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Review article

Centres of origin and genepool diversity in edible oilseeds : A global perspective

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Abstract

Edible oilseed crops include 10 major and minor crops that are ancient domesticates in the 12 world centres of diversity. Diversity is high in most of these crops, associated with sympatric distribution with related wild species and introgression resulting in build-up of diversity. *Sesamum* and *Glycine* are probably the exceptions where domestication has occurred outside the primary centre of concentration of wild species. The long history as domesticates is reflected in distinct primary genepools in each of the crop groups. Moreover, these show build-up of secondary and tertiary centres of diversity in adjacent regions. The edible oilseed crops represent systems where the demand for crop improvement is high and diversity required for this is available in the farmers' fields. Only a part of this is represented in *ex-situ* storage. Areas with high build-up of diversity would be important for *in-situ* conservation of diversity. Working out progenitor species and complexity of relationships between the crop and wild species and among the latter needs to be done using tools of biosystematics.

The oil quality and quantity of oilseeds are amenable to rapid change through breeding. To meet ever-increasing demands of the food industry, the crop base needs to be widened. A wide array of potential edible oilseed species have also been discussed. Overall strengthening of the work at a national level on such alternative sources of edible oilseed plants is envisaged following which selected plants may be added to the list of globally important crops of edible oilseeds.

Key words: Oilseeds, edible, genepools, diversity, centres, conservation

Introduction

Plants yielding oils have been in use since the distant past both for edible oils and for other multipurpose uses (Weiss, 1983; Robbelen *et al.*, 1989; Zohary and Hopf, 1993). Several of these are ancient domesticates. Their antiquity is corroborated by archaeological findings and other substantiating evidences (Bedigian and Harlan, 1986; Damania *et al.*, 1998). Edible oilseeds/oil crops constitute a major group of cultivated plants. The group is composed of over one tenth of the major oilseed crops originating both in the Old and New Worlds largely in tropical habitats except for sunflower and possibly some *Brassicas*. This paper deals with the geographical origin and distribution of species diversity in edible oilseed plants; and the genepools in oilseed crops and related wild species particularly in the primary centres which hold rich native diversity that has not been well collected, studied and exploited vis-à-vis conserved. Such information is also presented in diversity existing in secondary/ or tertiary centres. It also attempts to point out use of wild genepools in crop improvement. A synthesis is also presented on the major *ex-situ* collections held at various institutes located in primary and secondary centres of diversity of these oilseed crops, presenting a global scenario on the total extent of diversity in major oilseeds conserved/maintained at different locations. Need for basic studies in oilseeds and understanding diversity in areas of crop origin and domestication is stressed, and concern highlighted for its conservation. Implementing on-site measures to mitigate the impact of genetic erosion by priority-collecting and *in-situ* approach and through complementary conservation strategies is suggested.

Global diversity in oilseeds

The Dictionary of Economic Plants (Uphof, 1959) reported about 138 species of annual and perennial plants providing diverse kinds of oils used for cooking/ edible

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purposes, for medicine and indirectly used for other purposes. The edible oils come from diverse plant families. Several of these such as the Cruciferae/Brassicaceae (rapeseed/mustard), Compositae/ Asteraceae (sunflower, safflower, niger), Leguminosae/Fabaceae (soybean, groundnut), Palmae/Arecaceae (coconut, oil palm), Linaceae (linseed), Oleaceae (olive), Pedaliaceae (sesame), Malvaceae (cotton), are considered more important (Simmonds, 1976; Robbelen *et al.*, 1989). Table 1 presents this diversity numbering over 115 species which may be categorised into the major groups: major oilseeds which are well-known for their commercial value, with other relatively minor oilseeds under cultivation and gaining importance, and species of potential value, presently less-known but locally used and deserving study for exploiting diversity for better economic use (Uphof, 1959; Simmonds, 1976; Zeven and de Wet, 1982; Weiss, 1983; Robbelen *et al.*, 1989). For each category, the species are arranged alphabetically, and major use/economic importance is indicated.

A: Major and Minor Oilseeds

Centres of origin and domestication, genepool components and distribution of diversity

Oilseed crops have originated in the distant past, as is evident from the archaeological and ethnological data available. These include crops of both Old and New Worlds (Zeven and de Wet, 1982). Synthesis of information on centres of origin, domestication and development of secondary diversity in major edible oilseed crops is presented in Table 2. Despite the importance of oilseeds for food, the relative neglect of this group of crops in the global scenario is brought out from this analysis. One or the other oilseed crop has been domesticated in each of the larger landmasses. *Helianthus* and *Arachis* are native of North and South America, respectively, *Brassica* is native to the Mediterranean region and European area, *Guizotia*, and *Sesamum* in the African and the Indian regions, and *Glycine* and *Cocos* in the Chinese and Australian regions, respectively. Majority of these crops are therefore domesticates of the Old World. They are mostly crops of the tropical region grown in marginal lands and by small farmers in impoverished areas. Primary centre of diversity of the genus is noted in the same region as that of the crop with few exceptions, such as *Cocos*, *Glycine* and *Sesamum*. *Brassica* is one crop widespread and with multiple centres of diversity. For others, secondary centres of diversity are noted in adjacent regions; China, India and European regions adjoining the Mediterranean region have secondary centres of diversity for maximum number of species. Adoption in newer climates and habitat situations is yet to be done for the majority of the crops. The wild counterparts or related wild species usually occur in open disturbed habitats (Vavilov, 1951; Zeven and de Wet, 1982). Table 3 presents the synthesis of such information determining the centres of origin and development of primary and secondary centres of diversity in major edible oilseed crops; the location of these along with wild genepool in twelve centres of diversity of cultivated plants (Zeven and de Wet, 1982). A brief account for the major and minor oilseed crops is given below.

Arachis hypogaea (Groundnut)

Arachis hypogaea is an old domesticate dating back to 3000 BC or earlier (Simmonds, 1976; Smartt, 1990). Originating in the area southeast of Peru, secondary centres have developed within the same region (in Argentina and Bolivia), and tertiary centre in Congo in West Africa (Zeven and de Wet, 1982; Stalker, 1992). The *Arachis* genepool is composed of several species of which 20 have so far been described. Both the area of domestication and distribution of wild species occur in South America. The species occur over a wide range of habitat conditions ranging from arid to semi-aquatic conditions. Several species of section *Arachis* occur here apart from *A. hypogaea*, namely *A. monticola, A. batizocoi, A. cardensii, A. chacoense, A. correntina, A. helodes, A. duranensis, A. ipaensis, A. villosa;* several of these occur in northwest Argentina. *A. monticola* may have a common parent with *A. hypogaea*. Supportive evidence from isozymes, RAPDs, seed storage proteins and chloroplast DNA suggests that *A. duranensis* may be the parental species (Moss *et al.*, 1989; Smartt, 1990).

During subsequent adaptation and diversification of the crop, a great deal of variability in plant habit and seed characters has accumulated so that valencia, spanish and fastigiata types show restricted distribution and small areas of independent domestication and variation within each group.

Brassica: oleiferous species (Rapeseed and Mustard)

The oleiferous Brassicas belong to two groups, the rapeseeds and the mustards. Five cultivated species are important; *B. campestris* and *B. napus* in rapeseeds, and *B. juncea, B. nigra* and *B. carinata* in mustards (Simmonds, 1976; Weiss, 1983; Robbelen *et al.*, 1989; Chatterjee, 1992).

Rapeseed: *B. campestris* has the widest distribution among the oleiferous species of *Brassica* with a primary centre of diversity in the Indian gene centre, namely in the Himalayan region (Hedge, 1976). Diversity build-up is related to geographical location. The oldest among these is the brown *sarson* (*toria* and *lotni* forms). Yellow *sarson* (more related to *toria*) yielding higher oil is represented by two-valved erect forms which are more commonly available than the pendent and many-valved forms, the variety *toria* including the *B. tournefortii* group (Simmonds, 1976; Chatterjee, 1992).

Multiple domestication is indicated by differences in morphology and oil composition in the Asian and European regions, considered to be secondary centres of diversity (Zeven and de Wet, 1982; Robbelen *et al.*, 1989). *Brassica napus* originated in southern Europe near the Mediterranean region where the parental *B. oleracea* occurred. During spread to Asian region (1900s), it showed build-up of diversity through introgression and crossing with the local *B. campestris* particularly in the Chinese region. Variety *silvestris* of *B. campestris* is a weed of the Asian, European and North African regions (Simmonds, 1976).

Mustard: This group includes *B. nigra*, which has been cultivated, since ancient times initially widespread in use as a condiment and spice (Zeven and de Wet, 1982). Hemingway (1976) has suggested its centre of domestication to be in Asia Minor or Iran. It shows variation in erect to semi-erect pattern growth but has not been drastically modified since domestication. It is the parental species of *B. carinata* (x *B. oleracea*) restricted to Ethiopia and North Africa. However, build-up of diversity has occurred in more than one centre; and within the secondary centres of diversity through crosses with local *B. campestris* (or *B. nigra*) in the Chinese, northeastern India and Caucasus regions (Chatterjee, 1992).

The variability in wild forms of *B. oleracea*, *B. campestris* and cultivated species are all important in build-up of the *Brassica* genepool. Also among the wild species used for incorporating desirable traits into the crop genepool, species/related genera *Sinapis*, *Raphanus*, *Diplotaxis*, *Eruca*, *Moricanda* and *Lesquerella* (mostly of Mediterranean region) have been considered significant.

Carthamus tinctorius (Safflower)

Ashri and Knowles (1960) placed the centre of origin of safflower in the Near East because of the similarity of cultivated safflower to the closely related wild species- *C. persicus* (*C. flavescens*) found in Turkey, Syria and Lebanon; and *C. palaestinus* found in deserts of North Iraq and Israel. In this region, introgression may have occurred between the cultivated and wild types. Great variation occurs in the Afghanistan area within the distributional range from Middle East towards Pakistan. The crop is grown in many areas of the Old World and in North America.

Imrie and Knowles (1971) suggested that the weedy species *C. persicus* and *C. oxyacanthus* and the cultivated *C. tinctorius* are derived from the weedy species *C. palaestinus*. The four species are introgressible, producing fertile hybrids. Introgression of the weedy and cultivated species may still occur in natural conditions (Zeven and de Wet, 1982).

The Indian region is a secondary centre of diversity for safflower, and the crop is old in this region (10th century). Several sub-centres of diversity have been described in Europe, the Far East, Ethiopia, Egypt, Sudan and introgression of prevalent diversity through breeding programmes has been possible.

Carthamus genepool is composed of over 15 species; annual species are largely distributed in central and west Asia. The distantly related groups are composed of *C. curdicus*, *C. gypsicola*, *C. oxyacanthus*, *C. palaestinus*, *C. persicus* (*C. flavescens*) and *C. tinctorius*. *C. nitidus* seems to be isolated from these. Section Odonthagnathius includes *C. boissieri*, *C. dentatus*, *C. divaricatus*, *C. glaucus*, *C. leucocaulos* and *C. tenuis*; and section Atractylis includes *C. lanatus*, *C. creticus* (*C. baeticus*), and *C. turkestanicus*. These species also differ in their ploidy levels.

Wild genepool of species such as *C. lanatus*, *C. oxyacanthus* and *C. palaestinus* have been identified as good sources of resistance or tolerance to various diseases and pests (Kumar and Agrawal, 1989). Drought hardiness and resistance to alternaria leaf blight have been partly incorporated into cultivated types through repeated backcrossing and selection.

Cocos nucifera (Coconut)

Cocos nucifera on the basis of variation in small-fruited forms, multitude of local names and maximum uses in southeast Asia, and fossil evidences (in New Zealand) is considered native to parts of Australia (Robbelen *et al.*, 1989). Due to the littoral habitat and distribution by sea it is pantropical in distribution. Variability in oil-yielding plants is of taller types *typica* and dwarf types *nana* and hybrids between them through breeding programmes.

The genus is monotypic; other species (30) of tribe Cocoideae occur in Central and South America. Interestingly several neotropical palms of potential value are also available in these regions such as *Orbignya*, *Jessenia*, etc.(Uphof, 1959; Pareek *et al.*, 1998).

Elaeis guineensis (Oil palm)

Elaeis guineensis is native to the African region with great variation in shape of fruit, appearance of trees and productivity of fruit bunches in Africa. The species is distributed in the coastal belt from Sierra Leone to Angola where wild and semi-domesticated diversity occurs. Great variation is noted in fruit shape, size, bearing, etc. The western and central parts show high variation within populations but differences have been recorded between the two areas substantiated by biochemical evidences (Robbelen *et al.*, 1989). Cultivation has spread to the Far East (one and a half centuries ago) of the *dura* plant type with few large bunches of fruits, showing homogenous maturation and low vertical growth. The oil palm has been domesticated only at a few places. Large plantations are found in Africa, Southeast Asia and Central America (Zeven and de Wet, 1982).

E. oleifera with lower vertical growth is distributed in Central America, Colombia and in the Amazon area. It has been crossed with the African oil palm producing partially fertile hybrids. *E. odora* is another less-known oil palm species (Zeven and de Wet, 1982).

Table 1 List of major and minor edible oilseed crops and other potentially important oilseed plant species

Genus	Species	Family	Oil characteristics
Major and minor oilseed crops			
Arachis	*A. hypogaea*	Fabaceae/ Leguminosae	Oil lacking flavours after cooking, good keeping quality. 43% oil (42-52%), good source of Vit. E
Brassica	**B. campestris* *B. carinata* **B. juncea* *B. nigra* *B. napus*	Brassicaceae/ Cruciferae	Mustard/Rapeseed oil, linoleic acid from 3-10% 40% oil on dry weight basis
Cannabis	*C. sativa*	Cannabinaceae	Oil used for culinary purposes locally
Carthamus	*C. tinctorius*	Asteraceae Compositae	Oil with high levels of oleic and linoleic acids makes it closer to olive oil.
Cocos	*C. nucifera*	Arecaceae/ Palmae	65-72 % oil, in seed
Elaeis	*E. guineensis* *E. oleifera* *E. odora*	Arecaceae	Edible oil rich in carotene. Comparable to better grade cod liver oil.
Eruca	*E. sativa*	Brassicaceae	Oil used in pickling and mixing in mustard oil.
Glycine	*G. max*	Fabaceae	Oil 20% of seeds. Linoleic acid 3-8%
Gossypium	*G. barbadense* *G. herbaceum* *G. hirsutum* etc.	Malvaceae	Substitute for lard, margarine, cooking, salad oil
Guizotia	*G. abyssinica*	Asteraceae	Oil, having sweet/ pleasant aromatic odour, 52-75% linoleic acids
Helianthus	*H. annuus*	Asteraceae	Premium oil on basis of odour, flavour. High linoleic acid (90% of total oils)
Linum	*L. usitatissimum*	Linaceae	Cooking medium on a local scale
Olea	**O. europaea* *O. ferruginea* *O. glandulifera*	Oleaceae	Chiefly used as salad oil. Greenish- yellow oil resembles sesame oil. Quality and use is based on its acidity
Papaver	*P. somniferum*	Papaveraceae	Used for culinary purposes and manufacture of margarine
Sesamum	**S. indicum*	Pedaliaceae	Stable oil. 47% oleic acid and 39% linoleic acid with anti-oxidant sesamol
Sinapis	*S. alba*	Brassicaceae	White mustard oil source of 'hot' principle
Zea	*Z. mays*	Poaceae/Gramineae	'Hidden' oil, potential for human consumption
Potential oilseed plant species			
Acrocomia	*A. aculeata* *A. totai*	Arecaceae	Kernel rich in oil (35-60%) identical to coconut oil. 27.9 % fat in edible part.
Actinodaphne	*A. hookeri*	Lauraceae	Pisa oil. Good substitute for coconut oil
Aisandra	*A. butyracea*	Sapotaceae	Substitute for cocoa butter, ghee. Oil with good keeping quality (42-47%)
Argania	*A. sideroxylon* *A. spinosa*	Sapotaceae	Argan oil, used like olive oil
Astrocaryum	a) *Aculeatum* *A. jauari* *A. murumuru* *A. tucuma* *A. vulgare*	Arecaceae	Oil from fruit (33-40%) is like that from *Jessenia*

Table 1 (Contd...)

Genus	Species	Family	Oil characteristics
Attalea	*A. agrestris* *a) cohune* *A. excelsa* *A. funifera* *a) oleifera* *A. spectabilis*	Arecaceae	Edible oil from kernels
Bactris	*b) minor* *B. gasipaes*	Arecaceae	Source of Pupunha or peach palm oil
Bertholletia	*B. excelsa*	Lecythidaceae	65% fat in edible part
Buchanania	*B. lanzen*	Anacardiaceae	Chironji oil, substitute for olive and almond oils in confectionary
Butia	*B. capitata*		Minor source of oil
Butyrospermum	*B. parkii*	Sapotaceae	Greenish-yellow fat from seeds, pleasant odour and taste (50%). Substitute for cocoa butter, in chocolate manufacture, cooking medium
Canarium	*C. indicum* *C. ovatum* *C. schweinfurthii*	Burseraceae	73.2-75.9% oil from kernels
Carya	*C. illinoensis*	Juglandaceae	71.5% fat in kernels
Caryocar	*C. amygdaliferum C. brasiliense* *C. nuciferum* *C. tomentosum* *C. villosum*	Caryocaraceae	Suari fat from seed. Fruit pulp and kernels rich in edible oil (67/70%)
Caryodendron	*C. orinocense*	Euphorbiaceae	Oil (45-54%) from nuts
Ceratotheca	*C. sesamoides*	Fabaceae	Oilseed crop
Corylus	*C. avellana* *C. sieboldiana*	Betulaceae	50-60% golden yellow fat of pleasant odour
Couepia	*C. longipendula*	Chrysobalanaceae	Oil from kernels
Coula	*C. edulis*	Olacaceae	Oil from kernels
Cucurbita	*C. foetidissima*	Cucurbitaceae	Polysaturated edible oil. Compares favourably with soybean/ groundnut oils
Dacryodes	*D. edulis*	Burseraceae	Fruit pulp oil suitable for commercial production of cooking oil/ margarine
Dipteryx	*D. odorata*	Fabaceae	Tonka beans; oil from kernels
Euterpe	*E.edulis / E.oleracea*	Arecaceae.	Oil from kernels
Fagus	*F. orientalis*	Fagaceae	Oil of good quality from kernels
Garcinia	*G. cambogia* *G. indica*	Clusiaceae/ Guttiferae	Kokum butter (31%), white fat of good quality, substitute for cocoa butter 23-26% fat (*G. indica*)
Hesperia	*H. matronalis*	Brassicaceae	Edible oil used locally
Hodgsonia	*H. heteroclita*	Cucurbitaceae	Seed oil for cooking
Irvingia	*I. gabonensis*	Irvingiaceae	Substitute for cooking oil/ margarine
Jessenia	*J. bataua/J. polycarpa*	Arecaceae	Oil, almost identical to olive oil
Juglans	*J. mandshurica* *J. regia*	Juglandaceae	Clear oil yellow, sweet in taste for cooking/salad oil

Table 1 (Contd...)

Genus	Species	Family	Oil characteristics
Lecythis	*L. ollaria*	Lecythidaceae	Oil from seeds
Macadamia	*M. integrifolia*	Proteaceae	Oil from nuts
Madhuca	*M. indica* *M. longifolia*	Sapotaceae	51.1% fatty oil rich in oleic acid (46% of total); substitute for cocoa butter
Manicaria	*M. saccifera*	Arecaceae	Ubusou oil similar to coconut oil
Mauritia	*M. vinifera*	Arecaceae	Yellow oil (20%) from fruits
Mimusops	*M. djave*	Sapotaceae	Seed fat used in cooking
Nephelium	*N. lappaceum*	Sapindaceae	37-43% solid fat
Oenocarpus	*O. bacaba* *O. circumtextus* *O. discolor* *O. distichus* *O. minor* *O. tarampabo*	Arecaceae	Edible oil from fruits
Orbignya	*O. cuatrecasana* *O. martiana*	Arecaceae	60-70% oil similar to coconut oil
Pandanus	*P. boninensis* *P. brosimas* *P. whitmeeanus*	Pandanaceae	Oil used for perfuming coconut oil
Pentaclethra	*P. macrophylla*	Fabaceae	Misc. use as food
Persea	*P.schiedeana*	Lauraceae	Fruit good source of oil
Pistacia	*P. vera*	Anacardiaceae	Edible oil, low melting point
Protium	*P. brasiliense*	Burseraceae	Oil like olive oil
Prunus	*P. armeniaca* *P. sibirica*	Rosaceae	Oil bitter and sweet and resembles olive oil
Pyrularia	*P. pubera*	Santalaceae	Oil from kernels
Quercus	*Q. virginiana*	Fagaceae	Sweet oil in cookery
Roystonea	*R. oleracea*	Arecaceae	Fruits yield edible oil
Schleichera	*S. oleosa*	Sapotaceae	40 % oil from seeds
Shorea	*S. aptera* *S. robusta*	Dipterocarpaceae	Sal butter (19-20% fat), substitute for cocoa butter. 50-70 % (*S. aptera*)
Simarouba	*S. glauca*	Simaroubaceae	Aceituno oil used as cocoa butter substitute
Staphylea	*S. bolanderi* *S. trifolia*	Staphyleaceae	Oil from seeds sweet in taste
Telfairia	*T. occidentalis*	Cucurbitaceae	Oil from seeds
Terminalia	*T. catappa*	Combretaceae	Indian almond. Kernel with 55% oil
Treulia	*T. africana*	Moraceae	Seed rich in oil

*: Major and minor crops

Sources: Uphof, 1959; NAS, 1976; Simmonds, 1976; Zeven and de Wet, 1982; NOVODB, 1985; CSIR, 1986; Robbelen *et al.*, 1989; Chadha, 1991; Macmillan, 1991; Rehm and Espig, 1991; Pareek *et.al.*, 1998.

Table 2 Centres of diversity and domestication of edible oilseed crops

Crop	Centres of diversity												Archaeological evidences
	1	2	3	4	5	6	7	8	9	10	11	12	
Arachis hypogaea								#		+ @			A (2-3000 Peru)
Brassica campestris	@			+		+			@				B
Brassica carinata								+					-
Brassica juncea	@			@	+				@				C
Brassica napus							+						C
Brassica nigra									+				C
Cannabis sativa	@			@	+								-
Carthamus tinctorius				@		+							A (1600 Egypt)
Cocos nucifera		@	+										A (N. Zealand)
Elaeis guineensis								+					-
Eruca sativa				@		+							-
Glycine max	+		*										**A** (>11 China)
Guizotia abyssinica				@				+					-
Helianthus annuus									@			+	A (>1USA)
Linum usitatissimum					+		@						A (>1000 Egypt & Middle East)
Olea europaea							+						A (4 Mediter-ranean)
Papaver somniferum							+						-
Sesamum indicum	@			+				*					A(4000 Harappa, Babylon,Assyria)
Sinapis alba							+						-
Primary centre for crops	1		1	2	3	3	4	3	1	1		1	
Secondary/tertiary centres for crops	4	1		5			1	1	3	1			
Centre of diversity for wild spp.			1					1					

\+ Primary centre for crop and wild species @ Secondary centre for crop/wild species # Tertiary centre for crop species * Centre of diversity for wild species

Centres of diversity as per Zeven and de Wet, 1982: 1 China, 2 Indochina-Indonesia, 3 Australia-New Zealand, 4 Indian sub-continent, 5 C Asia, 6 West Asia, 7 Mediterranean, 8 Africa, 9 Euro-Siberia, 10 South America, 11 Central America, 12 North America

Archaeological evidences: A-Archaeological records (1-3000 BC or earlier), **B**-Indian texts (1500-2000 BC), **C**-Greek and Roman records (200-500 BC)

Sources: Simmonds, 1976; Zeven and de Wet, 1982; Robbelen *et al.*, 1989; Damania *et al.*, 1998.

Table 3 Centres of origin and diversity of potentially important edible oilseed species

Genus	Centres of diversity											
	1	2	3	4	5	6	7	8	9	10	11	12
Acrocomia (2)										+		
Actinodaphne		+										
Aisandra				+								
Argania (2)							+					
Astrocaryum (5)									+	+		
Attalea (6)										+	+	
Bactris (2)										+		
Bertholletia										+		
Buchanania				+								
Butia										+		
Butyrospermum								+				
Canarium (3)		+						+				
Carya												+
Caryocar (5)										+		
Caryodendron										+		
Ceratotheca								+				
Corylus (2)	+					+						
Couepia										+		
Coula								+				
Cucurbita											+	
Dacryodes								+				
Dipteryx										+		
Euterpe (2)										+		
Fagus							+					
Garcinia (2)				+								
Hesperia									+			
Hodgsonia	+											
Irvingia								+				
Jessenia (2)										+		
Juglans (2)	+				+							
Lecythis										+		
Macadamia			+									
Madhuca (2)				+								
Manicaria										+		
Mauritia										+		
Mimusops								+				
Nephelium		+										
Oenocarpus (6)										+		
Orbignya (2)										+		
Pandanus (3)		+										
Pentaclethra								+				
Persea											+	
Pistacia					+							
Protium										+		
Prunus (2)	+											
Pyruiaria										+		
Quercus												+
Roystonea										+		
Schleichera				+								
Shorea (2)				+								
Simarouba	+											
Staphylea (2)												+
Telfairia								+				
Terminalia		+										
Treulia								+				
Total genera	5	5	1	6	2	1	2	10	2	20	3	3

* Species as per Table 1; Centres of diversity as per Zeven and de Wet, 1982: 1 China, 2 Indochina-Indonesia, 3 Australia- New Zealand, 4 Indian sub-continent, 5 C Asia, 6 West Asia, 7 Mediterranean, 8 Africa, 9 Euro-Siberia, 10 South America, 11 Central America, 12 North America **Sources**: Simmonds, 1976; Zeven and de Wet, 1982; Robbelen *et al.*, 1989; Damania *et al.*, 1998.

***Glycine max* (Soybean)**

Soybean is an old crop domesticated around the 11th century BC in eastern/northern China. Since the 1st century AD it became widely introduced and landraces developed in China, Korea, India and other parts of Asia (Hymowitz, 1970; Zeven and de Wet, 1982). Its wild progenitor *G. soja* is widely distributed in the primary centre of diversity in north and northeastern parts adjoining central China, adjacent Russia and in parts of Eastern Asia/Korea, Japan and Taiwan. The annual *G. gracilis* occurs in this region and the cultivated soybean and wild and weedy species exhibit sympatric distribution and populations represent derivatives of hybrids between wild and cultivated soybean (Hymowitz and Newell, 1981).

Since its domestication and spread as a protein- rich legume species, it also developed into an oilseed crop, and the increase in seed size is associated with increase in oil and decrease in protein content. Overall selection has been for large erect herbs with low shattering pods, and relatively larger seeds. Variability in the area of origin is associated with its multipurpose use for food, in native rituals and as medicine. The genepool of perennial wild species occurs in the Australian region, where several of the species are endemic, e.g. *G. argyrea, G. canescens, G. clandestina, G. cyrtoloba, G. falcata, G. latifolia*. Other species have wider distribution - *G. tabicina* in China, Taiwan and Australia and *G. tomentella* also in Papua New Guinea and the Philippines interestingly associated with variation in ploidy levels.

The barrier to crossability between the perennial subgenus *Glycine* and annual subgenus *Soja* is complete and successful introgression of the genepool is possible following unconventional methods (Singh, 2000).

***Guizotia abyssinica* (Niger)**

Niger originated in the highlands of Ethiopia (Baagoe, 1974). It is an old crop which spread to East African highlands after domestication and around 2000 BC to India. The Indian region is a secondary centre of diversity for this crop (Zeven and de Wet, 1982). The genepool is composed of about six species of *Guizotia*, including both annuals and perennials, largely distributed in Ethiopia (Robbelen *et al.*, 1989; Getinet and Sharma, 1996). *G. arborescens* and *G. villosa* are confined to north and south western highlands of Ethiopia. *G. zavattarii* is endemic to southern Ethiopia and *G. reptans* to East Africa. Much variation occurs in *G. scabra* subspecies *scabra* widely distributed in East Africa, extending to West Africa, and subspecies *schimperi* confined to Ethiopia occurring as a common annual weed (Getinet and Sharma, 1996) and similar to cultivated type but possessing higher oil content (24-35%). Crop improvement and domestication in the Indian centre of cultivated plants has been for the shorter plant habit, non-shattering heads and seeds with thin hull.

***Helianthus annuus* (Sunflower)**

Sunflower is an ancient native of North America probably selected from weedy camp-following species. It got diversified and domesticated in the central and western parts of this region, and this area constitutes its primary centre (Heiser, 1978; Seiler and Rieseberg, 1997). This is also supported by archaeological findings (Simmonds, 1976; Robbelen *et al.*, 1989). Diversity developed in the ornamental types following its introduction into Europe in early 16th century, and its selection and improvement for high oil around the 18th century and in the development of a secondary centre in Russia (Heiser, 1978).

The genepool of *Helianthus* includes 39 species of which about 15 are annuals and the rest perennials (Schilling and Heiser, 1981; Seiler, 1992; Seiler and Rieseberg, 1997). This diversity occurs in central and western parts of North America. However, dwarf species are also distributed /localised in eastern parts. The species vary much in habit, life span and ploidy levels. Annual species of the section Annui are mostly occupants of drier habitat conditions and sandy soils (Rogers *et al.*, 1982). Enormous variation occurs in *H. annuus* within its distributional range and several subspecies have been recognised; some are widely distributed (subspecies *annuus* and *lenticularis*), and others more restricted (subspecies *texanus* and *jaegeri*). *H. argophyllus* is a closely related species and a probable progenitor of wild *H. annuus*. Among the allied genera are *Helianthopsis, Phoebanthus, Tithonia* and other components of *Viguiera* group mostly distributed in North America (Heiser, 1976, 1978; Robinson, 1979; Schilling and Heiser, 1981).

In general, self-incompatibility is widespread in *Helianthus annuus, H. agrestis* and other species. Introgression into the crop species during domestication and further improvement in Europe upon introduction has resulted in widening its diversity and development of cultivars suited to diverse requirements, possessing high oil content. The potential of wild species as sources of disease and pest resistance has in part been successfully utilised (Whelan, 1978; Chandler and Beard, 1983). Even distant species like *H. tuberosus* have been used as source of disease resistance in Europe and *H. petiolaris* as a source of CMS lines (Robbelen *et al.*, 1989).

***Linum usitatissimum* (Linseed)**

Linum usitatissimum is an old crop, which originated in the Central Asian region. It was domesticated in the Near East before 5200 BC, and its progenitor *L. bienne* occurs in this region. The genepool of *Linum* has over 200 species, of which *L. usitatissimum, L. bienne* and *L.*

angustifolium constitute an allied group. *L. bienne* is polymorphic occurring as two distinct geographic races. One is the Atlantic-Mediterranean coastline race, a perennial also described as *L. angustifolium* and possessing highest seed oil contents and seed weight among all wild species (Seetharam, 1972). The second is a winter annual grown in the mountains of south Germany, which may have arisen from the small-seeded linseed, cultivated by prehistoric central European dwellers. Its parental type is prostrate and multi-stemmed, cultivated since ancient times along the north coast of Turkey, the Caspian coast of Azerbaijan and areas adjoining the Black Sea and the continental winter annual of the semi-arid foothills of Iraq, Kurdistan and Iran. During domestication and further development, types both for oil and for fibre have developed (Zeven and de Wet, 1982). Subspecies *indo-abyssinicum* of India and adjoining areas is similar to linseed of Ethiopia and may have originated from the latter. It hybridises with subspecies *mediterraneum* resulting in a hybrid subspecies *hindustanicum*.

Variability is high in the *Linum usitatissimum* group. More variability in oilseed type occurs in Mediterranean area. In Italy, hybrid forms of subspecies *transitorinne*, subspecies *eurasiacum* and subspecies *mediterraneum* are found. Large-seeded forms are cultivated in North Africa. Those from Algeria are reported to be a source of fusarium resistance (Zeven and de Wet, 1982; Robbelen *et al.*, 1989).

Thus overall, in the cultivated and related wild genepools trends are indicative of build-up of diversity over a wide area, with Mediterranean area being the primary zone of diversity.

***Olea europaea* (Olive)**

Olive (*Olea europaea*) is one of the important oldest domesticates probably of the Near East (Turrill, 1951). North Africa has also been suggested as a centre of origin. Early artifacts associated with the oil extraction process (during bronze age, Liphschitz *et al.*, 1991) and the exploitation of wild forms before domestication (since palaeolithic times, Zohary and Spiegel-Roy, 1975) are available.

The *Olea europaea* genepool includes four subspecies (Besnard *et al.*, 1998). *O. europaea* subspecies *europaea* is distributed in the Mediterranean basin, and includes var. *sylvestris* (oleasters/ feral and wild forms) and var. *sativa* (cultivated forms) which are cross compatible (Zohary and Spiegel-Roy, 1975). The subspecies *laperrini* is distributed in the Saharan mountains and its variants close to subspecies *cuspidata* (= *O. macroccana*) in the Atlas mountains, Morocco and Canary and Madeira Islands (Robbelen *et al.*, 1989). Subspecies *cuspidata* includes variants in Asia (*O. cuspidata*), in Arabia and Ethiopia (*O. chrysophylla*) and eastern and southern Africa (*O. africana*).

New variation in cultivated forms propagated in the entire Mediterranean basin has been suggested to have originated through crosses between these and the local wild forms (Simmonds, 1976). The distributional range of these forms could overlap with that of the cultivated forms (Zohary, 1994). Secondary centre for large-fruited forms and selections from local wild forms has been noted. The present cultivars of olive therefore may have been derived from oleasters of different Mediterranean areas from three sources: a) wild x cultivated; b) selection of superior lines and parents; c) improved yield and quality (Robbelen *et al.*, 1989).

***Sesamum indicum* (Sesame)**

Sesamum indicum was domesticated and disseminated very early in the historical perspective of its cultivation so much so that its primary centre is not readily determinable. Equally high variability occurs in the African and the Indian regions. A secondary centre also occurs in China of dwarf types, under subspecies *quadricarpellum* (Zeven and de Wet, 1982).

