0.70**	0.61
RHA 293	-0.14	-6.60*	0.15	0.01	0.20	0.86**	-1.23
RHA 296	-0.55*	-4.69*	-0.01	0.02	0.19	-0.64**	2.20
RHA 586	-1.589**	0.10	0.56	0.07	0.04	0.71**	-0.35
RHA 6D-1	-1.811**	-8.48**	-0.22	-0.04	-0.02	-0.06	-0.14
RHA 274	-1.14**	0.53	-0.57	-0.08	0.52**	-1.28**	-0.61
RHA 278	-0.85	10.89**	-0.41	-0.04	-0.01	0.24	-1.39
S.E (Lines)	0.28	2.28	0.35	0.04	0.13	0.23	1.42
S.E (Testers	0.28	2.28	0.35	0.04	0.13	0.23	1.42

*,** Significant at 5 and 1% respectively.

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Short communication

Response of early *rabi* groundnut, *Arachis hypogaea* L. to spacing, irrigation and plant protection levels

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About 89% of the area under groundnut in Andhra Pradesh is rainfed. Chittoor and Nellore districts have the advantage of North-East monsoons from October onwards for nearly 75-85 days. This rainfall can be utilized for growing groundnut crop in early *rabi*. If rainfall during crop growth is inadequate with continuous drought, protective irrigation can be given. Studies conducted at RARS, Tirupati revealed that incidence of pests and diseases was very high in the crop sown during September and October months. Taking all the above factors into consideration, the present investigation was taken up to utilize the advantage of North-East monsoon, to increase the yields of early *rabi* crop with suitable population, protective irrigation and with proper pest and disease control measures.

A field experiment was conducted during early *rabi* season of 1998-99 at S.V. Agricultural College Farm, Tirupati. The soil of the experimental field was sandy loam, having pH 7.6, organic carbon 0.26%, 195.6, 45.7 and 140.6 kg/ha available N, P_2O_5 and K_2O, respectively. The treatments consisting of 3 spacings, 2 irrigation levels and 2 plant protective measures were applied to test variety TCGS-596 (Table 1). The experiment was laid out in Factorial Randomized Block design and replicated thrice. A total rainfall of 476 mm was received in 18 rainy days during the crop period. A dry spell of 20 days (45-65 DAS) occurred during the pegging and pod formation stage and another dry spell of 50 days (70-120 DAS) was experienced at pod filling and pod maturation stages. Other cultural operations were carried out as per the recommendations.

Plant height decreased with increase in spacing and significantly higher plant height was obtained with 30 x 5 cm spacing and protective irrigation. LAI was higher with 30 x 5 cm spacing and protective irrigation. Drymatter production, total number of pods and filled pods/plant, 100 pod weight, 100 kernel weight were higher with 30 x 15 cm spacing and protective irrigation. Growth and yield of groundnut was higher with protective irrigation compared to rainfed which might be due to moisture stress during pegging, pod formation and pod development stage. These results are in conformity with those of Patel and Golakiya (1988). Plant protection treatment had no significant influence on growth and pod yield.

Maximum pod yield was obtained with medium spacing (30 x 10 cm). Though yield attributes like filled pods/plant, 100 pod weight were higher at wider spacing (30 x 15 cm), lower plant population/ha could not compensate the yield. At closer spacing (30 x 5 cm) higher population could not compensate adequately for the reduction in number of filled pods/plant. Similar results of higher yield at 30 x 10 cm were reported by Jadhao *et al.* (1992). The pod yield was significantly higher with protective irrigation treatment than rainfed treatment. Higher number of filled pods/plant and 100 pod weight resulted in higher pod yield in protective irrigation treatment. Moisture stress at pegging, poo formation and pod filling stages reduced the number of total pods, filled pods/plant, peg set and pod set, which resulted in reduced pod yield in rainfed treatment. Similar results were reported by Parmar *et al.* (1989). Interaction effect of spacing and irrigation levels had significant influence on pod yield. The pod yield was maximum at medium spacing (30 x 10 cm) with protective irrigation. Haulm yield recorded was highest with closer spacing (30 x 5 cm), which might be due to more number of plants/m^2 as reported by Ramulu and Bucha Reddy (1998). More number of plants/m^2 with better growth in protective irrigation treatment resulted in higher haulm yield. Harvest index was significantly higher with medium spacing (30 x 10 cm) where the yield recorded was highest. Irrigation treatments had no influence on harvest index.

Based on these findings, it may be concluded that sowing of early *rabi* groundnut with 30 x 10 cm spacing, protective irrigation and minimal plant protection measures resulted in maximum growth and yield.

Table 1 Growth, yield attributes and pod yield of early *rabi* groundnut as effected by spacing, irrigation and plant protection levels

Treatment	Plant height (cm)	LAI	DMP (g/plant)	Total No. of pods/ plant	No. of filled pods/ plant	100 pod weight (g)	100 kernel weight (g)	Pod yield (kg/ha)	Haulm yield (kg/ha)	HI (%)
Spacing										
S_1 - 30 x 5 cm	17	2.7	15	8	5	106	44	1902	2748	41
S_2 - 30 x 10 cm	15	2.6	18	10	8	109	47	2177	2549	46
S_3 - 30 x 15 cm	13	2.3	20	12	9	114	49	1575	2097	43
SEm±	0.5	0.02	0.2	0.2	0.05	0.6	0.3	18.6	25.3	1.1
CD (P=0.05)	1.6	0.05	0.5	0.6	0.2	1.7	1.0	54.6	74.2	2.4
Irrigation levels										
I_1 - Rainfed	12	2.4	13	9	6	104	43	14.24	1900	43
I_2 - Protective irrigation	17	2.5	22	12	9	116	51	2345	3030	44
SEm±	0.5	0.01	0.1	0.2	0.04	0.5	0.3	15.2	20.7	0.9
CD (P=0.05)	1.3	0.04	0.4	0.5	0.1	1.4	0.8	44.6	60.6	NS
Plant protection levels										
P_1 - Minimal plant protection	15	2.5	17	10	7	109	47	1875	2458	43
P_2 - Intensive plant protection	15	2.5	18	10	7	110	47	1894	2471	43
SEm±	0.5	0.01	0.1	0.2	0.05	0.5	0.3	15.2	20.7	0.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction										
S x I										
SEm±	0.8	0.02	0.2	0.2	0.1	0.8	0.5	26.3	35.8	1.6
CD (P=0.05)	NS	NS	0.7	0.6	0.3	NS	NS	77.2	NS	NS
I x P										
SEm±	0.6	0.02	0.1	0.2	0.07	0.7	0.4	21.5	29.3	1.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x P										
SEm±	0.8	0.02	0.2	0.2	0.09	0.8	0.5	26.3	35.8	1.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x I x P										
SEm±	1.1	0.03	0.3	0.3	0.1	1.2	0.7	37.2	50.6	2.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P_1 = Minimal plant protection (seed treatment with Indofyl —45 0.3% + one spray of Dimethoate 0.03% and Bavistin 0.1% at 25 DAS).
P_2 = Intensive plant protection (seed treatment with Indofyl —45 0.3% + two sprays of Dimethoate 0.03% and Bavistin 0.1% at 25 DAS and 45 DAS + one spray of Chlorpyriphos 0.025% at 35 DAS)

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Short communication

Effect of potassium fertilization on growth, yield and yield attributes of groundnut, *Arachis hypogaea* L. cultivars in new Alluvial Zone of West Bengal

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Groundnut is a leading oilseed crops in India. In West Bengal, the groundnut is getting an important place in the cropping system. In new Alluvial zone, it is cultivated in post-rainy season in *diara* area with minimum input. In summer, season, it is cultivated with irrigation after winter crops like rapeseed-mustard, potato, vegetables, etc. So, there is need for identification of improved cultivars and agro-techniques for the zone. Efficient potassium management is an important aspect in groundnut, as it has beneficial role in increasing the yield of this crop (Adhikary *et al.*, 2001). Potassium fetilizers are mainly imported and increase in unit cost of potassium fertilizers increase the cost of cultivation and reduce the profit per hectare. Hence, it is necessary to work out the optimum dose of potassium on growth and yield of different cultivars of groundnut.

A field experiment was conducted at Central Research Farm, Goyespur of Bidhan Chandra Krishi Viswavidyalaya during summer and repeated during rainy (*kharif*) in 2000-2001. The soil was sandy loam in texture having 0.68% organic carbon, 0.062% total N, 16.8 kg/ha available P_2O_5 and 190.6 kg/ha available K_2O with pH 7.6. The experiment was laid out in Split Plot Design, keeping seven groundnut cultivars *viz.*, SB-11, ICGS-49, ICGS-44, ICGV-86699, B-95, TG-22 and JL-24 in main plots and three levels of potassium (0, 60 and 120 kg K_2O/ha) in sub plots. There were three replications. The recommended dose of Nitrogen (20 kg/ha) and P_2O_5 (60 kg/ha) in the form of urea and single super phosphate were applied as basal and gypsum (500 kg/ha) was applied at 25 days after sowing. The entire dose of potassium in the form of muriate of potash was applied at sowing as per treatment. Sowing was done in 1st week of March and 1st week of July and harvesting was done in middle of June and end of October in summer and *kharif* season, respectively. During the crop period, the site received 574 mm and 956 mm rainfall during summer and *kharif* season, respectively. All the data were recorded at the time of harvest from each treatment and separately for each replication and data were statistically analyzed. Economics were calculated on the basis of present market price. Seasons and treatment interaction were found nonsignificant, so data were discussed on the basis of pooled analysis.

Application of potassium at 60 kg/ha significantly increased the plant height, number of pods/plant, number of kernels/pod, 100 kernel weight, harvest index, pod and haulm yield at harvest compared with control, but it was statistically at par with application of potassic fertilizer at 120 kg/ha. This may be due to favourable effect of potassium on growth and yield attributes which was also reflected on pod and haulm yield. However, successive increase in K_2O levels over 60 kg K_2O/ha increase all growth and yield attributes and was not-significant. Highest pod and haulm yields were recorded with 120 kg/ha (Table 1 and 2). Pooled data followed similar trend. This is in conformity with the findings of Patra *et al.* (1996) and Bandopadhyay and Samui (1999).

Performance of cultivars: Groundnut cultivars had marked difference in their yield attributes and yield (Table-1). Highest plant height was recorded with cultivars JL-24 followed by SB-11 and lowest was with TG-22. Higher number of pod/plant, number of kernel/pod was found with cultivar ICGS-49, which was significantly higher over B-95 and TG-22 and lowest, was with B-95 in both the seasons. However, cultivar B-95 recorded highest 100-kernel weight, which was significantly superior over all the cultivars in both seasons. The highest pod and haulm yield were obtained in ICGS-49 followed by ICGS-44 in both the seasons, which were significantly superior over all the cultivars. Whereas, lowest pod and haulm yield were recorded with cultivar TG-22. The higher yield by ICGS-49 and ICGS-44 may be due to the higher number of pod/plant, number of kernel/pod and medium 100-kernel weight. Pooled data followed similar trend. This is in conformity with the findings of Adhikary *et al.* (2001).

Economics: During both the seasons, maximum gross return, net return and benefit : cost ratio were recorded with cultivars ICGS-49 followed by ICGS-44 and lowest was with TG-22. Among the potassium levels maximum gross return, net return and benefit : cost ratio were observed at 120 kg/ha. But, gross return and net return was at par with 60 kg/ha. However, application of 120 kg K_2O/ha gave significantly highest the benefit : cost ratio over 60 and zero kg K_2O/ha in summer season, but, in higher the benefit : cost ratio was obtained with application of 60 kg/ha in rainy season.

It is concluded that ICGS-49 and ICGS-44 are the promising cultivars of groundnut and 60 kg K_2O/ha is optimum in new Alluvial zone of West Bengal.

Table 1 Growth and yield attributes of groundnut cultivars as influenced by levels of potassium

Treatment/cultivar	Plant height (cm)			No. of pods/plant			No. of kernel/pod			100 kernel weight (g)			Shelling percentage		
	Summer	Rainy	Pooled	Summer	Rainy	Pooled	Summer	Rainy	Pooled	Summer	Rainy	Pooled	Summer	Rainy	Pooled
SB-11	64	72	68	26	24	25	1.9	1.8	1.9	54	53	53.5	64	62	63
ICGS-49	47	55	51	26	24	25	2.2	2.1	2.15	55	54	54.5	67	65	66
ICGS-44	51	58	55	25	23	24	2.1	2.1	2.1	55	55	55	66	64	65
ICGV-86699	50	57	54	24	21	23	2.1	2.1	2.1	53	52	52.5	63	60	62
B-95	47	54	51	17	16	17	1.5	1.3	1.4	90	89	89.5	68	65	67
TG-22	45	54	50	21	19	20	1.9	1.7	1.8	58	58	58	62	58	60
JL-24	67	74	71	25	23	24	1.9	1.9	1.9	60	59	59.5	66	63	65
SEm±	2.9	3.1	2.1	1.6	1.5	1.0	0.1	0.1	0.1	3.5	3.4	2.3	3.5	3.3	2.3
CD(P=0.05)	6.23	6.72	4.55	3.46	3.17	2.24	0.21	0.18	0.13	7.6	7.47	5.03	NS	NS	NS
Potassium (kg/ha)															
0	53	60	57	14	14	14	1.4	1.4	1.4	60	58	59	58	57	58
60	60	66	63	24	22	23	2.2	1.1	1.7	65	63	64	64	63	64
120	62	67	65	24	23	23.5	2.2	1.2	1.7	65	64	65	65	64	65
SEm±	3.1	3.2	2.1	0.9	0.8	0.6	0.1	0.1	0.1	1.5	1.4	1.0	3.3	3.6	2.4
CD(P=0.05)	6.42	6.53	4.35	1.92	1.64	1.21	0.22	0.16	0.13	3.2	2.9	2.04	NS	NS	NS

Table 2 Yield and economics of groundnut cultivars as influenced by levels of potassium

Cultivar	Pod yield (kg/ha)			Haulm yield (kg/ha)			B:C ratio		
	Summer	Rainy	Pooled	Summer	Rainy	Pooled	Summer	Rainy	Pooled
SB-11	1362	1228	1295	2832	3042	2937	1.86	1.67	1.76
ICGS-49	1403	1315	1359	2986	3146	3066	1.91	1.79	1.85
ICGS-44	1398	1286	1342	2946	3124	3035	1.91	1.75	1.83
ICGV-86699	1317	1208	1262.5	2845	3098	2972	1.80	1.65	1.72
B-95	1275	1186	1230.5	2665	2838	2752	1.74	1.62	1.68
TG-22	1263	1145	1204	2640	2802	2721	1.72	1.56	1.64
JL-24	1337	1214	1275.5	2808	3012	2910	1.82	1.66	1.74
SEm±	71.7	65.9	46.8	136.9	138.9	92.3	0.02	0.02	0.01
CD(P=0.05)	156.2	143.6	102.1	298.5	302.7	201.2	0.04	0.04	0.03
Potassium (kg/ha)									
0	1097	1015	1056	2581	2628	2605	1.57	1.45	1.51
60	1472	1341	1406.5	2889	2975	2932	2.01	1.83	1.92
120	1508	1396	1452	2994	3015	3005	2.06	1.82	1.94
SEm±	77.5	71.7	49.9	147.7	153.9	102.6	0.02	0.02	0.01
CD(P=0.05)	158.7	146.8	102.4	302.5	315.2	210.2	0.04	0.04	0.03

Groundnut pod = Rs. 1500/q; Nitrogen = Rs. 720/q; Phosphorus = Rs. 1675/q and Potassium = Rs. 830/q

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Short communication

Production potential and nitrogen requirement of Indian mustard, *Brassica juncea* (L.) Czern & Coss. in different crop sequences under brackish water

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Indian mustard *Brassica juncea* (L.) Czern & Coss. is mostly grown on soils where the supply of good quality surface water is either meagre or unavailable and the farmers are forced to use brackish underground water for irrigation purposes. Rajasthan is a leading state in mustard production, which contributes 42.3 and 44.5 % of total area and production in India, respectively. Poor quality of irrigation water is an important factor in reducing the growth and yield of Indian mustard (Kumar and Malik, 1983; Chauhan *et al.*,1988; Manoj Kumar *et al.*, 2002). However, out of the total ground water available in the state, 68 % is of poor quality (Minhas and Tyagi, 1998), due to which large area remain fallow in *kharif* followed by mustard in *rabi*, resulting in low cropping intensity and productivity. These aspects of sustained crop production per unit area per unit time for mono cropped mustard growing areas under brackish water conditions have received little attention. With this view, the present study was undertaken to find out the best crop sequence and nitrogen requirement of Indian mustard under brackish water situation.

The field experiment was conducted at NRCRM, Sewar, Bharatpur, Rajasthan during *rabi* 1999-2000 and 2000-2001. The soil was sandy loam, medium in organic carbon (0.37%) and available phosphorus (9.4 kg P_2O_5/ha). The experiment was laid out in Split-Plot Design with four replications. The treatments consisted of five cropping sequences, *viz.*, pearlmillet + black gram – mustard, pearlmillet + pigeonpea – mustard, black gram – mustard, clusterbean – mustard and fallow – mustard as main plot and four levels of N (0. 30, 60 and 90 kg/ha) to mustard as sub plot. The *kharif* crops were sown on 2nd July 99 and 7th July 2000 with recommended doses of fertilizers. Black gram was incorporated into the soil after taking first flush, whereas, pearlmillet + black gram were harvested on maturity. In *rabi* season sowing of Indian mustard, cv. RH-30 was done on 23 Oct., 1999 and 31 Oct., 2000 with a row spacing at 30 cm using 5 kg seed/ha after taking preceding *kharif* crops. The plant-to-plant distance was maintained at 10 cm by manual thinning at three weeks stage. The crop was fertilized with 40 kg P_2O_5 and 20 kg sulphur /ha. Half of nitrogen as per treatment and whole of P and S were applied as basal, whereas remaining N was applied after irrigation. The total rainfall received during the crop periods from July-March was 80.9 and 49.7 cm during 1999-2000 and 2000-2001, respect. Only, one irrigation at 35 days after sowing (DAS) was applied to mustard crop with brackish water (having mean electrical conductivity 7.92 dS/m and pH 8.44). The comparison among cropping sequences were done by converting grain or fodder yields into mustard equivalent on the basis of minimum support prices in respective years.

Effect of cropping sequences: The cropping sequences did not affect the growth, yield and yield attributes *viz.*, plant height, number of primary and secondary branches per plant, number of siliquae per plant and 1000 seed weight and yield of mustard in both the years (Table 1). The seed yield of mustard was higher during first year due to less incidence of insect pest and diseases and well distributed rainfall during crop growth periods.

Effect of nitrogen levels: The seed yield of mustard significantly increased with each successive nitrogen increment upto 60 kg/ha beyond which the increase was marginal. It might be due to improved N supply through symbiotic N-fixation by legumes during *kharif* season and residual effect to mustard crop. On an average, the increase in seed yield over control was 33.3 and 83.8 % with 30 and 60 kg N/ha, respectively. This increase was due to increase in yield contributing characters mainly number of primary, secondary branches and siliquae/ plant. The possible reason may be that increasing level of N resulted in greater accumulation of CHO, protein and their translocation to the productive organs which, in turn, improved all the growth and yield contributing characters. These findings are in agreement with the finding of Rana *et al.*, 1991.