The genepool of *Sesamum* is composed of about 36 species, largely distributed south of the Sahara, in Africa; about five species occur in the Indian region. Sesame has been under cultivation since ancient times in India, Sumeria, Egypt and throughout the Greek Roman regions for its seeds and as an oilseed crop (Simmonds, 1976; Damania *et al.*, 1998). It is the oldest oilseed plant used by humans, with archaeological evidences from Indus Valley Civilisation (Harappa between 3050-3500 BC) and other sites such as Egypt (1350 BC), Armenia (900-600 BC), Jordan (800 BC) and Turkey (700 BC).

Among the wild species of *Sesamum*, *S. malabaricum* is cross compatible with the crop species, exhibiting close morphological, genetical and phytochemical affinity and to the cultivated crop. Bedigian (1981) supported the contention that the domesticated sesame arose from this progenitor in the Indian subcontinent. Zohary and Hopf (1993) concurred with Bedigian and Harlan (1986) and the botanical evidences support a relatively late introduction into the northeast and Mediterranean region. Also, crosses were possible with *S. prostratum* and *S. schenckii*, species present in both the African and the Indian regions. The latter has been proposed as the ancestral genome (Nayar and Mehra, 1970; Simmonds, 1976). Furthermore with species of African region, such as *S. alatum*, *S. capense* and *S. angolense*, barriers to crossing were noted. Thus the group of African wild species appear to be more distant, which again supports the Indian region as a primary centre of diversity (Rana *et al.*, 1994; Thangavelu, 1994).

Miscellaneous minor crops

Several ancient domesticates are sources of edible oil which however have remained of local importance or in limited demand. Their cultivation has not increased and they are grown on a limited scale for specific traits, such as 'hot' principle and pungency which makes oils of *Sinapis alba* (White mustard) and *Eruca sativa* (Rocket), respectively important for specific uses such as pickling.

Crops of secondary importance as sources of edible oil constitute another category. *Gossypium* spp. (Cottonseed) and *Zea mays* (Corn kernels) are major crops gaining importance particularly in USA as edible oilseeds (Robbelen *et al.*, 1989). Hopi cottons in the New World are glandless types, a desirable character in edible oilseed forms. In India, domestication of cotton was for animal feed. Here glandless types are subject to pest damage. Hence, probably it is important for oil mainly in the New World unless genetically modified for disease and pest resistance. In corn, the 'hidden' oil quantity is higher in edible types associated with high embryo to endosperm ratio. The oils that are desirable in non-ruminant diets may with better processing improve the quality of oil.

This group of plant species include increasing numbers of other cereals and fruit plants, such as kernel oil from *Mangifera indica* (Mango), *Cannabis sativa* (Hempseed) and *Oryza sativa* (Rice bran) in the Indian region (Watt, 1889-1893; Rai, 1998). Similarly, *Papaver somniferum* var. *nigrum* (Poppy) is an ancient domesticate of the Middle East where otherwise agriculture has not developed (Robbelen et al., 1989). Dry fruits and nuts of *Prunus*, *Juglans*, *Pistacia*, etc. are other sources of good quality oil.

B: Potential/ Less-known Oilseeds

This includes both local domesticates and those gathered for use from the wild by the native people, and plants in local use for their oily nuts or kernels. Their oil quality and quantity generally match with those of the major crops (Table 1). Also the aroma and flavour of oils of several species are as good as or better than major oils like coconut oil, palm oil or olive oil. Table 3 gives the centres of origin and diversity in potentially important edible oilseed plants. South American region for neotropical palms, and Indian region for *Aisandra-Bassia-Madhuca* group of Family Sapotaceae are some important areas with diversity in edible oilseed plant species. In view of these points, the global diversity is described and classified under the following heads:

a) **Potentially important plants as substitutes for major edible oilseed crops**: Several of the plants have been indicated to have oils comparable to coconut oil and olive oil (Table 1). The neotropical palms are mostly multi-purpose plants usually collected from the wild. These predominate in the South American centre of diversity, inhabit marginal habitats or forestlands, and also establishing well in cleared lands, and hence may be important backyard cultigens. *Caryocar brasiliense* and related species are available over a wide range of conditions. Interestingly hybrids between species or with other genera in natural conditions provide a wide range of material for domestication and improvement. Other genera are available over a wide range of habitat conditions, *Orbignya-Attalea* in dry areas, *Jessenia-Oenocarpus* in wet or waterlogged areas. Other important palms again of the New World include *Acrocomia*, *Astrocaryum*, *Bactris*, *Mauritia*, etc. (NAS, 1976; Robbelen *et al.*, 1989; Pareek *et al.*, 1998). *Cucurbita foetidissima* (Buffalo gourd) is a species of desert areas of Central America with potential for being developed as an edible oilseed crop (NAS, 1976). *Carya*, *Staphylea* and *Quercus* are important in North America as edible oil yielders.

   Similarly in the Indian region *Shorea robusta* is important as a predominant component of the sub-tropical areas, used for edible oil extraction on a local scale. In this region edible oil-yielding species of the *Aisandra-Madhuca-Bassia* group are important components of the sub-tropical areas and also in social agro-forestry. *Garcinia* species are important as source of edible oil of high commercial value.

   Several species of edible oilseed plants are found in tropical West Africa- *Ceratotheca sesamoides*, *Coula edulis*, *Irvingia gabonensis* and *Dacryodes edulis* (Zeven and de Wet, 1982; Pareek *et al.*, 1998). *Canarium schweinfurthii* and *Butyrospermum parkii* are species of central parts of Africa.

b) **Crops with secondary use as edible oilseed**: This category of potentially useful plants may be extended to include many fruit and nut yielding plants such as *Mangifera indica*, *Prunus* and *Persea* species (Uphof, 1959).

c) **Potential oilseeds with low/local demand**: This category includes *Pandanus* spp., which is used for perfuming coconut oil and *Canarium ovatum* used in the Philippines for extracting oil (Zeven and de Wet, 1982).

Thus, the list of potentially important oilseeds is long and probably only a few qualify for domestication, with attributes such as rapid regeneration capacity, easy extraction of high quality oil, quantity of oil extracted especially its keeping quality, stability, etc.

Exploring edible oilseed genepools. Some global concerns

The earlier part of the paper has brought out the salient features of the distribution patterns and diversity build-up in various oilseed crops under cultivation and others with scope for domestication and use. However, oilseeds have remained less important as compared to other groups of food crops in terms of breeding for crop improvement. This is so despite a diverse range of uses envisaged to meet nutritional, dietary and economic considerations. Constraints in attaining the required goals are several.

a) **Occupation of marginal lands**: With few exceptions such as sunflower, brassicas and soybean in parts of their cultivation range, edible oilseeds are successful occupants of marginal and degraded lands. Crops such as *Cocos*, remain backyard cultigens in developing countries and despite their multipurpose uses, these are getting further marginalised.

b) **Narrow genetic base limiting range of cultivation**: Most oilseed crops in the course of domestication have developed a wider genetic base as compared to the parental material. This has been achieved, in the course of the development of the annual domesticates from the perennial species through hybrid origin as in sunflower and some *Brassica* species, or subsequent polyploidation in groundnut. Introgression with the wild species in centres of diversity in safflower, soybean, sunflower, sesame, etc. has also added to the diversity base of the crops.

   However, due to the antiquity of origin, the primary genepool of the crop is separated from the secondary and tertiary genepools. This is due to wide geographic separation as in *Glycine* or *Helianthus*, or local topographic and other habitat features or genetical factors in *Arachis* and *Carthamus* (Moss *et al.*, 1989; Smartt, 1990; Dajue and Mundel, 1996; Seiler and Rieseberg, 1997; Singh, 2000). Such a trend is also supported by cytogenetical, or biochemical evidences. In potentially important species the problem of the future is likely to be that of a narrower genetic base as commercial cultivation based on few high yielding cultivars replaces the native diversity. This may be true especially for groups such as the neotropical palms where a long time is required to monitor for promising attributes from generation to generation, unless hybrids are used or selected as the primary material for domestication.

c) **Local adaptation of variants within species**: Even within the crop species, secondary and tertiary centres of diversity are recognisable in species of *Brassica*, subspecies of *Arachis*, or races of *Carthamus* (Simmonds, 1976; Zeven and de Wet, 1982). These have been associated with crossability barriers and hence are reproductively isolated from the primary genepool. Parallel trends in habit and morphology have been noted in *Arachis* and *Brassica*, in planting seasons in *Guizotia*, geographical features affecting growth pattern in *Glycine* (Zeven and de Wet, 1982; Robbelen *et al.*, 1989; Smartt, 1990). In such cases crosses within the genepool of the crop species has potential value in *Guizotia* from Ethiopia and India, and in *Arachis* for better yield, uniformity on maturation, disease resistance and breaking specific linkages among economically important characters (Wynne and Gregory, 1981). Such programmes as are already underway in *Brassica* species, are needed in the other crops.

d) **Limitation of sources of disease and pest resistance:** With the occurrence of multiple centres of diversity in oilseed crops, resistance to major diseases is available within the crop genepool. Resistance to rusts in *Helianthus* has been recorded in the secondary centre in Europe, as also to downy mildew and verticillium wilt (Fick, 1978; Robbelen *et al.*, 1989; Seiler, 1992). In *Carthamus* resistance to major diseases is available in world collections of safflower. Resistance to the fungus *Leptosphaeria maculans* attacking *Brassica campestris* and *B. napus* is available in the latter and in *B. juncea*; resistance to *Albugo candida* has been identified in different lines and races of *B. campestris*, *B. juncea* and *B. napus* (Robbelen *et al.*, 1989). Wild species have been identified as sources of resistance to diseases and particularly for pests in *Helianthus* (Rogers *et al.*, 1982), perennial species of *Glycine* and African species of *Sesamum* (Arora and Riley, 1994; Robbelen *et al.*, 1989).

e) **Sub-optimal quality and quantity of oil**: Scope exists for dramatic increase in oil content, which is even lower than in the wild species in groundnut (Wynne and Gregory, 1981). Wild species similarly are important in other crops - *Helianthus petiolaris* has been identified as a potential donor for higher oleic acid in oil; *Olea ferruginea* when used for grafting of the cultivated type in China is more productive (Robbelen *et al.*, 1989).

f) ***Need for working out nature and extent of genepools***: In some crops such as *Sesamum*, several of the species have not been studied cytologically or cytogenetically. Even their distribution ranges are not well worked out and so grouping of species is a priority for future study and utilisation. The next case is that of *Arachis* where similarity in habit and morphology has made it difficult to delineate species through herbarium-based studies. Hence there is confusion regarding even the number of species in the genus (Smartt, 1990; Arora and Riley, 1994; Seiler and Rieseberg, 1997). Poor establishment and low seed production in field-grown situations make it difficult to resolve the problem.

On the other extreme is *Brassica* where transgenics for resistance to lepidoptera pests have been tried (Robbelen *et al.*, 1989). Introduction of phaseolin gene has been attempted in sunflower from *Phaseolus vulgaris* (Robbelen *et al.*, 1989). Thus, use of new technologies to resolve problems are finding application in the major edible oilseed crops.

Hence the diversity used or of potential use in improvement of edible oilseed crops may be available from the related crop or wild genepool. Since incorporating desirable traits or resistance may be done using various technologies, the major concern is that suitable and diverse sources of material should be available for use *vis-a-vis* exploitation of diversity.

Conservation of Genetic Diversity

The priority for conservation is for areas and germplasm where the threat to habitat is through introduction of other productive crops or reappropriation of lands for other purposes due to their marginal status. For *Glycine max* the centre of domestication is thought to be in what is now a major wheat growing area in northeastern China. Except for the major crops such as *Brassica*, diversity is still largely available for collection and conservation.

Ex- situ conservation: Table 4 indicates the wide range of materials reported to be conserved in gene banks of the world. Significantly among the crops listed, protein-rich leguminous crops are better represented. For others the collections reflect the area under cultivation. Furthermore, for wild species, except in *Arachis* where collections are conserved in the area of diversity, consolidated information on collections is not available.

Oilseeds are recalcitrant with comparatively shorter longevity of seeds as compared to non-oilseed groups of plants. Hence, these have been prime candidates for cryopreservation. Again information on these is not available. Moreover, such facilities too are available at few places.

***In-situ* conservation**: This is important in two groups of crops namely *Arachis* and *Olea*. In *Arachis*, the secondary centres of diversity have built up over short distances. Topographical differences have significantly affected the diversity build-up. Though it is known that the geocarpic mode of dissemination may be related to distributional patterns (Smartt, 1990), significant differences within and between species in relation to habitat features make these important for *in-situ* conservation. Moreover, the species do not produce repeatable performance in field conditions. In *Olea* where old clones and native diversity may be available (Robbelen *et al.*, 1989), 'on-farm' conditions of conservation may be the required method of conservation.

As was noted from the patterns of diversity build-up, adaptation to the local conditions has occurred in several crop species. However, diversification of species and development of endemics is significantly high only in selected areas- *Guizotia* in Ethiopian highlands, *Carthamus* species in the Middle East and to the east of it; *Helianthus* and *Arachis* in central North America and river valleys in South America, respectively. Regional surveys and screening of diversity would help to pinpoint areas with higher diversity for *in-situ* conservation.

Besides these conventional methods, 'on farm' conservation and particularly participatory breeding programmes are ideal methods for adoption in diversity studies of genepools of edible oilseed crops for conservation and use, especially in the annual crops.

Table 4 *Ex-situ* collection in oilseed crops : Germplasm holding with different centres/organisations

Oilseed crop	No. of organisations holding germplasm	Total accessions	Countries holding maximum material
Arachis hypogaea	109	85670	Argentina, Brazil*, China*, India, Indonesia, Philippines, Russia, USA*,,Zambia, Columbia, S. Africa#
Brassicaceae	1	1900	Spain
Brassica campestris	19	9639	Canada, China, Philippines
B. juncea	35	15481	Australia, Netherlands
B. carinata	16	537	China, France
Carthamus tinctorius	35	13671	China, India, Mexico, USA*; Germany
Glycine max	129	149613	Australia, Brazil, China, France, Germany, India, Indonesia, Japan, Korea, Mexico, Nigeria, Philippines, Romania, Russia, Taiwan, USA, Zimbabwe
Guizotia abyssinica	10	1296	Ethiopia, India
Helianthus annuus	57	26784	China, Romania, USA, Yugoslavia, Russia
Linum usitatissimum	42	27048	Romania, Russia
Sesamum indicum	51	33640	China, India, Israel, Kenya, Mexico, USA*, Venezuela, UK#

* Highest values of total holdings; # Rich in related species diversity

Source : IPGRI Database 2000

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Review article

Resistance genes for rust and yellow mosaic diseases in soybean - A review

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Abstract

Rust (*Phakopsora pachyrhizi* Sydow.) and yellow mosaic (mungbean yellow mosaic virus) are economically important diseases of soybean. On account of recent resurgence of rust and yellow mosaic in India, substantial yield losses have been experienced. To overcome these yield losses it becomes imperative to screen for resistant genes and transfer them in susceptible but agronomically superior varieties to have effective and eco-friendly management. In the present review an attempt has been made to compile and synthesize the information available on yield losses, races, resistant genes and breeding for resistance along with the approaches required for soybean improvement and for the management of diseases.

Key words: Soybean rust, yellow mosaic, mungbean yellow mosaic virus, *Phakopsora pachyrhizi*, resistance genes

Introduction

Taxonomically genus *Glycine* is divided into two subgenera, (i) *Glycine*, in which 16 perennial spp. are grouped and (ii) *Soja* (Moench) F.J. Herm. which includes two annual species, *G. soja* Siebold & Zucc. and *G. max* (L.) Merrill (Kollipara *et al.*, 1997). Thus, cultivated soybean [*Glycine max* (L.) Merrill, 2n = 40] falls under the subgenus *Soja* and the wild annual relative *Glycine soja*, is considered ancestor of cultivated soybean. *Glycine soja* hybridizes easily with the cultivated soybean. Wild perennial relatives, totaling about 16, belong to subgenus *Glycine* have low crossability rate with cultivated soybean (Singh and Hymowitz, 1999).

Soybean is the third largest oilseed crop of India. The mature seeds contain 20% oil and 40% protein of good quality with essential amino acids. The total world soybean production is 179 million tonnes (ASA, 2001) and India ranks 5th globally having 6 million ha area under soybean cultivation with annual production of 6.80 million tonnes (IASRI, 2002). Specht *et al.* (1999) suggested the theoretical limit of soybean production to be 8 t/ha based on the amount of light energy available in the field. The world average yield of soybean is 2.27 tonnes/ha (Tiwari *et al.*, 1999), whereas the average productivity in India is around 1.1 t/ha (NRCS, 2002a). This relative low productivity is mainly ascribed to a short growing period available in the Indian sub-tropical conditions and the narrow genetic base of soybean cultivars resulting in susceptibility to biotic and abiotic stresses (Singh and Hymowitz, 2001). Among biotic stresses, diseases are one of the major factors responsible for taking a heavy toll of the yield of soybean.

Presently more than 100 pathogens have been reported to infect the crop in different parts of the country (Gupta, 2001). Thirty-five of them are economically important. Annual yield losses from diseases in soybean are to the tune of 12% of the total production. The total yield loss due to diseases in soybean during 1994 in top 10 countries, including India, was estimated to be 14.99 million metric tonnes, valued at $ 3.31 billion (Wrather *et al.*, 1997). On account of recent and sudden resurgence of rust and yellow mosaic in India (Figure 1), it is imperative to screen for resistant genes and transfer them in susceptible but agronomically superior varieties. The approach will be cost effective and eco-friendly.

1. Soybean rust

The soybean rust fungus belongs to genus *Phakopsora*, family (Phakopsoraceae, order Uredinales) and is caused by two described species, *P. pachyrhizi* Sydow, which is predominant in Australia and Asia and *P. meibomiae*, which is found in south of North America, Caribbean area and South America down to Argentina (Carvalho and Figueired, 2000). The causal agent of rust in Africa has not been described taxonomically (Hartman *et al.*, 1999).

P. pachyrhizi is more aggressive than *P. meibomiae*. This text pertains with the rust species *P. pachyrhizi*. The disease is more severe under conditions of moderate temperatures (18° to 26° C) and extended leaf wetness. Long periods of temperatures above 28° C are unfavorable for rust development (Bromfield, 1984). Heavily infected plants have fewer pods and lighter seed (Hartman *et al.*, 1991; Yang *et al.*, 1991). Marketable yields are even less because of poor seed quality (Tschanz and Wang, 1980).

Rust caused by *P. pachyrhizi* was reported in India in 1970 (Sarbhoy *et al.*, 1972) at Pantnagar and low hills of Uttar Pradesh and West Bengal. After 1974 the rust disappeared till 1980 when it was experienced in northeastern states and became endemic to that area. From rainy season of 1994, the rust scenario took a turn and since then the rust has been reported from the states of Madhya Pradesh, Maharashtra, Karnataka, Tamil Nadu, Kerala, Andhra Pradesh and Rajasthan (Rao *et al.*, 1995; Patil *et al.*, 1997; Mathivanan *et al.*, 2000).

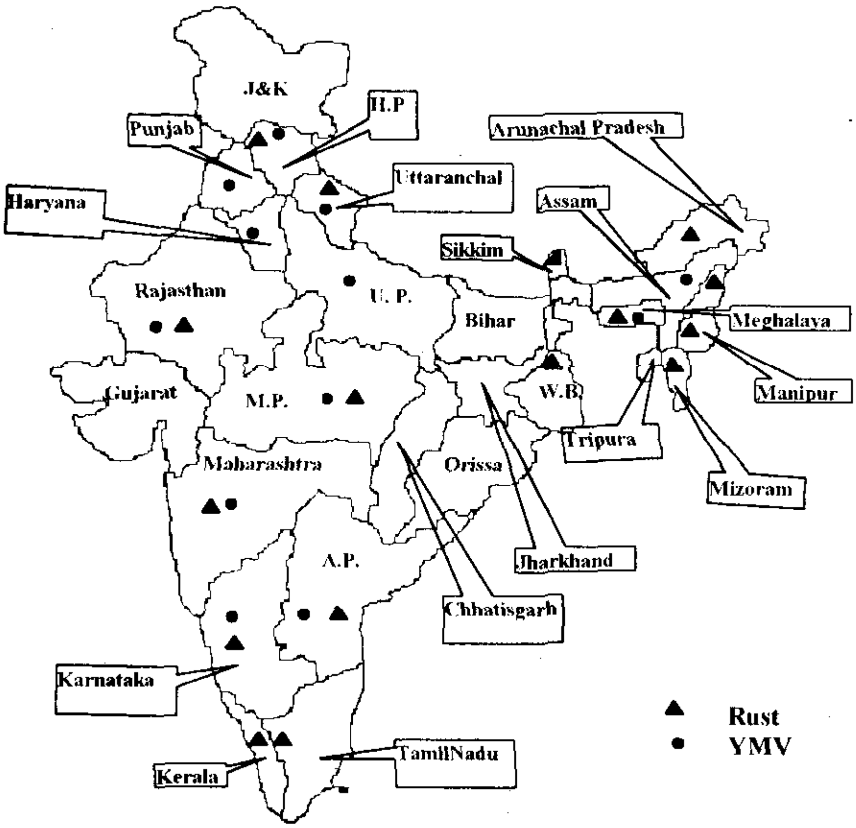

Fig-1 Distribution of rust and yellow mosaic of soybean in India

1.1. Yield losses

The yield losses have been reported from 30 to 100 % in India (Sarbhoy and Pal, 1997). Significant losses have been reported from different parts of the world, 10–40% in Thailand, 10-50% in southern China, 23-90% in Taiwan, and 40% in Japan (Hartman *et al.*, 1999). A study conducted at Asian Vegetable Research and Development Center, Taiwan (AVRDC, 1990b) revealed that the percentage of estimated total green leaf area loss was highly correlated (r^2 = 0.8) with yield loss in both susceptible as well as resistant cultivars. When Shin and Tschanz (1986) compared tolerant 'SRE-B15A' and susceptible 'Taita Kaohsiung 5' under artificial field infection, symptoms appeared earlier and spread was more rapid on the latter than the former. Defoliation increased rapidly after the later half of the pod filling stage. Infection increased the number of empty pods and imperfect seeds, decreased oil content and some yield components, but did not affect protein content. Yield losses due to infection were 22.3% in 'SRE-B15A' and 68.7% in 'Taita Kaohsiung 5'.

1.2. Races

The races of pathogen have been described on the basis of infection types. These infections are of three types: (i) TAN = TAN lesions (0.4 mm^2 with 2-4 uredinia per lesion); (ii) RB= reddish brown lesions (0.4 mm^2 with 0-2 uredinia per lesion) and; (iii) 0 = absence of macroscopically visible signs or symptoms (Bromfield, 1984). Using a set of five differentials cultivars/lines, three races among 50 single uredinial cultures were identified by Yeh (1983). In later studies, (AVRDC, 1985), 42 purified isolates were inoculated on 'Ankur', PI 200492, PI 230970, PI 230971, PI 239871 A, PI 239871 B, PI 459024 and PI 459025, 'TK-5', 'TN-4', and 'Wayne'. Most isolates caused TAN –type lesions on at least seven of the lines and these isolates were classified in to nine races. The data suggested that the predominant races are complex and these races possess multiple virulence factors for compatibility on most of the lines. Other isolates from Taiwan were reported to cause rust on all known or suspected sources of specific resistance including PI 200492, PI 230970, PI 459025 and PI 462312 (Tschanz *et al.*, 1986). The presence of multiple virulence genes in the pathogen population and the absence of multiple specific resistance genes in the host could make techniques like gene rotation and pyramiding of specific resistance genes ineffective.

1.3. Specific rust resistance genes and approaches for improvement of soybean

1.3.1. Resistance genes and their genetics

Soybean genotypes differ in their reaction to rust isolate (Nene, 1969; Lu, 1970; Sarbhoy *et al.*, 1972; Sathe, 1972; Tsai *et al.*, 1974; McLean and Byth, 1976; Thapliyal and Choudhary, 1976; Bromfield *et al.*, 1980;). Information on the genetics of resistance will help in enhancing and stabilizing the yields through the development of soybean cultivars resistant to the diseases. On the basis of studies undertaken to identify the rust resistant genes against different isolates, PI 230970 and PI 230971 were classified as resistant when inoculated with the rust isolates Australia-72-1, India-73-1, Taiwan-72-1and Philippines-77-1. Inheritance studies showed that these two lines have single dominant gene conferring specific resistance to rust (Bromfield and Hartwig, 1980).

Other studies revealed that the lines PI 462312 (Ankur) and PI 200492 (Komata) are also resistant (Cheng and Chan, 1968; Singh and Thapliyal, 1977; McLean, 1979). McLean and Byth (1980) concluded that PI 200492 carried a single dominant gene giving resistance to an Australian rust isolate and assigned the gene symbol Rpp. Singh and Thapliyal (1977) used PI 462312 in breeding studies at Pantnagar, India and reported that it also carried a single dominant gene for resistance. Genetic basis for rust resistance in PI 200492, PI 230970 and PI 462312 were further elucidated by Hartwig and Bromfield (1983). Studies showed that each of the soybean genotypes had a major dominant gene Rpp1, Rpp2 and Rpp3 respectively. Subsequently, the soybean line PI 459025 was also identified to have a broad type resistance to rust isolates Taiwan-82-2 as well as India 73-1 and Taiwan 72-1and had 4th major dominant gene Rpp4 (Table 1). All the four independent dominant genes had different locus (Hartwig, 1986).

Other soybean lines, Tainung-4, PI 459024 and one *G. soja* line (PI 239871B) are reported to have additional specific genes for resistance (Bromfield and Melching, 1982; McLean and Byth, 1980). Specific resistance has been also reported in wild *Glycine* spp. and some of these have been used as differential hosts for the identification of rust pathotype (Burdon and Speer, 1984). Additional research indicated that PI 239871A, TK-5, and Tainung-4 might also have single dominant genes for resistance (Tschanz *et al.*, 1986).

Table 1 Reaction of different rust isolates to soybean differentials possessing resistant genes*

Strains/differentials with gene	Fungal isolates		
	Taiwan 72-1	India 73-1	Taiwan 80-2
PI 200492 (Komata) Rpp1)	Susceptible	Immune	Susceptible
PI 230970 (Rpp2)	Resistant	Resistant	Susceptible
PI 462312 (Ankur) (Rpp3)	Susceptible	Resistant	Susceptible
PI 459025 (Rpp4)	Resistant	Resistant	Resistant

* modified after Hartwig (1986)

The inheritance of resistance to rust in soybean was studied by inoculating the pathogen onto detached leaves of F_1, F_2, B_1C_1 and B_1C_2 hybrids of diallele crosses of the four cultivars with different levels of resistance. It was observed that the four cultivars had significantly different genetic backgrounds for resistance. Resistance in PI 459025 was controlled by a dominant gene while in cultivars AGS 129 and AGS 181 it was conditioned by multiple genes (Tan *et al.*, 1991). At Taiwan (AVRDC,1990a) crosses were made between soybean accession PI 459025 and AGS 129 and backcrossed to AGS 129 four times. Progeny from each generation, except the BC_2, F_2 and F_3 were then field evaluated for resistance. SRE-C56A was the most resistant but this accession had a low stable yield of only 2.0 t/ha.

Rate reducing resistance has also been demonstrated (Tschanz *et al.*, 1980; Tschanz and Tsai, 1982). However, it was difficult to evaluate it because the rate of rust development was dependent on soybean development and maturity. Currently, evaluation for this type of resistance is time consuming and this limitation prevents the use of this method for screening large populations (Hartman, 1996).

1.3.2 Resistant sources/ genes in wild perennial species

Evaluation of wild perennial *Glycine* species for resistance to *P. pachyrhizi* revealed that accessions of *G. tabacina* and *G. tomentella* were resistant to soybean rust (Singh *et al.*, 1974b). At Taiwan, (AVRDC, 1990c) it was reported *that G. tomentella* (diploid and tetraploid), *G. argyrea, G. clandestine,* and *G. tabacina* (2n=80) contained resistance genes. This was also confirmed by Hartman *et al.* (1992) after conducting trial with a total of 294 accessions. Of these, 23% were resistant, 18% were moderately resistant and 58% were susceptible. In other two experiments, 59 and 40% of the accessions of *G. tabacina* (2n=80) were resistant. Resistance was also observed in the accessions of *G. argyrea, G. canescens, G. clandestina, G. latifolia, G. microphylla* and *G. tomentella*, but not in the accessions of *G. arenaria, G. cyrtoloba, G. curvata and G. falcata*. However, in *G. tomentella* the resistance in aneuploids (2n=78) was controlled by single dominant gene and in tetraploid (2n=80) by two or three gene loci (Schoen *et al.*, 1992).

Singh *et al.* (1998) reported the production, identification and breeding behaviour of monosomic alien addition lines (MAALs) each with 2n = 40 chromosomes of soybean and one chromosome from *G. tomentella* (accession PI483218, 2n = 78). *G. tomentella* contained genes controlling several economically useful traits such as resistance to soybean rust (*P. pachyrhizi*) and soybean cyst nematode (*Heterodera glycines*) and tolerance to salt and drought. Some 287 plants with 2n = 41 chromosomes were isolated from BC_3 and BC_4 progenies. On the basis of distinguishing morphological features, these lines were grouped into 22 MAALs (monosomic alien addition lines) and were designated as MT-I to MT-XXII.

1.3.3. Breeding for resistance

Taking cognizance of economic importance of soybean rust, efforts have been made abroad as well as in India to search resistance sources of rust in existing varieties, lines and germplasm. Breeding work to transfer the resistance gene in order to develop resistant varieties has also been taken up.

1.3.3.1. Breeding for resistance (abroad)

Soybean germplasm was evaluated during 1986-95 in China by Tan *et al.* (1997). Out of total 8711 soybean accessions from 14 Southern Chinese Provinces 0.9% were moderately resistant, 44.20% were moderately susceptible and 55% were highly susceptible to soybean rust.

In Thailand, Potan and Shanmugasundaram (1987) reported lines 7508-50-10 and 7608-25-4 as highly tolerant to rust, those also appeared to be moderately tolerant to anthracnose (*Glomerella cingulata*?) and bacterial pustule (*Xanthomonas campestris)*. They irradiated seeds of 11 cultivars at 15 and 30 kR and grown during 1979. In 1980, M_3 bulk and single populations and M_2 bulk populations were screened for resistance to *P. pachyrhizi* at two locations. After further selection, 16 lines with good seed yield and a low percentage of shriveled seeds were obtained as *P. pachyrhizi* tolerant mutants. Wongpiyasatid *et al.* (1993) selected advanced lines 2128, 2133, 2156 and 2160 from crosses between the variety 'Doi Kham' and mutant line 58608 of 'Doi Kham'. Lines 2128 and 2133 had larger seeds, higher seed yield and were more tolerant to rust and downy mildew (*Peronospora manshurica*) than the others and were recommended as varieties for general cultivation. 'Doi Kham' showed race-specific resistance to soybean rust.

In rust resistant germplasm line D 86-8286 derived from the cross 'Forrest' x PI 230970 by Hartwig (1988), the resistance was found to be controlled by the single dominant gene Rpp2 (from PI 230970). It is believed that Rpp2 is linked to a major gene for seed shattering.

Kilen (1997) identified a breeding line resistant to rust derived from the cross 'Hardee' x PI 459025 with the objective of transferring the gene Rpp4 for resistance to rust from primitive PI 459025 to a better-adapted genotype. Resistant plants in the F_2 generation were grown to maturity and seeds were harvested. In 1987, an advanced rust resistant F_3 line was used as a male parent in a cross with cv. 'Lamar'. Twenty-five lines uniformly resistant to rust were advanced to the F_6 generation. The best yielding line, D 91-5987, averaged about 80% of the seed yield of cv. 'Braxton' and had the lowest incidence of rust.

1.3.3.2. Breeding for resistance (India)

In India, extensive breeding efforts have been attempted for rust management. Singh *et al.* (1974b) identified six lines as resistant *viz.*, PI 200465, PI 200466, PI 200477, PI 200490, PI 200492, PI 224268, 13 lines *viz.*, EC 11695, EC 50081, PI 88816-5, PI 181567, PI 200455, PI200474, PI 200476, PI 224270, EC 26694, EC 36956, PI 200487, PI 285089 and PI 341359 as moderately resistant that exhibited a hypersensitive reaction. This moderately resistant reaction was corresponded to the resistant reaction described by Bromfield *et al.* (1980). Thapliyal and Choudhary (1976) rated 'Ankur' and 'PK 71-39' as highly resistant. Entries DS-7(122), DS 53(122), DS 97(121) and F_4 (JS 80-21 x G76-5) (122) were reported as tolerant (Madane *et al.*, 1996). Patil and Basavaraja (1997) screened 20 soybean varieties and found the lines *viz.*, EC-392530, EC-372538 and EC-392539 as moderately resistant.

The varieties 'PK 1024', 'PK 1029', 'Ankur', 'JS 80-21' and 'Indira soya-9', (Gupta *et al.*, 1999; Gupta, 2001) and lines AGS 93, DS97-11, DSb 2 , DSb 5, JS 90-29, JS 94-65, MAUS 49-2, MAUS 61-2, PK 1049, PK 1162, PK 1197, PK 1251, RAUS 97-2, SL 428, TS 98-21, TS 99-12, TS 99-76, EC 389160, EC 389165 and EC 389392 were found moderately resistant/tolerant during the testing undertaken at various centres of All India Coordinated Research Project on Soybean from 1995 onwards (Srivastava and Gupta, 2001). Lal *et al.* (2001) also identified resistant lines *viz.*, SL 427, DS-97-P40-4-1, DS-97-P40-4-5, DS-97-MM67A-5, DS-97-MM67A-7, DS-97-MM101-3, DS 967, TS-21, PK 1228 and HIMSO-1578.

In recent years, DNA markers in combination with PCR have enabled marker-assisted selection (MAS) to become a practical breeding method. Marker assisted selection was carried out for soybean rust resistant gene by Vodkin (1996) who isolated a RAPD marker located near the Rpp1 gene resistant to soybean rust. This RAPD marker would provide a means for screening for resistance gene at the places where rust is not endemic.

2. Yellow mosaic

Yellow mosaic disease is caused by mungbean yellow mosaic virus, which is a member of gemini viruses group. The disease is reported from India, Thailand, Bangladesh, Pakistan, Philippines and Sri Lanka (Thottappilly and Rossel, 1987). In India it is the most severe in North India and in some parts of Madhya Pradesh. The disease flourishes under high temperature and humidity and is transmitted by whitefly *Bemisia tabaci* Genn. (Nene, 1969). It is not transmitted by seed, soil or sap. The infection starts with vein yellowing along leaflets that later develops in to a severe bright yellow mosaic. Other reported hosts are mungbean, urdbean, cowpea and pigeon pea (Dhingra and Chenulu, 1985). Although indirect chemical methods of controlling the disease incidence by reducing whitefly population are available, the cost benefit ratio and chemical hazards involved indicated that the most desirable approach would be to exploit the genetic resistance.

2.1. Yield losses

Surveys in Uttar Pradesh (India) from 1971-72 and 1975-77 detected the disease in almost every area of the state, with incidence ranging from 20-80% (Nene, 1972; Suteri, 1974; Suteri and Srivastava, 1975). Yield was reduced from 15.8 to 72.9% in eight cultivars naturally infected at pre-bloom stage. Yield loss was of lower magnitude with infection at post-bloom stage. In Ludhiana (Punjab) yield loss was reported 36.6% (Gill and Rataul, 1991).

2.2. Isolate variability

Isolate variability in soybean strain of mungbean yellow mosaic virus has not been explored well. However, strains found in India and Thailand are reported to differ in their host range. The Thai strain is also transmissible by mechanical inoculation, while the Indian strain is not (Honda, 1986).

2.3. Specific rust resistant genes and approaches for improvement of soybean

2.3.1. Resistant genes and their genetics

The resistance to yellow mosaic virus (YMV) in PI 171443 (UPSM 534) is governed by two recessive gene pairs for which gene symbols rym1 and rym2 have been assigned by Singh and Malick (1978). Bhattacharya *et al.* (1999) also studied inheritance of resistance to YMV in the crosses of *G. soja* (Syn *G. formosana*) with susceptible cultivars 'Ankur', 'Bragg', 'PK 472' and 'Kalitur' of *G. max.* and reported that the resistance in *G. soja* was controlled by a single dominant gene.

2.3.2. Sources of resistance

Sources of resistance to yellow mosaic are well identified and documented in Indian varieties and germplasm. Singh *et al.* (1974a) identified PI 171443 (an introduction from China) as the resistant source for YMV. Resistance has also been observed in wild species *viz. G. formosana, G. tabacina, G. tomentella,* and *G. wightii* (Singh *et al.*, 1974b).

2.3.3. Breeding for resistance

No concerted efforts have been made abroad on breeding for YMV resistance. However, a meagre work on evaluation for resistance to YMV has been done in Pakistan (Aftab *et al.*, 1990; Ilyas *et al.*, 1992). In India substantial work has been taken up on this aspect. Ram *et al.* (1984) developed resistant lines PK 515 and PK 586 by single back crossing of *G. soja* with the variety 'Bragg'. Amongst the 60 genotypes evaluated by Sharma and Phul (1992) in 1988 and 1989, 'PK 416' had the lowest incidence of disease and was closely followed by Himso 1548, SL 104, SL 160 and 'PK 564'. In contrast, DS 81-1619 and DS 84-10 were highly susceptible. Koranne and Tyagi (1985) reported cultivars EC 107014, EC 107003 and EC 100777 as resistant. Kundu *et al.*, (1995) screened 35 high yielding varieties from different zones for reaction to YMV. Eleven of the 12 varieties from Pantnagar were highly resistant to YMV. The most resistant variety was 'PK 1046'. Siddiqui and Trimohan (1999) evaluated some indigenous lines in the field. Nine lines DS-93Br (OT) 2, PK1060, PK1061, PK1069, PK1042, PK 1189, PK 1180, SL 443 and SL 444 were found consistently the most promising sources of resistance. Currently, a large number of varieties possessing YMV resistance viz. 'PK 416', 'PK 564', 'PK 1024', 'PK 1029', 'PK 1042', 'SL 298' etc., are available (Gupta and Karmakar, 1999). Lines Himso 1588, MACS 730, MACS 740, PK 1188, PK 1189, SL 284, SL 328, SL 443, SL 459 and SL 517 were observed to be resistant at various AICRPS centres (Srivastava and Gupta, 2001). In India, extensive crosses are being affected utilizing resistance sources viz. 'PK 416' and 'PK 564' and also rust resistant lines for pyramiding the resistance genes for rust and YMV (NRCS, 2002b).

3. Approaches for soybean improvement for management of rust and yellow mosaic virus

The approaches so far attempted have been consisted of hybridization, back crossing, mutation, use of wide or interspecific crosses etc. The future approach for soybean improvement should be targeted to develop high yielding location specific varieties with broad genetic base possessing resistance to biotic and abiotic stresses. In order to achieve the target the current efforts have to be diversified by strengthening and facilitating conventional breeding programme undergoing at different locations in the country through distribution of the donors/ parental lines and segregating materials of soybean for rust and yellow mosaic resistance. NRC for soybean has undertaken a special programme on breeding for resistance against rust and yellow mosaic virus. The breeding lines possessing resistance were being identified through screening at hot spots at Dharwad for rust and Ludhiana, Pantnagar, Delhi and Jabalpur for yellow mosaic virus. Screening at hot spot was found to be laborious, expensive and time consuming.

Phenotypic evaluation of breeding populations may be often misleading. Therefore, there is a need to search an alternative way of selection for breeding populations. Marker-assisted selection (MAS) has a potential to become a practical breeding method. DNA markers in combination with PCR have become important tools for marker-assisted selection. MAS offers unique opportunities to circumvent many traditional problems associated with phenotypic selection for traits of interest. MAS increases the efficiency and flexibility of breeding programme by selecting for marker genotypes linked to target gene (Mohan *et al.*, 1997). Work on molecular mapping and tagging of resistant gene(s) for other diseases and insects in soybean have been carried out (Baltazar and Mansur, 1992; Heer *et al.*, 1998; Lewers *et al.*, 1999; Hayes *et al.*, 2000; Klos *et al.*, 2000). Keeping the importance of MAS in view, NRC Soybean, Indore, has started work on this aspect particularly for rust and yellow mosaic diseases.

4. Conclusion

Soybean rust and yellow mosaic diseases substantially reduce the yield of soybean crop. Several workers have identified resistance genes and deciphered their behaviour and inheritance pattern. Use of disease resistant varieties developed by transfer of identified resistance genes in agronomically superior lines has been the most desirable approach for the management of diseases. Such resistant varieties have been proved to be environment friendly and cost effective. Efforts have been made in many countries to develop lines/ varieties known to have specific resistance genes. In India, rust tolerant varieties 'PK 1029', 'PK 1024', 'JS 80-21' and 'Indira Soya 9' and yellow mosaic tolerant/resistant varieties 'PK 416', 'PK 564', 'PK 1024', 'PK 1029', 'SL 528' etc. have been developed. So far, through conventional breeding programme it has not been possible to develop immune and race/strain specific resistant varieties against rust and YMV. Therefore, there is an urgent need to lay special emphasis on alternative way of selection for breeding populations. Molecular breeding is the answer to it and is warranted to give a fillip to the current breeding programme and thus, marker-assisted selection (MAS) has a potential to become a practical breeding method.

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Constitution of a core collection from working collection of groundnut, *Arachis hypogaea* L., germplasm

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Abstract

Two-thousand nine hundred and forty three germplasm accession of cultivated groundnut have been characterized for 17 qualitative and 21 quantitative traits. The working collection represented four habit types *viz.*, 464 virginia bunch, 348 virginia runner, 1530 spanish and 601 valencia. A core collection was developed based on qualitative traits, quantitative traits, country of origin, special attributes and reaction to pests and diseases. The core group comprised 213 accessions drawn based on cluster analysis and random selection to represent entire variability available in the working collection. The core group developed had 41 virginia bunch, 18 virginia runner, 85 spanish and 69 valencia types. The core set thus selected showed entire spectrum of variability for both qualitative and quantitative traits and had representation of all countries. The quantitative traits also showed adequate representation, which was tested by testing the mean of population and core set. Among the countries of origin, the representation of 12 countries was more than 50 accessions. The Peruvian accessions had maximum representation followed by Bolivia and Sudan. The higher degree of variability for qualitative and quantitative traits was observed in these collections as groundnut had originated in South American countries. It was also reported that considerable range of secondary variation is available in African countries, which resulted in representation of the same in core collection as shown in collection of Sudan.

Key words: Groundnut, core collection, variability, virginia bunch, virginia runner, spanish, valencia

Introduction

The size of germplasm collection often restricts the quality of their management and it's utilization in research and breeding activities. To improve the management and characterization of germplasm, a limited number of accessions representing the entire variability of the collection would be more ideal. Such a selection would act as a good base when searching for new traits (Vaughan, 1991) and also offers a wider avenue for critical evaluation and to understand the entire collection in a better way (Knupffer and Van Hintum, 1995). The core collection approach offered a very effective tool for gene bank management (Brown, 1989). Now over a thousand gene banks worldwide have adopted the concept of core collection as a very useful tool to improve the conservation and utilization of germplasm (Brown and Spillane, 1999). For selecting members to a core collection various approaches have been used in different crops, subjected to the availability of information on germplasm, either passport or characterization data (Holbrook *et al.*, 1993; Bisht *et al.*, 1998; 1999).

The National Research Centre for Groundnut, Junagadh is a national repository of groundnut germplasm holds about 4350 accessions in the working collection for evaluation and subsequent utilization in the crop improvement programmes. These accessions have originated from more than 77 countries. The collection has a wide spectrum of variability for both qualitative and quantitative traits (Bhagat *et al.*, 1991;1993; Rajgopal *et al.*, 2001) and also has duplicates as most of the germplasm were acquired from various centers simultaneously. For better management, systematic screening, minimize redundancy and easy accessibility, limited number of accessions representing entire variability of the working collection would be ideal. Hence, an attempt has been made to develop a core collection from 2943 germplasm accessions extensively characterized during three *kharif* seasons. The passport information available, and information generated on characterization were used for stratification and clustering for the formation of a core sub group.

Materials and methods

The genetic resources of cultivated groundnut comprise mainly four botanical types *viz.*, virginia bunch (HYB), virginia runner (HYR) of ssp. *hypogaea* var. *hypogaea*, spanish (VUL) and valencia (FST) of ssp. *fastigiata*, where the spanish belongs to the var. *vulgaris* and the valencia types to var. *fastigiata* (Krapovickas and Gregory, 1994).

Two thousand nine hundred and forty three accessions belonging to four botanical types, representing 77 countries were grown during three *kharif* seasons *viz.*, *1998 and 1999 and 2000 for detailed characterization.* Each accession was sown in a row of 5 m in augmented block design at the onset of monsoon with check varieties of respective habit types. Recommended agronomic practices were followed during the crop period. The detail *of the characterization trial is as follows:*

Year	Accessions sown				Date of sowing	Date of harvest	Spacing
	HYB	HYR	VUL	FST			
1998	59	28	481	207	June,1998	Sept-Oct 1998	75X10 cm
1999	42	36	463	55	June,1999	Sept-Oct 1999	75X10 cm
2000	363	284	586	339	June,2000	Sept-Oct 2000	75X10 cm
Total	464	348	1530	601			

Characterization was done uniformly during three seasons as suggested in Descriptors for Groundnut (IBPGR and ICRISAT, 1992) for 17 qualitative traits *(Table 1) and 21* quantitative traits at various phenophases. Observation on sample population/plot basis was used for computing the mean values for quantitative traits. *The data generated* was subjected to cluster analysis based on squared euclidean distance as a distance of measure, using SPSS software package. Clustering was done using qualitative characters and quantitative characters separately. *For the* quantitative characters the values were standardized (so as to get Sd = 1 and mean = 0) before analysis.

Five sets of accessions were drawn as indicated below based on qualitative traits, quantitative traits, geographical *representation*, special features of accessions and for traits related to abiotic and biotic stresses.

Set I

The entire collection was grouped in to two parts; one consists of ssp. *hypogea* (HYB and HYR types) and other ssp. *fastigiata* (VUL and FST type). Twenty-five arbitrary clusters for ssp. *hypogaea* and 50 clusters for ssp. *fatigiata* were made based on qualitative characters in accordance with their total representation in the working collection, and one accession per each cluster was drawn. Thus 75 accessions were drawn in this group.

Table 1 Descriptors and descriptors states scored for qualitative traits

Descriptors	Descriptor states
Growth habit	(1) Decumbent- 1, (2) *Decumbent- 2*, (3) Decumbent- 3, (4) Erect
Branching pattern	(1) Alternate (2) Sequential with flowers on main stem (3) Irregular with flowers on main stem *(4) Irregular without flowers on main stem*
Stem pigmentation	(0) Absent, (1) Present
Stem hairiness	(1) Glabrous, (3) Sub-glabrous, hairs in one or two rows along the main stem, *(5) Moderately hairy, three or four rows along the main stem, (7) very hairy,* (9) Woolly
Type of inflorescence	(1) Simple, (2) Compound (more than one flowers/node)
Flower colour	(1), Yellow, (2) Orange,(3) *Dark orange, (4) Garnet*
Peg pigmentation	(1) Absent, (2) Present
Leaflet colour	(1) Yellowish green, (2) Light green, (3) Green, (4) Dark green
Leaflet shape	*(1) Oblong, (2) Lanceolate*
Leaflet hairiness	(1) Almost glabrous, (2) Almost glabrous above, hairs below (3) Almost glabrous above, hairs and bristles below
Leaflet tip	*(1) Obtuse (2) Acute*
Pod beak	(1) Absent, (2) Slight, (3) Moderate, (4) Prominent, (5) Very prominent
Pod constriction	(1) None, (2) Slight, (3) Moderate, (4) Deep, (5) Very Deep
Pod reticulation	(1) None, (2) Slight, (3) Moderate, (4) Prominent, (5) Very prominent
Testa colour	(1) Off white, (2) Light tan, (3) Tan, (4) Rose, (5) Salmon, (6) Salmon with white flecks, (7) Salmon with light tan flecks, (8) Salmon with purple flecks, (9) Salmon with dark purple flecks, (10) Light red, (11) Red, (12) Red with white flecks, (13) Red with salmon flecks, (14) Dark red, (15) Purple, (16) Purple with salmon flecks, (17) Dark purple
Seed shape	(1) Round, (2) Fusiform, (3) Elongated
Shell thickness	(1) Thin, (2) Moderate, (3) Thick

Set II

A second set of accessions was drawn from the groups on the basis of quantitative traits as mentioned in the previous step. The representatives were taken from each cluster. If the cluster was already represented by a sample in the previous step, such cluster has been omitted. In this way 26 accessions from ssp. *fastigaiata* and 13 accessions from ssp. *hypogaea* were selected.

Set III

The samples selected in previous two steps covered representation from 47 countries out of 77 present in total collection. One representative sample was drawn from rest of the countries which were not represented in the previous steps thus a total of 30 accessions have been added into this group.

Set IV

In our earlier evaluation programme carried out, a few accessions have been identified with desirable agro-economic traits. Preference has been given to cover these accessions in the previous steps. However, 27 such accessions that were omitted in the previous steps were also included.

Set V

This set covered 25 accessions to represent resistant/tolerant lines to various biotic and abiotic stresses. As in above set, these accessions were identified by screening by multi-disciplinary research programme at the Centre.

Results and discussion

The working collection comprised 15.8 % HYB, 11.8% HYR, 52.0% VUL and 20.4 % FST accessions. The qualitative traits and quantitative traits have been treated as separate entities for sub-grouping. Twenty-five accessions of HYB and HYR of ssp. *hypogaea* and 50 accessions of ssp. *fastigiata* were selected from each cluster in the first group (Table 2). The core collection developed on sesame germplasm (Zhang *et al.*, 1999) has considered varietal type, ecotypes and origin of accessions as criteria. The extreme values for 17 qualitative traits available in the working collection were thus captured *in toto* in the core collection (Table 3). The maximum number of descriptor states was observed for testa colour followed by pod characters.

Though selection of entries were made at random from each clusters, care was taken to have representation of maximum number of clusters based on quantitative characters. Similarly, 75 clusters formed based on quantitative traits have covered samples from 36 clusters based on qualitative traits. Hence, to have complete representation based on quantitative traits, 39 more accessions have been selected which were not available in the previous grouping. Thus a total of 114 accessions were drawn for core group based on both qualitative and quantitative traits.

The sub group based on both qualitative and quantitative traits had a representation of 30 countries from where groundnut germplasm had been collected. To have complete representation of rest of the countries, a third set of 47 accessions has been selected. The core collection developed by Holbrook *et al.* (1993) on 7432 accessions of groundnut has taken countries of origin as a main criteria for clustering whereas in present grouping the priority was given to habit types (sub-specific level) as information on detailed characterization was available.

In the working collection, the representation of 12 countries was more than 50 accessions. The accessions from Peru had maximum representation of 18.4 % followed by Bolivia (9.4 %) and Sudan (9.3 %) (Table 4). The higher degree of variability for qualitative and quantitative traits was observed in this collection as groundnut had originated in South American countries (Gregory *et al*, 1980). It was also reported that considerable range of secondary variation was available in African countries, which resulted in representation of the same in core collection as shown in collection of Sudan. Although 742 accessions of Indian origin were available in the collection, it's representation in core collection was a mere 1.8 % indicating low degree of variability in the genepool being a recently introduced crop.

Table 2 Habit group wise representation of core group

Group	No. of accessions				
	HYB	HYR	VUL	FST	Total
Qualitative traits	18	7	31	19	75
Quantitative traits	9	4	8	18	39
Geographical representation	3	3	30	11	47
Agro-morphological traits	7	2	6	12	27
Special features related to biotic and abiotic stresses	4	2	10	9	25
Total	41 (8.8)	18 (5.2)	85 (5.5)	69 (11.5)	213 (7.2)

*Figures in parenthesis indicate percentage representation of total collection

Table 3 The minimum, maximum code value for qualitative traits and percentage availability in core collection

Qualitative traits	Total		Core		
	Min.	Max.	Min.	Max.	% availability
Growth habit	1	4	1	4	100%
Branching pattern	1	4	1	4	100%
Stem pigmentation	0	1	0	1	100%
Stem hairiness	0	9	0	9	100%
Type of inflorescence	1	2	1	2	100%
Flower colour	0	3	0	3	100%
Peg pigmentation	0	1	0	1	100%
Leaflet colour	1	4	1	4	100%
Leaflet shape	1	2	1	2	100%
Leaflet hairiness	0	7	0	7	100%
Leaflet tip	1	2	1	2	100%
Pod beak	0	9	0	9	100%
Pod constriction	0	9	0	9	100%
Pod reticulation	0	9	0	9	100%
Testa colour	1	17+11	1	17+11	100%
Seed shape	1	3	1	3	100%
Shell thickness	1	3	1	3	100%

In any germplasm collection the accession identified for specific agro-morphological traits has it's own importance, as it was an immediate candidate for selection as parent in crop improvement programme. Over the years of evaluation programme carried out at the Centre, ample elite accessions have been identified with desirable agro-morphological traits and tolerant/resistant to various biotic and abiotic stress factors (Rajgopal and Bandyopadhyay, 1999). To encompass the variability from such a subset, 17 accessions with desirable agro-morphological traits, and 25 accessions which were resistant/tolerant to abiotic and biotic stresses factors were also supplemented.

Thus the core collection formed finally comprised 213 accessions representing 77 countries from where germplasm was collected and accessions numbering 41, 18, 85 and 69 comprising HYB, HYR, VUL and FST respectively. These numbers represented 8.8%, 5.2%, 5.5 % and 11.5 % in that order for total representation in each group. The core set of accessions accounting 7.2 % of the total collection is an ideal size for extensive screening for different economically important traits. Similarly in the core collection developed for sesame germplasm in India and China the passport information and agro-morphological data were used for selecting 10% of the total collection.

Table 4 The distribution of accession in major countries and the representation in core collection

Country of origin	Total No.	No. in Core set	% representation
India	742	13	1.8
United states of America	308	20	6.5
Zimbabwe	178	6	2.7
Peru	174	32	18.4
Argentina	124	10	8.1
Bolivia	106	10	9.4
Nigeria	99	7	7.1
Brazil	92	4	4.3
Tanzania	80	5	6.3
Zambia	93	4	3.3
Senegal	58	4	6.9
Sudan	54	5	9.3

The mean, range and standard deviation of both the collections for 21 quantitative traits were given in Table 5. The mean values of various quantitative traits of total population and the core collection were subjected to paired "t" test showed no significant differences indicating the true representation in the core group.

Table 5 Minimum, maximum, average and standard deviation (SD) values for 21 quantitative traits for total collection and core collection

Quantitative trait	Total collection				Core collection			
	Min	max	Average	SD	Min	Max	Average	SD
Days to germination	5.0	9.0	7.0	0.9	5.0	8.0	7.1	0.7
Days to initial flowering	12.0	27.0	18.6	2.7	14.0	26.0	18.3	2.5
Days to 50% flowering	14.0	30.0	21.1	3.3	15.0	28.0	20.7	3.0
Days to maturity	92.0	130.0	106.3	8.8	94.0	130.0	108.1	9.1
Leaflet length (cm)	3.6	8.7	6.0	0.8	4.0	8.7	6.1	0.9
Leaflet width (cm)	1.6	4.5	2.6	0.4	1.8	4.5	2.6	0.4
Leaflet length/width	1.4	3.2	2.3	0.2	1.4	3.1	2.4	0.3
Pod yield (g)/ plant	1.2	44.6	11.5	5.2	1.3	44.2	11.6	6.6
Pod yield (g)/M^2	10.0	282.0	108.0	45.7	26.1	268.0	100.7	46.0
Hundred pod mass (g)	38.0	274.1	93.6	29.4	44.7	274.1	104.4	35.9
% of one-seeded pods	0.0	98.0	16.9	11.7	0.0	91.7	37.2	15.0
% of two-seeded pods	0.0	100.0	71.6	22.4	0	100.0	60.8	28.8
% of three-seeded pods	0.0	100.0	11.0	21.9	0.0	100.0	19.2	29.6
% of four-seeded pods	0.0	63.8	0.6	3.6	0.0	63.8	2.5	8.7
Pod length (mm)	13.9	83.5	26.3	5.1	13.9	83.5	28.8	7.5
Pod width (mm)	8.8	19.0	11.6	1.2	9.0	19.0	12.1	1.5
Seed length (mm)	8.5	21.0	12.4	1.9	9.0	20.0	13.0	2.2
Seed width (mm)	5.0	9.9	7.7	0.6	6.0	9.3	7.6	0.6
Shelling out turn (%)	37.1	91.6	66.4	8.0	40.0	80.5	63.6	8.7
Sound mature kernel (%)	50.0	100.0	87.3	7.9	50.0	97.8	86.8	8.4
Hundred seed mass (g)	18.0	88.0	37.5	9.1	20.0	68.0	37.2	10.0

Extensive cultivation of the crop often predisposes itself to infestation by new pests and diseases. Peanut bud necrosis disease (PBND) has been a problem in different *agro ecological* regions and recently peanut stem Necrosis (PSND) has also been a cause of concern in the states of Andhra Pradesh and Karnataka. As against the working collection, the core group is an ideal size to systematically screen the accessions to identify promising sources of resistance against these diseases and also *Aspergillus flavus* colonization as suggested by Holbrook *et al.* (1993). The core collection can be further screened for identification of molecular markers owing to it's manageable size. The selection of parents in crop improvement programme will be easier with the core set of groundnut germplasm. The germplasm used for developing core group represented less than 50% of the total germplasm with the Centre. After characterizing the remaining accessions the core set will be supplemented with more accessions and will be validated in future.

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Genetic divergence analysis in Gobhi sarson, *Brassica napus* L.

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Abstract

A collection of *Brassica napus* L. (gobhi *sarson*) comprising 29 genotypes of different eco-geographical origin was evaluated for nine quantitative traits with the national check *B. juncea* (L.) Czern & Coss. (Kranti). Based on D^2 analysis the collection was divided into 13 genetically diverse clusters. Genetic diversity of the genotypes was attributed to secondary branches/plant, days to 50% flowering, 1000 seed weight, oil per cent, siliquae/plant and plant height. Cluster V and XI stood genetically most divergent excluding the cluster XIII (Kranti), Cluster V exhibited higher mean for seeds/siliqua, 1000 seed weight, oil content and seed yield, while lower plant height and days to 50% flowering. Cluster XI reflected higher mean for primary branches/plant, secondary branches/plant, siliquae/plant, seeds/siliqua, oil content and seed yield/plot. This suggested the potential of genotypes TERI(R) 9903 and GSC 864-61 (Cluster V) and GS 1 (Cluster XI) as parents in hybridization so that transgressive segregates could obtained in segregating generation.

Key words: *Brassica napus* L., genetic divergence, cluster analysis

Introduction

For an efficient hybridization programme selection of genetically diverse parents and superior genotypes is important, which ensures the better recombination of genes and exhibit transgressive segregants in selfing series. Gobhi *sarson* (*Brassica napus* L.) is high yielder, hardy enough to tolerate cold weather and can be a potential alternative to the brown *sarson*, the only crop under cultivation in Kashmir valley. Very little work has been done to estimate and categorise the genetic diversity in Gobhi *sarson* under temperate conditions of the valley. Hence, an effort was made to assess the existing genetic diversity in a collection of Gobhi *sarson* under temperate conditions.

Materials and methods

The experimental material consisting of 29 clusters of *Brassica napus* L., Gobhi *sarson* collected from different parts of the country were grown in a randomized complete block design with national check (NC) *B. juncea* (L.) Czern & Coss., variety Kranti at Experimental Farm, Khudwani campus of Sher-E-Kashmir University of Agricultural Sciences & Technology (Kashmir) during *rabi*, 1999-2000 and 2000-2001. Each entry was sown in a plot consisting of 5 rows of 5 m length and replicated thrice. The inter and intra row spacing was maintained at 30 x 10 cm, respectively. All the recommended agronomic practices were followed to raise the good crop. Data were recorded on 10 randomly selected competitive plants from each plot for quantitative and qualitative traits. Days to 50% flowering and seed yield were recorded on net plot basis. Oil content was estimated by NMR. Pooled data of two years were subjected to Mahalanobis D^2 analysis (Mahalanobis, 1928) as elaborated by Murty and Arunachalam (1966) and the cultivars were grouped into different clusters following Tocher's method as described by Rao (1952).

Results and discussion

The analysis of variance showed highly significant differences among the genotypes for all the traits in both the years as well as pooled analysis. Adopting Tocher's procedure, group constellation resulted in distribution of 30 genotypes into 13 diverse clusters (Table 1). Cluster I was the largest, comprising nine genotypes, followed by Cluster II and III with four genotypes each. Cluster IV, V and VI accounted fro two genotypes each, while other clusters had one genotype each, as these could not club with any other genotypes. Cluster XIII included Kranti (NC) and exhibited highest genetic distance from other clusters. The random distribution of cultivars was evident from cluster I having maximum cultivars including Delhi (5), Haryana (2) and one each from Uttar Pradesh and Punjab. The grouping pattern indicated that geographical distribution does not necessarily be indicator of genetic divergence, which is also emphasized by many workers (Mitra and Saini, 1998; Verma and Sachan, 2000). The possible reason could be the free exchange of germplasm among the breeders of different regions and/or unidirectional selection practiced by breeders in tailoring the promising cultivars for different regions. On the other hand, the study revealed the existence of genetic diversity within the region, as the cultivars of the same region could be distributed into different clusters. It was also observed that genotypes of quite different pedigree such as TERI (OE) R-15 [(*B. napus* x *Raphanobrassica*) x *B. napus*] and TERI (OE)R-986 [TBN5 x Cyclone] fall into same cluster, indicating that unidirectional selection pressure could bring the product genetically closer then that of their parents. *Similarly, it is also true that selection could produce* genetically diverse genotypes of same pedigree. Therefore, it si revealed that pedigree record does not necessarily be an indicator of genetic diversity.

The intra-cluster distances (D^2 values) ranged from 4.67 (cluster IV) to 9.54 (Cluster VI) excluding single genotype cluster (Table 2). Cluster XIII (Kranti) reflected higher inter-cluster distance from most of the clusters, owing to species differentiation as it belonged to *B. juncea*. Among the other clusters, the maximum inter-cluster D^2 value was recorded in between cluster VIII and XI (27.73) followed by Clusters VII and XI (25.65), clusters V and XI (25.03) and clusters V and XII (24.99), which indicates that the cultivars included in these clusters had much divergence. The minimum genetic distance (9.70) indicated close relationship among the genotypes included in the clusters I and III.

The cluster mean for nine characters (Table 3) indicated considerable differences between clusters for all the characters. Cluster VII had the maximum seed yield/plot (525 g), siliquae/plant (89) and minimum days to 50% flowering (150 days). Lowest cluster mean for plant height (70 cm) was recorded in cluster VIII. Highest cluster mean for primary branches/plant (5) and secondary branches/plant (11) was exhibited by Cluster XI, seeds/siliqua (17) and 1000 seed weight (3.8 g) by cluster V and oil content (43.3%) by cluster IX. Secondary branches/plant, followed by days to 50% flowering, 1000 seed weight, oil per cent, siliquae/plant and plant height *contributed most towards the total divergence of the* collection. Mitra and Saini (1998) and Verma and Sachan (2000) also reported the similar findings. These characters could form the basis in selection of parents for hybridization from distantly placed clusters to obtain high frequency of heterotic combinations.

In the present study, though the higher inter cluster distance was registered by cluster XIII (Kranti) from most of the other clusters but the superior derivatives can not be expected from their crossing due to species barrier and F_2 sterility. The crossing between the genotypes of Cluster V and XI would be the logical choice for obtaining heterotic combinations which was attributed to higher inter cluster distance as well as high *per se* performance for primary branches/plant, secondary branches/plant, siliquae/plant, seeds/siliqua, 1000 seed weight, oil content and seed yield.

Table 1 Group constellation of *Gobhi sarson* collections based on divergence analysis

Cluster	No. of cultivars	Designation	Origin*
I	9	NPN 01, TERI(OE)R-986, TERI(OE)R-15, NPN 04, NPN 02, HNS 9802, HNS 9605, PBN 9901, GSC 865-2	Delhi (5), Haryana (2), Uttar Pradesh (1) and Punjab (1)
II	4	TERI(OO)R-986-5, NPN 03, GL-2, RSPN-25	Delhi (2), Punjab (1) and J&K (1)
III	4	GSL-1, GS-2, GS-3, GS-5	Punjab (1) and J&K (3)
IV	2	TERI(OE)R-983, HNS 9603	Delhi (1) and Haryana (1)
V	2	TERI(R) 9903, GSC 864-6	Delhi (1) and Punjab (1)
VI	2	4-09-A-41, GSC 864-61	Punjab (2)
VII	1	TERI(OE)R-984	Delhi (1)
VIII	1	RKN 9806	Uttar Pradesh (1)
IX	1	TKG-G-24	Madhya Pradesh (1)
X	1	GSL-2	Punjab (1)
XI	1	GS-1	J & K (1)
XII	1	GS-4	J & K (1)
XIII	1	Kranti	Uttar Pradesh (1)

* Figures in parenthesis indicate the number of cultivars

Table 2 Average intra and inter cluster distances (D^2 values) for 13 clusters of *gobhi sarson* genotypes

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I	7.34	10.61	9.70	11.18	13.64	11.91	14.15	13.19	14.42	12.52	17.03	17.35	15.45
II		6.52	12.49	13.39	16.91	15.74	12.96	16.17	17.20	12.87	18.19	20.16	18.45
III			6.26	14.76	15.59	11.22	13.46	16.87	14.82	10.35	16.42	13.16	15.92
IV				4.67	18.96	12.85	13.71	18.90	15.47	19.28	23.43	14.67	17.41
V					6.41	18.57	12.86	19.89	20.23	22.01	25.03	24.99	25.55
VI						9.54	18.93	14.93	21.19	19.06	23.01	22.12	27.83
VII							0.00	12.91	20.27	20.16	25.65	22.99	12.95
VIII								0.00	21.88	20.61	27.73	21.19	30.34
IX									0.00	24.94	17.36	20.89	16.20
X										0.00	24.34	14.94	22.98
XI											0.00	18.19	21.06
XII												0.00	29.06
XIII													0.00

Table 3 Cluster mean for nine quantitative traits in *gobhi sarson*

Character / Cluster	Days to 50% flowering	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Siliquae/ plant	Seeds/ siliqua	1000 seed weight (g)	Oil content (%)	Seed yield/ plot (g)
I	154	79	3	5	56	13	3.7	40.7	309
II	153	96	4	4	75	15	3.3	41.1	406
III	156	92	3	8	74	14	3.0	38.9	338
IV	150	86	2	7	52	16	3.5	42.6	275
V	155	77	2	6	59	17	3.8	42.1	456
VI	153	82	2	6	36	16	3.4	37.8	211
VII	150	83	3	9	89	16	3.5	41.5	525
VIII	151	70	2	4	61	12	3.1	38.9	258
IX	154	97	2	8	61	7	3.0	43.3	250
X	157	101	4	3	88	16	3.0	39.3	398
XI	158	88	5	11	71	12	2.9	40.8	323
XII	157	86	3	9	84	14	2.0	40.8	253
XIII	153	98	3	11	86	11	4.1	43.1	478
% CTD	12	11	9	17	11	8	12.2	11.3	8.7

% CTD = Per cent contribution towards divergence

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Extra-early maturity genepool in castor, *Ricinus communis* L.

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Abstract

The development of extra-early genepool in castor (Ricinus communis L.) was aimed at enhancing the genetic base for developing extra-early maturing lines with enhanced seed yield and other desirable traits. Based on evaluation for four contiguous years, 21 stable extra-early maturing (75-110 days) accessions were selected and were random-mated for five generations in isolation. Consequently the range and mean of the major yield contributing traits and yield were considerably increased while the days to, 50% flowering, 50% maturity and node number to primary spike were comparable to parents. The genetically enhanced genepool of castor would certainly provide broad base for developing diverse high yielding extra-early maturing cultivars.