Mustard seed equivalent yield: The normal yield of all the *kharif* crops and the total productivity of all the crop sequences measured in terms of mustard seed equivalent

Table 1 Effect of crop sequence and nitrogen levels on growth, yield attributes, yield and mustard seed yield equivalent

Treatment	Plant height (cm)		Pri. branches/ plant		Sec. branches/ plant		Siliquae/ plant		1000-seed weight(g)		Harvest index (%)		Oil content (%)		Seed yield (kg/ha)		Yield of *kharif* crops (q/ha)						Mustard seed yield equivalent of cropping systems (kg/ha)		
																	Pearlmillets (grain)/ green fodder			Black gram (grain)					
Cropping systems	99-00	00-01	99-00	00-01	99-00	00-01	99-00	00-01	99-00	00-01	99-00	00-01	99-00	00-01	99-00	00-01	1999	2000	Mean	99-00	00-01	Mean	99-00	00-01	Mean
Pearlmillet + black gram-mustard	155	159	5	4	6	2	149	107	6.3	6.8	31.4	23.3	41.0	38.9	1887	1220	24.6 155.1*	9.2 230.4*	16.9 192.7*	1.6 -	0.6 -	1.1 -	3190	1680	2435
Pearlmillet + pigeonpea-mustard	151	153	5	4	7	2	157	99	6.6	6.6	30.9	24.1	40.9	39.7	1838	1100	26.5 163.3*	8.1 152.6*	17.3 157.9*	- -	- -	- -	3060	1490	2275
Black gram - mustard	167	159	5	4	6	2	152	102	6.9	6.9	29.5	24.7	41.2	39.4	2212	1380	-	-	-	4.2	2.6	3.4	2630	1630	2130
Clusterbean - mustard	153	162	4	4	6	3	142	108	6.1	6.8	31.6	22.4	40.7	39.5	2119	1220	- 295.8*	- 86.61*	- 191.2*	- -	- -	- -	2790	1400	2095
Fallow - mustard	159	164	5	3	6	2	149	102	6.6	7.3	30.1	22.3	41.0	39.8	1918	1400							1920	1400	1660
SEm±	4.7	5.1	2.0	0.3	0.4	0.3	4.7	4.2	0.2	0.3	1.3	1.6	0.1	0.4	148	131							151	73	91
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS							430	210	320
Nitrogen levels (kg/ha)																									
0	139	144	5	3	5	1	123	65	6.7	6.8	32.1	24.3	40.9	39.6	1501	610							-	-	-
30	150	151	5	4	6	2	140	93	6.4	6.8	31.8	23.1	41.1	39.5	1839	970							-	-	-
60	167	172	5	4	7	4	167	134	6.5	7.0	30.4	22.9	41.0	39.8	2213	1650							-	-	-
90	172	170	5	4	7	2	169	122	6.4	6.9	28.5	23.0	40.8	38.8	2425	1820							-	-	-
SEm±	2.7	3.3	0.2	0.2	0.5	0.4	8.5	9.0	0.1	0.1	0.7	0.7	0.1	0.4	94	81									
CD (P=0.05)	8	9	NS	1	1	1	24	26	NS	NS	1.9	NS	NS	NS	270	230							-	-	-

Note: * Indicates the green fodder yield

yield, which was significantly affected by crop sequences during both years and mean basis also (Table 1). The data indicated that mustard seed equivalent yield was significantly higher in pearlmillet + black gram – mustard (3190 kg/ha) cropping sequence followed by pearlmillet + pigeonpea – mustard (3060 kg/ha) and clusterbean – mustard (2790 kg/ha) during 1999-2000. In 2000-2001, the mustard seed equivalent yield of pearlmillet + black gram – mustard, pearlmillet + pigeonpea – mustard, was maximum and significantly higher than clusterbean – mustard and fallow – mustard. On the basis of mean the highest mustard seed equivalent was recorded in pearlmillet + black gram – mustard sequence (2435 kg/ha) followed by pearlmillet + pigeonpea – mustard (2275 kg/ha). The good potential yield of pearlmillet even under moisture stress conditions and contributions of pearlmillet (grain and green fodder) and black gram for grain and nitrogen fixation are the major factors responsible for higher production of mustard seed equivalent yield. Gautam *et al.* (1985) and Kaushik and Gautam (1987) also reported that intercropping of pearlmillet with short duration grain legumes increased total productivity per unit area per unit time in rainfed areas. The lowest mustard seed equivalent was obtained in fallow – mustard sequence.

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Short communication

Response of mustard, *Brassica juncea* (L.) Czern & Coss. to different land treatments and dates of sowing in sandy clay loam soils

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In Andhra Pradesh mustard is cultivated in an area of 2,800 ha with a productivity of 250 kg/ha which is very low (Statistical Abstract, 1998). Mustard, *Brassica juncea* (L.) Czern & Coss. is very sensitive to water logging. Due to bimodal type of monsoon at Tirupati, AP many a time it is subjected to ill drained conditions during early stages resulting in poor growth. Therefore different land treatments are needed for its proper establishment and growth. Suitable agro techniques like optimum time of sowing and land treatment should be developed to increase the productivity of mustard. If the mustard is sown late, crop duration is reduced due to high temperature during the reproductive phase with concomitant reduction in yield. Hence this investigation was conducted to find out appropriate treatment for sowing of mustard for good establishment and growth.

Field experiment was conducted during *rabi* season of 1999-2000 at S.V. Agricultural College farm, Tirupati on sandy clay loam soil having pH 7.7, 185 kg/ha available nitrogen 46 kg/ha available P_2O_5 and 128 kg/ha available K_2O. Three land treatments and three dates of sowing were tested in RBD with factorial concept and replicated thrice (Table 1). The crop was sown at a spacing in broad bed and furrow method, to maintain same plant population.

The other cultural operations were taken as per recommendations. The weekly mean temperatures ranged from 36.9 to 17.6, 32.4 to 17.2, 31.8 to 17.2 and 31.8 to 16.4° C during crop growth period of 15 September, 1 October and 1 November sowings, respectively.

Table 1 Effect of land treatments and dates of sowing on yield attributes and seed yield of mustard

Treatment	Plant *height* (cm)	Dry matter *Production* (g/m^2)	No. of *siliquae/* plant	No. of *seeds/* siliqua	Test weight (g)	Seed *yield* (kg/ha)	Stalk *yield* (kg/ha)
Land Treatment							
Flat bed	94	188	89	8.4	2.1	419	1396
Ridge and furrow	105	220	100	8.6	2.2	509	1634
Broad bed and furrow	108	231	107	8.8	2.3	515	1689
SE m±	1.2	4.3	2.8	0.2	0.04	10	58
CD (P=0.05)	3.6	12.6	8.5	NS	NS	32	174
Dates of sowing							
15th September	90	161	82	7.6	2.0	331	1172
1th October	115	252	113	9.6	2.4	602	1838
15th October	110	242	103	9.1	2.3	559	1760
1th November	95	196	97	8.2	2.1	432	1522
SE m±	1.6	4.9	3.3	0.2	0.05	12	67
CD (P=0.05)	4.9	14.6	9.8	0.6	0.2	37	201

Maximum plant height, number of siliquae/plant, seed and stalk yield were observed in broad bed and furrow method of sowing which was comparable to ridge and furrow method of sowing. Superior yield with broad bed and furrow (515 kg/ha) and also ridge and furrow method (509 kg/ha) compared to sowing in flat bed (419 kg/ha) was mainly due to increased number of siliquae/plant. These results are in consonance with the better performance of groundnut (Ingole *et al.*, 1996) with broad bed and furrow and in soyabean (Jayapaul *et al.*, 1996) with ridge and furrow method of sowing compared to other methods of sowing.

Time of sowing profoundly influenced the growth of mustard. Plant height, dry matter, number of seeds/siliqua, test weight an stalk yield recorded with October 1 and October 15 sowings were similar and further delay in sowing decreased the values. Sowing on 15 September resulted in significantly lowest values of yield attributes and yield.

Sowing on October 1 resulted in significantly higher seed yield (602 kg/ha) compared to sowing on October 15 and November 1. It is well known that under delayed sowing shorter days and lower temperatures in the initial stage of crop growth reduced photosynthesis and other physiological activities of the plant (Babu, 1985). This was probably the reason for reduced growth resulting in lesser number of siliquae/plant in October 15 and November 1 sown crops than the earlier sown crop. Significantly lowest seed yield in September 15 sowing might be due to decreased physiological activities of the plant resulting in significantly lower plant height, lesser number of siliquae/plant and lowest number of seeds per siliqua which ultimately recorded the low seed yield (331 kg/ha).

Based on these results, it may be concluded that in non-traditional areas with bimodal rainfall as in Tirupati (AP) Mustard may be sown under either a broad bed and furrow or a ridge and furrow method preferably by first fortnight of October to achieve higher yields.

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Short communication

Effect of organics on Indian mustard, *Brassica juncea* Czern & Coss.

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Organic farming offers a potential alternative to ecologically exploitative modern agriculture. The chemical based energy intensive agriculture, though appears to be leading towards sufficiency, but at a very heavy cost of creating ecological imbalance. This has created a spectre of unsustainability by declining factor productivity, emerging nutrient disorder, environmental degradation, susceptibility to new pests and diseases and ultimately human health hazards. In India where majority of farmers are small and marginal, the organic farming has a great scope in creating a sustainable production system through recycling of on farm resources. Such system will also be economically viable by reducing financial burden of chemical fertilizer on resource poor farmers. Thus, in the present study, it was attempted to produce mustard organically using either farm yard manure (FYM)/ vermicompost.

A field experiment was conducted during winter (*rabi*) season of 2001-02 at NRC R&M, Sewar, Bharatpur in randomized block design with eight treatments replicated four times (Table 1.). The soil of the experimental field was clay loam having pH 7.5, organic carbon 0.58%, available nitrogen 289 kg/ha and available phosphorus 11.3 kg/ha. The FYM and vermicompost were thoroughly mixed and soil incorporated 25 days before sowing. The mustard variety RH-30 was sown on 27th October at 30 cm row spacing. The plant space was maintained at 10 cm by thinning at 25 days after sowing. In case of recommended fertility level, whole P and half of N were applied as basal, whereas remaining N was applied after first irrigation (35 DAS). The data on yield attributes were recorded from five randomly selected plants. The results revealed that the maximum seed yield (1460 kg/ha) of mustard was recorded with recommended fertilizer level which was at par with vermicompost at 7.5 t/ha and FYM at 15.0 t/ha, which could mainly be contributed to higher number of siliquae/ plant and seeds/ siliqua in these treatments (Table 1). The beneficial effect of vermi compost and FYM could be attributed to the supply of nutrients through mineralisation and improvement of physico- chemical properties of the soil (Patel and Meisheri, 1997; Jain and Sharma, 1999). The other levels of organic manures such as FYM and vermicompost offered similar but significantly lower seed yield as compared with recommended fertilizer level. The yield attributing characters also followed similar pattern. The minimum seed yield was recorded in control plots, but it was comparable with vermicompost at 2.5 t/ha. The maximum additional net return of Rs.5990/ha was obtained with recommended fertilizer level over control followed by the application of FYM at 15/ 5 t/ha. At present the vermicompost treatments recorded a negative balance due to its high cost. The oil content was not influenced by different treatments.

Table 1 Effect of organic sources on yield attributes, yield and oil content of Indian mustard

Treatment	Plant height (cm)	Primary branches/ plant	Sec. Branches/ plant	Seeds/ siliqua	Siliquae/ plant	Oil content (%)	Seed yield (kg/ha)	Addl. Net returns over control (Rs.ha)
Recommended Fertilizer (80:40:0, N:P:K/ha)	186	7	7	13.6	306	37.8	1460	5999
FYM 5.0 t/ha	169	6	7	12.4	269	38.2	1090	2660
FYM 10.0 t/ha	171	6	7	12.6	283	38.3	1120	2240
FYM 15.0 t/ha	174	7	7	13.4	292	38.5	1340	3910
Vermicompost 2.5 t/ha	172	6	6	11.9	288	38.6	960	(-520)
Vermicompost 5 t/ha	180	7	7	13.0	296	38.7	1040	(-2140)
Vermicompost 7.5 t/ha	182	7	7	13.2	299	38.6	1310	(-1670)
Control	159	5	6	10.8	212	38.9	780	-
SEm ±	4	0.2	0.2	0.2	5.5	-	80	-
CD (P=0.05)	11	1	1	0.7	16	NS	230	-

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Short communication

Response of mustard, *Brassica juncea* (L.) Czern and Coss. to phosphorus and sulphur levels in rice lowlands

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Rice-wheat cropping system is predominant in low and under irrigated agro-ecosystem of Kymore plateau and Satpura hills zone, of Madhya Pradesh. Wheat is being rapidly replaced by mustard, *Brassica juncea* (L.) Czern & Coss. from this based cropping system because of severe infestation of *Phalaris minor* in wheat. The beneficial effects of adequate P and S fertilization on productivity and quality of mustard depending on the agro-ecosystem have been reported (Aulakh *et al.*, 1980; Narang *et al.*, 1993), However such information are meagre for mustard when it is grown in succession to rice. Hence, the present investigation was undertaken to determine the adequate requirement of P and S to mustard.

Field experiments were conducted on mustard cv. Pusa Bold during winter season of 1996-97 and 1977-98 in sandy loam soils of Jabalpur (M.P.). A paddy cv. Kranti was grown with a uniform fertilizer doses (100 kg N + 60 kg P_2O_5 + 30 kg K_2O (55kg/ha), medium in available K_2O (272 kg/ha) and low available S (12 kg/ha) contents with pH. 7.5. The rainfall was 25 and 373 mm during the crop season in the two consecutive years. Treatments consisted with 4 levels of each phosphorus and sulphur were tested in Randomized Block Design with four replications. Sowing was done on November 25, 1996 and December 16, 1997 by drilling 5 kg seeds/ha in rows 30 cm apart. A uniform dose of 60 kg N + 20 kg K_2O/ha was applied through urea and murate of potash respectively to all treatments besides P and S as per treatments. Phosphorus and sulphur were given through diammonium phosphate and elemental sulphur respectively. Half dose of N along with P,K and S was applied as basal, while remaining half dose of N was top dressed immediately after irrigation at 35 days growth stage of crop. Irrigation were given uniformly at 35, 55 and 70 days growth stage during first year but only one irrigation was given at 35 days stage as crop received rains during advance growth stage. Weed control and plant protection measures were followed uniformly under all treatments. Harvesting was done on March 29, 1997 and April 3, 1998. Data on various growth parameters, yield attributes and seed yields were recorded.

Effect of phosphorus levels

Both seed and stalk yields increased correspondingly with each incremental dose of P up to 75 kg P_2O_5/ha in both the years, but the difference was non significant beyond 50 kg P_2O_5/ha (Table 1). However, the net monetary returns (MNR)/ha and benefit - cost ratio (profitability) significantly increased up to 75 kg P_2O_5/ha. Plant growth parameters *viz.*, plant height and primary branches/plant significantly increased up to 50 kg P_2O_5/ha. Thus, improvement in plant due to P-application in desirable quantity resulted to produce higher stalk yields and also attributed to enhance the yield attributing characters *viz.*, length of siliqua, siliquae/plant, seeds/siliqua and 1000-seed weight. As a consequence, seed yield significantly increased up to 50 kg P_2O_5/ha. Similar results have also been reported by Tomar *et al.* (1996) and Jain *et al.* (1996).

Effect of sulphur levels

Seed and stalk yields also correspondingly increased up to 60 kg S/ha, but the differences in yields beyond 40 kg s/ha were not significant. Moreover, application of s did not prove remunerative with regard to NMR and profitability (Table 1). Though seed and straw yields significantly increased up to 40 kg S/ha, it was not remunerative because of relatively higher cost of S than the value of increased production with it. Similar beneficial effects of S on growth and yields of mustard have been reported by Jain *et al.*, (1996) and Patidar *et al.*, (1996).

Table 1 Effect of P and S levels on growth, yield attributes, yield and economics of mustard (Mean data of two years 1997 and 1998)

Treatment	Plant height (cm)	Primary branches	LAI at 60 DAS	Siliquae/ plant	Siliqua length (cm)	Seeds/ siliqua	1000 seed weight (g)	Grain yield kg/ha)	Stalk yield (q/ha)	NRM (Rs/ha)	B:C ratio
					P-levels (P_2O_5 kg/ha)						
0	123	3.4	1.8	58.6	4.1	10.6	4.7	918	61.0	3250	1.49
25	126	3.9	1.9	68.2	4.2	11.0	4.9	981	65.4	3650	1.53
50	134	4.3	2.2	75.4	4.6	11.8	5.0	1070	67.5	4200	1.58
75	136	4.9	2.6	81.5	5.1	12.7	5.1	1134	70.5	4600	1.61
					S-levels (S kg/ha)						
0	125	3.6	1.8	62.2	4.1	10.9	4.8	936	60.3	3990	1.66
20	127	3.9	1.9	67.9	4.5	11.6	4.9	978	65.3	3860	1.59
40	134	4.2	2.2	73.3	4.6	11.6	5.0	1075	69.4	4270	1.59
60	136	4.7	2.5	80.2	4.8	11.8	5.0	1114	70.5	4080	1.52
SEm±	0.86	0.05	0.02	1.25	0.10	0.11	0.04	30	0.51	158	0.03
CD (P=0.05)	2.46	0.16	0.08	3.65	0.29	0.32	0.13	86	1.46	451	0.08

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Short communication

Effect of biofertilizers on seed yield and quality of sunflower, *Helianthus annuus* L.

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Of all the oilseed crops, sunflower is gaining popularity because of its excellent quality oil owing to its richness with high degree poly unsaturated fatty acids (PUFA) and anti-cholesterol properties. Despite its remunerative nature, sunflower is said to be an exhaustive crop. Application of commercial fertilizers to soil, besides being expensive, often results in imbalance in soil reserve and this compelled the scientists in the world to find suitable alternative measures such as organic manures and biofertilizers. Seed inoculation with *Azospirillum* and use of farm yard manure to sunflower increased its yield as well as oil content (Ram *et al.*, 1992). However, the work in this regard with sunflower is very meager. Hence, in particular it was felt necessary to study the response of sunflower to *Azospirillum* and *Azotobacter*.

The field experiment was conducted during *rabi*, 2000 at the College Farm, College of Agriculture, Rajendranagar, Hyderabad. The soil the experimental site was sandy clay loam with a pH of 7.7, EC 0.4 dS/m and low in organic carbon (0.6%), low in available N (247.60 kg N/ha) medium in available P (44.88 kg P_2O_5/ha) and rich in available K (345.40 kg K_2O/ha). The experiment was laid out in randomized block design with three replications and 16 treatments which consisted of control (no nitrogen), 50%, 75% and 100% recommended doses of nitrogen (80 kg/ha) and seed inoculation with biofertilizer; *Azospirillum* and *Azotobacter* alone and in combination and also integration of these biofertilizers with former three recommended doses of nitrogen. The treatmental details are given in Table-1. Seed inoculation was done with *Azospirillum* or *Azotobacter* @ 50g/kg of seed before sowing. *Azospirillum* or *Azotobacter* culture is added to 150 ml starch solution. This mixture is added to 1 kg of seed and mixed thoroughly. After mixing, the uniformly coated seeds were dried under shade. The crop cultivar APSH-11 was fertilized with a uniform dose of 50 kg P_2O_5 and 30 kg K_2O/ha in the form of single super phosphate and muriate of potash, respectively. The crop was sown with a spacing of 60 x 20 cm on 9-9-2000 adopting a seed rate of 5 kg/ha and harvested on 9-12-2000. All the cultural practices besides the treatments adopted as per the recommended package of practices.

The results revealed that the seed inoculation of biofertilizers with either *Azospirillum* or *Azotobacter* or both combined with 100% recommended nitrogen resulted in significantly higher seed yield (T_{14} : 1987; T_{15} : 1972 and T_{16} : 2013 kg/ha) than in other treatments (Table 1). The next best superior treatment in giving higher seed yield was application of 75% N + biofertilizer treatments. The effect of which were same as that of 100% inorganic nitrogen alone. This assumes that seed inoculation with either of the biofertilizers could result in absolute saving of 25% nitrogen. Similar results were obtained by Khadse *et al.* (1991) in safflower.