Key words: Extra-early maturity, diversity, genepool

Introduction

The productivity of traditional castor cultivars in the marginal drylands is considerably low owing to the long duration of crop. Castor is essentially indeterminate in fruiting habit and sets spikes over a period of time. In general, the late types set less number of spikes due to limited availability of moisture in drylands. After appearance of first spike the spikes of other orders will develop in succession. Early maturity in castor is desirable in order to make the best use of available moisture. In the castor germplasm repository of 2856 accessions maintained at the Directorate of Oilseeds Research, Hyderabad, A.P., 21 extra-early maturing accessions were identified. These accessions matured in 75-110 days whereas the existing cultivars took about 150 to 180 days to maturity. But the productivity of extra-early accessions was very low because of low expression of major yield parameters. Keeping in view that the crop is cultivated mainly in dryland areas, we have decided to develop an extra-early maturing genepool with wide genetic base for developing extra-early maturing lines with enhanced yield and other desirable traits.

Materials and methods

Twenty three accessions which flowered within 35 days after sowing in three contiguous years (1991,1992 and 1993) at Hyderabad were initially selected as source material for extra-early maturity. These were further evaluated in Randomised Block Design with three replications in 1994 to know yield potential of individual parent, and then selected twenty one stable extra-early maturing accessions for making the genepool. While selecting accessions, variability for other morphological characters and the geographical origin of the accessions were not considered.

Equal quantity of seed from each 21 extra-early maturing accessions was bulked thoroughly. The bulked seeds were planted in March, 1995 at a spacing of 45 cm x 90 cm. Early summer (March) sowing was preferred to meet the required isolation distance of 1000 m. One thousand progenies of 21 parents were allowed to random mate. Since the initiation of flowering of primary and other spikes, all plants were shaken by hand to ensure near 100% open pollination in the population for achieving equilibrium. Seed was harvested from each plant and bulked thoroughly. Random sampling was done from this bulk seed to plant next generation in March, 1996. Among 2908 plants grown in 1996, about 43 plants flowered late while the remaining plants were in the range of early maturity. The late flowering plants were removed before flower initiation itself. The remaining plants were allowed to random mate under isolation. Third, fourth and fifth cycles of random mating were allowed in 1997, 1998 and 1999, respectively following the same month of sowing, method of harvesting, sampling of genepool and isolation distance. The population size of third, fourth and fifth cycles of random mating was 2959, 2978 and 2998 plants, respectively. Late maturing plants were removed every year. Occurrence of late maturing plants decreased after every random mating. After 5th random mating in 1999, the genepool was sown along with its 21 parents in July 2000. The data on plant height, number of nodes to primary spike, days to 50% flowering, days to 50% maturity, total length of primary spike, length of primary spike covered by capsules, total number of spikes/plant, 100-seed weight, oil content and seed yield/plant after 120 days of planting, were recorded on 200 randomly taken plants and 50 selective plants from genepool and 5 plants of each 21 parents.

Results and discussion

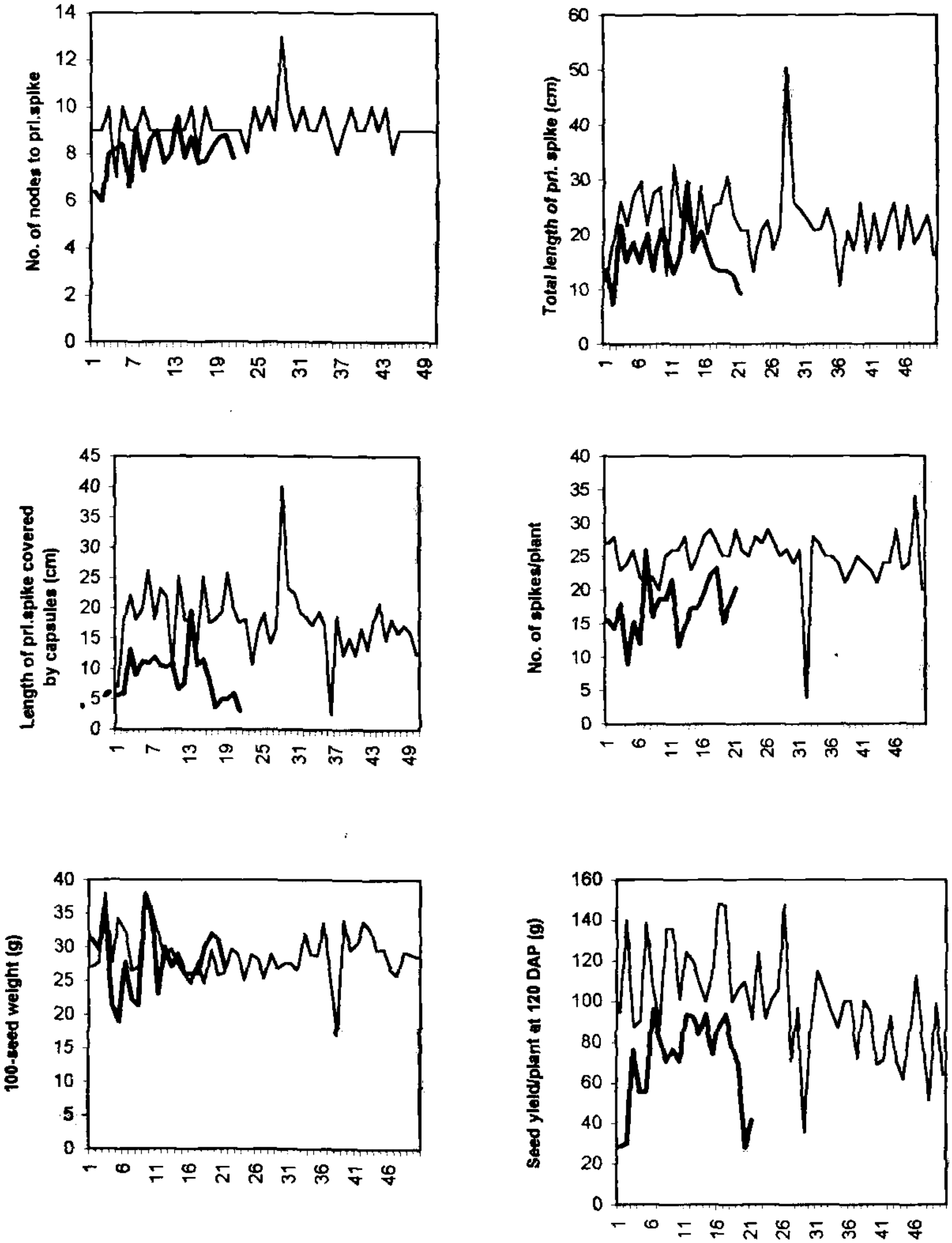
Increase in variation was observed for many traits in genepool after random mating (Table 1). Mean values of days to 50% flowering and days to 50% maturity of genepool were considerably closer to that of original parental accessions after random mating. The slight increase in range of these traits may be due to increase in node number range. Node number to primary spike has positive relation with days to primary spike initiation and is considered as an indication to days to maturity in castor (Domingo, 1945). The late flowering or high node types in genepool might have occurred due to expression of double recessive late flowering genes after random mating (Zimmerman, 1958). He indicated that two gene pairs were responsible for earliness and parents carried different genes for earliness. The mean values of days to 50% flowering and days to 50% maturity of genepool indicated the predominance of extra-early maturing genes in the population. Patel and Jaimini (1991) observed that under rainfed condition the relation between seed yield and days to flowering and nodes upto primary spike was negative. This indicated the significance of early flowering genotypes over late maturing ones in utilizing the minimal moisture available in their short period of growth under rainfed situation. The range in variation and means of the major yield contributing traits such as total length of primary spike, length of primary spike covered by capsules and number of spikes/plant and yield/plant were greatly increased in genepool after random mating. This increase may be due to heterotic effect/ or recombination. These parameters showed high positive correlation with seed yield (Muthiah *et al.*, 1982). Therefore, any increase in their value will help the breeder to select high yielding genotypes from genepool. The variability in seed weight and oil content could not be enhanced after random mating. The increased plant height of genepool was desirable for the improvement of yield components as it had significant positive association with major yield parameters (Giriraj *et al.*, 1973).

The range of variation for various yield parameters and yield/plant was also high among the 50 plants selected based on phenotype from genepool (Table 1). The means of these traits were also considerably higher than those of parental accessions. The selected plants were comparable with the parents with regard to node number, days to 50% flowering and days to 50% maturity. Individual potentiality of each selected plant against that of 21 parents is depicted in Fig.1. Though, the selected plants showed node number ranging from 7-13, most of them had 9-10 nodes to primary spike, indicating the earliness of the material. Similarly, the frequency of plants showing considerably higher values than the parental lines was high for all the yield parameters and seed yield/plant, baring seed weight. This proved that the genetic base for desirable traits was enhanced in the genepool.

Table 1 Diversity in extra-early genepool and parents

Character		Parental accessions	Genepool	
			Random plants*	Selective plants**
Plant height (cm)	Range	23-40	13.5-80.5	16.7-66
	Mean±SE	31.6±0.9	33.6±0.6	40.1±1.2
No. of nodes to primary spike	Range	6-9.6	5-20	7-13
	Mean±SE	8.5±0.17	9.7±0.12	9±0.16
Days to 50% flowering	Range	28-35	25-55	27-40
	Mean±SE	32±0.18	36±0.42	36±0.35
Days to 50% maturity	Range	75-110	73-130	75-110
	Mean±SE	95±0.98	98±0.35	96±4.6
Total length of primary spike (cm)	Range	7.4-29.6	4.5-60	10.5±0.8
	Mean±SE	16.2±1.0	21±0.48	23±0.8
Length of primary spike covered by capsules (cm)	Range	3-19.6	2-28	2.5-30
	Mean±SE	8.9±0.8	14±0.4	18±0.3
Total No. of spikes/plant	Range	9-26	3-33	4-34
	Mean±SE	17.3±0.86	21±0.3	25±0.4
100-seed weight (g)	Range	18.9-38	15-35	17-38
	Mean±SE	28.3±1.0	28.2±0.3	28.8±0.3
Yield/plant (g) at 120 days	Range	28-96	34-252	35.5-148
	Mean±SE	70.5±4.7	101.6±3.7	100.2±3.4
Oil content (%)	Range	45-51	40-50	41-50
	Mean±SE	48±0.3	46±-0.1	47±0.2

* 200 randomly taken plants from genepool after 5th random mating; ** 50 selective plants from genepool after 5th random mating



Parental accessions — Selective plants

Fig 1 Diversity in extra-early maturing parents and selective plants from genepool after random mating

Generally the major problem in germplasm material is a high level of duplication with little difference between many of the accessions. Burton (1978) and Witcombe (1984) suggested development of trait-specific genepools to reduce effective number of accessions drastically. In our repository duplication of extra-early material is not a problem, but their low productivity was undesirable. Therefore, the trait-specific (extra-early) genepool was made to enhance the genetic base for selecting diverse high yielding extra-early genotypes. This genepool is certainly better than individual parental accessions because of its high diversity and broad genetic base. Since, the genepool was developed by intercrossing, it may have homozygous loci at low frequency but has an advantage of allowing gene recombinations. The extra-early genepool would certainly provide broad genetic base for developing diverse, high yielding extra-early maturing cultivars and obtaining heterotic hybrids. The genepool was distributed to breeders and was being used by them as a population for improvement by single plant selection, recurrent selection and mass selection.

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Gene effects for yield contributing characters in castor, *Ricinus communis* L., by generation mean analysis

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Abstract

Estimates of gene effects based on analysis of generation mean were obtained for eight characters in five crosses of castor. Results indicated presence of additive, dominance and epistatic gene effects. Among non-allelic interaction dominance x dominance (l) interactions was of greater magnitude than main gene effects for almost all the characters, indicating the importance of heterosis breeding to utilize non-additive gene effects. The additive gene effects (d) also contributed significantly for different traits like, capsules on primary, capsules on S_1T_1 raceme and effective length of primary raceme in VP1 x RG 299 and RG184 x RG 299 crosses, for capsules on S_1T_1 raceme and effective length of S_1T_1 raceme in cross MCP 2 x RG 125. *Selection in segregating generations* of these crosses will be effective for development of inbreds possessing longer spikes and higher number of capsules on primary and S_1T_1 raceme. However to exploit additive as well as non-additive gene effects reciprocal recurrent selection procedure may be adopted.

Key words: Castor, gene effects, generation mean, gene action

Introduction

Castor, *Ricinus communis* L., an important non edible oilseeds is one of the cash crops grown in dry lands as well as irrigated situations. Multiple pathways involving different yield contributing characters influence seed yield. *Hence seed yield can be also improved through improve*ment of yield contributing characters (Solanki and Joshi, 2000). The *estimation of gene effects involved in the* inheritance of yield contributing or quantitative characters are helpful in planning breeding programs. Though gene effects for seed yield and other traits have been estimated in castor, information on epistatic gene effects is negligible. Thus the present investigation, genetic parameters namely additive, dominance and epistatic gene effects were estimated through generation mean study for eight quantitative traits in five crosses of castor.

Materials and methods

The experiment material comprised of six generation i.e. P_1, P_2, F_1, F_2, BC_1 (F_1 x P_1) and BC_2 (F_1x P_2) of five crosses namely VP1 x RG299, VP1 x RG184, RG184 x RG299, MCP2 x RG125 and RG125 x 846. The six generations of each cross were grown separately in randomized block design with two replications. In each replication parents and crosses were randomized separately, P_1, P_2 and F_1 were grown in two rows of 4.5 m length. The inter and intra *row spacing was 60 cm and 45 cm respectively. Plant* population in segregating generations was varying from 62-220 plants the crop was raised as per standard practices for irrigated crop. Observations on individual plants were recorded for eight quantitative characters (Table 1). The data were subjected to different biometrical techniques namely Scaling test (Mather and Jinks, 1982) and generation mean analysis by Haymans' six parameter model (Hayman, 1958) .

Results and discussion

Significant scaling test for different traits was observed in almost all crosses indicating the presence of digenic or higher order interactions. The non significant scaling test (Table1) indicated the absence of non allelic interactions for effective length of primary raceme in cross RG125 x 846, capsules on primary raceme in cross MCP2 x RG125 and nodes up to primary raceme in cross VP1 x RG184.Thus inheritance of these characters in above referred crosses could be explained on the basis of simple *additive-dominance model. The estimates of genetic* parameters m, d, and h in these crosses indicated that both additive (d) and dominance (h) gene effects were responsible for inheritance of traits in two crosses RG 125 x 846 and MCP 2 x RG 125. Absence of non allelic interaction for some characters also reported earlier like effective length of primary, number of capsules on main raceme and nodes up to primary raceme (Deepika Bhat and Reddy,1986 ; Patel, 1996).

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Table 1 Estimates of genetic components in castor

Cross	Components of generation mean (Hayman, 1958)						Scaling tests		
	m	d	h	i	j	l	A	B	C
P1 x RG 184									
Effective length of primary raceme	33.78**	9.38**	-9.70	-1.75	6.23**	40.66**	-13.4**	-25.90**	-37.90**
Total length of primary raceme	41.69**	2.60	-11.18	-9.48	-0.09	40.37**	-15.50	-15.30**	-21.40**
Capsules on primary raceme	56.37**	-0.23	-50.18**	-51.23**	3.11	37.68**	9.90	3.60	64.80**
Effective length of S_1T_1 raceme	25.06**	10.30**	-0.21	0.63	5.65**	24.95**	-7.10	-18.50**	-26.20**
Total length of S_1T_1 raceme	33.10**	5.64**	3.78	0.21	4.84**	20.83**	-5.40	-15.10**	-20.40**
Capsules on S_1T_1 raceme	27.20**	4.79**	-7.30	-10.95	2.44	28.61**	-6.40	-11.30**	-6.70
Nodes up to primary raceme	14.37**	-0.14	-0.15	-	-	--	1.90	2.20	1.40
Height up to primary raceme	99.21**	-38.39**	-18.15	-43.45**	2.80	52.03**	-1.50	-7.10	34.86
VP1 x RG299									
Effective length of primary raceme	34.49**	20.62**	-8.66	-11.51**	7.27**	30.55**	-2.20	-16.80**	-7.50
Total length of primary raceme	43.77**	11.08**	-2.61	-12.61**	5.48**	40.94**	-8.70**	-19.60**	-15.70**
Capsules on primary raceme	48.52**	22.86**	6.71	-7.98	17.46**	-4.73	23.8**	-11.10*	20.70**
Effective length of S_1T_1 raceme	19.87**	11.00**	9.81**	13.01**	2.07	-5.12	-1.20	-6.6**	-20.90**
Total length of S_1T_1 raceme	30.32**	6.01**	17.33**	-20.36**	16.73**	4.31**	6.10	-2.50	-13.10**
Capsules on S_1T_1 raceme	22.71**	6.23**	4.04	-0.80	5.28**	33.04**	-10.80**	-21.40**	-31.40**
Nodes up to primary raceme	16.5**	0.17	-3.04	0.67	-4.22**	-3.34	2.10**	0.70	6.10**
Height up to primary raceme	102.51**	-8.37	-21.23	-10.61	29.57**	14.52	42.10**	-17.00	35.70**
RG184 x RG 299									
Effective length of primary raceme	27.36**	9.53**	-6.78	-0.26	-8.58	41.29**	-16.60**	-16.10**	-24.10**
Total length of primary raceme	39.29**	7.89**	-2.54	-12.84	4.79**	55.10**	-16.30**	-25.90**	-29.40**
Capsules on primary raceme	42.78**	13.94**	11.99	-4.70	5.34	32.86**	-8.70	-19.40**	-23.40
Effective length of S_1T_1 raceme	17.51**	2.22**	1.28	2.08	-2.97	22.56**	-15.30**	-9.30**	-26.70**
Total length of S_1T_1 raceme	28.20**	-0.25	-1.34	-2.44	-1.95	30.66**	-16.00**	-12.10**	-25.70**
Capsules on S_1T_1 raceme	22.05**	6.47**	-18.47**	-13.41**	6.07**	34.83	-4.60	-16.80**	-7.90**
Nodes up to primary raceme	15.11**	0.31	5.42**	-1.02	0.56**	14.26**	-6.00**	-7.20**	12.20**
Height up to primary raceme	123.60**	-9.69	12.42	14.62	-7.59	-55.26**	12.70	27.90**	26.04**
MCP-2 x RG-125									
Effective length of primary raceme	30.18**	-13.33**	-16.12	-28.02	-28.53**	56.70**	-42.9**	14.20**	-0.70
Total length of primary raceme	30.83**	-6.16**	-1.52	-7.57	-16.26**	28.01**	-26.50**	6.00	-12.90
Capsules on primary raceme	44.57**	-33.20**	7.31*	-	-	-	4.90	3.00	12.30
Effective length of S_1T_1 raceme	21.69**	3.76**	-1.61	-8.16	-2.69	23.26**	-10.20**	-4.80	-6.90
Total length of S_1T_1 raceme	27.38**	-0.05	-1.55	-7.35	-1.15	19.15**	-7.00**	-4.70	-4.50
Capsules on S_1T_1 raceme	30.64**	8.18**	-9.88	-14.98	-7.71**	44.71**	-22.60**	-7.10	-14.70
Nodes up to primary raceme	16.98**	2.44**	-0.51	-2.91	-1.45	-4.90	2.40**	5.40**	10.70**
Height up to primary raceme	111.80**	21.43**	38.80**	3.90	-26.56**	-33.22	-11.90	41.20**	25.40
RG-125 x 846									
Effective length of primary raceme	11.17**	2.64**	-1.29**	-	-	-	0.20	-1.30	-0.20
Total length of primary raceme	24.61**	-8.70**	-10.07**	1.12	4.59**	2.90	2.60	-6.60**	-5.10
Capsules on primary raceme	17.21**	-6.73**	-3.82	-4.32	-2.73	-5.20	2.00	7.50**	13.80**
Effective length of S_1T_1 raceme	11.53**	0.19	3.55	0.65	-2.40	4.75	-5.10**	-0.30	-6.00**
Total length of S_1T_1 raceme	24.33**	-2.28	-1.97	-0.32	-1.88	15.49**	-9.50**	-5.70**	-14.80**
Capsules on S_1T_1 raceme	13.17**	0.48	1.01	0.76	-2.36	5.24	-5.40**	0.70	-6.80
Nodes up to primary raceme	12.25**	-3.46**	-3.45*	0.35	-0.76	-5.70**	2.30**	3.80**	6.40**

*Significant at P = 0.05 and ** Significant at P = 0.01

The estimates of genetic parameters for different yield contributing traits in cross VP1 x RG184 revealed that additive gene effects (d) governed the inheritance of effective length of primary raceme, effective and total length of S_1T_1raceme, capsules on S_1T_1 raceme and height up to primary raceme. Epistatic gene effects additive x dominance gene effects (j) were more important for inheritance of the traits, effective length of primary raceme, effective length of S_1T_1 raceme and total length of primary raceme. In same cross dominance x dominance (l) gene effects were more pronounced than additive gene effects for all the characters except effective length of S_1T_1 raceme.

Additive gene effects (d) governed the inheritance of all the traits except nodes up to primary raceme and height up to primary raceme in VP1 x RG 299 cross. Non allelic interactions *viz.*, dominance x dominance (l) and additive x dominance (j) were involved in the inheritance of effective length of primary raceme, total length of primary raceme, total length of S_1T_1 raceme and capsules on S_1T_1 raceme. Epistatic interaction like additive x dominance gene effects (j) was also observed for expression of the number of capsules on primary raceme and nodes up to *primary raceme* .

Additive gene effects (d) governed the inheritance of mostly yield contributing traits in cross RG184 x RG299 like, effective length of primary raceme, capsules on primary raceme, effective length of S_1T_1 raceme and capsules on S_1T_1 raceme. In this cross dominance x dominance gene effects (l) were also responsible for inheritance of traits namely effective length of primary raceme, capsules on primary raceme, effective length of S_1T_1 raceme and height up to primary raceme. However, non allelic gene effects like additive x dominance (j) also controlled the inheritance of capsules on S_1T_1 raceme.

Cross MCP2 x RG 125, exhibited the importance of additive gene effects (d) for inheritance of two characters i.e., effective length of S_1T_1 raceme, and capsules on S_1T_1 raceme. Dominance gene effects governed the inheritance of earliness in this cross. Epistatic gene effects namely dominance x dominance (l) governed the expression of effective length of primary raceme, total length of primary raceme, effective length of S_1T_1 raceme and capsules on S_1T_1 raceme. Non allelic interaction viz., additive x dominance gene effects (j) controlled the inheritance of plant height up to primary raceme.

The role of non allelic interaction as indicated by scaling test was not confirmed by estimates of genetic parameters in cross RG125 x 846 for the characters *viz.*, effective length of primary raceme and S_1T_1 raceme. It might be due to presence of higher order interactions for inheritance of these traits. In cross RG125 x 846 inheritance of earliness in emergence of primary raceme was governed by additive as well as dominance (h) gene effects.

The magnitude of epistatic interaction namely dominance x dominance (l) gene effects for most of the traits was higher in almost all traits under study. Such non additive gene effects may be exploited by heterosis breeding.

Additive gene effects observed in the inheritance of important yield contributing characters like effective length of primary raceme, capsules on primary raceme and capsules on S_1T_1 raceme in crosses VP1 x RG299, RG184 x RG299 and VP1 x RG184 can be utilized in breeding programe by selection methods.

Complementary type of gene action observed in cross VP1 x RG 299 for capsules on S_1T_1 raceme, and for capsules on primary raceme in cross RG184 x RG299 can be utilized in breeding programme. Duplicate type of gene action observed for other traits is not easy to use for breeding programme.

It is therefore concluded that heterosis breeding may be used where large magnitude of non- fixable gene effects is observed. A sizable amount of additive gene effects observed indicated that segregating generations of crosses VP1 x RG 299, RG184 x RG299 and VP1 x RG184 may be handled to develop inbred/varieties possessing longer spikes coupled with higher number of capsules at primary and higher order of raceme. Such type of inbred/varieties are likely to provide higher seed yield also. Considering importance of additive as well as non additive gene effects observed in present study reciprocal recurrent selection may be used to exploit both types of gene effects.

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Combining ability and heterosis for seed yield and yield components in castor, *Ricinus communis* L.

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Abstract

A line x tester analysis involving three pistillate lines, nine male lines and the resulting 27 hybrids was carried out to study the heterosis and combining ability for seed yield, its components and oil content. The estimated components of gca and sca variances showed predominance of non additive gene action for days to 50% flowering, number of nodes to primary, plant height, seed yield in first, second, third picking and total seed yield. Additive gene action was predominant for effective spikes per plant, hundred seed weight and oil content. The female line, M 619 for plant height, 100-seed weight, seed yield in all the three pickings and total seed yield, while M 584 for effective spikes per plant, yield at first picking and oil content were good combiners. Among the males, JI 240 for seed yield in all the three pickings, total seed yield and oil content, JI 220 for seed yield in second and third pickings, SKI 233 for effective spikes per plant and *SKI 229* and *JI 225* for 100-seed weight were good general combiners. The crosses exhibited heterobeltiosis from -13.45 to 206% for seed yield, -2.76 to 3.72% for oil content, -22.5 to 20.54% for effective spikes per plant and -18.96 to 12.06% for 100 seed weight. Standard heterosis for seed yield varied from 35.4 to 215% over GCH 4 and -4.2 to 123 % over DCH 32. The hybrids, M 619 x JI 240, M 619 x JI 220, M 584 x JI 240, M571 x JI 240 and M 619 x SKI 232 with >150% heterobeltiosis and 200% standard heterosis (over GCH 4) for seed yield are of commercial value.

Key words: Combining ability, gca, sca, heterosis, castor

Introduction

Genetic improvement of castor entered a new era with the introduction of TSP 10R, an exotic pistillate line and subsequent development of an indigenous stable pistillate line VP-1. VP-1 with its unique morphological characters like dwarf stem, condensed nodes, cup shaped leaves and triple bloom was also found to be a good general combiner for seed yield and yield components (Pathak *et al.*, 1989). However due to its susceptibility to Fusarium wilt, hybrids developed with VP-1 became susceptible to wilt. Several wilt resistant, mutant VP-1 lines were developed through irradiation with 55 Kr gamma rays at Directorate of Oilseeds Research, Hyderabad (Lavanya *et al.*, 2000). However, information on the general combining ability (gca), specific combining ability (sca) and magnitude of heterosis of hybrids developed from these mutant pistillate lines and fusarium wilt resistant male lines was lacking. The present study aims at assessing the extent of heterobeltiosis, standard heterosis, combining ability and type of gene action for yield, its components and oil content through line x tester analysis of wilt resistant pistillate and male lines.

Materials and methods

Three mutant VP-1 pistillate lines (M 571, M584 and M 619), nine pollen parents (PCS 1, PCS 121, JI 220, JI 225, JI 240, JI 260, SKI 229, SKI 232 and SKI 233) were selected on the basis of desirable agronomic, morphological characters and resistance to fusarium wilt and crossed in line x tester fashion during *Rabi* 2000-01. The resulting 27 hybrids along with 12 parents and two standard checks - DCH 32 and GCH 4 were evaluated in a RBD with three replications at Directorate of Oilseeds Research, Hyderabad during *Kharif* 2001-02 under rainfed conditions. Each plot consisted of 40 plants with a spacing of 90 cm x 45 cm. Observations were recorded on five randomly selected plants for six characters *viz.*, days to 50% flowering, number of nodes to primary spike, plant height upto main spike (cm), effective spikes per plant, 100-seed weight (g) and oil content (%). Seed yield per plot was recorded picking wise and cumulated as total seed yield and expressed in kg/ha. Heterosis over better parent (heterobeltiosis) and heterosis over checks (standard heterosis) were calculated as per standard

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formulae. Combining ability analysis was performed as per Kempthorne (1957). During the period of study, continuous rainfall during the month of September led to the incidence of Botrytis to the extent of 60-80% (Anonymous, 2001) resulting in complete loss of primary spikes in some entries. The ability of such entries to recover from losses by putting forth more number of effective spikes per plant or capsules per spike resulted in normal yields in the second or third picking. Hence mean values for seed yield were calculated as seed yield in three individual pickings along with the total seed yield to identify good combiners for different pickings. Predictability ratio was calculated as per the formula ($2\sigma^2g/2\ \sigma^2g + \sigma^2s$) given by Baker (1978).

Results and discussion

The analysis of variance for combining ability revealed the existence of significant differences among females for effective spikes per plant, 100-seed weight and oil content. Among males, significant differences were observed for 100-seed weight, yield at second and third picking, total seed yield and oil content (Table 1). However, mean squares due to females vs. males were significant for all the traits studied barring oil content. Predictability ratios were near to unity for oil content, 100-seed weight and effective spikes per plant, indicating the preponderance of additive gene action. For the traits, days to 50% flowering, number of nodes to primary spike, plant height, seed yield in all the three pickings and total seed yield the predictability ratios were far from unity, inferring the predominance of non-additive gene action governing the traits. Similarly, Chakrabarthy (1997) and Pathak *et al.*, (1989) reported predominance of non-additive gene action for seed yield. However, Kandasamy *et al.*, (1983) documented the predominance of non-additive gene action for effective spikes per plant in castor.

There was no correlation between mean values of parents and the gca effects for majority of the traits (Table 2) barring 100 seed weight and oil content. Thus, selection of the parents should be based on both *per se* performance and gca effects of parents. The present finding was in contrast to the reports of Patel *et al.*, (1984) and Pathak *et al.*, (1989).

The estimates of combining ability effects (Table 2) indicated that M 619 was the most desirable female parent with significant positive gca effects for majority of the characters *viz.*, 100-seed weight, seed yield in all the three pickings and total seed yield. M 584 was also a good general combiner for dwarfness, effective spikes per plant, seed yield in first picking and oil content, while M 571 was good combiner for effective spikes per plant.

Among the males, early flowering, low number of nodes to primary and good branching types with more number of effective spikes per plant are desirable traits to develop short duration hybrids suitable for rainfed areas. Such short duration types often complete their life cycle during the periods of monsoon by producing high seed yields in the first or second pickings. JI 225, the early duration male parent was a good general combiner for early flowering, number of nodes to primary spike, 100-seed weight, seed yield at first picking and total seed yield. Another short duration male parent, SKI 229 was also a good general combiner for less number of nodes to primary spike, high 100-seed weight and high seed yield in the first and third picking and oil content.

JI 240 was the most desirable medium duration male parent with good combining ability for seed yield in all the three pickings, total seed yield and oil content. JI 220 was a desirable short duration male parent with positive gca effects for seed yield at second and third pickings and total seed yield, while SKI 233 was good general combiner for effective spikes per plant.

The estimates of sca effects for total seed yield were significant for eight hybrids of which two hybrids *viz.*, M 619 x SKI 232 and M 619 x SKI 233 were good specific combiners for seed yield in all the three pickings (Table 3). The cross, M 584 x SKI 229 was a good combiner for seed yield in second and third pickings, total seed yield and hundred seed weight, while the crosses, M 571 x PCS 121 and M 571 x JI 225 were good specific combiners for seed yield at first and third pickings and total seed yield. M 584 x PCS 121 with good specific combining ability for early duration, short plant height, effective spikes per plant, seed yield in second and third pickings and total seed yield, indicated its ability to recover from the losses of Botrytis. Two crosses, M 619 x PCS 121 and M 619 x JI 220, were good combiners for oil content and may be used for selection and generation advancement to exploit its non additive nature.

The magnitude of heterobeltiosis for final seed yield ranged from 19.75% to 206 %, while standard heterosis ranged from 35.4% to 215.2 % and 26.2% to 123.1% over GCH 4 and DCH 32, respectively (Table 4). The hybrid, M 619 x JI 240 exhibited significant negative heterosis for days to 50% flowering and significant positive heterosis for 100-seed weight, total seed yield and oil content over check, DCH-32. The highest significant positive heterosis over checks, GCH 4 and DCH 32 was recorded in hybrid, M 619 x JI 240 followed by M 619 x JI 220, M 584 x JI 240, M571 x JI 240 and M 619 x SKI 232. These top five hybrids have good commercial value and could be exploited.