Highest seed oil content was noticed with lower levels of nitrogen is due to the less formation of seed proteins (T_2 50% recommended nitrogen) (Table 1). The seed oil content was observed lowest under 100% N + biofertilizer treatments (T_{14}, T_{15} and T_{16}) followed by 75% N + biofertilizers (T_{11}, T_{12} and T_{13}) and 100% inorganic nitrogen alone (T_4). Reduced oil content with increased levels of nitrogen was also reported in sunflower by Mohanamba (1992).

Highest oil yield was achieved with 100% N + biofertilizer treatments (T_{14} : 771; T_{15} : 767 and T_{16} : 777 kg/ha). Increase in oil yield is evident as it is the product of oil content and seed yield. While the treatments involving biofertilizer inoculations alone caused significantly higher oil yield than in control. Higher seed yield produced in those treatments as influenced by biofertilizers might be the reason for higher oil yield than in no nitrogen (control). These results were in accordance with Amruthavalli and Reddy (2000).

Highest B:C ratio was obtained with application of 100% N + biofertilizer treatments (T_{14}, T_{15}, and T_{16}). The next best being practice 75% N + biofertilizer treatments (T_{11}, T_{12} and T_{13}) followed by 100% inorganic nitrogen alone (T_4) (Table 1). This might be due to higher seed yield obtained in these respective treatments. This clearly indicates that in sunflower crop, inoculation of biofertilizers (either *Azospirillum* or *Azotobacter* or combination) along with 75% recommended nitrogen could have reduced the requirement of inorganic nitrogen by 25% to the extent supplemented by biofertilizers. It may be noted that the biofertilizers cost is almost negligible and this effect being more pronounced on the seed yield as that of 100% inorganic nitrogen, thereby saving 25% nitrogen cost without any reduction in seed yield is possible. These findings are in line with those of Karunakaran and Palaniappan (1989) and Kumar *et al.* (1993).

Table 1 Seed yield, oil content, oil yield and economics of sunflower as influenced by different bio-fertilizer treatments

	Treatment	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	B:C Ratio
T_1	No nitrogen (control)	985	41.4	407	0.5
T_2	50% recommended dose of nitrogen	1486	42.6	633	1.14
T_3	75% recommended dose of nitrogen	1685	40.6	684	1.36
T_4	100% recommended doe of nitrogen	1870	39.3	734	1.56
T_5	*Azospirillum*	1103	41.7	459	0.99
T_6	*Azotobacter*	1095	41.9	458	0.98
T_7	*Azospirillum* + *Azotobacter*	1110	41.6	461	1.00
T_8	50% N + *Azospirillum*	1645	40.2	661	1.37
T_9	50% N + *Azotobacter*	1615	40.4	652	1.33
T_{10}	50% N + *Azospirillum* + *Azotobacter*	1675	40.1	671	1.14
T_{11}	75% N + *Azospirillum*	1836	39.1	717	1.57
T_{12}	75% N + *Azotobacter*	1790	39.2	701	1.51
T_{13}	75% N + *Azospirillum* + *Azotobacter*	1865	39.1	729	1.62
T_{14}	100% N + *Azospirillum*	1987	38.8	771	1.71
T_{15}	100% N + *Azotobacter*	1972	38.9	767	1.69
T_{16}	100% N + *Azospirillum* + *Azotobacter*	2013	38.6	777	1.75
	SEm±	26	0.7	6	-
	CD (P=0.05)	84	1.9	17	-

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Short communication

Response of sunflower, *Helianthus annuus* L. hybrids to fertilizer levels on late sown rice fallows of lower Assam

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In Assam, a considerable area under rapeseed has been diverted towards the cultivation of Boro rice due to popularization of shallow tube-wells for irrigation. Large scale growing of non-conventional oilseed like sunflower in winter (*rabi/boro*) season has considerable scope because of higher productivity and lesser incidence of pests as compared to wet (*kharif/sali*) season. Moreover the vast fallows after the harvest of *sali* rice can be utilized to meet the deficit in oilseed production. Because of the non-conventional nature of this crop, an experiment was conducted to find out suitable variety and fertilizer requirement for winter season under late sown conditions of lower Assam.

A field experiment was conducted at Regional Rainfed Lowland Rice Research Station, Gerua, Assam during winter, 2000 on silty clay loam soil with pH 5.4 and organic carbon 1.1%. The soil was medium in available N (290 kg/ha), P (21 kg/ha) and K (303 kg/ha). The crop was sown in mid December after the harvest of *sali* rice. The experiment consisted of sunflower hybrids and levels of fertility. Short duration hybrids (Raja and Sunbred 212) were selected to overcome the problem of prolonged growing season due to low temperature and also to harvest the crop in dry weather of March to early April. The recommended fertilizer dose of 24-30-24 NPK kg/ha was tried along with the control (no fertilizer) and double the recommended fertilizer dose (48-60-48 NPK kg/ha). The experiment was conducted in Split-Plot Design with two hybrids in the main plots and three fertility levels in the sub-plots replicated four times. Half the dose of N and full dose of P and K were applied basally while remaining N was top dressed after first irrigation (30 DAS). The crop was sown with a spacing of 60 x 30 cm. Response function was worked out using orthogonal polynomial technique for treatments with equal intervals (Gomez and Gomez, 1984). Maximized rate of fertilizer application was worked out as $(-b)(2c)^{-1}$ from the response equation $y = a + bx + cx^2$ where (y) is the estimated yield at NPK level of (x). However, the most profitable rate of fertilizer application (Munson and Doll, 1959; Padhi, 1999) was found out as $(q/p - b)(2c)^{-1}$ where q is cost of one unit of NPK i.e. 1 kg N, 1.25 kg P_2O_5 and 1 kg K_2O through Urea, DAP and MOP. Unit price of sunflower seed (p) was based on the local market i.e., 14 Rs/kg.

Results revealed that hybrid Sunbred 212 was marginally taller by 5 cm than Raja. Higher number of seeds/head (989) and thousand seed weight (72.8 g) were recorded under the hybrid Sunbred 212 than under Raja. Plant population remaining same, these two yield components were responsible for higher seed yield of 2570 kg/ha with Sunbred 212 as compared to 2250 kg/ha with Raja (Table 1).

Table-1 Yield and yield attributes of sunflower hybrids as influenced by different levels of fertility

Treatment	Plant height (cm)	Seed diameter (cm)	Seed/ head	Thousand seed weight (g)	Seed yield (kg/ha)
A-Hybrids (H)					
Sunbred 212	139	17.3	988.7	72.8	2570
Raja	134	17.2	893.2	69.9	2250
B-Fertility levels (F) (NPK kg/ha)					
0-0-0	132	16.0	840.1	65.9	1820
24-30-24	137	17.5	957.3	70.3	2490
48-60-48	139	18.2	1025.8	73.4	2930
CD (P=0.05)					
H	2.45	NS	39.4	1.24	90
F	0.73	0.27	23.6	0.73	120
HxF	NS	NS	NS	NS	NS

Plant height, seed yield and yield attributes have increased significantly with the increase in fertilizer dose. Seed yield and yield attributes were significantly lower under the recommended fertilizer dose of 24-30-24 NPK kg/ha as compared to that under the higher fertilizer dose of 48-60-48 NPK kg/ha. Reddy *et al.* (2002) reported a higher response of sunflower to the fertilizer combination of 100-60-60 NPK kg/ha compared with 50-30-60 NPK kg/ha in a Vertisol with low available nitrogen and organic carbon, and medium available phosphorous and potassium. In the present experiment, the test soil was medium in available nitrogen and high in organic carbon, which might be responsible for less response to fertilizer

nitrogen. Higher response of sunflower to 60 kg P_2O_5 kg/ha compared with 30 kg P_2O_5 kg/ha is in agreement with Reddy *et al.*, 2002. The test soil was prone to leaching loss of cations such as K^+ and hence, a higher response was observed at 48 kg K_2O/ha compared with 24 kg K_2O/ha.

Yield response to fertilizer application was quadratic *viz.*, $y = 18.2 + 7.83x - 1.14x^2$ where y is seed yield in quintals and x is dose of fertilizer (kg/ha). The maximized rate of fertilizer application was worked out to be 82-103-82 NPK kg/ha considering yields only. However, fertilizer recommendation should be based on profitability (Munson and Doll, 1959) and hence, the most profitable rate of fertilizer application was worked out. A fertilizer dose of 51-64-51 NPK kg/ha to late sown sunflower crop in lower Assam was found to give maximum net return.

The interaction between the hybrids and fertility levels on yield and yield components was not significant. This was due to similar rate of increase in plant height, yield attributes and seed yield of both the hybrids with th- incremental dose of fertilizers under testing.

It can be concluded from this study that hybrid Sunbred 212 is better than Raja and the most profitable rate of fertilizer application is 51-64-51 NPK kg/ha instead of the recommended fertilizer dose of 24-31-24 NPK kg/ha for short duration sunflower hybrids under late sown conditions of lower Assam.

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Short communication

Balance sheet of nitrogen, phosphorus and potassium as influenced by spacing and nutrient management in sunflower, *Helianthus annuus* L.

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The balance sheet of available nitrogen, phosphorus and potassium indicated that there was build up of available nitrogen, phosphorus and potassium under 50 cm spacing and increased by increasing the level of nutrients. However, depletion in available phosphorus have been observed with either 125% or recommended level of nutrient combination.

A field experiment was conducted during 1997-1998 at instructional farm of IGAU, Raipur, on clay loam soil with low available nitrogen (266.9 kg/ha), low available phosphorus (9.87 kg/ha) and medium available potassium (160.8 kg/ha) with pH 7.25 to study the balance sheet of nitrogen, phosphorus and potassium as influenced by spacing and nutrient management in sunflower. The total rainfall received during the crop period was 125.4 mm.

The experiment was conducted with sunflower variety modern and sown on 13 Dec. 1997 with three row spacing *viz.*, 30 x 20, 40 x 20 and 50 x 20 cm and six nutrient treatment levels *viz.*, 75%, 100% (60 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha), 125%, 150%, 100% + Boron and 100% + Sulphur, replicated thrice in a Factorial Randomized Block Design. The basal dose consisting of half dose of N, and full dose of P_2O_5 and K_2O was applied to crop and remaining half of N was top dressed in lines at 38 DAS. Available N, P and K in soil were determined by the method of alkaline potassium permanganet, Olsen's method and flame photometrically while total N, P and K in plant were determined by micro-kjeldahl, vanadomolybdo acid yellow colour, and flame photometrically, respectively. The spraying of Boron and Sulphur were made at 0.2% and 0.5% respectively at 68 days after sowing (DAS) to the respective treatments through Broax and Sodium sulphate.

Table 1 Balance Sheet of Nitrogen, Phosphorus and Potassium as influenced by spacing and nutrient management in sunflower

Treatment / Spacing (cm)	Applied nutrient (kg/ha)			Total Nutrient avail.(kg/ha)			Nutrient uptake seed + stover (kg/ha)			Net availability (kg/ha)			Balance of avail. Nutrient after harvesting			Depletion (-) or build up (+) of avail. Nutrient (kg/ha)		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
30 x 20	65	18.61	26.97	331.17	28.55	188.22	56.74	15.83	90.28	274.43	2.72	98.04	291.93	11.36	120.38	17.50	1.36	22.34
40 x 20	65	18.61	26.97	336.56	28.57	186.07	58.34	16.02	83.37	278.22	2.55	102.70	293.86	12.61	137.54	15.64	0.06	34.84
50 x 20	65	18.61	26.97	328.00	28.33	188.91	51.83	16.28	82.05	276.17	2.05	106.86	297.25	13.38	141.69	21.08	1.33	34.83
SE m±		-	-	-	-	-	0.88	0.13	1.42	-	-	-	-	-	-	-	-	-
CD (P=0.05)		-	-	-	-	-	2.53	0.37	4.08	-	-	-	-	-	-	-	-	-
75% NPK	45	12.09	18.67	311.75	22.93	180.25	40.99	45.43	75.81	270.76	7.47	104.44	272.27	10.22	101.87	1.51	2.80	-2.57
100% NPK	60	17.20	24.90	317.56	27.21	183.23	48.31	15.67	80.76	269.25	1.54	102.47	288.02	12.46	133.85	18.77	0.92	31.38
125% NPK	75	21.50	31.12	336.35	30.96	188.99	64.03	16.18	90.91	272.32	4.78	98.08	305.00	13.32	139.12	32.68	-1.48	41.04
150% NPK	90	25.58	37.35	358.12	35.90	200.28	75.32	17.45	106.91	282.80	8.45	93.37	31.44	13.68	143.98	35.64	-4.77	50.61
100% NPK+B	60	17.20	24.90	334.96	26.79	185.43	55.09	15.53	82.39	279.87	1.26	103.04	300.81	12.50	138.95	20.94	1.24	35.91
100% NPK+B+S	60	17.20	24.90	333.48	26.76	186.43	56.17	15.62	86.34	277.21	1.14	100.09	311.53	12.53	141.46	24.22	1.30	41.37
SE m±	-	-	-	-	-	-	1.03	0.16	1.51	-	-	-	-	-	-	-	-	-
CD (P=0.05)	-	-	-	-	-	-	2.96	0.46	4.34	-	-	-	-	-	-	-	-	-

It is evident from the data, that increasing the spacing from 30 to 50 cm, there was a higher build up or accumulation of available nitrogen phosphorus and potassium over initial values under wider row spacing. This might be due to the fact that under wider spacing there was low uptake of nitrogen, phosphorus and potassium by crop (seed + stover) than the closer spacing which might directly reflected the more accumulation of available nitrogen, phosphorus and potassium.

Considering the balance sheet of available nitrogen, phosphorus and potassium, it was found that, accumulation of available nitrogen, and potassium over initial values increased with increasing the nutrient combination and maximum build up of available nitrogen (35.64 kg N/ha) and available potassium (50.61 kg/ha) were recorded under 150% of recommended level of nutrient combination. However, in case of phosphorus accumulation build up of available phosphorus decreased with increasing the phosphorus levels because of the higher fixation. In other words, depletion of phosphorus increased with increasing the phosphorus levels, maximum depletion of available phosphorus was recorded under 150% of recommended level of nutrient combination (-4.77 kg/ha). However, under 75% of recommended level it was helped in building up of available phosphorus by 2.8 kg/ha. Present studies are in accordance with the findings of Annadurai and Palaniappan (1994) and Kumar *et al.* (1995).

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Short communication

Effect of higher fertility levels combined with farmyard manure and row spacing on seed yield, oil yield and economics of sunflower, *Helianthus annuus* L.

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Sunflower is a newly introduced oilseed crop in Chattisgarh and became popular due to short duration, photo-insensitivity and suitability for agro-climatic condition. Sunflower production rose markedly from just 76 thousand tones in 1970-71 to 733 thousand tones during 2000-01 in response to increasing government support (Damodaram and Hegde, 2002). Price received from sunflower seed and quality oil is substantially higher than other oilseed crops. Sunflower performs well under higher fertility levels and produces better yield. Under field condition, application of N increases seed yield by increasing the size of flower heads. Further, increase in seed yield obtained through phosphorus application, which has invariably occurred in the presence of adequate potassium supply. However, to avoid the detrimental effects of chemical fertilizers on soil properties and to maintain soil fertility for long, using organic manures is also essential. Keeping these facts in view, an experiment was carried out to investigate the effect of higher fertility levels combined with organic manure and plant population on seed yield of sunflower, net return and available nutrient status of soil.

The experiment was carried out under All India Coordinated Research Project on Cropping Systems at India Gandhi Agricultural University, Raipur (Chattisgarh) during *rabi* season of year 1999-00 and 2000-01 in rice based cropping system on clay loam soil under irrigated condition. The soil was neutral in pH (6.9) and had available N, P_2O_5 and K_2O of 246, 21.5 and 233 kg/ha respectively. The sunflower Variety "Morden" was sown on December 7 and November 24 during 1999 and 2000, respectively. The experiment comprised with the combination of three fertility levels i.e. F_1-100% (100:60:40kg NPK/ha), F_2-125% (125:75:50 NPK kg/ha) and F_3-150% (150:90:60 NPK kg/ha) of recommended dose of fertilizers (100:60:40 kg/ha NPK/ha) and two levels of organic manure i.e. M_0-zero and M_1-10t farmyard manure (FYM)/ha in main plots and two plant population i.e. P_1 - recommended (60 X 20 cm) and P_2 - higher (45 X 30 cm) in sub plot treatments. The experiment was laid out in Factorial Split Plot Design with four replications. The entire P_2O_5 through SSP and K_2O through MoP along with 1/3 N through urea were applied at sowing as basal dose. The remaining N in two equal splits was applied at 35 and 70 days after sowing. The oil content was estimated by using soxlet extractor apparatus.

Different fertility levels contained with organic manure significantly influenced the seed and oil yield of sunflower (Table 1). The increase in fertility level from recommended dose (100:60:40 kg NPK/ha) to 125 and 150% and likewise addition of FYM at 10t/ha (M_1) over no application (M_0) had significant effects on head diameter, seed and oil yield during both the years. Highest seed yield (1758 kg/ha and 1740 kg/ha) were obtained with F_3 (150% of RDF) during 1999-00 and 2000-01 respectively. However, increase in fertilizer dose from 125% to 150% did not show any significant effect on seed and oil yield. Kumar *et al.* (1998), Singh and Bansal (1999) and Reddy *et al.* (2002) also reported similar findings. However, a non-significant but decreasing trend was observed with the increase in fertilizer dose with respect to oil content of seed (Sathiyavelu *et al.*, 1994). This could be due to the utilization of more photosynthates for protein formation and less for fat synthesis in highly nitrogenous fertilized plots (Raj and Singh, 1995). Significant effect of FYM on seed yield with 10 t/ ha might be due to the solubilizing effect on fixed forms of nutrients in soil which increased the availability of nutrients to the plants. FYM had not showed any significant effect on head diameter. The row spacing significantly influenced the head diameter (Table 2). There was a reverse trend in head diameter that the reducing the row spacing from 60 x 20 cm to 45 x 30 cm decreased the head size significantly. Similar result had also reported by Kumar and Singh (1995).

Table 1 Maximization of yield and net return of sunflower as attained by higher fertility levels and plant population

Treatment	Seed yield (kg/ha)		Oil yield (kg/ha)		Net Return (Rs./ha)	
	1999-00	2000-01	1999-00	2000-01	1999-00	2000-01
Fertility Levels (kg/ha)						
F_1: Recommended	1190	1150	493	478	5478	7573
F_2: 125% of rec	1604	1610	664	666	9983	12995
F_3: 150% of rec.	1758	1740	723	719	11253	14050
SEm ±	39	49	17	20	-	-
CD (P=0.05)	117	146	52	60	-	-
Organic Manure (t/ha)						
M_0: No FYM	1413	1410	584	580	7602	10677
M_1: 10 t/ha FYM	1621	1600	669	662	10206	12401
SEm ±	32	40	14	16	-	-
CD (P=0.05)	96	120	42	49	-	-
Plant Population (Row Spacing)						
P_1: Rec. (60 x 20 cm)	1467	1440	605	595	8275	10719
P_2 : Higher (45 x 20 cm)	1568	1570	648	647	9533	12358
SEm ±	43	-	19	16	-	-
CD (P=0.05)	NS	NS	NS	47	-	-
CV % (Error A)	10.20	13.0	14.9	12.6	-	-

Table 2 Effect of higher fertility levels, organic manure and plant population on head diameter and oil content of sunflower and available nutrient status of soil

Treatment	Head diameter (cm)		Oil Content (%)		Available N (kg/ha)		Available P_2O_5 (kg/ha)	
	1999- 00	2000-01	1999-00	2000-01	1999-00	2000-01	1999-00	2000-01
Fertility Levels (kg/ha)								
F_1:Recommended	13.5	13.1	41.4	41.4	256	254	19.1	21.3
F_2: 125% of rec	14.0	13.5	41.3	41.3	267	271	24.8	22.5
F_3: 150% of rec	14.8	14.5	41.2	41.2	281	272	28.2	27.1
SEm ±	0.17	0.20	-	0.01	3.0	2.1	0.59	0.7
CD (P=0.05)	0.53	0.58	NS	NS	8.9	6.4	1.8	2.3
Organic Manure (t/ha)								
M_0: No FYM	13.9	13.5	41.3	41.3	260	262.	23.4	22.2
M_1: 10 t/ha FYM	14.3	13.8	41.3	41.3	275	269	24.4	28.6
SEm ±	0.14	0.15	-	0.009	2.4	1.7	-	0.6
CD (P=0.05)	NS	NS	NS	NS	7.3	5.2	NS	1.8
Plant Population (Row Spacing)								
P_1:Rec. (60 x 20 cm)	14.4	14.00	41.2	41.3	266	263	23.5	23.4
P_2: Higher (45 x 20 cm)	13.90	13.5	41.3	41.3	271	268	24.5	23.9
SEm±	0.15	0.14	-	0.008	-	1.9	-	0.38
CD (P=0.05)	0.4	0.4	NS	NS	NS	NS	NS	NS
CV% (Error A)	5.2	4.9	-	0.1	-	3.5		6.9

Highest net return was obtained with F_3 (150% of RDF), which was 54.2 and 85.5% more than F_1 (100% of RDF) during 1999-00 and 2000-01 respectively (Table 1). Singh and Bansal (1999) reported similar findings. Application of 10t FYM/ha had not only increased the productivity by 14.7 and 13.5% but gave additional return over control during both the years.

Fertilizer levels and inclusion of FYM (10t/ha) over no application of FYM had significantly affected the N and P_2O_5 status during 2000-01 and only N status during 1999-00. Incorporation of FYM had significant effect on available P_2O_5 status of the soil during second year of investigation. This might be due to fixation of phosphorus during later stage of experiment.

The study revealed that sunflower will be a better option as a second crop in rice based cropping system with 125:75:60 NPK kg/ha and 10 t FYM/ha to fetch the maximum yield and net returns under Chhattisgarh agro climatic condition.

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Short communication

Study on sunflower, *Helianthus annuus* L. based intercropping systems for Satpura plateau zone of Madhya Pradesh*

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Sunflower, *Helianthus annuus* L. is photosynthetically C_3 type with tall, quick growing and wide canopy habits. Consequently, it is planted widely in rows depending on the varieties which provide an excellent opportunity to accommodate short statured intercrops in the vacant wide inter row spaces. The success of intercropping system would depend on minimization of crop competition by selecting the compatible intercrop and augmenting the spatial arrangement to push up the productivity and economic returns per unit area and time. Hence, the present investigation was aimed to select the compatible intercrop with sunflower under varying row proportion for increased and economical productivity.

Field experiments were carried out for two years at Research Farm, Tendani, Chhindwara (MP). The soil of the experimental field was clay loam in texture, neutral in reaction (pH 7.1) and had low available N (236 kg/ha) and P_2O_5 (22.6 kg/ha) and medium available K_2O (580 kg/ha) contents. Thirteen treatments were tested in Randomized Block Design with four replications (Table 1). The seed rate and fertilizer dose for all inter crops in intercropping systems were regulated to the proportionate area of crop components. Sowing was done as per treatments on 28th October, 1994 and 4th November, 1995.

Data on grain yield of crop components were recorded treatment wise and then sunflower equivalent was computed on the basis of existing market price and the crop yields. The land equivalent ratio (LER) of each treatment was worked out as suggested by Willey (1979). The stability of intercropping system was also evaluated on the basis of 2 year mean yields in terms of relative crowding coefficient.

Grain yield

The growth parameters (plant height and stem diameter) and yield attributes (head size, seeds/head and seed chaffiness) of sunflower were inferior in intercropped stands over its sole stand, but pea as an intercrop, particularly under 1:2 row proportion caused more determinal effects on these parameters of sunflower than other intercrops (Table 1). Consequently the seed yield of sunflower markedly reduced under sunflower + pea/chickpea intercropping system over its sole stand and the reduction was maximum in association with pea. Seed yields of all intercrops were significantly reduced over their respective sole stands because of shading effect of sunflower and its lesser proportion of plant population in inter cropped stands. All inter crops caused less competition stress on sunflower in 1:1 row ratio than 1:2 row ratio. Lesser plant population coupled with poor growth of plant due to competition can be attributed to lesser seed yield in 1:2 row ratio than 1:1 row planting system. But, all intercrops gave more seed yields under 1:2 row planting geometry because of higher plant population. These results corroborate the findings of several workers (Rao and Reddy, 1991; Shivaramu and Shivashankar, 1992; Malik *et al.*, 1993; Sharma *et al.*, 1995).

Sunflower equivalent

By and large, all intercropping systems barring sunflower + linseed/niger 1:2 row associations gave higher sunflower equivalent than sunflower or all inter crops raised as sole crops (Table 1). Among the intercropping systems, sunflower + pea in 1:1 row association was on top with regard to sunflower equivalent closely followed by sunflower + chickpea 1:1 row association. In general, 1:1 row crop associations were more advantageous in terms of sunflower equivalent than 1:2 row association under intercropping system confirming the views of Shivaramu and Shivashankar (1992).

All intercropping systems offered LER values more than 1.00 indicating that intercropping systems were more advantageous over sole cropping of either crop. Sunflower + niger 1:2 association registered the highest LER (1:37) among all intercropping system closely followed by sunflower + chickpea in 1:1 (1:27) and 1:2 (1:26) row associations. Farmer practice was more efficient and

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Table 1 Yield attributes, grain yields, sunflower equivalent yield, land equivalent ratio (LER) and relative crowding coefficient (K) of different sunflower based intercropping systems (pooled data for two years i.e., 1994-95 and 1995-96)

Treatment	Plant height (cm)	Stem girth (cm)	Head size (cm)	Seeds/ head	Chaffiness of seeds (%)	Grain yield (kg/ha)	Sunflower equivalent yield (kg/ha)	LER	K
Sole sunflower (Sun) - 50 cm	102	5.3	14.2	284	9.6	1859	-	1.00	-
Sole chickpea (Chick.) - 25 cm	-	-	-	-	-	-	1338	1.00	-
Sole pea - 25 cm	-	-	-	-	-	-	1815	1.00	-
Sole linseed (Lin.) - 25 cm	-	-	-	-	-	-	988	1.00	-
Sole niger (Nig.) - 25 cm	-	-	-	-	-	-	648	1.00	-
Sun. + Chick. (1:1 row) - 25 cm	100	4.8	12.1	273	9.0	1521	610	1.27	3.00
Sun. + Pea. (1:1 row) - 25 cm	98	4.6	10.7	257	9.2	1344	881	1.21	1.74
Sun. + Lin. (1:1 row) - 25 cm	98	4.8	12.5	273	8.6	1525	309	1.14	3.04
Sun. + Nig. (1:1 row) - 25 cm	97	4.7	12.2	279	8.1	1549	265	1.245	3.33
Sun. + Chick. (1:2 row) - 25 cm	98	4.7	11.5	265	8.7	1281	763	1.26	2.46
Sun. + Pea (1:2 row) - 25 cm	88	4.5	10.6	244	8.0	959	1101	1.13	1.13
Sun. + Lin. (1:2 row) - 25 cm	90	5.0	11.9	259	8.1	1201	470	1.13	2.03
Sun. + Nig. (1:2 row) - 25 cm	91	4.8	12.0	260	7.6	1232	461	1.37	2.18
CD (P=0.05)	NS	NS	0.3	20.8	1.3	182	96	-	-

stable in yields, but, companion crop niger was low yielding crop. Hence, the latter practices appeared to be equally efficient and stable intercropping systems. Though pea gave higher seed yield than other inter crops under inter cropping system, it caused maximum reduction in sunflower yield owing to less compatibility than other systems. Among different intercropping systems, 1:1 row associations proved superior to 1:2 row associations barring sunflower + niger system in terms of LER.

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Short communication

Feasibility of drip irrigation in castor, *Ricinus communis* L. under sandy loam soil of North Gujarat

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The crop production generally depends upon the prudent application of water essential for the higher production per unit area and time. Irrigation is one of the costliest inputs in the crop production. Its saving is very much essential in crop production. Some scientists worked out that the drip method of irrigation is more efficient from the water use efficiency and water saving point of view. Present investigation was therefore carried out to evaluate the drip method of irrigation with different IW/CPE ratios in castor crop.

An investigation was carried out at the Main Castor-Mustard Research Station, Gujarat Agricultural University, Sardar Krushinagar to test economic feasibility of drip irrigation method on castor hybrid GCH 4 grown on sandy loam soil for three years. The treatments comprising four levels of irrigation *viz.*, 0.4, 0.6 and 0.8 fraction of pan evaporation (through drip) and surface method of irrigation (farmers practice). The experiment was laid out in Randomize Block Design keeping net plot size of 10.8. x 1.8 m. With six replications. Irrigation was applied at the interval of 15 to 20 days with 60mm depth in surface method as farmer's practice. In drip irrigation method, the irrigation was applied alternate day on the basis of fraction of pan evaporation (FPE). The soil of the experimental plot was sandy loam in texture with 8.0 pH and contained 0.14 % organic carbon, 207 kg/ha available N, 65 kg phosphorus and 205 kg potassium. The bulk density of soil was 1.65 g/cc. The field capacity and permanent wilting point were 7.20 and 2.35%, respectively. The 4 l/hr hour discharge of drippers were fitted on lateral line at the distance of 60 cm. The system was operated at 1.2-kg/cm^2 pressure, which gave the uniformity coefficient of 88%. The water expense efficiency was computed as economical yield (kg/ha) divided by water applied to the crop (mm).

The crop was sown at a distance of 90 cm x 60 cm during second week of August during all the years of experimentation. The crop was fertilized with 100-50 N and P_2O_5 Kg/ha. Out of this dose, 40-50 N and P_2O_5 kg/ha was applied as basal and remaining 60 kg N/ha applied as top dressing in two equal splits at 40 and 70 DAS. Recommended package of practices were adopted for raising good castor crop.

The effect of irrigation levels through drip and flood (control) are presented in Table 1. Irrigation scheduled at 0.8 fraction of pan evaporation (FPE) gave significantly higher yield than other fraction of pan evaporation and surface irrigation of 60 mm depth in all the years as well as in pooled analysis. Ganesan (1993) also reported that drip irrigation system gave higher yield as compared to conventional method of major crops.

The results further revealed that there were saving of water from 25 to 63% under different fractions and was highest with the lowest fraction of 0.4 (Table 1). The water expense efficiency was higher (8.36 kg/ha-mm) with 0.4 FPE and decreased with increase in the fraction of pan evaporation. This might be due to better utilization of irrigation water at lower fraction, whereas in higher fraction, the rate of water loss as evapotranspiration might be high and relative increase in yield was not proportionate to the increase in water applied. These results are in close agreement with the findings of Patel *et al.* (1997) in castor.

The economical analysis showed that the gross income was maximum in the drip treatment 0.8 FPE as compared to surface irrigation. Considering the additional area that can be cultivated through drip due saving of water, the total net income (Rs.12955/ha) is higher with 0.8 FPE than surface method of irrigation for the same quantity of water.

The above results revealed that the irrigation scheduling for castor at 0.8 fraction of pan evaporation through drip after cessation of monsoon increased 36% castor seed yield with 25% saving of irrigation water.

Table 1 Effect of drip irrigation treatments on castor seed yield, water saving, water expense, efficiency and economics

Treatment	Castor seed Yield (kg/ha)				Per cent saving of water over control	Water applied (mm)	Water expense efficiency (kg/ha-mm)	Additional area irrigated (ha)	Total net realization (Rs./ha)	Extra income over control (Rs./ha)
	1991-92	1992-93	1993-94	Pooled						
Drip method of irrigation										
0.4FPE	2136	1322	1583	1680	62.3	200	8.36	1.65	2504	-
0.6 FPE	2624	1408	2063	2032	43.4	300	6.75	0.75	7411	-
0.8 FPE	3439	1939	2508	2635	24.5	400	6.57	0.30	12955	2280
Surface Irrigation (Control)	2810	1357	1632	1933	-	530	3.65	-	10675	-
SE m±	53	105	91	108						
CD (P=0.05)	*159*	*315*	*275*	*374*						

Selling Price : Castor Seed Rs. 1000/q

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Short communication

Performance of different safflower, *Carthamus tinctorius* L. genotypes with varied soil salinity levels

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Safflower, *Carthamus tinctorius* L. is grown for high quality edible oil in seeds. Edible oils are an inevitable part of a balanced nutritive diet and become prohibitively costly. The prevailing crunch in oil supply and increasing demand requires to explore the possibility of bringing more area including salt affected soils under cultivation. Soil salinity is wide spread problem in Maharashtra, Uttar Pradesh, Haryana and Punjab. Germination of seeds and survival of seedling under saline conditions is a serious problem. The poor germination results in thin crop stand, hence, decreased yield. One of the most useful strategies to combat soil salinity is to select salt tolerant crops and their varieties. The degree of salt tolerance varies not only with plant species but with the different varieties of the same crop show a differential behaviour to salt at germination stage. Safflower is considered to be salt tolerant crop ranking next to cotton in its ability to produce profitable yield in saline soils (Weiss, 1971; Yadav *et al.*, 2000). Safflower varieties show significant differences in salt tolerance. It was, therefore, thought worthwhile to study the degree of salt tolerance of some safflower cultivars under field conditions.

The multilocation field trials were conducted during *rabi* season 2000-01 at four sites *viz.*, Shiradshahapur, Murumba, Parva and MAU, Research Farm having pH 7.9, 8.0, 8.2, 8.3, natural salinity 4.9, 6.0, 7.4, 7.9 dS/m and ESP 11.3, 11.7, 12.1, 12.4, respectively. The experiment was conducted in Randomized Block Design replicated four times. Ten cultivars of safflower *viz.*, PBNS-32, A-1, S-13-5, S-13-6, Bhima, JSI-7, PBNS-28, NARI-2, DSH-129 and HUS-305 were used for the study. The recommended spacing of 45 cm between rows and 20 cm between the plants in a row was adopted. The recommended dose of fertilizer 60:30:0 NPK kg/ha was applied at the time of sowing. All the genotypes received same package of practices at all the locations. The germination count was taken at 4, 14 and 25 days after sowing (DAS), the per cent germination was estimated and the final plant stand at harvest was counted. Relative water content and osmotic potential in leaf tissue was recorded at 45 DAS as per the procedure suggested by Dhopte and Livera (1989). The seed yield of the safflower cultivars were also recorded.

The average percentage of germination of different cultivars irrespective of salinity level varied from 75 to 89. The cultivar PBNS-32 had the highest germination differing significantly with all varieties except S-13-5 and HUS-305 while Bhima had the lowest germination (74 %). Germination percentage of all the cultivars declined with increasing salinity levels (Table 1). The cultivar PBNS-32 recorded relatively higher germination percentage at all salinity levels as compared to other cultivars. More *et al.* (2002) recorded that the germination percentage of safflower cultivars decreased with increasing levels of salinity and PBNS-32 recorded highest germination percentage at higher levels of salinity. Patil *et al.* (1992) also recorded similar adverse effect of higher salinity on germination of safflower. PBNS-32, S-13-5 and HUS-305 had higher germination percentage even at the higher salinity level (7.9 dS/m). So they proved to be the most tolerant varieties among all.

Relative water content in leaf tissue decreased with increasing salinity levels (Table 1). On an average relative water content in leaf tissue of different safflower cultivars irrespective of salinity levels varied from 85 to 91. All the four levels of salinity showed significant differences among themselves. At higher salinity levels the cultivar PBNS-32 recorded maximum relative content while NARI-2 recorded relatively lower relative water content in leaf tissue than other genotypes. More *et al.* (2002) recorded similar adverse effects of higher salinity on relative water content in leaf tissue of safflower.

Osmotic potential was varied among the different cultivars (Table 1). On an average the genotype HUS-305 recorded lower osmotic potential (-7.79 bars) while PBNS-32 recorded higher osmotic potential (-6.00 bars). Repp *et al.* (1959) reported that resistant plant have the ability to

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accumulate maximum salts in cellular fluid, leading to an increase in osmotic pressure in the plant.

The seed yield of safflower cultivars decreased with increasing salinity levels. All cultivars recorded relatively higher seed yield at lower salinity levels. On an average, the cultivar S-13-5 recorded maximum seed (10.0 q/ha) under varied levels of salinity. The cultivars S-13-5, PBNS-32, S-13-6 and A-1 were found to be more tolerant to salinity and they were at par with each other. The cultivar NARI-2 recorded lowest seed yield at all salinity levels. Janardhan *et al.* (1986) and Gururaj Rao (1987) also reported that seed yield of safflower decreased with increasing salinity levels. Similar results were also recorded by Sinha (1991) in rye varieties.

Table 1 Effect of different salinity levels on germination, relative water content, osmotic potential and seed yield of safflower cultivars under field conditions

Cultivar	Germination % at ECe (dS/m)					Relative water content % at ECe (dS/m)					Osmotic potential (-bars) at ECe (dS/m)					Seed yield (q/ha) at ECe (dS/m)				
	4.9	*6.0*	*7.4*	*7.9*	*Mean*	*4.9*	*6.0*	*7.4*	*7.9*	*Mean*	*4.9*	*6.0*	*7.4*	*7.9*	*Mean*	*4.9*	*6.0*	*7.4*	*7.9*	*Mean*
PBNS-32	92	90	88	85	89	92	91	91	90	91	5.9	5.9	6.1	6.0	6.0	13.1	9.3	7.1	8.7	9.6
S-13-6	93	83	78	78	83	87	87	86	87	87	7.2	7.4	7.3	7.4	7.3	13.6	8.3	6.8	7.6	9.1
Bhima	88	73	72	64	74	87	88	88	84	86	7.6	7.9	7.4	6.6	7.4	12.5	8.9	5.7	5.2	7.3
A-1	91	84	81	79	84	87	87	87	86	87	6.9	7.0	7.1	6.7	6.9	13.5	8.3	6.6	7.1	8.9
JSI-7	86	76	72	65	75	89	86	86	87	87	6.3	6.5	7.2	6.9	6.7	9.2	6.2	5.7	5.4	6.7
S-13-5	92	87	85	79	86	91	91	91	90	91	6.2	6.1	6.4	6.1	6.2	14.6	9.3	7.3	8.7	10.0
PBNS-28	90	80	73	66	77	87	87	87	87	87	6.7	7.1	7.1	6.7	6.9	14.3	6.4	5.7	5.6	8.0
NARI-2	89	83	76	71	80	87	84	85	84	85	7.2	7.3	7.6	7.9	7.5	8.9	5.6	5.1	4.6	6.1
DSH-129	91	86	83	77	84	87	89	86	86	87	6.9	6.8	7.4	7.5	7.1	10.4	7.3	5.8	5.5	7.3
HUS-305	91	87	85	79	85	90	89	91	88	90	6.1	8.2	6.4	6.4	7.7	9.0	6.3	5.8	5.5	6.6
SEm±	3.49	3.50	2.77	4.26	1.70	2.05	1.52	2.35	2.68	0.42	0.14	0.17	0.18	0.17	0.22	1.26	0.63	0.48	0.39	0.47
CD (P=0.05)	NS	10.40	5.04	12.35	4.94	5.94	4.40	6.30	7.76	1.24	0.42	0.49	0.55	0.49	0.64	3.75	1.82	1.41	1.12	1.36

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Short communication

Profitable niger, *Guizotia abyssinica* (L.f) Coss. based intercropping studies with new crop combinations for different regions in India

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Niger, *Guizotia abyssinica* (L.f) Coss. is a minor oilseed crop of importance in respect of its oil quality. The crop has good potential of yielding satisfactorily even under unfertile soil and less moisture availability. Niger is cultivated in 0.57 m.ha with production of 0.17 m.tonnes. The average productivity of niger is only 300 kg/ha which is mainly due to its cultivation on hill tops and slopes, on marginal and sub-marginal lands with negligible inputs under rainfed condition. These factors result in lowering the productivity (Sharma, 1993). There is a need to increase per capita income of niger growers of the country with the introduction of newer technology such as intercropping (Kaushik *et al.*, 1980). It is generally cultivated by mixing crop with small millets or other crops. Suitable intercropping system can be more efficient practices of farming to maximize the productivity and profit besides minimizing of agricultural risks. Hence, the present investigations were undertaken to find the profitable niger based intercropping systems for different agroclimatic regions of India under rainfed conditions.