Table 1 Analysis of variance of combining ability for seven characters in castor

Source	DF	Mean sum of squares									
		Days to 50% flowering	No. of nodes to primary spine	Plant height	Effective spikes/ plant	100 seed weight	Seed yield: *First picking*	*Second picking*	*Third picking*	*Total yield*	Oil content
Replications	2	214.8**	1.62	26.3	0.265	25.13	57066	248225	414088	1809016	0.839
Females	2	10.72	0.44	797.8	21.94**	87.12**	172877	1348303	452821	4498800	12.73**
Males	8	17.81	3.96	454.8	1.99	27.78**	133238	2190690**	1890996 *	6763494 **	7.32**
Females x Males	16	23.91 *	1.83 *	220.2**	1.59**	6.11 *	88414**	511126**	537472**	1281106**	0.583
Error	32	10.06	0.96	42.32	0.59	2.64	4759	29309	64273	110348	0.628
σ_{gca}		-0.54	0.02	22.60	0.58	2.80	3591.31	69909.5	35246.46	241668.9 .	0.50
σ_{sca}		4.61	0.29	59.29	0.33	1.16	27885.15	160605.7	157733.2	390252.7	-0.01
$\sigma_{sca} / \sigma_{gca}$		8.54	14.50	2.62	0.57	0.41	7.76	2.30	4.47	1.61	0.02
Predictability ratio		-0.31	0.12	0.43	0.78	0.83	0.20	0.47	0.31	0.55	1.01

*, ** Significant at 5% and 1% levels, respectively.   *DF - degrees of freedom*

Table 2 Mean values and gca effects of parents for seed yield and its components in castor

Parents	Days to 50% flowering		No. of nodes to primary spike		Plant height (cm)		Effective spikes/ plant		100 seed weight (g)		Seed yield (kg/ha): First picking		Second picking		Third picking		Total yield		Oil content (%)	
Males	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca	Mean	gca
PCS 1	55.3	0.06	12.6	-0.55**	43.7	-0.38**	5.6	0.25	24.1	0.15	256	4.5	1096	-195.7**	1060	-553.9**	2413	-745.1**	51.4	0
PCS 121	56.7	1.28	18.5	0.94**	104.0	13.62*	6.4	-0.89**	19.6	-2.04**	148	-216.0**	418	-566.3**	1389	267.2**	1954	-515.1**	49.3	-0.92**
JI 220	57.3	4.00	13.0	-0.15	55.0	-4.05	6.9	0.18	22.8	-0.80	244	-12.0	638	306.5**	503	849.7**	1385	1144.3**	51.2	-0.93**
JI 225	57.3	-2.94**	11.3	-0.59*	40.7	-0.94	5.5	0.04	29.3	1.70**	210	182.8**	937	14.2	565	72.0	1712	269.1**	50.4	-0.5*
JI 240	57.7	-1.60	15.0	-0.02	73.3	-0.72	6.1	-0.62**	27.8	0.74	292	131.9**	723	1152.6**	1163	396.0**	2178	1680.1**	53.4	0.86**
JI 260	55.7	0.51	12.4	0.09	44.0	3.28**	6.5	-0.10	25.5	-2.24**	139	24.1	795	-30.2**	1185	-250.1**	2086	-256.0**	49.8	-0.63**
SKI 229	58.3	0.06	12.2	-0.68**	36.0	12.27**	6.7	0.39	34.6	3.32**	221	59.2**	1154	-296.8**	1050	245.4**	2425	-482.9**	54.3	1.61**
SKI 232	56.0	1.28	13.5	1.20**	118.3	5.40	7.0	0.23	25.0	-0.38	79	-114.5**	543	-229.6**	912	8.5**	1535	-336.0**	53.2	0.84**
SKI 233	55.0	0.95	14.4	-0.25	90.3	-2.94	6.9	0.53**	27.7	-0.45	77	-60.0**	365	-154.6**	375	-544.0**	817	-758.5**	51.8	-0.33
Females																				
M 571	56.7	-0.64	15.6	-0.08	48.3	2.91**	6.7	0.29**	24.6	0.01	83	-92.4**	1387	-163.8**	1546	-104.1**	3015	-360.2**	50.4	0.08
M 584	55.3	0.62	14.6	-0.07	29.7	-6.27**	7.1	0.72**	20.3	-1.80**	38	48.5**	895	-90.8**	1147	-40.9	2080	-83.2	51.7	0.64**
M 619	57.0	0.02	17.9	0.15	61.00	3.36**	6.2	-1.01**	28.0	1.79**	184	43.9	368	254.6**	1373	145.0**	1925	443.4**	49.2	-0.72**
Correlation between mean and gca	-0.214		0.537		0.325		0.416		0.862*		0.485		-0.109		-0.02		-0.073		0.88*	

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

Table 3 Specific combining ability effects of crosses for yield and yield component characters in castor

Cross	Days to 50% flowering	No. of nodes to primary spike	Plant height	Effective spikes/ plant	100 seed weight	Seed yield				Oil content
						First picking	Second picking	Third picking	Total yield	
M-571 x PCS-1	1.86	0.60	-4.91 *	-0.82**	0.76	-102.9 **	-205.8 **	271.09 **	-37.4	0.41
M-571 x PCS-121	-0.36	-0.56	4.75 *	-1.01**	2.08 **	92.25 **	-0.86	358.98 **	449.94 **	-0.34
M-571 x JI-220	-1.47	0.40	-2.25	0.46	0.23	109.6 **	190.02 **	-352.8 **	-53.4	-0.72 *
M-571 x JI-225	1.2	1.38 **	7.64 **	-0.21	-1.53 *	85.14 **	-378.6 **	545.2 **	251.72 *	0.04
M-571 x JI-240	2.2	-0.42	-11.25 **	0.22	-1.87 **	38.36	-204.1 **	97.2	-68.62	0.39
M-571 x JI-260	-0.58	-1.37 **	-9.91 **	-0.16	-0.15	-155.9 **	618.02 **	254.02 **	208.49	0.08
M-571 x SKI-229	-0.8	0.60	5.98 *	0.21	-1.92 **	2.36	242.02 **	-36.8	207.38	0.06
M-571 x SKI-232	-4.69 **	0.35	12.64 **	0.87 **	1.01	18.47	-277.2 **	-471.7 **	-730.51 **	0.14
M-571 x SKI-233	2.64 *	0.23	-2.69	0.44	1.39 *	-87.42 **	16.47	-157.1	-227.62	-0.06
M-584 x PCS-1	-0.4	-0.07	-4.06	-0.59 *	-0.63	216.3 **	149.88 *	-138.7	227.35	0.31
M-584 x PCS-121	-2.6 *	-0.36	-5.40 *	0.89 **	-0.64	-34.94	233.43 **	349.49 **	548.01 **	-0.4
M-584 x JI-220	1.6	0.06	4.94 *	0.39	-0.75	-134.9 **	-90.35	4.05	-221.32	0.08
M-584 x JI-225	-1.4	-0.40	4.49	0.52	1.45 *	39.62	-43.01	21.72	18.79	-0.02
M-584 x JI-240	-2.73 *	-0.16	0.27	0.12	1.08	259.8 **	253.54 **	-359.3 **	154.46	-0.21
M-584 x JI-260	0.83	0.79 *	6.27 **	-0.3	-1.08	-51.72 *	-676 **	51.49	-676.43 **	0.25
M-584 x SKI-229	-0.4	0.63	0.83	-0.12	1.82 **	-21.82	510.32 **	295.09 **	775.79 **	0.07
M-584 x SKI-232	2.05	-0.22	-6.84 **	-0.37	-0.48	-182.1 **	-116.2	-75.51	-374.43 **	0.08
M-584 x SKI-233	3.05 **	-0.27	-0.51	-0.53	-0.77	-82.27 **	-221.6 **	-148.3	-452.21 **	-0.15
M-619 x PCS-1	-1.47	-0.52	8.98 **	1.41 **	-0.12	-113.4 **	55.88	-132.4	-189.95	-0.72 *
M-619 x PCS-121	2.98 *	0.92 *	0.64	0.12	-1.44 *	-57.31 *	-232.6 **	-708.5 **	-997.95 **	0.73 *
M-619 x JI-220	-0.14	-0.46	-2.69	-0.85 **	0.52	25.36	-99.68	348.75 **	274.72 *	0.65 *
M-619 x JI-225	0.2	-0.98 **	-12.14 **	-0.31	0.09	-124.8 **	421.65 **	-566.9 **	-270.51 *	-0.02
M-619 x JI-240	0.53	0.59	10.98 **	-0.35	0.79	-298.2 **	-49.46	262.09 **	-85.84	-0.18
M-619 x JI-260	-0.25	0.58	3.64	0.47	1.23 *	207.6 **	57.99	202.53 *	467.94 **	-0.32
M-619 x SKI-229	1.2	-0.02	-6.80 **	-0.09	0.1	27.47	-752.4 **	-258.3 **	-983.17 **	-0.13
M-619 x SKI-232	2.64 *	-0.14	-5.80 *	-0.5	-0.54	163.6 **	393.43 **	547.2 **	1104.94 **	-0.22
M-619 x SKI-233	-5.69 **	0.04	3.20	0.1	-0.62	169.7 **	205.1 **	305.42 **	679.83 **	0.21

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

Table 4 Heterobeltiosis and standard heterosis for five characters in top five crosses in castor

Character		Range	Cross				
			M 571 x JI 240	M 584 x JI 240	M 619 x JI 220	M 619 x JI 240	M 619 x SKI 232
Days to 50% flowering							
Heterebeltiosis		-8.67 to 10.91	-2.31	-8.67	-0.58	-2.92	7.74
Standard heterosis	Over GCH-4	-8.83 to 7.64	-0.59	-7.06	-0.01	-2.36	6.46
	Over DCH-32	-15.30 to 0.00	-7.65	-13.66**	-7.10	-9.29*	-1.09
Effective spikes/plant							
Heterebeltiosis		-22.50 to 20.54	0.00	-0.94	-17.30	-22.16*	-21.43*
Standard heterosis	Over GCH-4	-16.23 to 42.53	16.35	22.16*	-10.99	-16.23	-4.01
	Over DCH-32	-19.60 to 36.80	11.68	17.25	-14.57	-19.60	-7.87
100-seed weight							
Heterebeltiosis		-18.96 to 12.06	-8.26	-4.19	0.60	7.02	-1.67
Standard heterosis	Over GCH-4	-22.46 to 14.75	-8.06	-3.97	1.43	7.91	-0.85
	Over DCH-32	-13.52 to 27.98	2.54	7.10	13.12*	20.35	10.57*
Seed yield/plant							
Heterebeltiosis		-13.45 to 206.32	75.36**	165.77**	208.32**	178.92**	172.56**
Standard heterosis	Over GCH-4	35.43 to 215.22	174.41**	200.36**	206.12**	215.22**	172.38**
	Over DCH-32	-4.15 to 123.09	94.21**	112.57**	116.65**	123.09**	92.77**
Oil content							
Heterobeltiosis		-2.76 to 3.72	0.00	-0.06	-0.33	-2.56	-2.32
Standard heterosis	Over GCH-4	-5.91 to 1.56	-0.30	-0.37	-4.66**	-2.86*	-2.98*
	Over DCH-32	-0.46 to 7.44	5.47**	5.40**	0.86	2.77*	2.63*

*, ** Significant at 5% and 1% level respectively; SH - Standard heterosis

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Influence of environment on sex expression in castor, *Ricinus communis* L.*

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Abstract

Castor pistillate lines *viz.*, VP 1, DPC 9 and LRES 17 were sown at monthly intervals starting from January, 2001 to December, 2001 with an aim to characterise the expression of pistillate, monoecious and staminate flowers to standardise the time of sowing for hybrid seed production and maintenance of parental lines for need based manipulation. From the study, maximum expression of pistillateness was found in the September 15th sowing whereas it was lowest in March 15th sowing. With respect to interspersed staminate flowers (ISF) which maintain pistillate lines, the expression was maximum in February 15th sowing. Among different genotypes studied VP 1 produced highest number of pistillate whorls while DPC 9 produced maximum number of ISF irrespective of dates of sowing. Primary spikes produced maximum number of pistillate whorls compared to secondary, tertiary, quaternary and pentenary spike orders whereas, maximum number of ISF was produced in the secondary spikes.

Key words: Castor, sex expression, pistillate lines, pistillate whorls, ISF

Introduction

Castor (*Ricinus communis* L.) is grown under varied agro-climatic conditions for its non-edible oil, which has diversified uses especially in lubricants, printing inks, varnishes, detergents, wax, etc. India is the principal producer of castor by growing in an area of 0.71 m. ha with a production of 0.85 mt (Damodaram and Hegde, 2002). The seed yield in castor is directly/indirectly influenced by several factors out of which sex expression i.e., per cent pistillate whorls is very important. Castor is a sexually polymorphic species with different sex forms *viz.*, monoecious bearing staminate (male) flowers at bottom and pistillate (female) flowers at the top of the spike, pistillate spike with only pistillate flowers along the entire spike, pistillate with interspersed staminate flowers (ISF), sex reversals in which 100 % pistillate spikes will be reverted to monoecists in different order spikes. Sex expression in castor is known to be influenced by several environmental factors namely temperature, photo period and rainfall besides age of the plant, nutrition, etc. (Shifriss, 1960; Zimmerman and Smith, 1966).

Several castor varieties were developed and released for commercial cultivation in India by simple selection from local populations during 1960s which could not make any significant contribution to increase the productivity because of their long duration and susceptibility to diseases. Subsequently, early maturing, high yielding and disease resistant varieties like Kranti, Jyothi, Jwala, etc., were developed which made a significant impact in the castor production under rainfed conditions. In addition to the cultivar development, heterosis breeding gained importance and several hybrids have been developed in India based on pistillate lines and released for commercial cultivation. Due to lack of cytoplasmic and genetic male sterility lines in the crop, the hybrid breeding is dependent on pistillate mechanism wherein the pistillate lines are maintained by the interspersed staminate flowers, the expression of which is highly environmentally sensitive (Ramachandram and Ranga Rao, 1988).

Keeping in view the influence of environment on sex expression, the present investigation was undertaken at College Farm, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad during 2001-02, to study the influence of environmental factors in the expression of female and male flowers in order to identify the ideal environment with respect to time of planting for hybrid seed production and multiplication and maintenance of parental lines.

Materials and methods

The present study was conducted using three pistillate lines of castor *viz.*, VP 1, DPC 9 and LRES 17 obtained from the Directorate of Oilseeds Research, Rajendranagar, Hyderabad. These lines were sown at monthly intervals starting from January, 2001 to December, 2001 in randomized block design with three replications. All the sowings were done using seed material from a single lot and uniform package of inputs

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were supplied throughout. Ten pistillate plants in each entry were selected by confirming the sex in primary spike and were tagged. Observations were recorded on these plants for number of pistillate whorls and number of ISFs upto pentenary order spike. The data were analysed through Factorial experiment laid out in RBD.

Results and discussion

The analysis of variance for pistillate whorls and ISF expression (Table 1) indicated the presence of significant differences among the genotypes and sowing dates while interaction of genotypes and dates of sowing was found to be non-significant in primary, secondary, tertiary order spikes and significant in quaternary, pentenary order spikes. The interaction effect was found to be significant for expression of ISF in all the spike orders studied. Among the genotypes, VP 1 produced highest mean values for number of pistillate whorls (112.43) over all spike orders over different dates of sowing followed by LRES 17, while DPC 9 produced maximum mean values for number of ISF over different order spikes (62.27), showing variability among genotypes for the expression of characters *viz*., number of pistillate whorls and number of ISF.

Table 1 Analysis of variance for sex characters in castor

Character	Mean sum of squares				
	Replications	F_1 (genotypes)	F_2 (dates of sowing)	$F_1 \times F_2$	Error
Primary spike					
No. of pistillate whorls	0.063	1178.77*	9.53*	4.26	3.61
No. of ISF	1.97	261.20*	788.36*	24.60**	2.62
Secondary spike					
No. of pistillate whorls	0.4162	1068.10*	0.63	2.26	1.48
No. of ISF	1.26	249.22*	901.12*	26.86*	1.48
Tertiary spike					
No. of pistillate whorls	0.60	219.50*	2.39**	1.42	1.01
No. of ISF	3.36	204.79*	763.48*	32.32*	2.22
No. of staminate whorls	0.028	33.33*	33.33*	33.33*	0.28
Quaternary spike					
No. of pistillate whorls	0.48	306.49*	1.84*	2.39*	0.71
No. of ISF	1.02	135.70*	790.61*	44.04*	0.95
No. of staminate	-	-	-	-	-
Pentenary spike					
No. of pistillate whorls	0.45	244.45*	2.08*	1.77*	0.47
No. of ISF	1.04	129.05*	352.51*	38.49*	0.72
No. of staminate whorls	-	-	-	-	-

** = at 1% significance   * = at 5% significance

The mean maximum temperatures recorded 15-20 days prior to the emergence of primary, secondary, tertiary, quaternary and pentenary spikes during September and

October sowings were considerably low i.e., about 30°C or even lower at which the production of ISFs were also comparatively low which is very favourable for quality hybrid seed production by reducing the selfed seed, while the mean maximum temperatures recorded during emergence of primary, secondary, tertiary, quaternary and pentenary spikes were 34.5°C, 35.5°C, 38.3°C, 37.8°C and 36.5°C respectively during February 15th sowing (Table 2) which can be considered the best time for taking up pistillate line multiplication. These results are inconsonance with the findings of Shifriss (1960), Zimmerman and Smith (1966), Sharma and Premnath (1971) and Ankineedu and Rao (1973).

Table 2 **Mean maximum temperatures recorded 15-20 days prior to the emergence of primary, secondary, tertiary, quaternary and pentenary spike orders of VP 1, DPC 9 and LRES 17 under different dates of sowing**

Date of sowing	Mean maximum temperatures (°C)				
	Primary spike	Secondary spike	Tertiary spike	Quaternary spike	Pentenary spike
15.01.01	34.2	34.5	35.5	38.3	37.8
15.02.01	34.5	35.5	38.3	37.8	36.5
15.03.01	35.5	38.3	37.8	36.5	28.5
15.04.01	38.3	37.8	36.5	28.5	33.0
15.05.01	37.8	31.5	28.5	33.0	30.2
15.06.01	36.5	28.5	33.0	30.2	30.4
15.07.01	28.5	33.0	30.2	30.4	30.8
15.08.01	33.0	30.3	30.4	30.8	29.3
15.09.01	30.3	30.4	30.8	29.3	29.3
15.10.01	30.4	30.8	29.3	29.3	31.2
15.11.01	30.8	29.3	29.3	31.2	35.5
15.12.01	29.3	29.3	31.2	35.5	38.6
Mean	32.5	32.1	31.8	31.8	31.8

Among different dates of sowing studied, highest mean values for number of pistillate whorls over different order spikes (Table 3) were recorded with September 15th sowing (93.5) whereas February 15th sowing produced highest mean values for number of ISF (120.11) in different order spikes irrespective of genotypes (Table 4).

Primary spikes produced maximum mean values for number of pistillate whorls (24.8) compared to different spike orders studied while secondary spikes produced highest number of ISF (12.1) over all genotypes and dates of sowings (Table 3 and 4). Similar observations were also noticed by Zimmerman (1958) and Shifriss (1960). Interestingly, it was noticed that there was no significant reduction of pistillate flowers with increasing temperatures but effect was very prominent on the expression of ISFs with its peak with higher temperature and decreased with

Table 4 Mean values for number of ISF in different order spikes of VP 1, DPC 9 and LRES 17 under different dates of sowings

	Primary spike				Secondary spike				Tertiary spike				Quaternary spike				Pentenary spike				
Date of sowing	VP 1	DPC 9	LRES-17	Mean	VP 1	DPC 9	LRES-17	Mean	VP 1	DPC 9	LRES-17	Mean	VP 1	DPC 9	LRES-17	Mean	VP 1	DPC 9	LRES-17	Mean	Total
15-01-2001	26.1	16.0	16.0	19.3	31.8	28.5	18.5	26.2	32.0	26.6	19.5	26.0	21.5	28.0	38.1	29.2	12.5	24.0	15.0	17.1	118.1
15-02-2001	28.0	29.0	17.5	24.8	33.2	32.0	19.0	28.0	34.5	38.0	21.0	31.1	22.5	30.0	36.1	29.5	11.5	15.0	17.0	14.5	120.1
15-03-2001	26.2	25.0	15.0	22.0	20.1	24.0	12.0	18.7	16.6	15.0	8.5	13.3	6.0	13.0	10.7	9.9	9.5	9.5	4.5	7.8	71.9
15-04-2001	20.5	20.5	14.0	18.3	25.0	25.0	19.0	23.0	14.7	15.0	13.5	14.4	8.0	12.0	9.5	9.8	8.7	6.5	5.0	6.7	72.3
15-05-2001	22.7	23.0	18.0	21.2	15.0	18.0	16.0	16.3	12.0	16.0	14.2	14.0	10.0	6.8	7.0	8.1	5.5	4.3	4.5	4.7	64.5
15-06-2001	15.0	18.5	9.2	14.2	10.0	12.4	9.3	10.6	8.0	6.9	7.1	7.3	5.2	3.0	6.0	4.7	5.0	1.5	3.7	3.4	40.3
15-07-2001	10.0	10.9	9.0	9.9	8.5	8.4	7.0	7.9	6.3	7.1	5.5	6.3	3.0	4.5	5.5	4.3	4.8	1.2	2.0	2.6	31.2
15-08-2001	8.0	6.0	5.0	6.3	5.5	4.0	4.0	4.5	6.0	3.5	0.0	3.1	0.0	2.5	5.0	2.5	4.0	1.5	0.0	1.8	18.3
15-09-2001	0.0	4.0	0.0	1.3	0.0	3.0	0.0	1.0	0.0	2.9	0.0	0.9	3.1	3.5	3.0	3.2	2.9	6.0	1.9	3.6	10.1
15-10-2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	4.1	3.9	3.8	4.5	7.5	3.6	5.2	5.0	15.6	7.0	9.2	18.2
15-11-2001	0.0	0.0	0.0	0.0	4.4	5.0	0.0	3.1	4.0	9.2	4.5	5.9	6.8	15.8	3.8	8.8	5.5	20.5	13.2	13.0	30.9
15-12-2001	3.0	7.0	0.0	3.3	4.6	8.5	4.8	5.9	9.0	16.6	8.0	11.2	13.5	20.5	14.0	16.0	20.0	26.2	16.5	20.9	57.4
Mean	13.3	13.3	8.6	11.7	12.1	12.2	11.9	12.1	12.2	13.4	8.8	11.4	8.7	12.2	11.8	10.9	7.9	10.9	7.5	8.8	
CD (P=0.05)																					
Genotypes(F_1)				0.74				1.56				0.69				0.45				0.39	
Dates of sowings (F_2)				1.49				1.12				1.38				0.90				0.78	
Interaction ($F_1 x F_2$)				2.59				1.94				2.39				1.56				1.36	

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low temperatures. Therefore, it can be concluded that September 15th sowing is ideal to take up hybrid seed production as it is conducive for the production of highest number of pistillate flowers with minimum expression of ISF. When September sowing is not possible due to other reasons, one may also take up during October with additional care in observing and removing ISFs as and when noticed especially in the later order branches. It was observed that a few plants with ISFs irrespective of sowing time appeared which shows involvement of some inherent factors in sex expression and may create problems during hybrid seed production leading to more amount of selfed seed in the hybrid seed lots. So, there is a need to isolate 100 % pistillate lines that are sensitive to expression of ISF at higher temperatures by stringent selection pressure to avoid the problem of selfed seed in hybrid seed production and to improve the quality of seed. Regarding the sensitive expression of ISF in order to maintain the pistillate parents, February 15th sowing produced more number of ISF which provides ideal environment for multiplication and maintenance of female parents in castor through refined method of pistillate line maintenance. The studies are in concurrence with those of Ramachandram and Ranga Rao, 1988.

It was also observed in the present study that the expression of good number of interspersed staminate flowers even upto May sowing in different order spikes which gives an idea that the pistillate lines can also be maintained in early *kharif* sowings.

Though the present study provided valuable information in respect of planting for maintenance of pistillate lines and for hybrid seed production, it is very much essential to take up further investigation under controlled conditions of temperature and photoperiod to understand the sex mechanism and the expression of male and female flowers to improve further, the castor hybrid seed production technology.

Table 3 Mean values for number of pistillate whorls in different order spikes of VP 1, DPC 9 and LRES 17 under different dates of sowings

Date of sowing	Primary spike				Secondary spike				Tertiary spike				Quaternary spike				Pentenary spike				Mean of different order spikes
	VP 1	DPC 9	LRES-17	Mean	VP 1	DPC 9	LRES-17	Mean	VP 1	DPC 9	LRES-17	Mean	VP 1	DPC 9	LRES-17	Mean	VP 1	DPC 9	LRES-17	Mean	
15-1-2001	33.0	22.3	23.0	26.1	28.0	18.8	19.5	22.1	18.5	13.9	16.2	16.2	17.0	12.2	14.7	14.6	14.0	11.3	10.7	12.0	91.0
15-2-2001	30.1	19.0	20.8	23.3	29.1	17.5	18.5	21.7	19.7	14.3	16.5	16.8	19.1	12.5	14.3	15.3	16.7	10.7	11.5	13.0	90.2
15-3-2001	28.7	19.1	20.0	22.6	28.5	18.1	19.0	21.8	18.5	14.0	15.6	16.0	19.7	12.0	14.2	15.3	17.0	10.2	11.0	12.7	88.6
15-4-2001	33.1	18.9	23.0	25.0	29.7	18.1	19.5	22.4	18.7	13.9	18.2	16.9	19.5	12.6	14.5	15.5	16.7	10.4	12.0	13.0	93.0
15-5-2001	32.5	20.1	25.0	25.8	30.1	18.4	18.7	22.4	19.0	13.4	14.2	15.5	19.2	12.2	13.9	15.1	15.2	10.6	11.7	12.5	91.5
15-6-2001	31.0	21.5	24.8	25.7	29.0	18.5	20.1	22.5	19.1	13.5	15.9	16.1	19.0	12.4	14.2	15.2	15.1	10.9	12.1	12.7	92.4
15-7-2001	30.0	21.2	23.7	24.9	28.0	18.9	19.7	22.2	19.5	14.1	15.9	16.5	19.0	12.8	14.1	15.3	15.0	11.0	11.9	12.6	91.6
15-8-2001	30.0	22.5	22.5	25.0	27.0	19.1	20.0	22.0	19.4	14.0	15.9	16.4	18.9	12.6	15.2	15.5	15.1	11.1	10.5	12.2	91.2
15-9-2001	32.5	18.3	22.8	24.5	29.2	17.8	19.6	22.2	20.6	15.0	16.9	17.5	19.1	12.9	14.8	15.6	17.5	10.5	12.6	13.5	93.5
15-10-2001	32.0	22.1	22.8	25.6	27.5	19.2	19.9	22.2	18.0	13.7	16.5	16.0	16.0	13.0	14.5	14.5	14.5	10.9	11.0	12.1	90.5
15-11-2001	31.0	19.9	22.5	24.4	27.3	18.2	20.0	21.8	18.2	14.1	17.0	16.4	16.5	12.8	14.2	14.5	14.7	10.5	10.9	12.0	89.2
15-12-2001	31.5	19.8	22.7	24.4	27.0	18.9	19.8	21.9	17.7	14.0	16.7	16.1	16.2	12.7	14.4	14.4	14.9	10.8	10.8	12.1	89.1
Mean	31.2	20.3	25.4	24.8	28.3	18.4	19.5	22.1	18.9	13.9	16.3	16.4	18.2	12.5	14.4	15.0	15.5	10.7	11.4	12.5	
CD (P=0.05)																					
Genotypes(F_1)				0.88				0.56				0.47				0.39				0.32	
Dates of sowings (F_2)				1.76				1.12				0.93				0.78				0.63	
Interaction (F_1xF_2)				3.04				1.94				1.61				1.35				1.09	

stem, capsules on primary branches and harvest index. This indicated the additive or synergistic effect of the component characters on seed yield as also reported by Dikshit and Swain (2000).

Combining ability: *The ANOVA for combining ability* (Table 2) revealed that general and specific combining ability were highly significant for all the characters indicating that both additive and non-additive gene actions were important for the characters studied. In general, the variances due to *sca* were larger than those due to *gca* for majority of the traits except for plant height and capsule length, indicating the significance of non-additive gene action in their inheritance as was also reported by Jayalakshmi *et al.* (2000). Biparental or selective mating or any other forms of recurrent selection in early generations were more useful to exploit non-additive gene action in the improvement of these characters. Additive gene action was important for plant height. These results are in agreement with those of Pathirana (1999). Pedigree method of selection would be more useful for accumulation of this character. Both additive and non-additive gene effects were equally important for capsule length. Similar results were reported by Fatteh *et al.* (1995). Breeding methods like reciprocal recurrent selection might be effective in the improvement of this trait.

Table 1 Heterobeltiosis in 28 F_1 progenies for 13 characters in sesame

Hybrid	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches	Number of secondary branches	Capsules on main stem	Capsules on primary branches	Capsules on secondary branch	Capsule length	Seeds/ capsule	1000-seed weight	Seed yield/ plant	Harvest index
Madhavi X													
YLM-11	-6.52*	-2.79**	21.89**	16.67**	126.32**	6.87**	-52.14**	37.32**	2.34**	-12.38**	-4.02**	-17.91**	0.32
Vinayak	-6.00*	-2.39*	-2.14	35.90**	-36.73**	43.70**	59.78**	-60.94**	-15.13**	-11.77**	-8.89**	12.92**	-4.32**
Rajeswari	0.00	-4.10**	20.77**	23.08**	6.67	80.24**	40.44**	9.86*	-13.54**	-15.29**	-2.98**	23.24**	19.43**
Krishna	-6.48**	4.78**	-13.73**	17.95**	146.67**	36.44**	-8.48**	-17.74**	-3.24**	-7.28**	-6.48**	12.49**	-14.03**
YLM-17	-2.17	2.39*	23.27**	46.15**	83.33**	-10.49**	-12.32**	28.14**	-1.30	-8.74**	-7.72**	1.89	-0.30
NSI-4	-14.52**	-5.63**	-11.03**	-21.15**	-44.83**	65.40**	-7.50**	-79.40**	-0.25	-5.10**	-0.51	14.90**	-8.75**
T-Brown	-5.05**	1.59	7.12**	37.50**	0.00	-0.69	-35.95**	10.16**	3.12**	-4.85**	-2.64**	-1.46	1.02
YLM-11 X													
Vinayak	0.00	12.44**	6.15**	11.90**	-30.61**	19.93**	22.36**	-48.71**	-3.31*	-6.14**	-12.14**	9.37**	7.59**
Rajeswari	-2.13	-3.36**	-15.82**	-7.14	31.58**	-25.77**	-0.57	124.10**	0.66	2.40**	-6.39**	2.95	-2.85**
Krishna	-4.63*	11.11**	29.24**	26.19**	152.63**	-21.28**	-26.64**	-10.08*	-11.47**	1.92**	-9.15**	11.45**	2.87*
YLM-17	-1.09	11.59**	35.70**	11.90*	147.37**	-21.68**	5.43**	40.26**	-5.21**	-7.67**	-7.17**	7.96**	3.13*
NSI-4	-16.13**	-5.28**	-36.67**	-30.77**	-34.38**	-4.69**	-25.36**	-60.30**	1.75*	0.77*	-5.41**	-20.53**	-18.57**
T-Brown	5.05*	3.27**	-5.92**	11.90*	16.22**	-26.38**	-1.79	56.25**	-0.78	-9.21	-6.07**	12.64**	-1.90
Vinayak X													
Rajeswari	6.00*	-5.60**	10.36**	26.47**	-22.45**	56.69**	93.32**	-53.22**	-11.14**	-16.27**	-11.83**	12.75**	10.63**
Krishna	-12.04**	10.91**	-2.33	58.62**	-79.59**	-4.66**	43.39**	-74.25**	-7.33**	-13.87**	-8.38**	3.79	-6.79**
YLM-17	4.00	10.30**	8.61**	57.89**	-40.82**	-10.02**	9.01**	-47.21**	-3.31**	-8.31**	-11.68**	-5.01**	0.75
NSI-4	-5.65**	-6.34**	-0.66	0.00	-24.49**	-0.29	-2.38	-57.51**	4.73**	-3.46**	-9.82**	-2.65	-3.45**
T-Brown	0.00	5.71**	-2.77	-2.50	-65.31**	-20.18**	-61.70**	-71.46**	-1.65*	-4.16**	4.64**	-29.51**	-5.86**
Rajeswari X													
Krishna	-6.48**	-4.10**	17.25**	58.82**	46.67**	-5.54**	49.31**	-70.97**	-12.23**	6.31**	-6.40**	16.88**	5.13**
YLM-17	0.00	-3.73**	20.90**	34.21**	50.00**	-32.26**	-14.44**	20.78**	-10.26**	3.40**	-4.62**	12.97**	2.09
NSI-4	-13.71**	-4.23**	-18.21**	-13.46**	-62.07**	2.05	-4.75**	-84.92**	0.87	11.48**	3.8**	14.83**	-2.65*
T-Brown	3.03	-1.87**	6.05	-32.50**	-86.49**	4.36**	-68.31**	-72.66	-9.83**	6.56**	-5.79**	-32.35**	-1.61
Krishna X													
YLM-17	-0.93	11.16**	29.70**	18.42**	88.89**	-11.42**	-16.03**	-25.00**	-1.00	-0.53	-8.69**	-1.09	0.60
NSI-4	-5.65**	-6.34**	-42.78**	-11.54**	51.72**	5.25**	25.96**	-46.37**	5.49**	3.17**	-10.82**	11.86**	-9.02**
T-Brown	-1.85	7.76**	-0.94	-2.50	-27.03**	-18.12**	-39.64**	-27.34**	-5.99**	3.30**	-8.31**	-7.38**	-6.30**
YLM-17 X													
NSI-4	-2.42	-2.11*	-39.13**	-7.69*	65.52**	-36.60**	-15.76**	33.74**	-2.50**	8.82**	-6.69**	-1.45	-11.94**
T-Brown	10.10**	6.94**	-17.13**	7.50	5.41	-23.39**	-39.64**	40.04**	0.53	8.67**	-1.83**	0.24	-8.35**
NSI-4 X													
T-Brown	0.00	-2.82**	-12.47**	23.08**	21.62**	-41.28**	-9.85**	5.49**	11.00**	17.34**	-1.55**	2.84	-2.65*
CD (P=0.05)	1.64	1.75	4.09	0.25	0.21	0.79	0.83	0.71	0.03	0.34	0.02	0.45	0.53
CD (P=0.01)	2.17	2.02	4.73	0.34	0.28	1.05	1.11	0.95	0.05	0.45	0.03	0.60	0.70

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

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Heterosis and combining ability in sesame, *Sesamum indicum* L.

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Abstract

The extent of heterosis and combining ability was studied in a diallel cross of sesame for yield and its components. The crosses Madhavi x Rajeswari and Rajeswari x Krishna were the best combinations for seed yield, which also expressed heterosis for plant height, primary branches, capsules on main stem, capsules on primary branches and harvest index. Non-additive gene action played the major role in determining majority of the characters except for plant height and capsule length. For plant height additive gene action was important where as both additive and non-additive gene actions were equally important for capsule length. The parents YLM-17 and Madhavi were good general combiners for yield and some of the yield components. The crosses YLM-11 x T-Brown, Rajeswari x YLM-17 and Rajeswari x Krishna were found to be best combinations for most of the yield and yield components on the basis of *sca* effects, heterosis and *per se* performance.

Key words: Sesame, heterosis, combining ability, gene action

Introduction

Sesame (*Sesamum indicum* L.) is an important oilseed crop of the tropics as well as sub-tropics. Choice of the parents for a breeding programme is important to improve quantitative characters like seed yield and its components. The reproductive biology of sesame like cotton crop offers good scope for exploitation of heterosis. The present study was undertaken to estimate heterosis and combining ability of selected sesame cultivars.

Materials and methods

The materials comprised of eight parents *viz.*, Madhavi, YLM-11, Vinayak, Rajeswari, Krishna, YLM-17, NSI-4 and T-Brown and their 28 F_1s (excluding reciprocals) obtained through diallel cross. The trial with parents and 28 crosses was laid out in completely randomized block design with three replications during summer, 2001. Five plants selected randomly from each treatment were used to record observations on 13 characters (Table 1). Heterosis was estimated as per Hayes *et al.* (1965) and combining ability as per model I and method II of Griffing (1965b).