The studies were carried out under the All India Coordinated Niger Improvement Project at three locations *viz.*, Chhindwara (Madhya Pradesh), Igatpuri (Maharashtra) and Semiliguda (Oissa). The characteristics of soils for these locations are given in Table 1. At all the locations, treatments were arranged in Randomized Block Design and replicated three times at Igatpuri and Semiliguda, whereas, it was four times at Chhindwara. The crops were sown in the month of July in 30 cm apart rows and harvested in the month of November. The recommended doses of fertilizer were applied to all the sole crops at sowing. The fertilizer doses for intercrops were determined on the basis of area occupied by each component crop. The studies were carried out for two years (2000 to 2001) at Chhindwara, three years (1999 to 2001) at Igatpuri and Semiliguda. The yield data were pooled over the years after the test of homogeneity of variance and only mean data were presented. The niger equivalent yield and economics were worked out and presented for interpretation.

Table 1 **Performance of different niger based intercropping treatments on mean niger seed equivalent yield, net returns and benefit : cost ratio at various centres**

Treatment	Location								
	Chhindwara (C)			Semiliguda (S)			Igatpuri (I)		
	Niger Eq. Yield (kg/ha)	Net returns (Rs/ha)	B:C ratio	Niger Eq. Yield (kg/ha)	Net returns (Rs/ha)	B:C ratio	Niger Eq. Yield (kg/ha)	Net returns (Rs/ha)	B:C ratio
Sole niger (C, S and I)	450	2783	1.87	523	3669	1.26	457	6640	2.65
Sole cowpea (C)/Sole cowpea (S)/Sole Nagali (I)	451	2526	1.56	410	2174	0.68	359	5168	2.56
Sole Maize (C)/Frenchbean (S)/Ricebean (I)	794	7154	2.50	416	2464	0.94	291	3409	1.86
sole Castor (C)/Uridbean (S)	1229	18517	4.85	354	1689	0.64	-	-	-
Niger + Cowpea 2:2 (C)/Niger + Cowpea 2:2(S)/Niger+Nagali 2:4(I)	462	2977	1.82	517	3574	1.25	462	6984	1.30
Niger+Cowpea 4:2 (C)/Niger+Cowpea 4:2 (S)/Niger+Nagali 4:2(I)	462	2843	1.92	511	3460	1.14	378	5253	2.34
Niger+Maize 2:2 (C)/Niger+Frenchbean 2:2 (S)/Niger+Ricebean 2:2(I)	643	5482	2.35	528	3852	1.40	428	6105	2.65
Niger+Maize 4:2 (C)/Niger+Frenchbean 4:2(S)/Niger+Ricebean 4:2(I)	613	5166	2.43	566	4417	1.69	422	6036	2.68
Niger+Castor 2:2 (C)/Niger+Uridbean 2:2 (S)	1467	15561	5.03	516	3842	1.47	-	-	-
Niger + Castor 4:2 (C) / Niger + Uridbean 4:2 (S)	1112	11399	3.98	586	4927	2.05	-	-	-

Details of experimental soils:

Centre	Soil taxonomy	Soil texture	Soil pH	O.Carbon (%)	E.C (m.mhos/cm)	Available nutrient (kg/ha) N	P	K	Recommended doses of fertilizer (N:P:K kg/ha)
C	Vertisol	Sandy clay loam	7.4	0.60	0.26	240	17	422	Chhindwara (C) = Niger - 20:20:10; Cowpea - 20:50:20; Maize - 70:40:20 and Castor - 40:40:20
S	Alfisol	Sandy loam to clay loam	5.2	0.25	0.20	210	8	208	Semiliguda (S) = Niger - 40:40:00 and Pulse - 20:40:40
I	Vertisol	Sandy loam	5.8	0.22	0.20	120	8	210	Igatpuri (I) = Niger - 20:00:00; Niger + Nagali - 80:40:00 and Niger + Rice bean - 25:25:00

Sale price (Rs/kg)	
Chhindwara (C)	= Niger - 13; Maize - 4.50; Cowpea - 13 and Castor - 10
Semiliguda (S)	= Niger - 15; Frenchbean - 6; Cowpea - 6 and Uridbean - 25
Igatpuri (I)	= Niger - 20; Nagali - 9 and Ricebean - 18

On Vertisols at Chhindwara, among the intercrop combinations, niger + castor (2:2) intercropping gave highest niger equivalent yield of 1467 kg/ha, net return of Rs. 15651/ha and B:C ratio of 5.03. However, maximum net returns of Rs. 18517 was recorded with the sole crop of castor (Table 1). These results are in close conformity with the findings of Thakur *et al.* (2002). However, at Igatpuri on Vertisols, niger + nagali (2:4) gave maximum niger equivalent yield (462 kg/ha) than the sole crop of niger (457 kg/ha) and highest net return of Rs. 6984/ha. Net return of Rs. 6640/ha was higher with sole crop of niger than niger + ricebean (2:4) Rs. 6105/ha. The B:C ratio (2.67) was higher with niger + ricebean (4:2). These results are confirming the findings of Jain *et al.* (2000).

On Alfisols at Semiliguda, niger + urdbean (4:2) produced higher niger equivalent yield (586 kg/ha) over niger + frenchbean (4:2) which recorded 566 kg/ha. The intercropping system niger + urdbean (4:2) also fetched higher net monetary returns of Rs. 4927/ha with higher B:C ratio of 2.05 (Table 1). Paikary *et al.* (1994) also reported the similar results.

It may be concluded from the results of the study that among the intercrop combinations, niger + castor (2:2) intercropping system on the Vertisols of Chhindwara niger + nagali (2:4) on the Vertisols of Igatpuri and niger + urdbean (4:2) on the Alfisols of Semiliguda were found to be the best and profitable intercropping systems with maximum niger equivalent yield, net monetary returns and benefit-cost ratio.

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Short communication

Evaluation of niger, *Guizotia abyssinica* (Coss) productivity under resource constraints

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Niger (*Guizotia abyssinica* Coss) is an important oilseed crop in tribal belts of Satpura Plateau of Madhya Pradesh. Generally, it is grown without using costly inputs, just by seeding and finally harvesting consequently, it has very low productivity (105 kg/ha). However it has yielding potential of 6.0-7.0 q/ha by growing high yielding varieties with improved production technology even under adverse weather conditions (Sharma and Kewat, 1998). Therefore, it is imperative to determine the contribution of various managerial production factors for optimization of productivity of niger under resource constraints.

Field experiments were conducted on niger in sandy soils of Chhindwara (M.P.) during *kharif* season for three consecutive years from 1997 to 1999. The soil of the experimental field was shallow depth (30 cm), pH 7.20 with low available N (236 kg/ha), available P_2O_5 (18 kg/ha) and high available K_2O (560 kg/ha). The total rainfall was 1209, 858 and 1379 mm during the crop season of 1997, 1998 and 1999, respectively. Seven treatments comprising of full package of practices (FP) and curtailing each of fertilizer application (F), line sowing (LS), improved variety (V), weed control (WC), LS + WC, and F + V in FP were tested in randomized block design with four replications. FP includes improved variety Ootacamund which was the only improved variety available that time in 30 cm x 10 cm planting geometry (LS) with use of 20 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha (F) and weed control twice at 20 and 45 days after sowing (WC). In case of missing V, local variety in farmers language known as Jagni was sown. Sowing of crop was done on July 9, 1997, July 14, 1998 and July 15, 1999. Which was harvested on November 11, 5 and 22 in the three consecutive years. Data on growth parameters yield attributes and seed yields were recorded and finally, averaged because of similar trend of treatments for all the observations in all the years of experimentations.

Growth parameters and yield attributes

Based upon of the mean data for three years on growth parameters *viz.*, plant height, basal branches/plant and yield attributes *viz.*, capitulam/plant, seeds/capitula, harvest index and 1000-seed weight had their maximum values in niger under FP and these values reduced by curtailing production factors each of F, LS, V and WC either alone or in combination of LS + WC and F + V (Table 1). The reduction was maximum among the individual 4 factors due to curtailing of weed control mainly in branches/plants, capitulam/plant, seeds/capitula and test weight, while reduction in plant height and harvest index due to FP-V was not significant over FP alone. The effect of curtailing production factors on reduction of these parameters over FP was in descending order of WC, V, LS and F. the values further reduced when two factors together *viz.*, WC + LS and F + V were curtailed. These results are in close conformity with the opinion of Upadhyay (1993); Paikaray *et al.* (1997) and Deshmukh *et al.* (2000).

Seed yield

During 1998, heavy rains followed with high wind velocity after September 15 caused lodging therefore pollination was affected which resulted poor seed setting ultimated very low yield was recorded.

Growing of niger with FP produced maximum seed yields during all the three years of experimentation and the yield significantly reduced by missing any of 4 production factors (F, LS, V and WC) either alone or in combination of WC + LS and F + V. However, reduction in seed yield over mean seed yield of FP (419 kg/ha) was maximum with WC + LS (44.2%) followed by F + V (42.5%), WC (34.6%), V (31.3%), LS (21.0%) and F (18.9%). Thus, it can be inferred that missing of weed control in niger cultivation alone caused maximum reduction in the seed yields among the 4 factors because of the poorest physiological parameters of the crops. Improved variety was next to it in this regard. Missing of fertilizer application in FP had minimum reduction in the yield. Such findings are reported by Upadhyay (1993); Paikaray *et al.* (1997) and Deshmukh *et al.* (2000).

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Table 1 Growth parameters, yield attributes, yield and economics of niger influenced by various production components

Treatment	Plant height (cm)	Branches/ plant	Capitulam/ plant	Seeds/ capitula	1000-seed weight (g)	Seed weight/plant (g)	Harvest index	Mean seed yield (kg/ha)	Net monetary returns (Rs/ha)	Benefit : Cost ratio
FP	114	10	52	21	4.1	1.3	7.8	419	5192	2.6
FP – F	103	9	46	18	3.8	1.2	8.6	340	4250	2.7
FP – LS	110	9	46	18	3.8	1.2	6.8	331	3667	2.2
FP – V	112	8	40	17	3.7	1.1	7.5	288	2592	1.8
FP – WC	109	8	39	17	3.6	1.1	7.0	274	3017	2.2
FP (LS + WC)	104	7	32	13	3.3	0.8	6.6	234	2475	2.1
FP – (F + V)	101	7	35	14	3.2	0.9	7.2	241	2308	1.9
SEm±	1.4	0.2	1.2	0.4	0.05	0.02	0.12	7.0	158	0.04
CD (P = 0.05)	4.2	0.5	3.7	1.1	0.15	0.06	0.36	20.0	492	0.12

FP – Full package; F – Fertilizer; LS – Line sowing; V – Improved variety; WC – Weed control

Economic returns

Niger cultivation with FP resulted in the highest net monetary returns (NMR) and benefit cost ratio on the basis of three years mean data and these values reduced by missing F or LS or V or WC alone as well as LS + WC, or F + V. The reduction in these values was in ascending order of F + V, LS + WC, V, WC, LS and F for NMR and V, F + V, LS + WC, WC, LS and F for benefit cost ratio. It reveals that NMR and profitability reduced drastically by missing improved variety and weed control, while missing of fertilizer alone had least contribution in the monetary gain.

It may be concluded that maximum seed yield, net return and B: C ratio can be obtained by adoption of full package of practices as discussed. Weed control and improved variety was the most important production factor, which contribute more yield as compared to other factors.

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Short communication

Field efficacy of different insecticides against stem fly, *Melangromyza sojae* Z. and girdle beetle, *Obereopsis brevis* S. on soybean, *Glycine max* Merill.

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Soybean, *Glycine max* Merill. is an important crop for its protein and good quality oil. In India it is cultivated over an area of 60 lakh hectare with an average production of 61.8 lakh ha and average seed yield of 1.03 t/ha. In Maharashtra area under soybean cultivation in the year 2000-2001 was 11.42 lakh ha with an average production of 14.04 lakh tonne and average seed yield of 1109 kg/ha (Raut, 2003). The area under soybean crop in Maharashtra in 1994-95 was 5.68 lakh ha and now in 2000 it has becomes 11.42 lakh ha. As the area under this crop is increasing, several pests and diseases are also becoming serious; which are one of the major constraints in its gainful cultivation (Kundu and Tri Mohan, 1986). In India about 20 insect pest species have been recorded infesting the soybean crop (Munde, 1982). Among them leaf miner, stemfly, girdle beetle, aphids and white flies are important. The loss in seed yield primarily due to *Melanagromyza sojae* (Zehnt) is the principal limiting factor in soybean cultivation. Yield losses in soybean caused by stem fly (*M. sojae*) ranged from 18.6 to 40.1 % (Kundu *et al.*, 1995) Therefore it is necessary to manage these pests effectively. The present study was conducted to evaluate the efficacy of different insecticides against *M.sojae* and *O.brevis*.

Eleven insecticides were evaluated against *M.sojae* and *O.brevis* (Table 1) in Randomized Block Design replicated thrice at Marathwada Agricultural University, Parbhani during *Kharif* 1996-97. Variety PK-472 was sown in plots 5 m x 2.7 m having spacing 45 cm x 5 cm. Stem fly damage was recorded by uprooting 10 plants randomly at harvest and length of stem tunneled was recorded by splitting the stem. Total number of healthy and affected plants in 1 m row length at four places in each net plot were recorded and per cent infestation was counted. For girdle beetles healthy and girdled plants were counted in 1 m row length at four places in each net plot and was transformed in angular values before subjected for statistical analysis. Observations for both the pests were recorded 1 day before, 3 days and 7 days after spraying. Insecticidal spray using 500 lit. of spray solution per hectare was given 20 days and 50 days after sowing. Observation of both the sprayings were consolidated and subjected to statistical analysis. At the time of harvesting grain yield of soybean was recorded and cost: benefit ratio was also calculated.

Stem length tunneled by stem fly recorded at the time of harvesting indicated that significantly lowest per cent tunneled length was recorded in quinalphos 0.05 % which was at par with deltaphos 0.07 % and acephate 0.10 % treated plots. The lowest per cent infestation of stem fly 3 days after spraying was recorded in treatment with acephate. The treatment with trizophos 0.06 %, quinalphos 0.05 %, profenofos 0.15 % and chloropyrifos 0.06 % were at par with each other. Present studies are in accordance with the findings of Venkateshan and Kundu (1994). Earlier Gain and Kundu, (1988) also reported that quinalphos was one of the most effective treatment in reducing percentage stem tunneling. Lowest infestation of girdle beetle 3 days after spraying was observed with the treatment acephate 0.10 %, however all insecticidal treatments were at par with each other. Lowest infestation was observed in plots treated with acephate 0.10 %, which was at par with quinalphos 0.05 % and significantly superior over rest of treatments at 7 days after spraying. Singh (1986) reported that quinalphos 0.03 % was highly toxic to eggs and grubs of O. *brevis* causing 93.3 % mortality of grubs. Higher yield was recorded in plots treated with quinalphos 0.05 % (3124 kg/ha), profenofos 0.15 % (2962 kg/ha),acephate 0.10 % (2950 kg/ha) and deltamethrin 0.0025 % (2939 kg/ha) and were at par with each other. Highest cost: benefit ratio was recorded in deltamethrin treated plots (1:17.8) followed by endosulfan (1:15.4), quinalphos (1:14.3) and acephate (1:13.7).

To sum up, the treatment with quinalphos 0.05 % recorded lowest per cent tunneling by stem fly which was at par with deltaphos 0.07 % and acephate 0.1 % treated plots. The lowest per cent infestation of stem fly and girdle beetle was recorded in treatment with acephate 0.10 %. Quinalphos treated plots recorded higher yield (3124 kg/ha); whereas highest cost: benefit ratio (1:17.8) was recorded in deltamethrin treated plots.

Table 1 Efficacy of different insecticides against *M. sojae* and *O. brevis* on soybean

Treatment	Per cent infestation of *M. sojae*		Per cent stem length tunneled by *M. sojae*	Per cent infestation of *O. brevis*		Grain yield (kg/ha)	Cost : Benefit ratio
	3 DAS	7 DAS**		3 DAS	7 DAS		
Profenofos (Curacron 50 EC 0.15%)	17.2 (24.5)	25.1 (30.0)	5.0 (12.9)*	1.1 (4.9)	2.1 (8.9)	2962	1:5.1
Deltamethrin (Decis 2.8 F0.0025 %)	19.0 (25.8)	26.1 (30.7)	7.5 (15.9)	1.4 (6.7)	3.0 (9.9)	2939	1:17.8
Acephate (Asataf 75 SP 0.10 %)	13.6 (21.3)	22.9 (28.5)	3.6 (10.8)	0.9 (4.4).	1.3 (6.4)	2950	1:13.7
Methomyl (Lannate 12.5 L)	20.1 (26.6)	26.7 (31.1)	3.8 (11.3)	1.6 (7.3)	4.0 (11.4)	2545	1:0.9
Ethion (Fosmite 50 EC 0.15 %)	20.9 (27.2)	27.0 (31.2)	5.4 (13.4)	2.1 (8.3)	4.0 (11.5)	2320	1:2.0
Chloropyrifos (Radar 20EC 0.06 %)	17.9 (25.0)	25.5 (30.3)	4.5 (12.2)	1.5 (7.1)	3.8 (11.3)	2499	1:6.1
Deltaphos (Spark 36 EC 0.07 %)	18.4 (25.4)	25.9 (30.6)	3.2 (10.4)	1.5 (7.0)	3.6 (11.0)	2916	1:6.5
Endophos (50 EC 0.10 %)	19.9 (26.5)	26.4 (30.8)	5.9 (14.0)	1.4 (6.9)	3.1 (10.2)	2684	1:4.8
Triazophos (Hostathion 40 EC 0.06 %)	15.8 (23.4)	24.6 (29.7)	4.1 (11.7)	1.2 (5.2)	2.5 (9.0)	2857	1:8.4
Quinalphos (Ekalux 20 AF 0.05 %)	16.2 (23.6)	24.9 (29.9)	2.9 (9.8)	1.0 (4.6)	1.5 (7.1)	3124	1:14.3
Endosulfan (Thiodon 35 EC 0.07 %)	20.4 (26.9)	26.9 (31.2)	8.3 (13.2)	1.5 (7.0)	3.4 (10.7)	2881	1:15.4
Control (Untreated)	41.8 (40.3)	46.3 (42.9)	8.3 (16.7)	9.8 (18.3)	10.0 (18.4)	2129	---
SE M ±	0.6	0.3	0.5	1.4	0.3	168.7	
CD (P= 0.05)	1.8	1.0	1.4	4.6	1.0	493.9	

* Figures in parenthesis are angular transformed values.
** DAS – Days After Sprayings

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Short communication

Integrated management of Alternaria leaf blight of sunflower, *Helianthus annuus* L. caused by *Alternaria helianthi*

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Sunflower, *Helianthus annuus* L., is one of important oilseed crop of world and is known to suffer from several foliar diseases of which Alternaria leaf blight caused by *Alternaria helianthi* (Hansf.) Tubaki and Nishihara is most serious (Balasubramanyam and Kolte, 1980; Kolte, 1985). It produces symptoms on all parts of plant causing severe yield losses which may go up to 80% (Balasubrahmanyam and Kolte, 1980; Hiremath *et al.*, 1990). The disease has assumed epiphytotic proportions in recent years in many parts of Karnataka and other neighbouring states. Integration of chemicals, plant extracts, bio-agents along with plant resistance has been considered as a novel approach for disease management (Papavizas, 1973). Hence, in the present studies an attempt was made to manage the Alternaria leaf blight of sunflower using plant extract, bio-agent and fungicide.