Results and discussion

Heterosis: Heterosis over better parent exhibited a wide range for seed yield and its important attributes (Table 1). For seed yield/plant, 13 out of 28 crosses showed significant positive heterosis over better parent. The crosses Madhavi x Rajeswari and Rajeswari x Krishna showed maximum heterosis over better parents. Similar results were also reported by Backiyarani *et al.* (1998). For the characters that contributed to vegetative growth *viz.*, plant height, number of primary branches and secondary branches, significant positive heterobeltiosis was expressed in YLM-11 x YLM-17, Rajeswari x Krishna and YLM-11 x Krishna. A desirable degree of vegetative growth was essential fro releasing high yield as total drymatter production is one of the components deciding high grain yield in crops (Kavitha *et al.*, 2000). The cross combinations Madhavi x Rajeswari, Vinayak x Rajeswari and YLM-11 x Rajeswari exhibited significant positive heterobeltiosis for the yield related trait *viz.*, capsules on main stem, capsules on primary branches and secondary branches which was in agreement with the results of Navadiya *et al.* (1995). The high values of heterobeltiosis for these yield components were due to dominance or epistasis or both. Out of 28 crosses, 15 and 12 showed significant negative heterobeltiosis for days to maturity and days to flowering, respectively. These results were in concurrence with Alam *et al.* (1999). Six crosses for capsule length, 11 crosses for seed/capsule and six crosses for harvest index exhibited significant heterobeltiosis. But, the extent of heterosis was moderate which is in agreement with the findings of Anitha and Dorairaj (1991). As regard to test weight only two out of 28 crosses showed significant heterosis over better parent but the extent of heterosis was limited. Ray and Sen (1992) also reported similar results.

Hybrids, Madhavi x Rajeswari and Rajeswari x Krishna recorded high heterosis for yield also expressed high heterosis for yield components *viz.*, plant height, number of primary and secondary branches, capsules on main

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The estimates of *sca* effects (Table 4) revealed that the hybrids YLM-11 x T-Brown and Rajeswari x YLM-17 exhibited good specific combining ability and high *per se* performance for seed yield/plant.

The relationship of *per se* performance of parents with *gca*, *per se* performance of hybrids with *sca* and heterobeltiosis with *sca* effects (Table 5) revealed that the parents with high *per se* performance for most of the characters also exhibited high *gca* effects indicating *per se* performance was a good indicator of its general combining ability. The hybrids exhibiting high *per se* performance also recorded high *sca* effects similarly the cross combinations which are showing high *sca* effects also showed high heterotic performance over the better parent implying the role of specific combining ability effects in hybrid vigour or heterotic performance.

NSI-4 x T-Brown, Rajeswari x Krishna, YLM-11 x Vinayak and Madhavi x T-Brown involved atleast one good general combiner whereas the cross Vinayak x Rajeswari involving both poor combiners exhibited significant sca effects for grain yield. Most of the crosses involved atleast one good general combiner in their parentage and could be expected to throw transgressive segregants. It is therefore, suggested that the adaptation of biparental approach followed by recurrent selection (or) selective diallel mating system in these crosses was a judicious approach to exploit both additive as well as non-additive kinds of gene effects (Goyal and Sudhir Kumar, 1991). The further, exploitation of such segregants would through lines possessing high yielding ability.

Table 4 Specific combining ability effects for thirteen characters in a 8 x 8 diallel cross of sesame

Hybrid	Days to 50% flowering	Days to maturity	Plant height	Number of primary branches	Number of secondary branches	Capsules on main stem	Capsules on primary branches	Capsules on secondary branch	Capsule length	Seeds/ capsule	1000-seed weight	Seed yield/ plant	Harvest index
Madhavi X	-1.189*	-1.389**	18.880**	0.144	0.828**	-1.872**	-17.327**	1.106**	0.086**	-3.151**	0.041**	-1.916**	0.543**
YLM-11	-0.322	-0.356	-13.227**	0.438**	0.048	-0.345	13.990**	-3.197**	-0.242**	0.949**	-0.055**	0.822**	-1.193**
Vinayak	0.744	-0.956	8.567**	0.258**	-0.085	5.604**	9.170**	2.343**	-0.120**	-6.851**	0.000	0.748**	1.710**
Rajeswari	1.011	4.778**	-11.113**	0.044	0.728**	5.508**	-4.327**	2.590**	0.048**	-0.678**	0.062**	0.994**	-1.737**
Krishna	-1.122**	0.978	15.400**	0.511**	0.188*	-0.542*	2.916**	3.336**	0.023	0.442**	-0.077**	0.516**	1.100**
YLM-17	-0.589	-0.889	11.120**	-0.616**	-0.845**	12.075**	-1.237**	-6.897**	-0.034*	0.636**	0.031**	0.720**	0.653**
NSI-4	-1.022	-0.522	2.560	0.598**	0.495**	1.822**	0.270	4.163**	0.114**	1.889**	-0.088**	1.056**	1.770**
T-Brown													
YLM-11 X													
Vinayak	1.244**	4.07**	9.013**	0.204**	-0.122	3.642**	14.603**	-0.237	0.054**	1.682**	-0.188**	1.380**	1.427**
Rajeswari	-0.356	1.478**	-15.193**	-0.176*	0.155	-4.742**	5.450**	3.503**	0.276**	1.016**	-0.100**	0.542**	-1.003**
Krishna	1.244*	2.211**	12.193**	0.678**	1.101**	-2.638**	-8.957**	3.016**	-0.210**	1.789**	-0.048**	0.399**	1.151**
YLM-17	-1.222*	3.744**	16.573**	0.011	0.761**	1.311**	3.730**	4.363**	-0.121**	-1.291**	-0.047**	0.634**	1.021**
NSI-4	-1.689**	1.211*	-16.840**	-0.782**	-1.005**	1.195**	-8.157**	-5.204**	-0.018	0.502**	-0.009	-2.182**	-2.659
T-Brown	-1.878**	0.578	2.467**	0.231**	0.535**	-0.592*	12.483**	11.190**	-0.030*	-2.778**	-0.071**	2.204**	0.257
Vinayak X													
Rajeswari	2.511**	0.178	-2.233	0.118	1.041**	5.318**	12.210**	2.290**	-0.179**	-5.084**	0.225**	0.927**	0.927**
Krishna	-3.222*	0.911	4.887**	0.238**	-1.412**	-0.912**	10.270**	-7.197**	-0.058**	-4.111**	-0.133**	0.270	-0.786**
YLM-17	1.311*	3.444**	6.733**	0.904**	-0.419**	2.571**	10.623**	4.184**	0.084**	-1.524**	-0.245**	-0.085	-0.684**
NSI-4	0.844	0.911	27.187**	0.311**	0.215**	0.122	-2.397**	-0.617**	0.128**	-0.998**	-0.087**	-0.678**	1.337**
T-Brown	-1.256*	3.278**	-8.707**	-0.276**	-1.179**	-0.86599	-18.090**	-9.957**	0.109**	-0.211	0.500**	-2.225*	-0.446*
Rajeswari X													
Krishna	0.11	0.644	23.280**	0.924**	0.255**	-0.629*	13.850**	-3.124**	-0.116**	2.756**	0.021**	1.602**	1.617**
YLM-17	1.311*	-0.822	17.593**	0.458**	0.315**	-3.306**	0.403	5.290**	-0.027*	3.142**	0.009	1.988**	0.754**
NSI-4	-0.156	-1.689**	-2.420**	-0.002	-0.652**	1.138**	-1.684**	-4.544**	0.130**	5.602**	0.284**	0.835**	1.307**
T-Brown	-0.256	0.011	-0.447	-0.922**	-1.112**	6.751**	-20.444**	-6.884**	-0.036**	4.122**	-0.142**	-2.699**	0.291
Krishna X													
YLM-17	-2.156**	3.244**	16.447**	-0.022	0.195**	1.158**	-2.604**	-3.864**	0.101**	0.449**	-0.106**	-0.823**	0.307
NSI-4	2.711**	0.044	-22.167**	-0.016	0.961**	0.508	7.310**	-0.6308*	0.091**	0.509**	-0.121**	0.951**	-0.406*
T-Brown	2.278**	4.07**	12.340**	-0.202**	-0.232**	-1.278**	-5.584**	-2.104**	-0.054**	1.696*	-0.047**	-0.663**	-0.889**
YLM-17 X													
NSI-4	2.711**	2.244**	-25.653**	-0.149	0.955**	-5.876**	-2.270**	4.716**	-0.100**	0.562**	-0.026**	0.137	-1.569**
T-Brown	2.278**	1.611**	-14.213**	-0.202*	0.295**	-3.262**	-11.630**	2.843**	0.008	1.616**	0.141**	-0.134	-1.786**
NSI-4 X													
T-Brown	2.478**	0.744	11.173**	1.138**	0.795**	-7.845**	12.350**	2.876**	0.238**	3.809**	-0.087**	1.623**	0.701**
SEm±	0.53	0.49	1.15	0.08	0.07	0.26	0.27	0.23	0.01	0.11	0.08	0.15	0.17
CD (P=0.05)	1.05	0.97	2.28	0.16	0.13	0.51	0.53	0.45	0.02	0.21	0.01	0.29	0.34
CD (P=0.01)	1.39	1.27	3.02	0.21	0.18	0.67	0.71	0.60	0.03	0.28	0.02	0.38	0.45

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

Table 2 Analysis of variance for combining ability for thirteen characters in a 8 x 8 diallel cross of sesame

Character	Mean squares				
	GCA df=7	SCA df=28	Error df=70	$\sigma^2 g_i$	σ^2_{sij}
Days to 50% flowering	41.90**	2.65**	0.33	4.15	2.31
Days to maturity	69.94**	12.39**	0.29	6.96	12.10
Plant height	1386.43**	258.47**	1.59	138.48	256.87
Number of primary branches	0.211**	0.34**	0.008	0.02	0.33
Number of secondary branches	0.89**	0.68**	0.005	0.08	0.67
Capsules on main stem	26.03**	23.75**	0.08	2.59	23.67
Capsules on primary branches	110.46**	129.10**	0.08	11.00	129.01
Capsules on secondary branches	85.22**	33.69**	0.06	8.51	33.63
Capsule length	0.09**	0.01**	0.00	0.009	0.01
Seeds/capsule	29.67**	11.06**	0.01	2.96	11.05
1000-seed weight	0.03**	0.02**	0.00	0.003	0.02
Seed yield/plant	3.68**	1.99**	0.02	0.36	1.96
Harvest index	5.50**	1.86**	0.03	0.54	1.83

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

A perusal of *gca* effects (Table 3) indicated that the parent YLM-17 was a good general combiner for seed yield, capsules on primary branches and secondary branches. Madhavi was the good general combiner for days to 50% flowering, primary branches and capsules on main stem. Vinayak was good general combiner for days to maturity in desirable direction followed by YLM-11. In case of capsule length and seeds/capsule highest gca was recorded by Rajeswari. Similarly, Krishna for 1000-seed weight; NSI-4 for plant height and harvest index. High general combining ability effects were related to additive or additive x additive gene effects Griffing (1956a) which represented the fixable genetic components of variance. Thus, YLM-17 was appeared to be of worthy for exploitation in breeding programmes aimed at yield improvement through component characters.

Table 3 General combining ability effects of eight parents for thirteen characters in sesame

Parent	Days to 50% flowering	Days to maturity	Plant height	No. of primary branches	No. of secondary branches	Capsules on main stem	Capsules on primary branches	Capsules on secondary branches	Capsule length	Seeds/ capsule	1000-seed weight	Seed yield/ plant	Harvest index
Madhavi	-2.275**	-0.408	2.547**	0.142**	-0.137**	2.216**	-4.468**	-1.130**	-0.086**	0.687**	-0.050**	-0.429**	-1.102**
YLM-11	-1.842**	-2.175**	-11.160**	-0.025	0.223**	-2.838**	3.652**	-0.290*	-0.049**	0.420**	-0.057**	0.193**	-0.256**
Vinayak	-0.042	-2.875**	3.347**	-0.052	0.203**	-0.764**	-1.142**	3.057**	0.046**	-3.347**	0.062**	-0.668**	-0.452**
Rajeswari	-1.108**	1.725**	4.420**	-0.205**	-0.663**	-1.247**	-3.022**	-4.217**	0.171**	2.520**	-0.006	-0.551**	-0.222**
Krishna	0.958**	-2.008**	-15.767**	-0.125**	-0.07**	0.249	-0.815**	-1.263**	-0.050**	0.747**	0.109**	0.546**	-0.109
YLM-17	-0.575*	-0.208	-6.347**	0.142**	0.197**	0.700**	5.232**	4.123**	-0.079**	-1.173**	0.021**	0.974**	0.321**
NSI-4	4.225**	5.325**	22.800**	0.202**	0.097**	0.082	-1.015**	-2.643**	0.104**	0.633**	-0.057**	-0.456**	1.434**
T-Brown	0.658*	0.625*	0.160	-0.078	-0.157**	1.602**	1.878**	2.363**	-0.057**	-0.487**	-0.021**	0.391**	0.384**
SE (gi)	0.17	0.08	0.37	0.03	0.02	0.08	0.09	0.07	0.004	0.03	0.003	0.05	0.05
SE (gi-gj)	0.26	0.24	0.56	0.04	0.03	0.13	0.13	0.11	0.006	0.05	0.004	0.07	0.08
CD (P=0.05)	0.52	0.48	1.11	0.08	0.06	0.26	0.26	0.22	0.012	0.09	0.008	0.14	0.16
CD (P=0.01)	0.69	0.63	1.48	0.10	0.08	0.34	0.34	0.29	0.016	0.13	0.010	0.18	0.21

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

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Drymatter production, nodule dry weight and nitrogen uptake of *rabi* groundnut as influenced by residual fertility of different nitrogen management practices to *kharif* rice

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Abstract

Field experiment was conducted during two consecutive *rabi* seasons of 2000 and 2001, to find out 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, nodule dry weight and nitrogen uptake of groundnut at different stages of crop growth. Application of 100% N through FYM to preceding rice crop has resulted in the highest total dry matter production, nodular dry weight and nitrogen uptake of groundnut.

Key words: Residual fertility, groundnut, drymatter production, nodule dry weight

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 became 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 applied to it. For maintaining balanced nutrition in a cropping system, residual effect on the succeeding crop deserved a careful docideratum and quantitative evaluation to sustain the level of productivity as well as soil health.

Materials and methods

Field experiments were conducted during two consecutive years (2000 and 2001) on sandy loam soils of wetland block of S.V. Agricultural College Farm, Tirupati, with rice during *kharif* and groundnut cv. K-134 comprising 12 treatments during *rabi* and laid out in randomized block design replicated thrice (Table 1). The same layout was followed during both the years of study. The recommended dose of fertilizers was 80 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. 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.

Results and discussion

Supply of 100% N through FYM to preceding rice has recorded the highest dry matter production (Table 1) and N uptake (Table 3) at all the stages of groundnut crop *viz*., 30, 60, 90 DAS and at harvest. At 30 and 60 DAS the dry matter produced and N uptake with FYM N_{100} (T_5) was in parity with all the N management practices, except F N_{100} (T_6), *Azospirillum alone* (T_2) and no N (T_1) imposed to preceding rice. This was due to substantial amount of residual nitrogen (Table 4) left by the treatment of FYM N_{100} (T_5) applied to preceding rice crop on succeeding groundnut crop.

At 90 DAS and at harvest, the highest dry matter accumulation and N uptake registered with FYM N_{100} (T_5), was 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) applied to preceding rice crop. This was due to the substantial residual effect with the treatments of the combination of FYM and the exclusive organic source of N, which was comparatively higher than the other combinations of organics and fertilizer N applied to preceding rice crop. Within the organic sources, differential residual response with different sources can be attributed to their pattern of mineralization and proportion of their substitution. The higher uptake of nitrogen by groundnut crop with application of 100% N through FYM (T_5) to preceding rice crop might also be attributed to enhanced dry matter production in addition to higher availability of nitrogen in the soil. The economic yields recorded with groundnut were in accordance with the dry matter production.

At 30 and 60 DAS, nodule dry weight (Table 2) was the highest with 100% N through FYM (T_5) applied to

Table 5 Relationship between the best parents, best hybrids (*per se* performance), high heterotic crosses (over better parent), best general combiners and best specific combiners identified for thirteen characters in a diallel of sesame

Character	Best parents	Best hybrids (*per se*)	Best heterotic crosses (over BP)	Best general combiners	Best specific combiners
Days to 50% flowering	YLM-11 YLM-17	Madhavi x YLM-11 Madhavi x YLM-17	YLM-11 x NSI-4 Madhavi x NSI-4	Madhavi YLM-11	Vinayak x Krishna Krishna x YLM-17
Days to maturity	Vinayak Krishna	Madhavi x YLM-11 Vinayak x Krishna	Krishna x NSI-4 Vinayak x NSI-4	Vinayak YLM-11	Rajeswari x NSI-4 Madhavi x YLM-11
Plant height	NSI-4 T-Brown	Vinayak x NSI-4 Madhavi x NSI-4	YLM-11 x YLM-17 Krishna x YLM-17	NSI-4 Rajeswari	Vinayak x NSI-4 Rajeswari x Krishna
No. of primary branches	NSI-4 YLM-11	NSI-4 x T-Brown Vinayak x YLM-17	Rajeswari x Krishna Vinayak x Krishna	Madhavi YLM-17	NSI-4 x T-Brown Rajeswari x Krishna
No. of secondary branches	Vinayak NSI-4	YLM-11 x Krishna YLM-11 x NSI-4	YLM-11 x Krishna YLM-11 x YLM-17	YLM-17 NSI-4	YLM-11 x Krishna Vinayak x Rajeswari
Capsules on main stem	T-Brown YLM-17	Madhavi x NSI-4 Madhavi x Krishna	Madhavi x Rajeswari Madhavi x NSI-4	Madhavi T-Brown	Madhavi x NSI-4 Rajeswari x T-Brown
Capsules on primary branches	T-Brown YLM-17	YLM-11 x T-Brown YLM-11 x Vinayak	Vinayak x Rajeswari Madhavi x Vinayak	YLM-17 YLM-11	YLM-11 x Vinayak Madhavi x Vinayak
Capsules on secondary branches	Vinayak T-Brown	YLM-11 x T-Brown YLM-17 x T-Brown	YLM-11 x Rajeswari YLM-11 x T-Brown	YLM-17 Vinayak	YLM-11 x T-Brown Rajeswari x YLM-17
Capsule length	Rajeswari Vinayak	Rajeswari x NSI-4 YLM-11 x RAJESWARI	NSI-4 x T-Brown Krishna x NSI-4	Rajeswari NSI-4	YLM-11 x Rajeswari NSI-4 x T-Brown
Seeds/capsule	Madhavi Rajeswari	Rajeswari x NSI-4 Rajeswari x T-Brown	NSI-4 x T-Brown Rajeswari x NSI-4	Rajeswari Krishna	Rajeswari x NSI-4 NSI-4 x T-Brown
1000-seed weight	Krishna Vinayak	Vinayak x T-Brown Rajeswari x NSI-4	Vinayak x T-Brown Rajeswari x NSI-4	Krishna Vinayak	Vinayak x T-Brown Rajeswari x NSI-4
Seed yield/plant	T-Brown YLM-17	Rajeswari x YLM-17 Rajeswari x NSI-4	Madhavi x Rajeswari Rajeswari x Krishna	YLM-17 Krishna	YLM-11 x T-Brown Rajeswari x YLM-17
Harvest index	NSI-4 T-Brown	Rajeswari x NSI-4 NSI-4 x T-Brown	Madhavi x Rajeswari Vinayak x Rajeswari	NSI-4 YLM-17	Madhavi x T-Brown Madhavi x Rajeswari

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Table 3 Nitrogen uptake (kg/ha) at various stages of groundnut as influenced by different nitrogen management practices to preceding rice

Treatment	30 DAS		60 DAS		90 DAS		At harvest	
	2000	2001	2000	2001	2000	2001	2000	2001
T_1 : No N	14.3	14.2	63.8	64.2	77.4	74.0	81.6	77.4
T_2 : *Azospirillum* alone	14.4	14.3	66.5	66.2	77.9	76.4	82.5	80.2
T_3 : GM N_{100}	16.6	15.6	75.8	70.2	87.2	83.8	91.2	88.6
T_4 : GLM N_{100}	16.8	15.7	75.8	71.6	87.7	85.3	91.5	90.6
T_5 : FYM N_{100}	17.3	16.6	77.7	75.5	93.4	90.0	96.4	94.4
T_6 : F N_{100}	14.5	14.4	68.3	66.8	79.5	76.8	84.1	80.7
T_7 : GM N_{50} + F N_{50}	15.7	15.3	72.1	68.7	83.8	78.8	88.5	83.9
T_8 : GLM N_{50} + F N_{50}	16.4	15.6	74.1	69.9	85.0	80.7	89.7	86.5
T_9 : FYM N_{50} + F N_{50}	17.1	16.1	76.8	75.0	90.4	88.3	96.2	93.0
T_{10} : GM N_{50} + F N_{50} + *Azo.*	15.8	15.4	72.6	68.8	82.2	78.1	87.9	82.9
T_{11} : GLM N_{50} + F N_{50} + *Azo.*	16.3	15.5	73.6	69.5	84.6	80.1	89.6	85.0
T_{12} : FYM N_{50} + F N_{50} + *Azo.*	16.9	16.0	76.5	74.4	88.3	87.0	94.4	91.3
SEm±	0.57	0.65	2.19	2.46	2.45	2.56	2.05	2.17
CD (P=0.05)	1.7	1.9	6.4	7.2	7.2	7.5	6.0	6.4

Table 4 Residual nitrogen status after *kharif* rice and economic yield of *rabi* groundnut

Treatment	Residual nitrogen (kg/ha)		Pod yield of groundnut (kg/ha)	
	2000	2001	2000	2001
T_1 : No N	130.8	130.8	2223	1962
T_2 : *Azospirillum* alone	136.5	136.5	2243	2023
T_3 : GM N_{100}	187.5	187.5	2433	2176
T_4 : GLM N_{100}	187.5	187.5	2449	2228
T_5 : FYM N_{100}	198.3	198.3	2553	2320
T_6 : F N_{100}	166.5	166.5	2306	2040
T_7 : GM N_{50} + F N_{50}	170.8	170.8	2356	2069
T_8 : GLM N_{50} + F N_{50}	173.3	173.3	2397	2093
T_9 : FYM N_{50} + F N_{50}	177.7	177.7	2544	2296
T_{10} : GM N_{50} + F N_{50} + Azo.	177.5	177.5	2331	2067
T_{11} : GLM N_{50} + F N_{50} + *Azo.*	170.0	170.0	2489	2080
T_{12} : FYM N_{50} + F N_{50} + *Azo.*	175.8	175.8	2475	2267
SEm±	9.82	6.65	54.6	76.9
CD (P=0.05)	28.8	19.5	160	226

The above results clearly indicated that organic sources at higher proportions can sustain the nutrient status of soil to produce reasonable residual effect. Significant carry over effect due to substitution of nitrogen with higher proportions of organic sources to rice on the succeeding crops was also reported by Thimmegowda and Deva Kumar (1994) and Paulraj and Velayudham (1996).

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preceding rice, which was at par with the N management practices imposed to *kharif* rice, except with F N_{100} (T_6), *Azospirillum* alone (T_2) and no N (T_1), while at 90 DAS and at harvest, there was no significant variation in nodule dry weight due to different N management practices to preceding rice. This was perhaps due to the residual fertility, especially soil P with the treatments of combinations of organic sources during the early stage of crop growth, while during the later stages, the effect of residual fertility might be insignificant and also the activity of nodules would have been ceased.

Table 1 Drymatter production (kg/ha) of groundnut as influenced by different nitrogen management practices to preceding rice

Treatment	30 DAS		60 DAS		90 DAS		At harvest	
	2000	2001	2000	2001	2000	2001	2000	2001
T_1 : No N	660	664	2433	2468	4723	4565	6453	5609
T_2 : *Azospirillum* alone	681	669	2530	2554	4787	4628	6463	5642
T_3 : GM N_{100}	754	728	2843	2649	5253	4986	6893	6008
T_4 : GLM N_{100}	758	731	2863	2651	5307	5026	6913	6163
T_5 : FYM N_{100}	796	779	2987	2882	5590	5390	7213	6441
T_6 : F N_{100}	688	682	2567	2569	4840	4684	6540	5787
T_7 : GM N_{50} + F N_{50}	718	715	2781	2609	5143	4787	6730	5836
T_8 : GLM N_{50} + F N_{50}	746	721	2807	2643	5210	4827	6773	5997
T_9 : FYM N_{50} + F N_{50}	786	741	2913	2820	5410	5258	7170	6330
T_{10} : GM N_{50} + F N_{50} + *Azo.*	714	702	2690	2600	5077	4706	6653	5795
T_{11} : GLM N_{50} + F N_{50} + *Azo.*	742	718	2787	2616	5190	4821	6750	5978
T_{12} : FYM N_{50} + F N_{50} + *Azo.*	770	735	2893	2797	5343	5146	7003	6315
SEm±	29.0	27.3	78.1	104.0	122.4	139.8	149.0	148.0
CD (P=0.05)	85	80	229	305	359	410	437	434

GM = Green manure (dhaincha); GLM = green leaf manure; FYM = Farm yard manure

Table 2 Nodule dry weight (mg/plant) of groundnut as influenced by different nitrogen management practices to preceding rice

Treatment	30 DAS		60 DAS		90 DAS		At harvest	
	2000	2001	2000	2001	2000	2001	2000	2001
T_1 : No N	33.0	36.0	126.0	126.0	108.0	116.3	99.7	103.7
T_2 : *Azospirillum* alone	33.3	36.2	128.0	127.0	107.0	113.3	98.7	99.7
T_3 : GM N_{100}	35.0	39.1	134.7	136.7	112.7	114.7	104.7	112.7
T_4 : GLM N_{100}	35.3	39.2	135.3	138.7	111.0	118.7	105.7	110.3
T_5 : FYM N_{100}	36.0	39.7	142.5	143.3	116.7	122.7	112.7	116.7
T_6 : F N_{100}	33.3	36.5	128.0	129.7	108.7	115.7	102.7	104.7
T_7 : GM N_{50} + F N_{50}	35.0	38.5	130.7	134.7	112.3	117.3	103.7	113.0
T_8 : GLM N_{50} + F N_{50}	35.0	38.8	134.7	136.0	109.7	120.3	105.7	108.7
T_9 : FYM N_{50} + F N_{50}	36.0	39.4	136.7	142.7	118.7	124.7	110.7	119.0
T_{10} : GM N_{50} + F N_{50} + *Azo.*	34.3	38.2	130.0	132.7	109.7	116.7	104.7	109.7
T_{11} : GLM N_{50} + F N_{50} + *Azo.*	35.0	38.6	134.0	135.7	110.7	119.0	103.7	110.7
T_{12} : FYM N_{50} + F N_{50} + *Azo.*	35.7	39.2	135.3	139.0	117.7	123.7	111.7	114.7
SEm±	0.78	1.02	4.54	4.06	5.01	5.82	5.18	6.2
CD (P=0.05)	2.3	3.0	13.3	11.9	NS	NS	NS	NS

treatments. Sulphur application increased plant vigour and production of photosynthates through increased leaf area and chlorophyll content of leaves (Tandon, 1991). The favourable nutritional environment in the root zone thus created by the addition of FYM, sulphur and micronutrients resulted in increased absorption of these nutrients which could be responsible for increased growth and yield attributing characters of taramira. These findings are in conformity with those reported by Singh (1963) and Sarmah and Debnath (1999).

Seed yield: The taramira crop responded well to additional fertilization with sulphur, zinc, boron and FYM combined with the recommended doses of N and P fertilizers (Table 1). Application of 100% RF + 10 t FYM + 40 kg S + 25 kg $ZnSO_4$ + 1.0 kg boron/ha (T_5) also recorded significantly higher mean seed yield (1075 kg/ha) of taramira than rest of the treatments barring T_4-(100 % RF + 10 t FYM + 40 kg S + 25 kg $ZnSO_4$/ha) and T_3 (100% RF + 10 t FYM + 40 kg S/ha). The increased seed yield was mainly due to higher number of siliquae/ plant, seeds/siliqua and test weight with these treatments. This is evident from the fact that when the application of S, Zn and B was with held, there was significant reduction in seed yield. These findings are in agreement with those of Tiwari and Pathak (1982) and Rana *et al.* (2001).

Economics: The treatment T_5 was found the most economical which offered the maximum net returns (Rs. 6487/ha) followed by T_4 (Rs. 6335/ha), while the lowest net returns (Rs. 4333/ha) was obtained with 75% RF (T_6).

Table 1 Growth, yield attributes and seed yield of taramira as affected by integrated nutrient management
(Pooled mean of three years)

Treatment	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Siliquae/ plant	Seeds/ siliqua	Test weight (g)	Seed yield (kg/ha)	Net returns (Rs/ha)
T_1 : 100% RF (30 kg N+20 kg P_2O_5/ha)	106	6	9	167	19	3.3	768	5819
T_2 : T_1 + 10 t FYM/ha	110	7	10	185	19	3.0	870	5465
T_3 : T_2 + 40 kg S/ha	112	7	10	202	20	3.5	993	6221
T_4 : T_3 + 25 kg ZnSO4/ha	114	7	12	215	21	3.4	1035	6335
T_5 : T_4 + 1 kg boron/ha	117	8	13	227	21	3.5	1075	6487
T_6 : 75% RF	104	7	7	136	17	3.3	689	4333
T_7 : T_6 + 10 t FYM/ha	108	6	8	149	19	3.3	761	4426
T_8 : T_7 + 40 kg S/ha	109	7	9	162	19	3.3	849	4796
T_9 : T_8 + 25 kg $ZnSO_4$/ha	111	7	10	175	19	3.4	861	4565
T_{10} : T_9 + 1 kg boron/ha	112	7	11	187	20	3.4	909	4825
SEm±	1.5	0.5	0.7	4.7	0.7	0.04	46.8	-
CD (P=0.05)	4.3	1.4	2.0	13.3	1.9	0.11	132.7	-

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Integrated nutrient management in taramira, *Eruca sativa* Mill., under dryland conditions of Rajasthan

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Abstract

Field studies conducted during *rabi* seasons of 1998-99 through 2000-01 at S.K.N. College of Agriculture, Jobner to study the effect of integrated nutrient management on growth and yield of taramira under dryland conditions. The treatment comprising 100% RF + 10 t FYM + 40 kg S + 25 kg $ZnSO_4$ + 1.0 kg B/ha resulted in significantly higher seed yield (1075 kg/ha) than other treatments except 100% RF + 10 t FYM + 40 kg S + 25 kg $ZnSO_4$/ha (1035 kg/ha) and 100% RF + 10 t FYM + 40 kg S/ha (993 kg/ha). The growth and yield attributes *viz.*, plant height, primary and secondary branches/plant, number of silique/plant, seed/siliqua and test weight were also influenced by integrated use of organic manures and inorganic fertilizers. All the above three treatments also recorded higher net returns.

Key words: Integrated nutrient management, taramira, growth and yield

Introduction

Taramira (*Eruca sativa* Mill.) is an important oilseed crop among rapeseed and mustard group. Being highly drought tolerant because of efficient root system to extract moisture from deeper soil horizons, it is specially suitable for arid and semi-arid regions of Rajasthan (Singh and Sharma, 1976). During the periods of severe drought coupled with late *rabi* rains, taramira is the only alternative crop for soils having limited moisture supply. It is generally cultivated on marginal and sub-marginal lands of poor fertility without fertilizers which is one of the most important reasons for its low productivity. Besides nitrogen and phosphorus, global reports of sulphur deficiency and consequent crop responses are quite ostensible (Tandon, 1991). Sulphur plays an important role in the formation of amino acids, synthesis of proteins, chlorophyll and oil. Micro nutrients also influence the yield and oil content in oilseed crops (Muralidharudu and Singh, 1990). Systematic work on fertilizer requirement of taramira is meager and needs immediate attention to increase its productivity in drylands. Integrated nutrient management by judicious combination of organic manures and inorganic fertilizers holds great promise in meeting the growing demands of intensive agriculture and sustaining soil health. Therefore, the present investigation was undertaken to study the effect of integrated nutrient management on growth and yield of taramira.

Materials and methods

A field experiment was conducted during winter season of 1998-99, 1999-2000 and 2000-2001 at S.K.N. College of Agriculture, Jobner (Rajasthan) to evaluate the effect of integrated use of organic manures and inorganic fertilizers in taramira. The soil of the experimental field was loamy sand in texture, alkaline in reaction (pH 8.2) with EC-1.13 dS/m, organic carbon -0.19%, available N-125 kg/ha, P_2O_5-16.4 kg/ha and S-8.4 ppm. Ten treatments were laid out in randomized block design and replicated thrice (Table 1). The recommended dose of fertilizers (RF) : 30 kg N and 20 kg P_2O_5/ha was applied at the time of sowing through urea and diammonium phosphate, respectively as per treatments. Sulphur as elemental sulphur, zinc as zinc sulphate and B as borax were also pre-plant incorporated as per treatments. The taramira variety 'RTM-314' was sown in rows spaced 30 cm apart in the second fortnight of October in all the three years. Except pre-sowing, no irrigation was applied in standing crop and no rainfall was received during the crop season. Adequate management practices and plant protection measures were followed to raise a good crop. Observations were recorded on growth, yield attributing characters and seed yield were statistically analyzed. Net returns were also computed taking into account the cost of inputs and returns through seed.

Results and discussion

Growth and yield attributes: The data pooled over years (Table 1) indicated that growth and yield attributing characters of taramira *viz.*, plant height, primary and secondary branches/plant, number of siliquae/plant, seeds/siliqua and test weight were favourably influenced with the integrated use of organic manures and inorganic fertilizers. These characters were significantly more with the treatment T_5 (100% RF+10 t FYM+40 kg S+25 kg $ZnSO_4$+1.0 kg boron/ha) in comparison to other treatments. It was closely followed by T_4 and T_3

during June the amount of rainfall received was 19 mm indicating delayed onset of monsoon. Rain of 52 mm during July first week helped the sowing of crops. During the entire season the soil moisture could not reach to a level of 150 mm. The crops were exposed to extended water deficits. The two years of experimentation was different in terms of the meteorological environment in particular with respect to the amount of rainfall and its distribution (Figures 1 & 2).

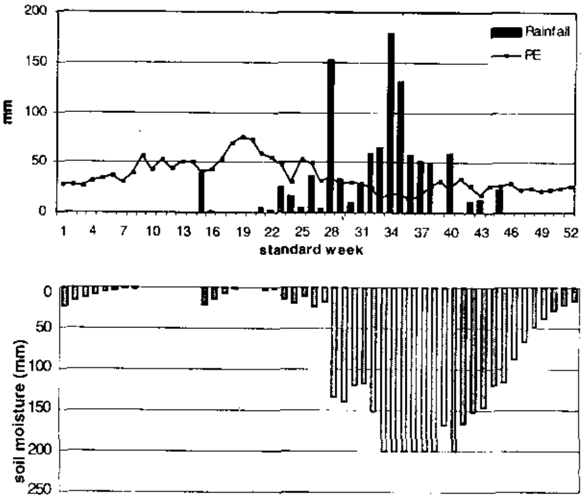

Fig-1 Rainfall and soil water storage during 1996

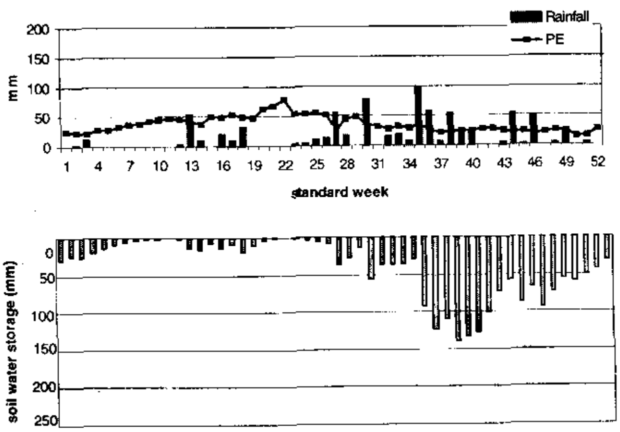

Fig-2 Rainfall and soil water storage during 1997

The rates and sources of nitrogen were imposed as main plot treatments and the cropping systems (sole soybean; soybean/sunflower 4:1; sole pigeonpea; sorghum/ pigeonpea 2:1) were assigned to subplots. The broad bed (120cm) and furrow (30cm) were tilled with a multi-purpose tool bar immediately after harvesting the previous crop. The treatments were allocated in the field in a split plot design with three replications. FYM (1.2% N) was incorporated into the top 10 cm soil @ 20 and 40 kg N/ha as per treatments ahead of the sowing of crops. The fertilizer N (as KNO_3) was applied @ 20, 40 kg N/ha. A basal dose of 250 kg/ha of single super phosphate (16% P_2O_5) was uniformly incorporated. The crop varieties used were soybean-PK 472; pigeonpea-ICPL 87119; sunflower-Morden and sorghum-CSH 9. Crops were harvested from an area of 27 m^2. The yield data was analyzed in factorial RBD (for soybean, pigeonpea) and by the analysis of variance (for sunflower, sorghum). Critical differences or least significant differences (LSD) were used to compare the performance of various treatments. Yield data of the two years of experiments were analyzed separately as these (years) differed significantly in their rainfall patterns. Pooled analysis also indicated that except soybean all other crops differed significantly between wet year and dry year.

Results and discussion

Year 1 (1996-97) a wet year

Sole soybean: Irrespective of source and amount of nitrogen applied seed yield increased significantly over control (Table 1 & 2). A significantly higher yield ($P \leq 0.05$) was obtained @ 40 N/ha kg (fertilizer) application compared to all other treatments. The grain yield recorded in 20 kg N/ha (FYM): 20 kg N/ha (fertilizer) treatment was significantly higher than that of 40 kg N/ha (FYM) and 20 kg N/ha (FYM) treatments, however it was on par with the 20 kg N/ha (fertilizer) treatment. Amongst the 20 kg N/ha treatments, supplementing N through fertilizer recorded significantly higher yield than in the treatments where N was applied through FYM. Irrespective of source of N, 40 kg N/ha recorded 12 and 27% higher yield over 20 kg N/ha and control. The increase in the crop yield (due to application of N) also increased canopy leaf area, and led to a higher N uptake in the plant (data not included). *These attributes facilitated a better utilization of solar* energy by the crop and the synthesis of carbohydrates in larger amounts. Patel and Chandravanshi (1996) hold the view that soybean crop required a large quantity of N especially during its initial growth phase although it is a leguminous crop. Our results are in line with those of Asanuma *et al* (1992) who showed a high positive correlation between total top weight of soybean and total amount of N removed by plants and seed. Patel *et al* (1996) and Sharma and Mishra (1997) also reported increased yield of soybean due to N application.

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Grain yield of soybean and pigeonpea based intercropping systems in vertisols with integrated nutrient management options

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Abstract

A field experiment was conducted at ICRISAT Patancheru centre on a Vertisols watershed during the rainy cropping seasons of 1996-97 and 1997-98 to evaluate the productivity of four cropping systems *viz*; sole soybean, soybean/sunflower, sole pigeonpea and sorghum/pigeonpea in six nitrogen management treatments under rainfed conditions. The N treatments included three levels of N (0, 20, 40 kg N/ha) from two sources (FYM and fertilizer). The rainfall in 1996 (a wet year) was 1062 mm, 18 % above the long term average, whereas in 1997 (a dry year) the rainfall totaled 743 mm, 18% less than the long term average. During the wet year, the productivity of all the test crops was significantly higher when N @ 40 kg/ha was added through fertilizer. However in the dry year yields were not affected by fertilizer N. Soybean yields were not significantly differed between the years. Pigeonpea yields were significantly higher in wet year compared to dry year. Intercropped sunflower and sorghum yielded significantly higher in the dry year than that of wet year.

Key words: Nitrogen, soybean, pigeonpea, cropping system, semi-arid tropics

Introduction

The crop-growing environment in the semi-arid tropics is highly variable due to erratic spacing and timing of seasonal rainfall. Thus the length and the patterns of the growing season are irregular. In order to sustain crop production and to contain risks of crop failures, a wide variety of sole and inter cropping systems including combinations of cereals and legumes are practiced. Introduction of grain legumes in the rainfed cropping systems has always been given prominence because these crops, apart from providing a rich source of dietary protein, also contribute to the maintenance and restoration of soil fertility by biologically fixing atmospheric nitrogen (BNF). Pigeonpea has been traditionally grown in the SAT regions of India. It is invariably intercropped with cereals (e.g. Sorghum). Of late, the cultivation of soybean has become popular, particularly in the central peninsular India.

The yields of soybean and sorghum based cropping systems are limited by soil N in the SAT. It is known that the efficiency of soil and applied N varies considerably in rainfed agriculture because it is modulated by the amount and distribution of rainfall. Fertilizer N use in the rainfed SAT can be profitable, particularly when improved fertilizer and rain water management practices are combined with the high yielding varieties of crops in appropriate cropping systems (Katyal, 1989). With this in view, an experiment was conducted to evaluate the efficacy of some N management systems in soybean and pigeonpea based cropping systems.

Materials and methods

The study was conducted over a two year period, (1996/97-1997/98) at ICRISAT Patancheru centre (17°35' N, 78° 15' E) in India. The research farm of the centre is located in the Deccan Plateau. It has a characteristic semi arid tropical climate. The soil at the watershed site is deep Vertisol (typic Pellustert) belonging to the Kasireddypalli series (Murthy and Swindale, 1993). The physical and chemical properties of experiment site are presented in Table 1.

Table 1 Soil physical and chemical properties of the experiment site

Property	Soil depth (cm)					Mean
	0-15	15-30	30-60	60-90	90-120	
PH	8.2	8.3	8.3	8.3	8.3	8.3
EC (ds/m)	0.15	0.17	0.19	0.22	0.22	0.19
Mineral N (mg/g soil)	3.8	2.5	1.9	1.8	1.6	2.3
Organic carbon (g/kg soil)	6.4	4.4	3.6	3.7	3.2	4.3
Available P (mg/kg soil)	0.71	0.10	0.10	0.10	0.10	0.23
Available K (mg/kg soil)	180	109	157	159	169	155

In year 1 (1996), the annual rainfall was 1062 mm. All crops were sown in June with sufficient moisture (rain 87 mm). Rainfall received during August (451 mm) caused water logging. Soil moisture was estimated using Ritchie's model. Thirty eight per cent of rainfall was lost as run off and deep drainage. In the year 2, (1997) the seasonal rainfall was irregular and maldistributed. It totaled 741 mm,

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sunflower population was maintained under intercropping). In addition at the flowering time of the crop heavy rains occurred, which resulted in pollen wash, lower seed set, and thus low crop yield. These results, though in line with the observations of Gimenez *et al.* (1994) and Mishra *et al.* (1995) who found increased dry matter production due to increase in the amount of N applied in sunflower, yet show that stable yields of sunflower crop can be obtained only when it is grown outside the main rainy season or its sowing time is manipulated such that the flowering of the crop did not coincide with the peak rainy period.

Sole Pigeonpea: A higher seed yield of pigeonpea was recorded when 40 kg N/ha (fertilizer) N or 20: 20 kg (FYM: Fertilizer) N/ha was applied compared to all other treatments. Yield of pigeonpea did not differ significantly when 20 kg N/ha was sourced either from FYM or fertilizer (Table 2). The yield improvement over control (0, N) when 20 and 40 kg N/ha (irrespective of source) was applied was 25% and 41%, respectively. Chittapur *et al.* (1994) and Singh *et al.* (1994) had observed similar results in experiments conducted on Vertisols in Maharashtra these lend support to the data gathered in the present investigation.

Sorghum/Pigeonpea: Seed yield of intercropped pigeonpea showed a range from 906 to 1613 kg/ha and was significantly influenced by N application (Table 2). Higher yield of pigeonpea was obtained when 40 kg N/ha was applied either from fertilizer or FYM +fertilizer compared to all other treatments. Application of 20 kg/ha fertilizer N produced higher yield compared to the application of 20 kg/ha N sourced from FYM (Table 2).

Nitrogen application significantly (P£0.05) increased grain yield of sorghum (1076 kg/ha) when 40 kg (fertilizer) N/ha was applied. The yield improvement when 20 kg N/ha and 40 kg N/ha (irrespective of source of N) over control was 57% and 151% respectively. Several authors (Shaik Mohammed *et al.*, 1993; Dashora and Porwal, 1994; Kasole *et al.*, 1994; Rao *et al.*, 1995) have reported similar results with regard to the response of sorghum to N application.

Year 2 (1997-98) dry year

In the dry year when several episodes of drought spells occurred during the cropping season (Figure 2), no response to N application was noted in any of the cropping systems. The mean seed yields obtained in sole soybean, and intercropped soybean/sunflower were 989, 672 and 396 kg/ha respectively (Table 1 & 2). Soybean seed yields did not vary much between sole and intercropped systems. The yield of sunflower was 2-fold and sorghum 6-fold more than that of the yields recorded when these crops were grown during 1996-97 cropping season (188; 630 kg/ha) in a wet year. The mean seed yields recorded in the dry year (1997-98) were 1362, 620 and 3558 kg/ha for sole pigeonpea, intercropped pigeonpea and sorghum respectively. Sole pigeonpea yield did not show any variation between the wet and dry years which indicated that this crop was less affected by the excess of water or by drought. But the intercropped pigeonpea yielded only 50 % that of sole or intercropped pigeonpea production recorded during the wet year 1996-97. This had occurred as the intercropped sorghum utilized most of soil moisture built in the profile during early rains. In the wet year of 1996 sorghum yield and quality was several folds lower than that of the dry year (1997) mainly due to the occurrence of waterlogging and a severe attack of grain molds.

In conclusion, it can be stated that the results of this study demonstrated that crop production in the SAT is significantly exposed to environmental risks inherent to this agroecological zone. Crop yields can be sustained by including grain legumes in rotation and by inter cropping of short and long duration crops. The evidence on N fertilization showed that its application was necessary in the tropical SAT soils due to their low N content and poor organic matter status. But a judicious program of N application which built soil N reserves by the addition of organic farm manures, as primary sources of N must be adopted. Fertilizer N should be applied to supplement organic N as and when opportunity presents itself during the crop growing season. When soil moisture reserves are sufficiently recharged, split application of fertilizer N is suggested. The results of this study also demonstrated that intercropping particularly with medium duration pigeonpea would increase sustainability of crop production in the rainfed SAT in central-peninsular India.

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Table 1 Seed yields (kg/ha) of soybean and sunflower

Treatment	1996			1997		
	Soybean	Soybean/sunflower		Soybean	Soybean/sunflower	
		Soybean	Sunflower		Soybean	Sunflower
Control (0 N)	770	550	90	770	730	370
20 kg N/ha FYM	760	550	120	970	675	365
20 kg N/ha Fertilizer	1000	710	155	1095	610	375
40 kg N/ha FYM	820	725	190	1080	740	385
40 kg N/ha Fertilizer	1135	845	300	1000	605	465
20:20 kg N/ha (FYM : Fertilizer)	980	790	275	1020	670	420
Mean	911	695	188	989	672	397

	Soybean				Sunflower	Soybean				Sunflower
	N	C	NC	CN	N	N	C	NC	CN	N
SEm±	38	15	45	35	14	43	25	61	61	25
CD (P=0.05)	119**	45**	135^{NS}	109	44**	135^{NS}	77**	178^{NS}	187	79^{NS}

Table 2 Seed yields (kg/ha) of pigeonpea and sorghum

Treatment	1996			1997		
	Soybean	Soybean/sunflower		Soybean	Soybean/sunflower	
		Soybean	Sunflower		Soybean	Sunflower
Control (0 N)	1165	905	325	1270	595	3215
20 kg N/ha FYM	1400	1085	330	1340	555	3565
20 kg N/ha Fertilizer	1510	1310	690	1515	715	3310
40 kg N/ha FYM	1460	1300	560	1380	515	3825
40 kg N/ha Fertilizer	1820	1615	1075	1345	640	3765
20:20 kg N/ha (FYM : Fertilizer)	1650	1535	800	1330	700	3680
Mean	1500	1290	630	1363	620	3560

	Soybean				Sunflower	Soybean				Sunflower
	N	C	NC	CN	N	N	C	NC	CN	N
SEm±	60	33	83	81	63	106	42	129	104	187
CD (P=0.05)	188**	102**	243^{NS}	249	197**	334^{NS}	130**	382^{NS}	319	589^{NS}

CD at (P=0.05): ** = ($P \leq 0.01$); * = ($P < 0.05$); NS - non-significant; N-nitrogen levels and sources
C-Crops; NC & CN - interaction between nitrogen and crops

Soybean/Sunflower: Significantly higher ($P \leq 0.05$) grain yield of soybean was obtained in the 40 kg (fertilizer) N/ha treatment followed by 20:20 kg (FYM: fertilizer) N kg/ha (Table 1). The yield improvement over control by the application of 20 and 40 kg (FYM or fertilizer) N/ha was 15% and 43%, respectively. Seed yield of intercropped soybean was significantly lower (-31%) compared to the sole soybean. Significantly higher yields of soybean were obtained in the 40 kg N/ha treatments. The yield of soybean in the 20 kg N/ha and 40 kg N/ha treatments irrespective of source of N was 53% and 183% higher when compared to control. Relatively low yield of sunflower observed in the present study was due primarily *to less than normal planting population (1/3rd of the sole*

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Effect of nutrients and moisture conservation practices on growth, yield and economics of *rabi* sunflower under rainfed vertisols

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Abstract

On farm trials were conducted to study the effect of nutrients and moisture conservation practices on growth, yield and economics of sunflower, *Helianthus annuus* L. cultivars during *rabi* 2001-02 on Vertisols of Raichur district (Karnataka). The results revealed that, recommended method of moisture conservation along with recommended fertilizer practice significantly recorded higher seed yield (858 kg/ha), net returns (Rs.5913/ha) and benefit: cost ratio (1.85) than farmer's method of moisture conservation and fertilizer practice. KBSH-44 showed significant favourable response with respect to growth and yield besides recording higher economics than rest of the cultivars.

Key words: *Sunflower, nutrient, moisture and* vertisols

Introduction

Sunflower (*Helianthus annuus* L.) occupies an area of 1.61 lakh hectares in Raichur district (Karnataka) with the production of 0.687 lakh tonnes and productivity of 425 kg/ha (Damodaram and Hegde, 2002). The low productivity of the crop is attributed to unfavorable weather coupled with poor nutrient management practices. There is a shift in recent years in area from *kharif* to *rabi* sunflower due to unprecedented rainfall during *Kharif* besides necrosis disease. Moisture and nutrition have been identified as critical component in enhancing sunflower productivity.

The yield losses were reported highest when moisture stress occurred during 20 days before to 20 days after flowering (Pirjol *et al.*, 1972) and combination of the stress at vegetative and flowering stage affected the yields more than the combination of stress at vegetative and grain filling stages (Subba Reddy *et al.*, 2000). Similarly, fertilizer requirement of sunflower revealed that application of 100 kg N, 100 kg P_2O_5 and 50 kg K_2O/ha gave higher seed yield under rainfed conditions (Vijay *et al.*, 1975). Since the farmers of this area have poor investment capacity on cash inputs the choice of appropriate cultivar for variable nutrient and moisture situation is of paramount importance to enhance the productivity of sunflower in the region. Improvement in productivity of sunflower under rainfed environment necessitated, the present on-farm trial to evaluate the effect of moisture conservation and fertilizer practices on the performance of sunflower cultivars during *rabi* season in Vertisols.

Materials and methods

On-farm trials were conducted during *rabi* season of 2001-02 in Vertisols of Raichur district (Karnataka) to study the effect of nutrients and moisture conservation practices on growth, yield and economics of *rabi* sunflower. The experimental site has covered five villages varying in soil fertility. The soil of the experimental field was sandy clay to clay with pH 8.13, organic carbon 0.36%, available phosphorus 11 kg P /ha, and available potassium 445 kg K/ha. The soil has field capacity of 28 % and permanent wilting point of 13%with available water holding capacity of 17.06 cm at 75 cm depth. The potential hybrid KBSH-44 and recommended hybrid KBSH-1were evaluated against check hybrid MSFH-17 under farmer's and recommended method of moisture conservation in combination with either farmer's or recommended fertilizer application. The experiment was laid out in Split Plot Design with three-moisture conservation and fertilizer practice combination as main plot and three cultivars as sub plots having seven replications while keeping each farmer as a replication. The sunflower crop was sown on 25.10.2001 at a spacing of 60 cm x 30 cm with the application of recommended dose of fertilizer (35:50:35 N: P_2O_5:K_2O kg/ha) or farmer's fertilizer practice (17.5:25:17.5 N: P_2O_5:K_2O kg/ha). Moisture conservation practices under farmer's method were repeated harrowing and inter cultivation twice while the recommended method of moisture conservation consisted of key line cultivation and opening furrow between two rows of sunflower after 30-35 days of sowing. The rainfall received during September (115.4 mm) and

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The maximum additional net returns were obtained under recommended method of moisture conservation combined with recommended dose of fertilizer followed by farmer's method of moisture conservation and recommended dose of fertilizer over farmer's method of moisture conservation and fertilizer. The hybrids KBSH – 44 and KBSH – 1 registered more additional net returns over MSFH-17. Interaction effect between moisture conservation and fertilizer and cultivars was significant in respect of net returns where in maximum net returns was obtained in KBSH–44 under recommended method of moisture conservation and recommended fertilizer application (Table 4).

Therefore, it can be concluded that KBSH-44 hybrid was best suited under recommended method of moisture conservation along with recommended dose of fertilizer to achieve increased seed yield of sunflower under rainfed Vertisols of northeastern dry zone of Karnataka.

Table 1 Effect of moisture conservation and fertilizer on yield, growth and yield attributes of sunflower cultivars

Treatment	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	1000 weed weight (g)	Head diameter (cm)	Stem girth (cm)	Plant height at harvest (cm)
Moisture conservation - MC and fertilizer practice - FP (M)							
Farmers method MC+FP	559	34.9	196	39.9	10.5	4.4	120
Farmers method MC+RDF	692	36.3	253	40.8	11.8	4.8	131
Rec.MC+RDF	858	35.6	309	41.9	12.7	5.3	138
SED	40.5	0.83	18.3	1.01	0.26	0.14	2.46
CD(P=0.05)	88.2	1.80	39.9	NS	0.57	0.32	5.37
C.V %	18.66	7.51	23.54	8.05	7.23	9.90	6.16
Cultivars (S)							
MSFH-17	637	33.9	217	39.6	10.9	4.3	121
KBSH-1	704	39.6	281	41.0	11.5	4.9	131
KBSH-44	768	33.4	259	42.0	12.5	5.3	137
SED	10.5	0.70	5.29	0.59	0.43	0.19	1.69
CD(P=0.05)	21.3	1.43	10.73	1.20	0.88	0.38	3.43
C.V %	5.84	6.41	6.79	4.68	12.02	12.75	4.22
M x S							
SED	43.1	1.30	19.80	1.31	0.66	0.31	3.43
CD(P=0.05)	NS	NS	42.71	NS	NS	NS	7.23
S x M							
SED	18.2	1.22	9.16	1.02	0.75	0.33	2.92
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS

NS: Not Significant; RDF: Recommended Dose of Fertilizer
*M x S; Comparison of main plot (M) at the same level of sub-plot (S)
*S x M; Comparison of sub-plot (V) at the same level of main plot (M) or different levels of main plot.

October 2001 (233.0 mm) was favourable for growth and yield of the crop. After establishment of the crop, there were no rains. However, the crop survived on the residual moisture. The oil content was estimated by using Nuclear Magnetic Resonance (NMR).

Results and discussion

Growth and yield attributes

The growth parameters of sunflower cultivars such as head diameter, stem girth and plant height at harvest differed significantly due to moisture conservation, fertilizer practice and cultivars (Table1). The recommended method of moisture conservation along with recommended fertilizer practice recorded significantly larger sized head having higher head diameter of 12.7 cm, higher stem girth (5.3 cm) and plant height at harvest (138 cm) compared to rest of the treatments. The values for these parameters were lowest with farmer's method of moisture conservation and fertilization.

Hybrid KBSH-44 recorded significantly higher head diameter (12.5cm), stem girth (5.3 cm) and plant height at harvest (137 cm) compared to rest of the hybrids. The check hybrid MSFH-17 recorded significantly lower head diameter (10.9 cm), stem girth (4.3 cm) and plant height at harvest (121 cm) than KBSH-1 and KBSH-44.

Yield parameters such as 1000 seed weight was not significantly influenced by the different fertilizer and moisture conservation practices but greatly influenced by the different cultivars. The hybrid KBSH-44 recorded significantly higher test weight 42 g/1000 seeds as compared to KBSH-1 (41g) and MSFH-17 (39.6g).(Table-1). Plant height resulted in significant interaction where in maximum plant height was recorded in KBSH-44 under recommended moisture conservation and fertilizer practice followed by KBSH-1 under same level of recommended practices.

Seed yield and oil yield

Seed yield of sunflower differed significantly due to the combined effect of nutrient and moisture as well as cultivars. Significantly higher seed yield of 858 kg/ha was obtained under recommended method of moisture conservation along with recommended dose of fertilizer as compared to rest of the treatments (Table 1). The magnitude of the seed yield increase under recommended method of moisture conservation along with recommended dose of fertilizer was 24% and 53.5% over the farmer's method of moisture conservation along with recommended dose of fertilizer and farmer's method of moisture conservation and fertilizer practice respectively. Significant differences were observed in oil yield, which was similar to that of seed yield. The extent of oil yield increase under recommended method of moisture conservation combined with recommended dose of fertilizer was 22.1% and 57.7% over the farmer's method of moisture conservation in combination with recommended dose of fertilizer and farmer's method of moisture conservation along with fertilizer practice respectively.

The seed yield of *rabi* sunflower differed significantly due to different cultivars. The hybrid KBSH-44 recorded significantly higher seed yield (768 kg/ha) followed by KBSH-1 (704 kg/ha) and MSFH-17 (637 kg/ha). The increase in seed yield of hybrid KBSH-44 was 9.1 % and 20.6 % over KBSH-1 and MSFH-17 respectively. The oil content was markedly differed among the hybrids. KBSH-1 recorded higher oil content of 39.6 % followed by KBSH-44 (33.4%) and MSFH –17 (33.9 %) which were on par for oil content. Significant differences were observed in oil yield where in KBSH-1 recorded highest oil yield (281 kg/ha) followed by KBSH-44 (259 kg/ha) and MSFH-17 (217 kg/ha). The higher oil content and relatively higher seed yield were responsible for increased oil yield in KBSH-1.

The interaction effect between cultivars as well as moisture conservation and fertilizer application was not significant for seed yield whereas oil yield resulted in significant interaction where in maximum oil yield (346 kg/ha) was recorded in KBSH-1 under recommended moisture conservation and fertilizer practice followed by KBSH-44 under same level of recommended practices(Table 2).The larger sized head resulting in more number of seeds coupled with increased test weight have contributed to the higher seed yield of KBSH-44. Favourable response of sunflower hybrids under adequate fertilization has been observed by Megur *et. al*,1993; Devi Dayal and Agarwal, 1998.

Economics

The maximum gross returns and cost of cultivation (6957/ha) were obtained under recommended method of moisture conservation combined with recommended dose of fertilizer (Table 3). Among different cultivars, KBSH-44 registered maximum gross returns while cost of cultivation was maximum in MSFH-17 due to higher cost of seed. The higher net returns and B: C ratio (1.85) were realized under recommended method of moisture conservation combined with recommended dose of fertilizer whereas lower net returns and B:C ratio (1.56) were realized under farmer's method of moisture conservation and fertilizer practice which was on par with the farmer's method of moisture conservation and recommended dose of fertilizer. Among cultivars, significantly higher returns and B: C ratios (1.87) were realized in KBSH-44 than the rest of the cultivars. Higher gross returns and lower cost of cultivation were responsible for increased net returns in KBSH-1. The lower net return and B: C ratios (1.49) were obtained in MSFH-17.

ıble 4 Interaction effect on net return (Rs/ha) of sunflower under variable nutrient and moisture

Sub Plot / ʼlain Plot	MSFH-17	KBSH-1	KBSH-44
ːarmers method ʼIC + FP	2285	2969	3825
ːarmers method ʼIC + RDF	2506	3907	5076
՚ec. MC + RDF	4529	6029	7209

	SED	CD (P=0.05)	CV (%)
ʼlain (M)	612	1334	47
;ub (S)	154	313	47
ʼ1 x S	650	1405	
‹ x M	267	541	

x S : Comparison of main plot (M) at the same level of sub-plot (V)
‹ M : Comparison of sub-plot (V) at the same level of main plot (M) or different levels of main plot

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Table 2 Interaction effect of moisture conservation and fertilizer on oil yield of sunflower cultivars

Main Plot \ Sub Plot	MSFH-17	KBSH-1	KBSH-44
Farmers method MC+FP	175	211	201
Farmers method MC+RDF	215	285	259
Rec. MC +RDF	262	346	318
	SED	CD (P=0.05)	
Main (M)	18.3	39.9	
Sub (S)	5.3	10.7	
M x S	19.8	42.7	
S x M	9.2	18.6	

Table 3 Economics of sunflower under variable nutrient and moisture

Treatment	Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio	Additional net return over farmers method of MC+FP (Rs/ha)
Moisture conservation - MC and fertilizer practice - FP (M)					
Farmers method MC+FP	8393	5367	3026	1.56	-
Farmers method MC+RDF	10373	6507	3866	1.59	840
Rec.MC+RDF	12870	6957	5913	1.85	2887
SED			612	0.09	
CD(P=0.05)			1334	0.20	
C.V %			47	18	
Cultivars (S)					
MSFH-17	9553	6410	3143	1.49	-
KBSH-1	10562	6260	4302	1.69	1159
KBSH-44	11523	6160	5363	1.87	2220
SED			154	0.02	
CD(P=0.05)			313	0.05	
C.V %			47	4.8	
M x S					
SED			650	0.09	
CD(P=0.05)			1405	NS	
S x M					
SED			267	0.04	
CD(P=0.05)			541	NS	

NS: Not Significant; RDF: Recommended Dose of Fertilizer

Table 1 Chemical characterization of soils selected for study

Village	pH	EC (dS/m)	Exch. Sodium (meq/100g)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Ammapally	8.4	0.60	10.6	32.13	560
Lingampet	8.9	1.20	11.3	16.06	560
Kurvagaddapalli	8.4	1.08	11.9	11.02	168
ICRISAT	8.1	1.00	10.9	17.32	840

Twelve castor genotypes were selected for the study, encompassing released varieties (DCS-9, 48-1, Aruna, Kranti), hybrids (GCH-5, DCH-177, DCH-32, GCH-4) and parental lines of hybrids (GC-2, DPC-9, DCS-5, DCS-33). At Ammapally and Lingampet, the crop was spaced at 90 x 90 cm and sown on 29-7-2000 and 31.7.2000, respectively. At Kurvagaddapalli, it was sown at 80 x 80 cm on 6.10.2000, while at ICRISAT it was sown on 4.10.2000 with 75 x 75 cm spacing. The experiments were conducted in RBD with three replications. At Kurvagaddapalli and ICRISAT, one life saving irrigation was given, while at other locations it was raised as rainfed crop. The observations were recorded on growth parameters, physiological parameters like relative water content (RWC) and osmotic potential and yield attributes like test seed weight, seed yield and oil content. Oil content was estimated by nuclear magnetic resonance technique. For measurement of osmotic potential, the electrical conductivity (EC) of the saturation extract of the plant was used and the potential was calculated as A = 0.36 (EC x 10), where (EC x 10) is in mmhos/cm and A is in bars (Richards, 1954). The relative water content of the plant was calculated using the formula:

$$\text{Relative water content} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

Results and discussion

Germination and growth

The germination of different castor genotypes across the locations showed that the genotypes Kranti (95.4%), GCH-5 (94.7%), DCH-177 (92.6%), DCS-9 (91.3%) and 48-1 (89%) while being comparable gave significantly higher germination than the rest of the genotypes under actual farm situations (Table 2). This indicated that these genotypes could withstand the natural sodicity at different locations and emerged better than rest of the genotypes. Yadav (1975) also reported that alkalinity delayed and reduced germination and there was considerable variation in tolerance of varieties. Raghavaiah *et al.* (2002) observed a decline in germination with increasing sodicity, and genotypes DCH-151, DCH-149, 48-1, DCH-32 and DCS-86 showed better germination even at higher sodicity level of 10 dS/m.

The plant height, a measure of crop growth, exhibited differential response at various locations. At Ammapally and Lingampet, the variation in plant stature of different castor genotypes was not discernible, whereas at Kurvagaddapalli, GCH-5 and GC-2 while being comparable were taller than the rest. At ICRISAT, all the genotypes were significantly taller than DCS-9 and DCS-5, which could be due to lower pH (8.2) (Table 2). By and large, the genotypes raised in *kharif* season assumed taller stature than those grown in *rabi* season, which could be due to better availability of soil moisture because of rains received intermittently resulting in better nutrient availability to the crop. During *rabi* the crop growth was probably conditioned by low temperatures and lesser availability of nutrients under receding soil moisture conditions in Vertisols.

The dry matter production of various genotypes recorded at 30 days after sowing (DAS) did not exhibit much variation at Lingampet, Kurvagaddapally and ICRISAT. At Ammapally, the hybrid DCH-32 produced substantially higher dry matter than rest of the test genotypes. However, Kranti and 48-1 offered the next best dry matter production (Table 2). Sensitivity of castor pistillate lines like VP-1, DPC-9 and LRES-17 in terms of shoot growth, was reported due to sodicity (Raghavaiah *et al.*, 2002a).

Physiological parameters

The relative water content (RWC), which is a measure of plant turgidity, was not discernible between genotypes at Ammapallly and Kurvagaddapally at 20 DAS. However, DCS-5, DCH-32, DCS-9 and GCH-5 at Ammapally, and DCH-177, 48-1, Kranti at Kurvagaddapalli recorded the highest RWC. At Lingampet, GCH-5 and DCS-33 were inferior to rest of the genotypes in RWC. At ICRISAT, GCH-5, DPC-9, Kranti and GCH-4 maintained distinctly lower RWC than rest of the genotypes (*Table 3*). The relative water content of the genotypes did not vary much at 40 DAS at different locations.

The physiological response of living cells to water stress is closely related to the free energy of water in the cells. The availability of water for physiological processes decreases as the potential is lowered. The osmotic potential (-bars) of leaf tissue of castor raised at Lingampet was significantly greater in 48-1(-36.9bars) and Kranti (-36.9bars) genotypes, whereas it was lower in GC-2, DPC-9, DCH-32, DCS-33 (about-20 bars). At ICRISAT, Kranti and DCS-33 exhibited the highest osmotic potential (-36.9bars), whereas relatively lower values were observed in GCH-5, DCH-177 and 48-1 (Fig. 1). In the current experiment the genotypes possessing lower osmotic potential have higher water availability for physiological processes *vis–a-vis* those having higher osmotic potentials.

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Production potential of castor, *Ricinus communis* L. genotypes under farmers field conditions in sodic vertisols of semi-arid tropics*

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Abstract

Three experiments conducted on farmers fields under natural sodic conditions (Ammapally, Lingampet and Kurvagaddapally villages) during 2000 in Jadcherla mandal of Mahaboobnagar district and one on-station trail at ICRISAT, Andhra Pradesh, to evaluate 12 genotypes of castor showed that the genotypes *viz.*, GCH-5, Kranti, DCS-9, DCH-177 and 48-1 exhibited better seed germination than the rest. At Kurvagaddapally GCH-5 and GC-2 were taller than the rest, while at ICRISAT, DCS-9 and DCS-5 were significantly taller than the rest. The drymatter production of genotypes at 30 DAS was not discernible at three locations, while at Ammapally DCH-32 followed by Kranti and 48-1 produced higher dry mater than the rest of genotypes. The relative water content was significantly lower in GCH-5, Kranti and GCH-4 at ICRISAT. The osmotic potential of leaf tissue at Lingampet was lower in GC-2, DPC-9, DCH-32 and DCS-33 than the rest, while at ICRISAT the genotypes GCH-5, DCH-177 and 48-1 had lower osmotic potential indicating higher water availability for physiological processes. Across the locations, the castor hybrids GCH-5, DCH-32, 48-1, DPC-9 and GC-2 offered significantly superior yield performance than the other genotypes, which was due to enhancement in test seed weight. By and large, with the increase in soil pH there was a reduction in oil content and test seed weight of genotypes.