A field experiment was conducted during *rabi*/summer 1999-2000, at the RRS, Raichur. The experiment was laid out in Randomized Block Design (RBD). There were eleven treatments with three replications and each treatment three sprays were given from on set of disease at 30 days after sowing (DAS), second and third spray at 42 DAS and 54 DAS, respectively on alternaria susceptible variety Morden. In each treatment different combination of fungicide, one *pongamia* leaf extract and a bio-agent (*Pseudomonas fluroscens*) was given. Mancozeb three sprays and one water spray control were maintained. Plant extracts were prepared by collecting plant samples and washed with tap water and air-dried and made 5.0% on W/V basis by adding water. Pure culture of *P. fluroscens* was grown on King's broth media and concentration was made to 2.0×10^5 Colonies Forming Unit (CFU) in water and before spraying teepol was added. For scoring disease intensity ten plants were randomly selected in each treatment and disease intensity was recorded each time one day before spray using the scale given by Mayee and Datar (1986). Further, per cent disease index (PDI) was calculated.

Results revealed that at 30 DAS, all treatments did not differ significantly in their performance over unprotected control (Table 1). On the contrary at 45, 55 and 65 DAS they differed significantly over control. At 65 DAS, minimum PDI (25.9%) was observed in HPB (T_7) treatments, which is at par with T_{10} (MMM) followed by CPB (T_4) treatments. The treatments, HPB (T_7), MMM (T_{10}), CPB (T_4) and MPB (T_1) were found effective in reducing PDI at all the stages. Highest hundred seed weight (4.6 g) was obtained in MMM (T_{10}) treatment, which was at par with HPB (T_7) and MPB (T_1) and least (3.2 g) was observed in untreated control. The highest seed yield 946 kg/ha was recorded in MMM (T_{10}) which was significantly superior over other treatments followed by HPB (T_7) and CPB (T_4) and least seed yield was found in unprotected control. Maximum per cent oil content (38.7%) was noticed in MMM (T_{10}) treatment which remained at par with HPB (T_7) (37.9 %) treatment followed by MPB (T_1) and CPB (T_4). Present studies are in concurrence with the earlier findings (Anonymous, 1997).

The present study clearly indicated that the plant extracts and bioagent could be incorporated in the spraying schedule to manage the disease effectively and reduce the cost of input.

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Table 1 Management of *Alternaria* leaf blight of sunflower through fungicides, plant extracts and bioagents during *rabi*/summer

Treatment	Per cent Disease Index (PDI) at				Yield (kg/ha)	Per cent increase over control	Test weight (g)	Oil content (%)
	30 DAS	45 DAS	55 DAS	65 DAS				
MPB (T_1)	6.7 (14.8)	10.4 (18.8)	22.9 (28.6)	31.9 (33.4)	850	23.2	4.3	37.0
PMB (T_2)	5.9 (14.0)	18.5 (25.5)	32.4 (34.7)	40.7 (39.7)	790	14.5	3.9	35.3
BPM (T_3)	5.9 (13.9)	24.4 (29.6)	35.7 (36.1)	37.7 (37.9)	750	8.7	3.5	34.8
CPB (T_4)	5.9 (14.0)	7.4 (15.8)	14.7 (22.6)	29.6 (33.0)	900	30.4	3.6	37.0
PCB (T_5)	6.7 (14.8)	17.8 (24.9)	25.2 (30.1)	36.3 (37.0)	790	14.5	3.4	35.7
BPC (T_6)	6.7 (15.0)	26.7 (31.1)	36.3 (37.0)	40.8 (39.7)	770	11.6	3.5	35.3
HPB (T_7)	6.7 (14.8)	8.9 (17.3)	18.5 (24.5)	25.9 (30.6)	920	33.3	4.3	37.9
PHB (T_8)	6.7 (15.0)	27.4 (31.6)	31.9 (34.3)	39.3 (38.8)	850	23.2	4.1	37.0
BPH (T_9)	8.1 (16.6)	28.1 (32.0)	37.2 (37.9)	40.8 (39.7)	790	14.5	4.1	35.9
MMM (T_{10})	5.9 (14.0)	12.6 (20.7)	20.8 (27.1)	26.7 (31.1)	950	37.7	4.6	38.7
Control (T_{11})	7.4 (15.8)	33.3 (33.6)	47.4 (43.5)	48.9 (48.9)	690	-	3.2	33.7
SEm±	NS	1.2	0.5	0.6	10	-	0.2	0.4
CD (P=0.05)	NS	3.4	1.4	1.9	20	-	0.5	1.0

Figures in parenthesis are Arcsine-transformed values

In each treatment three sprays were given at 30, 42 and 54 DAS:

T_1 (MPB) - Mancozeb - *Pongamia* leaf extract - Bio-agent
T_2 (PMB) - *Pongamia* leaf extract - Mancozeb - Bio-agent
T_3 (BPM) - Bio-agent - *Pongamia* leaf extract - Mancozeb
T_4 (CPB) - Clorothalonil - *Pongamia* leaf extract - Bio-agent
T_5 (PCB) - *Pongamia* leaf extract - Chlorothalonil - Bio-agent
T_6 (BPC) - Bio-agent - Chlorothalonil - *Pongamia* leaf extract
T_7 (HPB) - Hexaconozole - *Pongamia* leaf extract - Bio-agent
T_8 (PHB) - *Pongamia* leaf extract - Hexaconozole - Bio-agent
T_9 (BPH) - Bio-agent - *Pongamia* leaf extract - Hexaconozole
T_{10} (MMM) - Mancozeb - Mancozeb - Mancozeb
T_{11} - Control

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Short communication

Effect of temperature and pH on growth and sporulation of wilt causing pathogen, *Fusarium oxysporum* f.sp. *lini* (Bolley) Snyder and Hansen in linseed, *Linum usitatissimum* L.

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Linseed or flax (*Linum usitatissimum* L.) is an important *rabi* oilseed crop in India. Amongst the various stresses responsible for the low productivity of the crop diseases are the major ones. Wilt disease incited by *Fusarium oxysporum* f. sp. *lini* is one of the serious diseases causing loss in quality and yield of seeds (Richardson, 1979). The crop losses in the range of 80-100% have been reported from the country (Sattar and Hafiz, 1952; Vasudeva, 1962; Sharma and Mathur, 1971). Soil temperature and pH are some of the abiotic factors, known to play important role in incidence of the disease. Wilt incidence is known to be higher at higher temperature (Schuster and Anderson, 1944; Wilson, 1946 and Kommendahl *et al.*, 1970) and higher incidence of wilt was reported at soil pH 5.5 to 7.5 (Nair, 1957; Houston and Knowels, 1953; Goel and Swarup, 1964). The present investigation was therefore, an effort to demonstrate the effect of different temperatures and pH levels on the growth and sporulation of wilt inciting pathogen under study in vitro.

The experiment was carried out during 2001-02, selecting the most suited potato dextrose broth media for the entire study. To find the effect of different temperatures the fungus was grown in 150 ml Erlenmeyer flasks filled with 25 ml liquid media sterilized at 15 lb pressure/square inch for 15 minutes. The pH of the media was adjusted to 7.0. The flasks were inoculated with 5 mm culture discs, cut with a sterilized cork borer from 4 day old culture on potato-dextrose-agar medium and then kept at 5, 10, 15, 20, 25, 30, 35, 37, 40 °C in three replications. For pH study the media were prepared by the same method described as above. The pH was adjusted at 3.0, 4.0, 5.0, 6.0, 6.5, 7.0, 7.5, and 8.0 by adding the required quantity of IN solution of HCL or NaOH in cool sterilized flasks. The quantity of HCl or NaOH to be added for each pH level was estimated in an extra flask. The flasks were incubated at 25°C after inoculation. In both the experiments the flasks were incubated for 10 days.

Table 1 Effect of pH ranges on growth and sporulation of *Fusarium oxysporum* f. sp. *lini*

pH range	Dry weight of mycelium (mg)	Sporulation
3.0	101.0	Moderate
4.0	152.6	Moderate
5.0	172.0	Good
6.0	208.0	Good
6.5	245.3	Excellent
7.0	236.6	Good
7.5	199.6	Moderate
8.0	134.0	Poor
CD (P=0.05)	21.6	

It is evident from the Table 1 that the pathogen could grow well on temperature range between 10-37°C but the growth and sporulation was best at 25°C followed by 30°C and 35°C. The mycelial weight (238.3 mg) at 25°C was significantly higher over other temperatures except that of 30°C, which was statistically at par. The results supported the finding of Jones and Tisdale (1922), who found 75-82°F (24-28°C) to be the optimum temperature for growth and sporulation of *F. oxysporum* f.sp. *lini* and there was no infection at 96.4°F (38°C). It was observed that the pathogen grew well on pH range between 5.0 to 7.5 but pH 6.5 was optimum for growth (245.3 mg mycelial wt) and sporulation. The mycelial weight at pH 7.0 (236.6 mg) was however statistically at par. The superiority order with respect to growth on different pH was 6.5, 7.0, 7.5, 6.0, 5.0, 4.0, 8.0 and 3.0 in descending order. These findings are in agreement with that of Nair (1957) who reported pH 5.5 to 7.5 to be the optimum for growth of wilt pathogen in linseed. Under rainfed conditions of Indian Agriculture, soil pH is slightly tilted towards alkaline range i.e. 7.5 and

above. Under these high pH conditions, inherent soil suppressiveness due to fungal antagonists such as *Trichoderma* sp. is negligible. Further, even the activity of bacterial antagonists is also doubtful in lieu of low soil moisture. Under these circumstances a higher incidence of Fusarial wilt in alkaline soils under rainfed situation is expected.

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Short communication

Field evaluation of linseed, *Linum usitatisimum* L. germplasm for resistance to alternaria blight and powdery mildew diseases

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Linseed (*Linum usitatisimum* L.) is an important *rabi* oilseed crop in India, grown over an area of 754 thousand ha with a production of 244 thousand m t and productivity of 324 q/ha (Damodaram and Hegde, 2002). Among several diseases, responsible for its low productivity Alternaria leaf spot and black bud (*Alternaria lini* Dey) and powdery mildew (*Oidium lini* Skoric) are serious ones in India causing crop losses up of to 26-60% (Chauhan and Srivastava, 1975; Rai, 1984). Very little information is documented from India on host resistance (Kalia *et al.*, 1965; Singh *et al.*, 1974; Ji, 1975 on *Alternaria* blight and Shukla and Pathak, 1967; Singh and Kaurav, 1973 and Prasada *et al.*, 1988 on powdery mildew), which is a prerequisite for planning proper breeding programme. The Linseed Germplasm Management Unit (GMU) has therefore, a regular programme of screening the available germplasm against various characters including reaction to major diseases and pests. As Kanpur is a hot spot location for Alternaria blight and powdery mildew diseases concerted efforts have been during *rabi* 1991 to 1997 to evaluate the available linseed germplasm against these two economically significantly diseases.

A total of 4965 linseed germplasm were screened against Alternaria blight and powdery mildew, the predominant foliar diseases during *rabi* 1991-1997 (2876 during 1991 to 1994; 2766 from same set + additional 1955 = 4721 in 1995; same 4721 + 244 additional in 1996; the new set of 1955+244 + 504 = 2747 in 1997) as there is augmentation of germplasm in GMU. The test cultures were sown in 3 m single rows, 30 cm apart, distance between plant to plant was kept approximately 10 cm. The susceptible checks Chambal and Kanpur local were sown after 20 rows of the test entries. An infector row (Kanpur local) was planted all around the plots to supplement the inoculum. The experimental fields were supplemented with 80 kg N (40 kg each as basal and top dressings), 40 kg P_2O_5 and 40 kg K/ha and irrigated three times (30, 50 and 70 days after sowing) during crop season. The observations were recorded after full appearance of diseases. All entries were assessed visually for both diseases based on percent leaf area affected using 0-5 scale (Anon., 1991) detailed as under:

0 = Free	(F)
1 = 0.1 to 10% leaf area affected	(R)
2 = 10.1 to 25% leaf area affected	(MR)
3 = 25.1 to 50% leaf area affected	(MS)
4 = 50.1 to 75% leaf area affected	(S)
5 = 75.1 to 100% leaf area affected	(HS)

For Alternaria blight percent bud infection was also taken into consideration using the same 0-5 scale. The disease reactions presented in Table 1 are based on three years observations (the reaction is not the average).

The results revealed that 28 cultures *viz.*, Acc Nos. 1336, 2921, Ayogi/Alyagi, EC-170492, EC-384154, EC-278988, EC-322643, H-5, H-12, H-14, H-15, H-18, H-40, H-41, H-43, JRF-1, JRF-2, JRF-4, Pink Petal, Polf-2, Polf-5, Polf-14, Polf-17, Polf-31, Polf-34, Polf-34, Polf-35 A, and Polf-39 were resistant to both Alternaria blight (AB) and powdery mildew (PM) diseases, nine were resistant to AB and moderately resistant to PM, 51 cultures were resistant against PM and moderately resistant to AB, 194 were moderately resistant to both AB and PM and 54 were moderately resistant to PM and moderately susceptible to AB. It is noteworthy that in the first category most of the cultures were flax (tall) type. The genotypes reported to be resistant to AB earlier from India (Singh, *et al.*, 1974; Ji, 1975) are now obsolete. Two varieties *viz.*, R-7 and R-17 reported to be tolerant to Alternaria blight by Singh *et al.*, (1974) were not found tolerant in the present study. For PM the cultures namely, Mahoba local, KL-31 and KL-43, reported to be resistant by Prasada *et al.* (1988) were found moderately resistant in present study also. The resistant genotypes reported in the first category i.e. resistant to both AB blight and PM were mostly exotic and flax type.

The results are based on screening under natural field conditions, however, 28 linseed germplasm having field tolerance against AB and PM will be re-evaluated under artificial conditions to confirm resistance against these major diseases in linseed.

Table 1 Disease resistance in linseed germplasm against *Alternaria* blight and powdery mildew diseases

Category	Germplasm
R to both AB and PM (0.1-10%)	Acc. No. 1336, 2921, Ayogi-Alyagi, EC-170492, EC-384154, EC-278988, EC-322643, H-5, H-10, H-12, H-14, H-15, H-18, H-40, H-41, H-43, JRF-1, JRF-2, JRF-4, Pink Petal, Polf-2, Polf-5, Polf-14, Polf-17, Polf-31, Polf-34, Polf-35A, Polf-39 (28)
R to AB (0.1-10%) and MR to PM (10.1 - 25%)	A-9-2-1, EC-4752, EC-397752, ES-44, JRF-3, OR-3-1, Tikamgarh, RL-903, RL-906 (9)
R to PM (0.1-10%) and MR to AB (10.1-25%)	6-9-2-1, 4/47, 21/412, A-1-3-1, A-21-2-2, ARMY, BAU-610 A, C-1-2063, DPL-21, EC-544, EC-41496, EC-41770, FRW-12, FX-168, H-34, IC-54, JRF-5, KL-168, KL-169, KL-178, KL-187, L-3, LC-2045, LC-2057, LCK-8605, LCK-8776, LCK-89512, LCK-9018, LCK-9211, NP (RR)-120, NP (RR)-272, Polf-11, Polf-15, Pof-16, Polf-23, Polf-29, Polf-30, R-2, R-966-5, RL-33-5, RL-45-4-4-5, RL-49-3-6-2, RL-49-4-5, RL-49-4-7, RL-49-4-8-2, RL-50-3, RL-904, RL-961, RL-993, Tikamgarh Trans local, W/17-1 (51)
MR to both AB and PM (10.1-25%)	Acc. Nos. 314, 335, 338, 356, 1084, 1142, 1295, 1319, 1321, 1327, 1335, 1348, 1350, 1404, 1463, 1479, 1518, 1547, 1651, 1741, 1925, 2242, 2244, 2277, 2351, 2363, 2364, 2444, A-202, A-367B, A-487, B-67, BAU-152, Behraich, Bhatira, C-5-82, CI-1477, CI-1538, CI-1956, CI-1978, Cherrapuram, DPL-17, DPL-19, EC Nos. 14, 256, 533LS, 568, 571, 1005B, 1042, 1394, 1404, 1411, 1414, 1453, 1462, 1918, 9969, 10663, 13219, 14339, 22637, 22638, 22644, 41475, 41484, 41492, 41500, 41572, 41590, 41609, 41617, 41628, 41750, 278952, 278956, 298972, 279854, 282795, 282810, 313895, 313896, 313899, 313901, 312949, 312952, 312953, 322640, 322680, GS Nos. 105, 110, 138, 157, 194, 198, 202, 203, 204, 205, 206, 213, 219, 220, 229, 248, 252, 253, 254, 271, 278, 297, 401, 407, 411, 412, GP-164 (Garhwal local), Gewargi-12, Gram 6xRR9, H-8, H-22, H-25, I/276, IC-31682, ICAR-1, IPI-42, Jaishri-21, Jawargi-1-11, Kangra local, KL-1, KL-31, KL-37, KL-122, KL-188, KL-190, Kota-8, Kota-13, KP-8, Kanpur 40/2, Kanwartola, Karam (Banda), KYS-7, L-26, L-93, LC-54, LC-283, LC-2021, LC-2023, LCK Nos. 148, 8504, 8520, 8673, 87312, 88062, 9121, 9011, 9111, 9119, 9209, 9213, 9216, 9303, 9324, 9420, LMH-16-5, LW-82-81, MP-89, NP-26, NP-36, NP(RR)-38, NP(RR)-152, NP(RR)-166, NP(RR)-272, NP(RR)-401, NP(RR)-450, NP(RR)-591, PKDL-1, Polf-9, Polf-12, Polf-13, Polf-19, Polf-22, Polf-24, Polf-25, Polf-33, R-849, R-1156, R-966, R-56-6-2, RL-75-6-2, RLC-18, RLC-37, RLC-44, RLC-47, T-51(194)
MR to PM (10.1-25) and MS to AB (25.1-50%)	5/47-2/1-10/10, H-11, H-17, ICAR-4, ICAR-7, ILS-56, ILS-60, ILS-65, ILS-73, J-23, KL-43, L-62, L-106, LC-54, LCK Nos. 11, 152, 241, 863, 8642, 9319, 9406, 9411, 9414, LHCK-69, Lakhimpur-3, LMH-38, LMH-43, Luigd. Mohoba Local, No. 3xRR-45-8, NDL-8809, NP-58M, NP-77, NP(RR)-120, NP(RR)-665, Punjab-T4, R-1, RA-0-1, RL-29-8, RL-39-4, RL-43-5, RL-59-2-2, RLC-33, RLC-34, RLC-40, RLC-43, RLC-46, RLC-48, RLC-55, R-20x4/29, SLS-7, SPS-77/30-3, Silwani, Sirmor (54)

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Short communication

Quality characteristics of some castor, *Ricinus communis* L. hybrids and varieties

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Castor is an important source of industrial oil. Its oil is distinguished from most other oils by its high viscosity, specific gravity and acetyl value. Castor oil consists principally of ricinoleic acid, which occurs to the extent of 90 % and is responsible for the high viscosity and other peculiar characteristic of the oil. The dynamics of accumulation of fatty acids in castor seeds has its own properties. Considerable variations in fatty acids composition have been found due to differences in the variety and the growing conditions (Salunkhe *et al.*, 1991). Looking to the importance of castor oil as a industrial raw material, oil of some released hybrids/varieties i.e., 48-1, GAUC-1, GAUCH-1, GCH-2, GCH-4, GCH-5 and GCH-6 were analysed for oil colour (Lovibond Y+5R units), viscosity (Centipoise at 20° C) Acid value, Iodine value (wijs), Saponification (mg/g) value and ricinoleic acid (%) as per standard methods.

Looking to the data presented in table, oil colour was in the range of 1 - 6. The hybrid GAUCH-1 having the lowest colour value and GCH-2 possessed the maximum value which might due to colour variation of the seed hull. Crude castor oil is yellow to brown in colour. For different industrial utilization colourless oil is preferred. Industrialists can take benefit of low colour value oil. The viscosity of castor oil at 25° C was in the range of 623.7 to 695.3 Centipoise with the lowest in GCH-2 and the highest in GCH-5. The recent released hybrid GCH-6 stood second in viscosity. The hydroxy group of ricinoleic acid imparts a very high degree of viscosity and oxidative stability which was four times more stable than olive oil . The oil is mainly used as a lubricant because of its property to remain liquid at very low temperatures (-32° C), high density and Viscosity (18 times that of other vegetables oil) (Nagaraj, 1995). The acid values of different oils of hybrids/varieties were found to be in the range of 0.56 to 0.90, the maximum being in GCH-5 and the lowest in GAUC-1. Acid value indicates the free fatty acids present in oil. A good quality castor oil should have the acid value within the range of 3-4 (Kulkarni and Ramanamurthy, 1977). Expelled castor oil is generally of low free acidity (< 3) while solvent extracted oils has acid values higher than the required standards. Iodine value was in the range of 75.9 to 83.5. The highest value was recorded in GCH-6 and the lowest in GAUC-1. Iodine value did not correlate with ricinoleic acid content, as other fatty acids might effect on iodine value. As per Indian Standard Specification, castor oil should have the iodine value in the range of 82-90.

Table 1 Quality analysis of castor varieties/hybrids

Quality parameters	Genotypes						
	48-1	GAUC-1	GAUCH-1	GCH-2	GCH-4	GCH-5	GCH-6
Oil colour(G)	3-4	2-3	1-2	5-6	2-3	2-3	2-3
Viscosity	661.7	678.7	644.2	623.7	666.7	695.8	687.5
Acid value	0.75	0.56	0.76	0.71	0.87	0.90	0.65
Iodine value	76.3	75.9	77.4	76.3	79.8	83.1	83.5
Saponification Value	179.4	179.8	180.2	182.2	180.6	179.4	178.6
Ricinoleic Acid (%)	84.1	85.7	85.1	86.3	85.7	86.6	86.8

The saponification value of different hybrids/varieties was in the range of 178.6 to 182.2. The lowest value was noted in GCH-6. Ricinoleic acid was in the range of 84.1 to 86.6. The highest value was recorded in GCH-6. The specificity of castor oil is due to the fact that 81-86 % of it is composed of glycerides of ricinoleic acid (Moshkin, 1986). Ricinoleic acid is characterized by a high molecular weight (298) and low melting point (5° C) (Salunkhe *et al.*, 1991).

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Short communication

Variation in auxin production in the rhizosphere of soybean, *Glycine max* L. (Merrill) genotypes

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Bioproduction of plant growth regulators (PGRs) such as auxins play a crucial role in plant growth and development. Indole-3-acetic acid (IAA) is considered as one of the major auxin-like compounds in the soil and being synthesized from L-Tryptophan (Davies, 1987). Exogenous application of L-Tryptophan increased plant growth and yield and this was attributed to microbial synthesis of IAA, assimilation of IAA by developing roots and its storage/utilization by the plant. As there is no information available on the differential auxin production *vis-a-vis* growth performance of soybean genotypes, an attempt was made in the present study to generate information on variation in auxin production in the rhizosphere of soybean genotypes and its relationship with some pertinent biochemical and growth parameters

A green house study was conducted at National Research Centre for Soybean, Indore. The selected soil belonged to sarol series with following characteristics *viz.*, pH 8.2; organic carbon 4.6 g/kg and clay content 56.2%. The air dried soil was passed through a 2 mm sieve filled in polythene bags and brought to field capacity. Inorganic fertilizer was added at 20:26:17 (N:P:K) kg/ha as urea, single super phosphate and muriate of potash, respectively. Eight inoculated soybean seeds were sown in each bag and after germination three plants were maintained. The treatments were replicated three times and arranged in a complete randomized block design with a control (fallow) included to study the changes in auxin production and other biological parameters in the absence of plants. After 45 days of crop growth, shoots were cut 5 mm above the soil surface and rhizosphere soil was collected from loosely adhering soil on the roots by gentle tapping. Roots were separated carefully from the soil, washed and root length was measured accordingly to the line interception method. Root surface area was determined by using the formula: $2\sqrt{\pi v l}$ where v= volume of roots, l = root length assuming that root is a cylindrical tube with a constant radius. The root volume was determined by the amount of water displaced when roots were immersed in water. Soil samples were sieved (<2 mm) and stored at 5° C until analysis for biological and biochemical characterization. Dehydrogenase activity (DHA), a measure of microbial activity was assayed as per Cassida (1977) and expressed as μ g TPF/g soil/24hr. Microbial biomass carbon (MB-C) and N (MB-N) were determined by the fumigation-extraction method with 0.5 M K_2SO_4. L-Tryptophan derived auxin production was assayed by the method of Sarwar *et al.*, (1992) and expressed as mg IAA - equivalents/kg soil.

There was a significant variation in dry matter accumulation, root/shoot ratio, root surface area, and nodule number and their dry weight among soybean genotypes (Table 1). The rhizosphere of soybean genotypes had higher levels of auxin as compared to non-rhizosphere soils (Table 2). Auxin production increased between 44-182% as compared to non-rhizosphere soils. Rossi *et al.*, (1984) reported a 3-fold increase in IAA content in the rhizosphere soil as compared to non-rhizosphere environment. Among the soybean genotypes, auxin production was found to be higher in MACS 450, NRC 7 and LS 71-05, which could be due to higher microbial activity through increased rhizodeposition as these genotypes had higher root weight and root surface area. Microbial growth in the rhizosphere is often stimulated by the continual input of readily assimilated organic substrates from the roots. Plants transfer large amount of fixed C to the root system and some of these organic compounds can be lost as rhizo-deposition into the soil environment. These organic compounds include sugars, amino acids and organic acids, which may be lost from the roots. Differences in the pattern of root exudation and rhizodeposition in soil by different plant species apparently result in differential effects of on microbial community structure in the rhizosphere an effect which have also been demonstrated between cultivars of the same species (Liljeroth and Baath, 1988). Martens and Frankenberger (1994) also reported differential growth response in wheat genotypes, respectively and attributed this to microbial synthesis of IAA, assimilation of IAA by developing roots and storage/utilization by the plant.

Table-1 Drymatter accumulation, root to shoot ratio, root surface area and nodulation of soybean genotypes (45 DAS)

Genotype	Shoot dry weight (g/plant)	Root dry weight (g/plant)	Root : shoot ratio	Root surface area (cm^2)	Nodule number/ plant	Nodule dry weight (mg/plant)
MACS 450	5.93	1.54	0.26	188	122	350
MACS 124	5.47	1.36	0.25	155	98	380
JS 335	5.29	1.26	0.24	138	85	240
JS 7105	4.68	1.58	0.33	162	104	270
JS 8021	5.64	0.95	0.17	111	78	220
NRC 7	5.84	1.73	0.30	168	93	450
NRC 2	4.25	0.84	0.20	117	58	160
NRC 12	5.95	1.26	0.21	121	62	240
Pusa 22	5.47	1.42	0.26	132	80	220
PK 564	5.26	0.95	0.18	104	70	300
PK 472	5.78	1.15	0.20	148	91	420
LSD (P=0.05)	0.65	0.23	0.01	26	21	100

Table-2 Auxin production and pertinent biological properties in the rhizosphere of soybean genotypes

Genotype	Dehydrogenase (µ g TPF/g soil/day)	Auxin (mg IAA-equivalent/ kg soil)	Microbial biomass carbon (mg C/kg soil)	Microbial biomass nitrogen (mg N/kg soil)
MACS 450	131	148	228	17.8
MACS 124	99	125	204	12.4
JS 335	95	136	209	13.6
JS 7105	117	152	234	21.7
JS 8021	83	94	196	9.3
NRC 7	115	142	244	18.4
NRC 2	88	78	190	12.0
NRC 12	98	104	196	11.4
Pusa 22	103	112	204	13.6
PK 564	87	96	214	11.8
PK 472	93	109	224	17.0
Non-rhizosphere	62	54	176	7.2
Initial	46	44	162	5.9
LSD (P=0.05)	8	14	6	1.9

In the present study, a strong positive association was observed between auxin production in the rhizosphere of soybean genotypes with root weight (r=0.850**), root/shoot ratio (r=0.850**) and root surface area (r=0.865**). This indicated that increased root growth might have resulted in an increased production of auxins as has also been reported by Sarwar and Frankenberger (1994). The IAA production was also positively associated with nodule (r=0.850**) and nodule dry weight (r=0.499*) indicating the involvement of *Bradyrhizobium japonicum* in the production of PGPR like auxins as reported by Antoun *et al.* (1998).

Attempts were also made to relate auxin production to some pertinent biological and biochemical changes in the rhizosphere of soybean genotypes and non-rhizosphere soils. Microbial biomass-C and N in the rhizosphere of soybean genotypes increased between 8 to 39% and 29 to 156% respectively, over the non-rhizosphere soil. Similarly, dehydrogenase activity also increased from 42 to 111% as compared to root-free soil. As in the case of auxins, genotypes, MACS 450, NRC 7 and JS 71-05 also had higher microbial activity compared to rest of the genotypes included in the study. The production of PGPRs as microbial metabolite in soils is often linked to substrate availability. The availability of soluble carbon compounds is believed to be the factor most limiting to

microbial activity in soils and it is generally accepted that growing roots are a significant source of C for microbial biomass. Auxin production in the present study was better explained by its strong positive association with MB-C (r=0.842**) and MB-N (r=0.843**) indicating that auxin is synthesized by proliferating soil microorganisms in response to the presence of suitable substrate. This is further supported by a strong relationship between auxin production and dehydrogenase activity (r=0.902).

In conclusion, the present study revealed that there is a considerable variation in auxin production among the soybean genotypes.

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Short communication

Yield variations caused by source sink alterations in sesame, *Sesamum indicum* L.

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Sesame is indeterminate in growth, as vegetative and reproductive growth continues simultaneously till harvest. Therefore, competition for assimilates between vegetative and reproductive growth was reported to be one of the reasons for low yields of sesame (Saha and Bhargava, 1980). Unlike the capsules formed early, those that are formed during the later stages do not get sufficient time to develop completely, which results in partially filled seeds. Because of the indeterminate growth habit, sesame could recover from loss of leaf/capsule partially or fully from damage caused to foliage or reproductive structures (Sharma *et al.*, 1980; Tewolde *et al.*, 1994). In order to understand the limitations for yield with respect to competition for assimilates between vegetative and reproductive growth, an experiment was conducted with different levels of source and sink.

Eleven treatments consisting of different levels of source and sink were evaluated in a randomized block design with three replications (5 rows of 5 m length comprised one replication) during *summer* season (January to April 1999) with variety YLM – 1 at DOR farm, Hyderabad. The crop was planted at a row to row distance of 30 cm and plant to plant distance of 10 cm. Irrigation was provided whenever necessary. Crop received the recommended dose of fertilizer (30-30-20 NPK kg/ha). P, K and 50% N were applied as basal and remaining N was applied at flowering.

Half of leaves and capsules (treatments 2 and 3) were removed starting from 50% flowering by removing alternate leaf or capsule starting from base and continued till maturity at weekly intervals. Lower levels were not tried as earlier studies indicated no effect on growth and yield (Reddy, 1997). To know the contribution of different order branches to yield, secondary and tertiary branches were removed (treatments 4 and 5) as and when they appeared. Terminal clipping of primary, primary and secondary branches (treatments 6 and 7) was done at 65 days after sowing (DAS) mainly to know whether the diversion of assimilates to existing reproductive sinks could improve yield or not. Starting from capsule formation, the capsules that were formed in the 1st, 2nd, 3rd and 4th weeks (treatments 8, 9, 10 and 11) were removed to understand whether the plant could compensate for loss of capsules formed during that period or removal of some capsules divert assimilates to the rest of capsules so that yield could be improved.

The effect of source sink alterations on different growth parameters, yield and its components are presented in Table 1.

Plant height and Stem weight: Though an increase in plant height was observed in all treatments except 50% leaf removal, differences among treatments were not significant. Similar increases in plant height by different levels of defoliation in sesame (Tewolde *et al.*, 1994) and indeterminate soybean (Hintz and Fehr, 1993) have been reported. Significant increase in stem weight was observed only with removal of 50% capsules indicating diversion of assimilates to vegetative growth when sink is limited. But reduction in stem weight was significant only with 50% leaf removal suggesting diversion of assimilates from stem when source limited. Increase in stem weight was also observed due to early season bud removal or fruit shedding in cotton by Perumal (1996).

Leaf number and Leaf weight: Except with 50% leaf removal, significant reduction in both number and weight was not observed in any of the treatments. In spite of the reduction in leaf number when secondary branches were removed, and terminal clipping of primaries and secondaries was done, leaf weight was at par. Though increase in leaf weight was observed when available sink was limited through removal of 50% capsules and 4th week formed capsules compared to control, it was not statistically significant. Tewolde *et al.* (1994) also reported ability of sesame to recover from defoliation when applied during early stages. Many reports in other crops are also available on increase in leaf weight and leaf number with removal of sink (Wittenbach, 1983; Biswas and Ghosh, 1989; Venkanna, 1989; Craig *et al.*, 1992).

Capsule number and Capsule weight: Even with 50% of leaf or capsule removal, significant reduction either in capsule number or in capsule weight was not observed suggesting that sesame can compensate for loss upto 50% if it occurs at this stage of crop growth. Removal of 50% of capsules stimulated leaf production which is evident from increased leaf number in this treatment and consequent increase in the number of capsules as the capsules appear in the leaf axils. Removal of secondaries, removal of capsules formed during 2nd and 3rd weeks significantly reduced capsule number but not affected weight. Significant improvement in capsule weight was observed only when tertiary branches were removed suggesting they are the strong competitors for assimilates. Though Tewolde *et al.* (1994) observed similar results, Biswas and Ghosh (1989) reported that fruit removal from 70 day old plants significantly affected seed yield per plant in sesame.

Total Dry Matter (TDM): Total dry matter increased significantly by 25% compared to control with removal of 50% capsules and also 4th week formed capsules as a result of increase in weight of leaf, stem, and capsule. In indeterminate soybean also increase in TDM was observed with decreased sink size (Prasad, 1983).

Seed yield: Significant reduction in seed yield was observed only with removal of secondary branches (36 % reduction) clearly indicating that they are the main contributors of yield. Sesame could compensate for loss of leaf /capsule upto 50% if the loss occurred from flowering. Removal of tertiary branches and terminal clipping of primary and secondary branches 65 DAS, and removal of capsules formed between 60-67 DAS (4th week), increased seed yield significantly which showed that there is competition for assimilates at the later stages of crop growth i.e., seed filling. Saha and Bhargava (1980) also reported competition for assimilates between stem and capsules at the beginning of grain filling period as both continued to grow. However, capsule development is dependent on the availability of current photosynthates rather than stored assimilates (Narayanan and Balakrishna Reddy, 1982). Therefore, arresting vegetative growth 60 DAS helped in diversion of assimilates to reproductive sinks which is evident from high HI and shelling percentage in the above treatments.

These results suggested that sesame can compensate for loss of leaf or capsule even up to 50% if it occurs from flowering. Removal of tertiary branches as and when they are formed, terminal clipping of primary and secondary branches 65 DAS, and removal of capsules formed between 60-67 DAS (4th week), increased seed yield significantly. Cessation of vegetative growth 60 DAS helps in diversion of assimilates to reproductive sinks. This clearly indicated that source is not a major limiting factor for yield in sesame and competition for assimilates occurs only during seed filling period. This suggested the possibility of improving sesame yield by breeding for *determinate types*.

Table 1 Effect of different levels of source and sink on partitioning of drymatter and seed yield per plant

Treatment	Plant height (cm)	Leaf No.	Leaf weight (g)	Stem weight (g)	Capsule No.	Capsule weight (g)	TDM (g)	Seed yield (g)	HI (%)	Shelling %
Control	85	76	4.6	10.3	57	13.9	28.8	4.2	15	30.1
50% leaf removal	75	55	2.7	6.7	57	11.1	20.4	3.9	19	35.2
50% capsules removal	90	86	6.1	13.6	52	16.4	36.0	4.2	12	25.5
Removal of secondaries	99	52	4.6	8.9	36	10.8	24.3	2.7	11	26.7
Removal of tertiaries	96	71	3.6	10.2	68	17.3	31.1	7.2	23	41.5
Terminal Clipping of Primary	80	62	4.1	10.5	72	12.1	26.7	4.2	16	34.7
Terminal Clipping of Primary and Secondary	91	52	4.6	12.3	54	15	31.9	6.3	20	42.2
Removal of 1st week Capsules	91	76	4.1	10.8	48	13.7	28.6	4.0	14	29.2
Removal of 2nd week Capsules	87	60	4.1	10.0	38	11.2	25.3	3.1	13	28.8
Removal of 3rd week Capsules	87	60	4.1	10.9	36	12.7	27.7	3.7	14	29.8
Removal of 4th week Capsules	92	60	6.1	13.0	55	16.8	35.9	5.9	16	35.1
Mean	89	65	4.4	10.8	52.2	13.7	28.9	4.5	16	32.6
CD (P =0.01)	16.5	15.8	1.92	2.83	16.0	3.28	5.84	1.12	4.3	10.67
C V (%)	10.8	14.4	18.6	11.2	18.1	10.3	8.6	10.8	12	14.1

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Short communication

Effect of Cycocel on safflower, *Carthamus tinctorius* L. growth and yield under rainfed Vertisol conditions

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Plant growth regulators can be considered as new generation agrochemicals after fertilizers, pesticides and herbicides. These are chemical substances, when added in low doses, modify the growth of plants usually by stimulating (growth promoters) or inhibiting (growth retardants) part of the natural growth regulatory system. The role of growth retardants in modification of plant growth and development has been extensively studied (Bhattacharjee and Gupta, 1984). Literature revealed that the time of application with respect to growth stages of plant (Kamp and Nightingale, 1979) and concentration of chemical (Lovette and Orchard, 1974) play an important role on growth modification and yield. Safflower is an important oilseed crops commonly grown under residual moisture situations in Vertisols. Under such conditions, it is imperative to use the major part of available soil moisture for reproducive growth to get higher yields. Growth retardants can play an important role in achieving this objective. In the light of this, the present experiment was undertaken to study the effect of cycocel on growth and yield of safflower.

The field experiment was conducted at Agricultural Research Station, Annigeri (Karnataka) during *rabi*, 1999-2000 under rainfed conditions. The soil of the experimental site was deep black (Vertisols) with 8.1 pH, having low available N (251 kg/ha), medium in P_2O_5 (14 kg/ha) and high in K_2O (675 kg/ha). The experiment was laid out in Randomized Block Design with three replications. The treatments comprised two concentrations of cycocel (500 and 1000 ppm), two growth stages (flower initiation and 50% flowering), water spray at two growth stages and compared with a control. Safflower cv. A-1 was sown on 3rd October, 1999 and the crop was raised by following the recommended package of practices. The spray schedule was followed as per the treatments. The total rainfall received was 446 mm, as against the normal of 661 mm which was 32% less than the normal. At harvest, the growth and yield observations were recorded from five randomly selected plants in each treatment and were statistically analysed. The economics were worked out based on the prevailing market prices.

Foliar application of cycocel showed a significant effect on drymatter production/plant, growth, yield components and yield of safflower. It was clearly observed that all the cycocel sprayed treatments recorded lesser plant height, drymatter production and biological yield compared to water spray and control. Spraying of cycocel @ 500 ppm at 50% flowering stage recorded significantly lower plant height (58.0 cm) compared to water spray and control. The least drymatter production/plant (74.1 g) was recorded in cycocel @ 500 ppm sprayed at flower initiation stage compared to others (Table 1). This could mainly be attributed to inhibition of endogenous auxin transport and inhibition of apical dominance. Similar results were reported by Kar *et al.* (1989). Though there was no significant difference in seeds/capitulum and branches/plant, cycocel spray @ 500 ppm at 50% flowering stage recorded maximum seeds/capitulum (32.2) compared to other.

The maximum capitula/plant (32.2) and 100-seed weight (6.7 g) was recorded with 500 ppm cycocel sprayed at 50% flowering and they were lowest in water spray and control. These results are in conformity with the findings of Deotale *et al.* (1994). There was an increase in harvest index ranging from 17.4 % in control to 24.2 % in cycocel sprayed @ 500 ppm at 50% flowering (Table 1).

Foliar application of cycocel @ 500 ppm at 50% flowering recorded significantly higher seed yield (732 kg/ha) compared to rest of the treatments, the increase being 18% over control due to more capitula/plant and 100-seed weight. Deotale *et al.* (1994) reported the similar results in safflower. According to Suo and Wu (1990), growth retardants like TIBA and B_9 have regulating effects on the transport rate of assimilation products between source and sink causing yield increase. The economics followed the similar trend. The same treatment recorded significantly higher gross returns (Rs. 8047/ha) and B:C ratio (1.45) over water spray and control. Significantly higher oil content (29.5 %) and oil yield (216 kg/ha) was recorded with same treatment.

Table 1 Growth, yield components, yield, economics and oil content of safflower as influenced by cycocel application

Treatment	Plant height (cm)	Branches/ plant	Capitula/ plant	Seeds/ capitulum	100-seed weight (g)	Drymatter production at harvest (g/plant)	Biological yield (kg/ha)	Harvest index (%)	Seed yield (kg/ha)	Gross returns (Rs/ha)	B:C ratio	Oil content (%)	Oil yield (kg/ha)
Cycocel spray @ 500 ppm at flower initiation	59	11.9	30	28	5.9	74.1	3178	21	680	7479	1.4	27.5	187
Cycocel spray @ 500 ppm at 50% flowering	*58*	*11.4*	*32*	*30*	*6.7*	*98.3*	*30.23*	*24*	*732*	*8047*	*1.5*	*29.5*	*216*
Cycocel spray @ 1000 ppm at flower initiation	61	11.7	29	27	5.9	97.1	2995	24	708	7790	1.0	28.3	200
Cycocel spray @ 1000 ppm at 50% flowering	62	10.2	26	28	5.7	102.3	3272	22	706	7768	1.0	27.6	195
Water spray at flower initiation	62	11.4	22	26	5.7	107.9	3452	18	617	7035	1.1	28.2	174
Water spray at 50% flowering	64	11.2	20	24	5.7	103.7	3217	19	615	6768	1.1	28.6	176
Control	63	11.3	19	27	5.7	137.6	3558	17	619	6807	1.1	28.6	177
SEm±	1.3	0.9	1	1.1	0.1	1.2	91	0.7	5	119	-	0.1	2
CD (P=0.05)	4	NS	3	NS	0.4	3.8	282	2	17	366	-	0.4	6

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Short communication

Stress management in insect pests on oil palm, *Elaeis guineensis* Jacq.

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Oil palm, *Elaeis guineensis* Jacq is infested with comparatively few pests during the first, few years of its growth. However, as the age increases, the plantation becomes more congenial environment for the development of various insect pests. Of these, leaf-eating lepidopterons are important pests that cause direct stress on the palms in way of reduction of FFB yields. Moderate to heavy defoliation by these pests resulted into crop losses in excess of 40-50% (Liau Siau Suan and Awl, 1993). A wide spread attack by a defoliator can cause yield losses of as much as 50% during 4-6 months after attack. Full recovery of severely infested area can take several years. Wood *et al.* (1973) reported that defoliation of upper half of the crown of leaves had greater detrimental effect than of the lower half. Total defoliation of middle upper part caused a marked drop in yield during the next two years with 45% in the first year alone. McKenzie (1977) estimated yield reduction upto 10-25% due to psychid and limacodids in Sumatra. In Sabah, Malaysia, Hoong and Hohchristopher (1992) determined a reduction of 27t of FFB during the 30 months period following a defoliation of 60%. In India, the after effects of the defoliator infestation on oil palm was however, not quantified in earlier studies. The result of the attack is predicted as the loss of chlorophyll content which is responsible for the growth of the palms and thereby the yield. This ultimately results into low FFB production and the yield loss. In the present study incidence of leaf eating caterpillars on oil palm and their effect on the yield levels was studied in 10 years old gardens.

Random survey was carried out in the oil palm orchards of Krishna, Vizianagaram, Visakhapatnam and West Godavari districts of Andhra Pradesh during 1995-2002 to find out the incidence of insect pests on different aged palms. In each village at least two orchards with 20 palms/orchard were surveyed. Observations on number of leaves infested with the particular pest were recorded for each palm. For the leaf webber and slug caterpillar, observations on number of larvae present on the 25th leaf and for bagworms, number of bags present on the 19th leaf were taken up.

Case studies were carried out to observe the yield losses due to pest attack by selecting two leaf eating caterpillar infested gardens (10 years old) in Billanapalli village of Krishna District of Andhra Pradesh. The leaves of adjacent palms were intermingling with each other. Both the gardens were at their peak yielding stages. Leaf eating webber attack was observed in both the gardens during the month of January, 1999. Data on FFB yield was collected for the preceding as well as following years of attack to draw the yield losses due to these pests.

Psychid, *Metisa plana* (Psychidae : Lepidoptera), leaf webbers, *Ambadra* sp. (Notodontidae : Lepidoptera) were observed as endemic pests where as incidence of limacodid, *Darna catenatus* was observed for the first time during 1999 in West Godavari district. The stress due to defoliation by these pests resulted into yield loss, which continued for two to three years after attack. Control measures (root absorption techniques) that were taken immediately after the attack led to the effective control of the pests. Even after that the resultant effect on the yield could be seen for next 18 months period. However, not protected gardens at correct time showed prolonged yield loss for more than two years.

Scenario of the infested gardens: Heavy incidence of leaf eating webbers (more than 10 caterpillars/leaf let) as holes on leaves was observed during January, 1999. Monocrotophos at 10 ml mixed in 10 ml water was applied as root absorption technique after 5 days of attack. The pest was effectively controlled within two days of the treatment implant. However, quite low yield levels i.e., 17.87 q/ha were observed in the subsequent years with a yield loss of 6.6 tonnes representing 27% yield reduction. This was calculated based on the yields (24.5 t/ha) obtained during the year of attack (1999-00). Same yield would have been obtained had the orchard been free of pest attack, as oil palm continues to produce the peak yield for 10 years i.e., during 8th to 18th year after planting.

The yield reduction continued in the second year after attack with a loss of 5.9 tonnes (24%) compared to the initial year observations. However, there was a slight increase in the yield (18.6 t/ha) compared to the previous

year which was the result of control measures applied and the reduction of pest population. This caused slight increase (4.2 %) in yield reduction compared to the previous year. However, during this year again heavy incidence of leaf webber outbreak was observed. This resulted into low yields (12.5 t/ha) till the end of December, 2002 which was the compound effect of first attack and second attacks. This resulted to the yield losses of 12 t/ha increasing the reduction to 49% over the base year and 32.9% compared to the previous year (Fig.1). The yield change (22.5) was positive during 1999-00 when compared with the previous year yields. This was due to the inherent character of the oil palm. Leaf eating caterpillar incidence during 1999, caused a negative change (27%) in the yield during next year (Fig.2). Control measures taken against the pest well in time resulted into the decrease of infestation with increase in the yield though at lower rate causing positive change (4.2%). This indicated that the palms took nearly two years to recover from the pest incidence and rejuvenate from the attack.

The yield performance of the second experimental garden was found steadily progressing before the pest attack with 19.1 t/ha during 1998-99 and 22.5 tonnes during 1999-2000. With the outbreak of pest incidence during January, 2000 the plantation recorded severe defoliation. There was a delay of 20 days in taking up the control measures, which resulted the pest to reach to middle whorl. This caused heavy reduction in the yields with 19.4 t/ha and 17.3 t/ha with a reduction of 3.1 t and 5.3 t, respectively during the first and second year after attack. In this garden, the yield levels did not show any positive trend as observed in the other plot. Since the farmer has initiated the control measures very lately, this enabled the pest to reach the middle whorl of leaves causing heavy defoliation. Thereby, the yields were lower during third year after attack. However, the per cent change was comparatively less in this garden during the third year after attack which could be due to non-recurrence of the pest attack as was seen in the other orchard.

The yearwise per cent change was however found negative during all the three years indicating the palms could not recoup from the pest attack even after three years (Fig.3). This can be attributed to the severe initial attack of the pest followed by delay in implementing control measures. This allowed the pest to reach to the upper half of the crown which resulted into heavy drop in yield. Similar observations were recorded by McKenzie (1977) in Honduras, where the defoliators caused losses for nearly three years after attack which is in accordance with the present findings. Likewise, Hoong and Christopher (1992) determined a reduction of 27t of FFB during the 30 months following a defoliation of 60% in Malaysia.

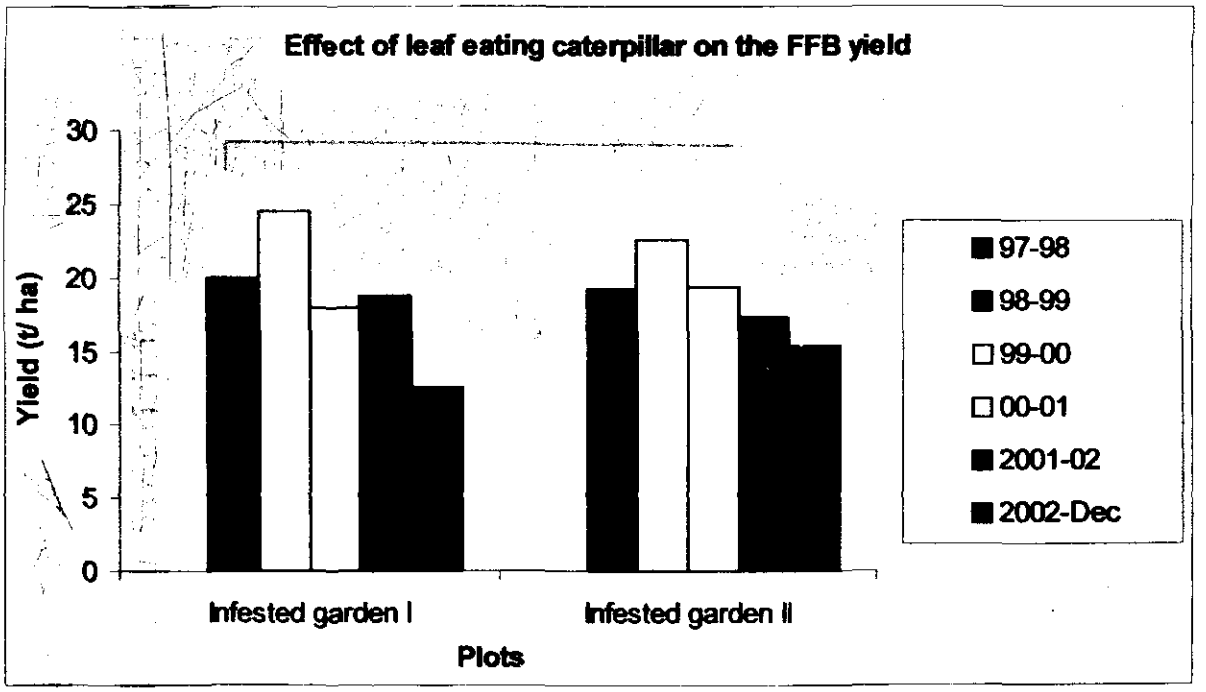

Fig-1 Effect of leaf eating caterpillar damage on the oil palm FFB yield

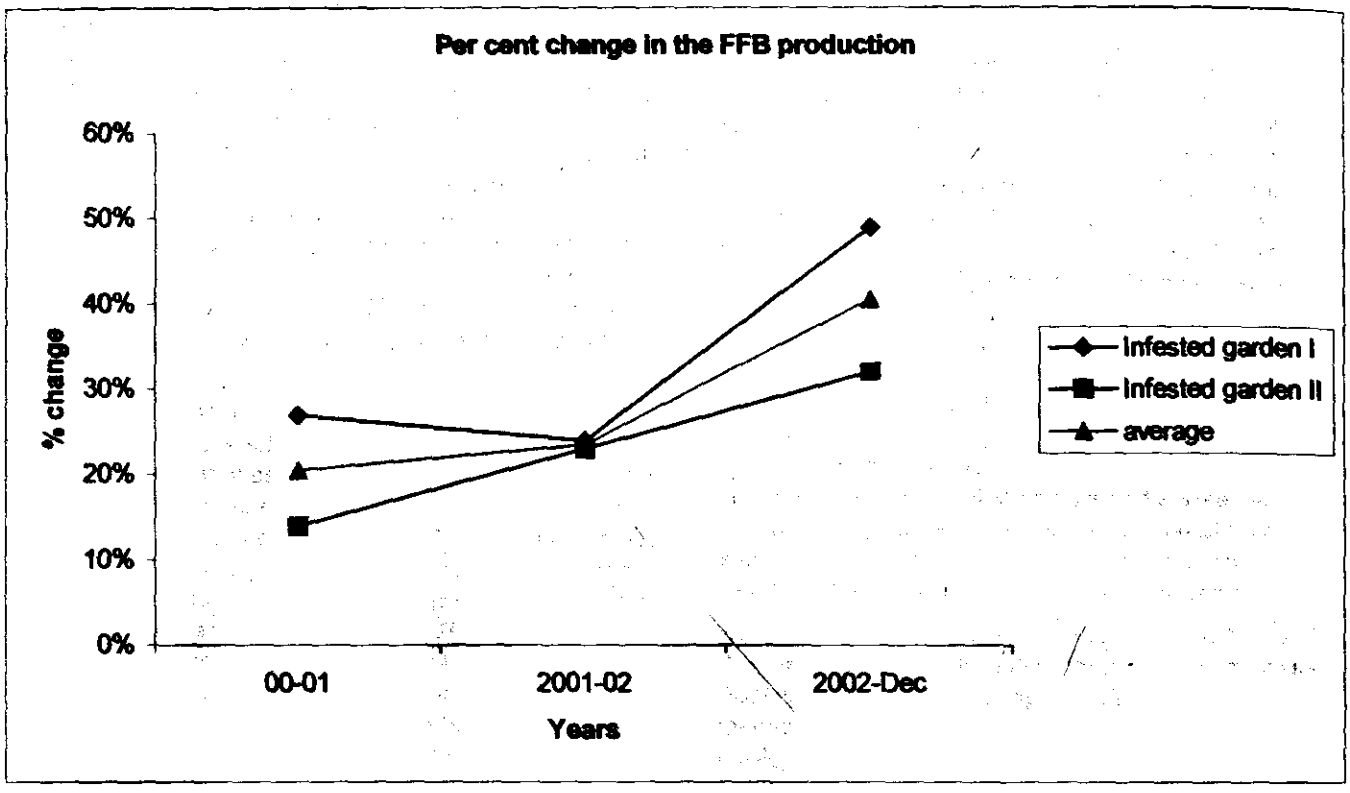

Fig-2 Per cent change in the FFB production (based on the 10th year (1999-00) yield)

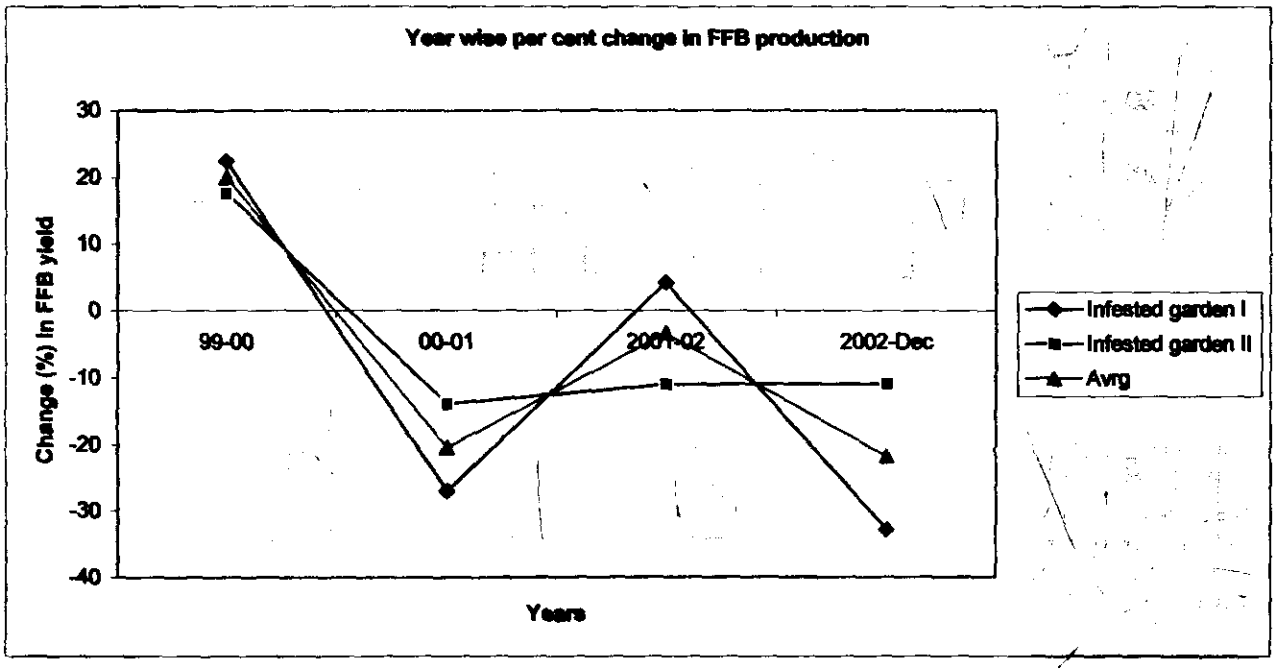

Fig-3 Year wise change (%) in the FFB production (based on the previous year yields)

In India, severe infestation of leaf eating caterpillars namely psychid, leaf webbers and slug caterpillars on oil palm was observed for the first time during, 1999. Moderate incidence of leaf eating caterpillars particularly the leaf webbers caused yield losses upto three years after the attack. Control measures in the form of root absorption techniques effectively controlled the pest infestation. Control measures applied immediately after the pest outbreak caused low impact on the yield losses. Delay in the implementation of the control measures resulted into severe defoliation with reduced yields for nearly three years.

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