Key words: Castor genotypes, sodicity, semi-arid tropics

Introduction

In India sodic soils are often encountered in different agro-ecological zones with arid and semiarid climate as a result of hydro-geo-chemical conditions and relief, and they span over 8.6 million hectares (Singh *et al.*, 1988) rendering them unproductive for farming of crops. With ever-growing demography and limited natural resources, it becomes imperative to utilize these problem soils for crop production. Reclamation of these soils is fraught with high cost and is always not feasible within the means of the resource-poor peasants operating in these areas. However, adoption of sodicity tolerant genotypes of oilseed crops can form a viable alternative in such soils. Oilseed crops may exhibit differential response to alkalinity as they differ in their intrinsic ability to tolerate alkalinity (Richards, 1954). Castor is an important oilseed crop raised in Telangana region of Andhra Pradesh in the districts of Mahaboobnagar (0.51 lakh ha), Nalgonda (0.23 lakh ha) and Medak (0.16 lakh ha) where sodic soils occur. Farmers usually raise castor on Alfisols leaving sodic Vertisols for cultivation of cotton, which has of late become non-remunerative due to biotic stresses. This prompted us to evaluate various genotypes of castor for tolerance to sodicity and management technologies for enhancing castor productivity under farmers field conditions.

Materials and methods

The experiments were conducted on farmers fields during *kharif*, 2000 in Jadcherla mandal of Mahaboobnagar district of Andhra Pradesh, with a view to improve castor productivity through identification of castor genotypes and management practices under sodic conditions. These soils are Vertisols (medium deep to deep black soils) characterized by medium to high in clay content, poor drainage, pH 8.5, low in available N, P and high in K, and low in CEC. For this study, soils in 10 villages covering 24 farmers' fields were characterized for chemical properties (Table 1). The pH ranged from 8.4 to 8.9, EC 0.6 to 1.2 dS/m and exchangeable Na 10.6 to 11.9. Another experiment was conducted at ICRISAT, Patancheru, which is characterized by pH8.1, EC 1.0 dS/m, 17.3 kg/ha available P_2O_5 and 840 kg/ha available K_2O.

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Yield and yield attributes

At Ammapally, the genotype 48-1 produced the highest yield of 401 kg/ha, followed by DPC-9 (358), DCH-177 (308) and DCS-9 (298). At Lingampet, the hybrid GCH-5 recorded the maximum yield (420 kg/ha), followed by DCH-32 (391) and DCS-5 (333) (Fig. 2). At Kurvagaddapally, GCH-5 recorded the maximum yield (510 kg/ha) followed by DCS-9 (347), DCH-32 (343) and GCH-4 (321). At ICRISAT, DCH-32 recorded the maximum yield (732 kg/ha) followed by GCH-5 (729), Kranti (695) (Fig. 2). Analysis of data across the locations revealed that the hybrids GCH-5 (477 kg/ha) remaining comparable with DCH-32 (430), 48-1 (411), and GC-2 (386) and DPC-9 (396) produced substantially higher bean yield than rest of the test genotypes. The enhancement in test seed weight in GCH-5, DCH-32, 48-1, DCS-9, DCH-177 and GCH-4 has substantially contributed to increased seed yield compared with other genotypes. The genotypes Aruna (11.4 to 18.6g) and DPC-9 (11.2 to 29.8g) produced seeds of distinctly lower test weight than other genotypes across the locations (Table 3). Muralidharudu *et al.* (2000), based on a laboratory study, reported that castor genotypes such as DCH-32, 48-1, DCS-9 and PCS-4 were tolerant to sodicity.

Oil content

The oil content of genotypes was not altered much across the locations, barring at ICRISAT where all the genotypes possessed significantly higher oil content compared to DCS-9 and DCS-5, which could be due to low soil pH (Table 3). The oil content at ICRISAT ranged from 47.2-52.9%. The oil content at Ammapally ranged from 43.2 to 49.7 % whereas at Lingampet it varied between 30.2 and 41.6, and it oscillated between 37.1 and 48.7 % at Kurvagaddapalli. Decrease in oil content with increase in soil pH irrespective of genotypes was also observed by Raghavaiah *et al.*, (2002a).

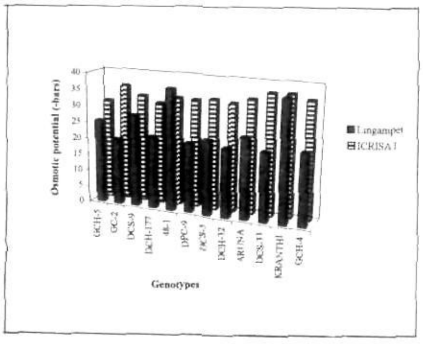

Fig 1 Osmotic potential of different castor genotypes at various locations

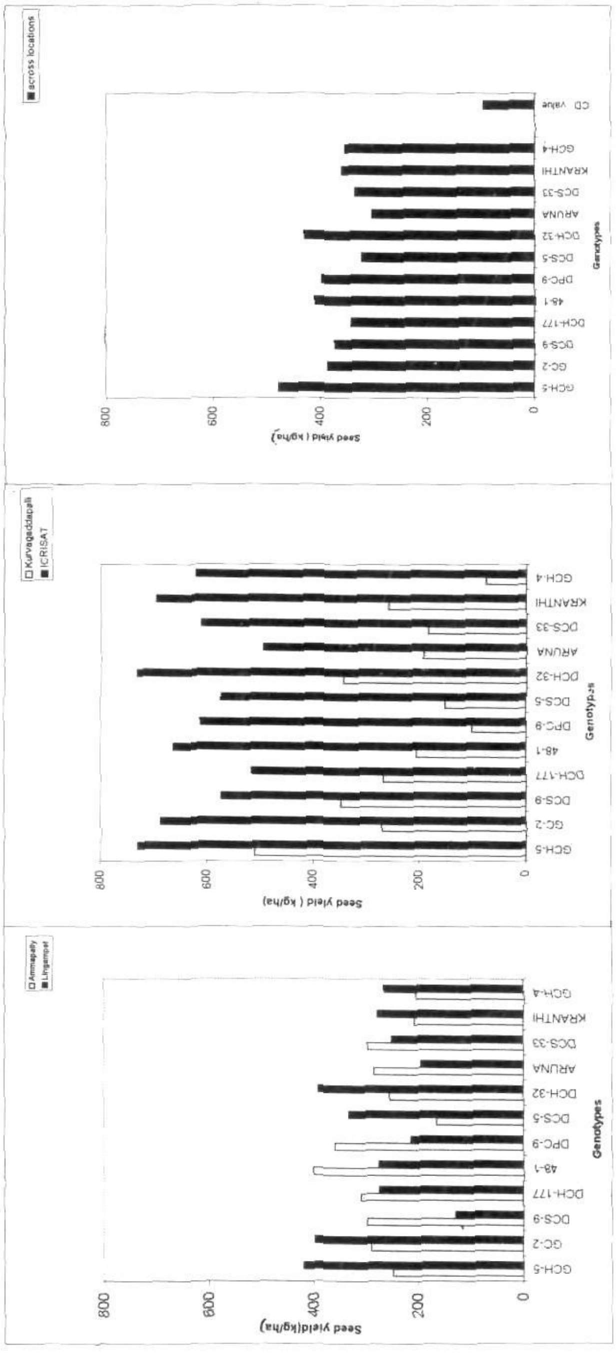

Fig:2 Seed yield (kg/ha) of castor genotypes on alkaline vertisols at different locations and across the locations

Table-2 Germination (%), plant height (cm) and drymatter (g/plant) at 30 DAS of different castor genotypes at various locations in sodic soils

Genotype	*Ammapally*			*Lingampet*			*Kurvagaddapally*			*ICRISAT*		
	Germination	Plant height	Dry matter	Germination	Plant height	Dry matter	Germination	Plant height	Dry matter	Germination	Plant height	Dry matter
GCH-5	90	126	0.7	98	104	0.9	94	89	1.4	96	88	1.3
GC-2	78	155	0.7	93	98	1.9	79	85	1.4	79	93	1.8
DCS-9	81	101	0.8	93	60	2.6	95	59	1.0	96	56	1.3
DCH-177	91	126	0.5	95	84	2.1	89	65	1.8	85	93	1.1
48-1	93	142	1.5	77	115	1.7	98	76	1.7	88	81	1.2
DPC-9	75	98	0.5	94	72	1.4	79	61	1.1	94	93	1.0
DCS-5	79	99	0.5	90	92	1.5	84	56	1.2	91	66	1.1
DCH-32	82	129	3.3	97	90	2.3	80	63	1.5	89	78	1.6
ARUNA	88	121	1.0	96	92	1.8	87	65	0.9	63	74	0.8
DCS-33	88	112	0.5	92	98	0.9	91	69	1.3	66	80	1.4
KRANTI	96	134	1.8	95	96	2.3	91	70	1.6	100	71	1.7
GCH-4	64	120	0.7	77	87	1.7	86	68	1.2	76	72	0.8
SEm±	5.4	13.7	0.4	3.0	9.5	0.4	3.79	4.3	0.2	6.9	7.4	0.3
CD (P=0.05)	15.9	NS	1.2	8.9	NS	NS	11.1	12.6	NS	20.2	21.8	NS

Table 3 Relative water content (%), test weight of seed (g) and oil content (%) of different castor genotypes in sodic soils at various locations

Genotype	Ammapally			Lingampet			Kurvagaddapally			ICRISAT		
	RWC	Test weight	Oil content	RWC	Test weight	Oil content	RWC	Test weight	Oil content	RWC	Test weight	Oil content
GCH-5	91.3	26.0	45.4	77.7	22.2	39.1	57.1	25.5	44.6	80.7	32.0	51.6
GC-2	87.3	23.8	46.8	96.0	21.5	39.5	39.2	26.1	46.5	84.9	26.8	51.2
DCS-9	92.3	26.0	44.1	91.3	17.0	37.6	64.9	24.8	40.8	87.4	27.7	47.2
DCH-177	72.0	25.8	45.8	93.7	20.2	37.3	82.3	25.7	44.1	85.7	30.4	52.1
48-1	80.7	29.8	49.7	94.7	25.3	40.5	81.4	22.7	41.5	94.4	32.1	51.6
DPC-9	70.3	21.8	46.2	95.3	11.2	30.2	55.7	15.5	37.1	61.9	29.8	52.9
DCS-5	93.0	21.4	43.2	92.3	18.2	37.8	69.7	24.4	47.1	89.4	26.1	49.8
DCH-32	92.3	28.7	48.7	95.7	22.2	41.5	67.2	25.9	48.3	83.4	29.3	51.9
ARUNA	88.0	16.0	46.2	92.0	11.4	39.3	58.6	18.6	44.1	92.8	18.1	51.5
DCS-33	61.0	21.2	47.2	78.3	16.1	38.6	73.0	18.9	42.1	84.9	26.0	51.1
KRANTI	75.0	22.1	45.9	91.7	19.7	41.6	79.7	23.3	43.0	65.8	26.7	51.6
GCH-4	87.7	25.1	45.4	88.0	23.1	41.4	59.7	30.5	48.7	79.4	31.5	52.2
SEm±	9.7	2.0	2.4	3.4	1.8	2.1	10.2	1.9	2.6	4.55	0.5	0.4
CD (P=0.05)	NS	5.9	NS	9.9	5.3	NS	NS	5.5	NS	13.35	1.5	1.3

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Evaluation of Spanish type groundnuts for resistance to stem-and pod-rot caused by *Sclerotium rolfsii* Sacc.

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Abstract

Evaluation of 13 Spanish groundnut genotypes along with resistant checks (ICGV 86590 and ICGV 87165) under artificially inoculated conditions for stem and rot, *Sclerotium rolfsii* indicated significant differences among genotypes, seasons and genotype x season interaction for disease, yield and yield-related parameters. Five ruling cultivars of Karnataka (TMV 2, JL 24, Dh 40, KRG 1 and R 8808) and three leaf spot resistant mutants (VL1-28-2, VL1-45 and VL1-110) were susceptible. While, a released cultivar Dh 8 was either comparable with or superior to the resistant checks. Resistant genotypes had undesirable agronomic features necessitating need for improvement through hybridization.

Key words: *Sclerotium rolfsii*, stem-and pod-rots

Introduction

The stem and pod rots incited by *Sclerotium rolfsii* have been assuming the status of disease of serious concern in almost all regions of groundnut production. The reported yield losses due to *S. rolfsii* range from 10 to 25% but may reach upto 80% in severely infected fields (Mehan and Mc Donald, 1990). Various cultural, chemical and biocontrol practices have been recommended for the control of this disease but, individually they are not completely effective (Sherwood *et al.*, 1995). Integrated disease management incorporating different approaches has been suggested for effective management of the disease. Host plant resistance is an important component of such an approach. Spanish bunch varieties of groundnut are the most popular in India as these possess desirable pod features and mature early, thus facilitating double cropping under rainfed conditions. But, there is no information on the degree of resistance available in Spanish bunch cultivars currently cultivated in India. Screening for resistance in the field is complicated by the non-uniform spatial distribution of the pathogen (Shew *et al.*, 1984). As a result, consistent and reliable data is difficult to obtain in fields under natural infestation. The present study reports the evaluation of a set of Spanish bunch cultivars under artificial epiphytotics over two seasons.

Materials and methods

Thirteen genotypes *viz.*, released cultivars (TMV 2, JL 24, Dh 8, Dh 40, R 8808, KRG 1), foliar disease resistant mutants (VL 1-45, VL 1-28-2, VL 1-110), germplasm (ICG 5125 and ICG 5247) along with resistant checks (ICGV 87165 and ICGV 86590) were evaluated over post-rainy and rainy seasons. The crop was raised in 3.38 m^2 plots with four replications in randomized block design under artificially inoculated conditions. The recommended package of practices for groundnut cultivation for respective seasons was adopted. Harvesting was done according to the maturity of different entries.

S. rolfsii was isolated from diseased groundnut plants grown in vertisols and mass multiplied on sand-corn meal medium for 3 to 4 weeks (Abeygunawardena and Wood, 1957). Inoculum containing mycelium and sclerotia was applied to the soil surface at the base of groundnut plants @ 125 g/2.5 m row, between 50-60 days after sowing. Sorghum stubbles (3-4 cm long pieces) were also spread along the rows to enhance the fungal growth. After two weeks, the inoculation was repeated. During post-rainy season, the field was irrigated until pod formation at seven days interval to promote stem rot development. The interval was later increased to 15 days to promote pod infection. In rainy season the crop was raised completely under rainfed condition.

Plants showing stem rot, pod rot, stem and pod rot symptoms were counted and percentage incidence was computed from the total number of plants in each plot. Healthy pods from all the plants were collected and dried. The seed yield was expressed in kg/ha. As an index of seed yield potential, pod yield of healthy plants was expressed as g/plant. Hundred seed mass and shelling out turn were computed from a sample of pods. ANOVA was done for each season and over seasons using pooled analysis.

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Results and discussion

Analysis of variance revealed significant differences among genotypes, season and genotype x season interaction for all the characters (Table 1). ICGV 87165 and ICGV 86590 showed very low incidence of stem and pod rot thus confirming their resistance (Mehan *et al.*, 1995). All the Spanish bunch cultivars of Karnataka (TMV 2, JL 24, Dh 40, KRG 1 and R 8808) except Dh 8 and germplasm lines (ICG 5125 and ICG 5247) were susceptible by recording significantly more disease than the checks. Dh 8 (22.6%) was comparable to the resistant checks. All the foliar disease resistant Spanish bunch mutants *viz.*, VL 1-28-2, VL 1-45 and VL 1-110 were susceptible and among these, VL 1-45 recorded highest incidence (81.4%). VL 1-45 was earlier reported to be resistant to late leaf spot (Motagi *et al.*, 1996) and to *Spodoptera* and thrips (Rajendraprasad, 1997). Its extreme susceptibility to stem and pod rots revealed the importance of assessing potential cultivars for non-target diseases and pests to avoid emergence of new disease and pest outbreaks. The genotype R 8808 recorded low disease incidence (49.6%) in post-rainy season than in rainy season (83.0%) emphasizing the need for evaluation over seasons and locations for confirming the resistance and its stability. Though, Spanish types have been reported to be more susceptible than Virginia-bunch and runner types (Grichar and Smith, 1992), present study showed a possibility of identification of sources of resistance among Spanish types through extensive testing.

The resistant genotypes, in spite of lower yield potential (Table 2) compared to ruling cultivar (JL 24), yielded more than the susceptible cultivars emphasizing the importance of resistant cultivars in enhancing the productivity in the stem and pod rot endemic areas (Grichar and Smith, 1992). But the resistant lines identified in the present study possessed some undesirable agronomic features, hence, can not be utilized directly for cultivation. Their low yield potential, especially in post-rainy season, could be due to photo-thermo sensitivity associated with most resistant germplasm (ICRISAT, 1989). ICGV 87165 matured late (120-125 days) and has red kernels. ICGV 86590 possessed undesirable pod features. Dh 8 also has low hundred-seed mass and poor shelling out turn (Table 2) limiting their direct use in cultivation. These genotypes could however, be exploited for incorporation of resistance in to agronomically superior backgrounds.

Table-1 Mean performance of groundnut genotypes for disease incidence and pod yield over seasons

Genotype	Disease Incidence (DI)			Yield (kg/ha)		
	Post-rainy	Rainy	Pooled	Post-rainy	Rainy	Pooled
TMV 2	57.1de	72.1fh	66.4ef	660	660	660
Dh 8	22.3a	22.9ab	22.6a	1030	3210	2120
KRG 1	50.6cd	65.3ef	57.9c	550	930	740
JL 24	50.2cd	64.3e	57.2c	760	1310	1040
R 8808	49.6cd	83.0i	66.3f	1040	640	840
ICG 5125	50.1cd	78.2hi	64.1df	880	780	830
ICG 5247	61.8ef	52.3d	57.0c	630	970	790
Dh 40	67.2f	65.0e	66.1ef	470	1400	940
VL 1-45	76.9g	85.7j	81.4g	540	3900	460
VL 1-28-2	55.9e	65.1e	60.5ce	1000	1130	1070
VL 1-110	50.2cd	67.1efg	58.7cd	1250	1150	1190
ICGV 86590	32.2b	22.5a	27.4a	1090	3330	2210
ICGV 87165	43.4c	30.6c	37.0b	790	3160	1970
SEm±	3.28	2.40	2.03	4.6	5.5	3.6
CD (P=0.05)	9.41	6.88	5.70	132	157	100
CV (%)	9.03	5.70	7.33	7.99	5.30	6.30

Note: Values with same subscripts do not differ at 5% level of significance

Table 2 Performance of groundnut genotypes for yield components

Genotype	Yield potential (g/plant)			100 seed mass (g)	Shelling out-turn (%)
	Post-rainy	Rainy	Pooled	Pooled	Pooled
TMV 2	10.3c	10.8g	10.6ef	33.1f	74.9bc
Dh 8	7.5g	13.4ce	10.4eg	28.6g	67.2ef
KRG 1	10.1cd	12.8df	11.5cd	36.4de	74.9bc
JL 24	9.0ce	17.2a	13.1a	38.9cd	74.4bc
R 8808	10.9ab	13.7cd	12.3b	41.8c	74.9bc
ICG 5125	8.7ef	15.5b	12.1bc	32.2f	76.8ab
ICG 5247	8.2eg	11.5fg	9.8g	32.8f	79.2a
Dh 40	8.1eg	14.0c	11.1de	34.2ef	70.3de
VL 1-45	10.5c	9.4h	9.9fg	48.1ab	67.5ef
VL 1-28-2	11.9ab	12.4ef	12.2bc	45.5b	72.3cd
VL 1-110	12.8a	12.3ef	12.5ab	49.3a	67.8ef
ICGV 86590	8.2eg	11.7fg	9.9fg	38.2d	65.4f
ICGV 87165	7.6fg	14.1c	10.8de	46.7ab	66.8ef
SEm±	0.4	0.37	0.27	1.11	1.36
CD (P=0.05)	2.49	1.06	1.06	3.09	3.78
CV (%)	6.02	4.06	4.06	5.75	3.79

Note: Values with same subscripts do not differ at 5% level of significance

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Post-harvest losses caused by painted bug, *Bagrada hilaris* (Burm.) in rapeseed mustard

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Abstract

Post harvest losses caused by *Bagrada hilaris* (Burn.) were estimated, under field and laboratory conditions by creating infested and control treatments, in four varieties of rapeseed-mustard i.e., BSH-1 (rapeseed, *Brassica campestris* var. brown sarson), Varuna, RH-30 and RH-8812 (Indian mustard, *B. juncea*). The crops were protected against the incidence of painted bug at seedling stage and mustard aphid, *Lipaphis erysimi* (Kaltenbach) at reproductive phase. The produce was left to the incidence of *Bagrada* for 21 days both under field and laboratory conditions. Loss in oil content varied from 0.81 to 3.83, 0.68 to 3.32, 0.62 to 3.44 and 0.59 to 3.25% under field conditions as against 0.05 to 1.32, 0.05 to 1.19, 0.04 to 1.18 and 0.06 to 1.14% under laboratory conditions in BSH-1, Varuna, RH-30 and RH-8812, respectively at 7 to 21 days exposure period. Losses in protein content varied from 0.96 to 3.81, 0.82 to 3.48, 0.79 to 3.37% and 0.77 to 3.23% in BSH-1, Varuna, RH-30 and RH-8812, respectively, at 7 to 21 days exposure period under field condition. The losses in total soluble sugar sugars were 0.48% (RH-8812) to 2.93% (BSH-1), 1000 seed weight 0.25% (RH-30 and RH-8812) to 1.26 (BSH-1) and standard germination from 0.20% (Varuna) to 2.20% (BSH-1, RH-30) under field conditions with exposure of 7 to 21 days. Losses under field conditions were more for all the parameters studied because of heavy painted bug population.

Key words: Post harvest loss, *Brassica*, *Bagrada hilaris*

Introduction

Painted bug, *Bagrada hilaris* (Burn.) attacks rapeseed-mustard at two stages of crop growth i.e., seedling and maturity. Many a times, its infestation is carried to the mature crop in the field and also on the harvested crop in the threshing floor. There, the adults and the nymphs feed on the grains in the pod and result in loss of grain weight and quality (Singh *et al.*, 1980). Therefore, the present investigations were endeavoured to determine the post-harvest losses caused by *B. hilaris* to rapeseed-mustard cultivars under field and laboratory conditions.

Materials and methods

Four varieties i.e., BSH-1 (*Brassica campestris* var. brown *sarson*), Varuna, RH-30 and RH-8812 (*B. Juncea*) were sown in the field in a plot size of 50 m^2 each during *rabi*, 1997-98 with a basal dose of 80 kg N and 30 kg P_2O_5/ha in three replicates. At seedling stage, the crop was sprayed with malathion (0.05%) to protect from the incidence of painted bug and at reproductive stage with oxydemeton methyl (0.025%) to protect the crops from aphid, *L. erysimi* (Kalt.) infestation. The care was taken to ensure that no incidence of painted bug occurred from maturity till harvest. After harvest the crop bundles of 50 plants/bundle (for all the four varieties) were left in the field for 21 days. Two sets of bundles were maintained i.e., protected (application of malathion 0.05%) and unprotected i.e., open for painted bug infestation.

In the laboratory, one thousand siliquae of each genotype were kept in glass chimneys and 50 pairs of field collected painted bug were released in each chimney. Both the open ends of the chimney were covered with muslin cloth. The bottom end was placed in petridish of the size that could accommodate its bottom end. The moisture was provided from both the ends of the chimneys by putting a wet absorbent cotton swab on top and in the petri dish. A control set (no bugs) was also run side by side. The experiment was replicated three times for each interval i.e., 0, 7, 14 and 21 days exposure.

Seed samples from both the experiments i.e., field and laboratory were drawn from each variety under protected and unprotected sets at 0, 7, 14 and 21 days after exposure and analysed for thousand seed weight, oil, protein, total soluble sugars and standard germination. Rom the field experiment, eight hundred siliquae were gently plucked from each bundle at each interval to get desired quantity of seed for further analysis, whereas, in

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each of laboratory experiment as the three replications for each specified period were terminated, the seeds were collected for analysis. The standard germination was observed as per International Seed Testing Association (ISTA, 1985 rules). Oil content was estimated by nuclear magnetic resonance (NMR) technique. Nitrogen content was estimated by traditional Kjeldhal method and protein content was calculated by multiplying the figures for nitrogen content with 6.25 and total soluble sugars were *estimated as per Hulme and Narain (1931) by taking 10g* seed for each biochemical parameter.

Results and discussion

The data on post-harvest losses caused by painted bug, *B. hilaris* in four cultivars of rapeseed mustard [BSH-1 (rapeseed), Varuna, RH-30 and RH-8812 (mustard)] with respect to oil, protein and total soluble sugar contents, thousand seed weight and standard germination at weekly interval under field and laboratory conditions are presented in Table 1. The losses in terms of oil content varied from 0.81 to 3.83, 0.68 to 3.32, 0.62 to 3.44 and 0.59 to 3.25% under field conditions as against 0.05 to 1.32, 0.05 to 1.19, 0.04 to 1.18 and 0.06 to 1.14% under laboratory conditions in BSH-1, Varuna, RH-30 and RH-8812, respectively, at 7 to 21 days exposure period. Similarly, losses in protein content varied from 0.96 to 3.81, 0.82 to 3.48, 0.79 to 3.37 and 0.77 to 3.23% in BSH-1, Varuna, RH-30 and RH-8812, respectively, at 7 to 21 days exposure under field conditions. The losses in protein content under laboratory conditions were less as compared to field conditions and the losses increased with the increase in exposure period. The losses in total soluble sugars were 0.48% (RH-8812) to 2.93% (BSH-1) thousand seed weight. 0.25% (RH-30 and RH-8812) to 1.26 (BSH-1) and standard germination from 0.20% *(Varuna) to 2.20% (BSH-1, RH-30) under field conditions* with exposure of 7 to 21 days. The losses under laboratory conditions were less for all the parameters studies. Obviously, it was because of heavy painted bug population under field conditions as compared to that under laboratory conditions. The extent of loss for each parameter studied was more in BSH-1 (*B. campestris*) when compared with other cultivars i.e., Varna, RH-30 and RH-8812 (*B. Juncea*). This suggested that the crop should be threshed as early as possible after harvest as leaving the harvested crop in the field will lead to losses in seed quality due to painted bug incidence. The post harvest losses in terms of all the parameters studied are in conformity with Singh *et al.* (1980). However, Batra and Sarup (1962) observed slightly higher losses in oil content (4.5 %) when the mustard seeds were fed to the painted bug under laboratory conditions.

Table 1** **Post-harvest losses caused by painted bug, Bagrada hilaris in brassicae

Exposure Period (days)	Oil content (%)				Protein content (%)				Total soluble sugars (%)				Thousand seed weight (g)				Standard germination (%)			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Field condition																				
7	0.81	0.68	0.62	0.59	0.96	0.82	0.79	0.77	0.52	0.51	0.51	0.48	0.31	0.26	0.25	0.25	1.00	0.20	0.80	0.80
14	1.82	1.72	1.63	1.53	1.65	1.99	1.88	1.78	1.59	1.44	1.39	1.32	0.74	0.64	0.62	0.62	1.40	0.80	1.60	1.60
21	3.83	3.62	3.44	3.25	3.81	3.48	3.37	3.23	2.93	2.81	2.68	2.57	1.26	1.15	1.12	1.08	2.20	1.60	2.20	1.40
Laboratory condition																				
7	0.05	0.05	0.04	0.06	0.31	0.24	0.22	0.22	0.18	0.10	0.12	0.14	0.09	0.04	0.02	0.03	0.20	0.40	0.20	0.40
14	0.59	0.38	0.33	0.29	0.70	0.61	0.58	0.51	0.71	0.65	0.63	0.55	0.24	0.21	0.19	0.16	0.60	0.60	0.80	0.80
21	1.32	1.19	1.18	1.14	1.24	1.14	1.09	1.03	1.38	1.29	1.26	1.13	0.49	0.71	0.68	0.40	1.80	0.80	1.40	1.00

1 = BSH-1; 2 = Varuna; 3 = RH-30; 4 = RH-8812

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Eco-friendly management of insect-pests and diseases of mustard

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Abstract

Mustard variety, Varuna was sown for three winter (*rabi*) seasons from 1993-94 to 1995-96 at two dates and two spacings using two chemicals and one botanical pesticide. Highest grain yield of mustard 1929 kg/ha was recorded from the sowing of October 10-15, in which no mustard aphid, minimum pressure of mustard saw fly and white rust disease was recorded. Slightly lower incidence of alternaria blight was recorded in wider spacings (60x20 cm). Likewise intensity of white rust was lower in closer spacing (45 x 20 cm) however the difference was nonsignificant. Closer spacing attracted higher number of mustard sawfly and mustard aphid although it gave 7.91% higher yield over wider spacing. Oxy-demeton-methyl and Dithane M-45 were found most effective for the control of aphids and diseases respectively. Soil application of neem leaf powder @ 75 kg/ha at the time of sowing in furrows also reduced the population of mustard saw fly, mustard aphid, Alternaria blight and white rust diseases and increase the grain yield 5.20% over control.

Key words: Pests, mustard, management

Introduction

Oilseeds comes next to food grains in volume and value in the country. The average oilseed productivity (815 kg/ha) is quite low when compared with developed countries (2.5-3.0 tone/ha) and even world average (1.5 tone/ha) (Singh *et al.*, 2002a). The depreciation in oilseeds yield is mainly due to biotic stresses specially insect-pests and diseases. Large scale use of insecticides has developed resistance in mustard aphid (Dhingra and Phokela, 2001). Spray of fungicides for the control of diseases is also non-eco-friendly. Therefore the present studies were endeavoured to find out the eco-friendly management of insect-pests and diseases of Indian mustard.

Materials and methods

A field trial was conducted during winter (*rabi*) seasons of 1993-94 to 1995-96 at Regional Research Station, Mainpuri (C.S. Azad University of Agriculture and Technology, Kanpur, UP). The experimental soil was sandy loam having 8.6 pH and low fertility status. The experiment was laid out in split plot design with three replications. The treatments comprised of two dates of sowing, two pesticides (oxy-demeton-methyl and Dithane M-45), one botanical pesticide (neem leaf powder), control and two plant spacings (60 x 20 cm and 45 x 20 cm). The Indian mustard variety, Varuna was used during all the three years of experimentation. An uniform dose of NPK @ 80 : 40 : 40 kg/ha was applied to the crop. Half dose of N and full dose of P and K was applied at the time of sowing and rest half dose of N was top dressed after final thinning and first irrigation.

Weekly observations were recorded on the incidence of mustard saw fly (*Athalia proxima* Klug.), mustard aphid [*Lipaphis erysimi* (Kalt.)], *Alternaria* blight (*Alternaria brassicae* Berk.) and white rust (*Albugo candida* (Pers. Ex. Hook) Kuntze) on five tagged plants. Incidence of mustard leaf miner and downy mildew was economically insignificant, therefore, not taken into account. Finally, the yield data were recorded for the interpretation of the results.

Results and discussion

Higher incidence of mustard saw fly (3.6 larvae/plant) was recorded in second sowing date 25-30 October in comparison to 10-15 October sown mustard crop (1.1 larvae/plant) (Table 1). Earlier, Mathur and Singh (1986) also observed that late sowing of mustard harboured more saw fly population than sown at normal time.

Mustard aphid (*L. erysimi*) incidence has a definite pattern of distribution on the plants. Its number was higher on upper and lower leaves than the middle leaves in the early stage of the crop. Present observation is also in the support of Mathur and Singh (1986). It was revealed that 10-15 October down crop escaped the aphid incidence and gave highest yield (Table 1). Misra *et al.* (2001) also reported that early sown crop had the lowest mustard aphid and highest yield. Singh *et al.* (2002) reported that sowing of mustard by mid October helped in checking the severe onslaught of aphids in late December/early January, because crop completed flowering before the arrival of aphids, thus created asynchrony between aphid

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infestation and vulnerable stage of the crop. Crop sown between October 25-30, scored 15.5 aphids/plant (at 10 cm central twigs), which hampered the yield. Phadke and Prasad (1987) and Bhadauria *et al.* (1992) reported that date of sowing of crop has significant influence on aphid infestation. Lowest infestation of mustard aphid had been noticed by Prasad and Lal (2001) in timely sown crop.

It is quite clear from results presented in Table 2 that more *Alternaria* blight disease (30.4%) was recorded in October 10-15 sown crops than October 25-30 sown crop (21.3%). These findings are in support of Howlider *et al.* (1989) and Mian and Akande (1989). Inspite of more *Alternaria* blight more yield was registered in October 10-15 sown crop. This high yield was contributed due to no incidence of mustard aphid and less incidence of mustard saw fly grubs (Table 1). Decreased incidence of *Alternaria* blight in late5 sowing date and higher crop yield in early sown crop also has been reported by Singh *et al.* (1998) and Godika *et al.* (2001).

Minimum incidence of white rust (1.2%) was recorded in October 10-15 sown crop. This lower incidence of white rust was resulted in increased yields of mustard in October 10-15 sown crop (Table 2).

There was a significant difference of spacing on the incidence of mustard aphid. It was higher in 45 x 20 cm in comparison to 60 x 20 cm sown crop, but its impact on incidence of mustard saw fly, *Alternaria* blight and white rust disease of mustard was non-significant. Significantly higher yield (7.9%) was recorded in 45 x 20 cm in comparison to 60 x 20 cm, which is in agreement with the findings of Chaniyara *et al.* (2002).

Table 1 Impact of sowing date, spacing and pesticide application on the appearance of insect-pests of mustard, *B. juncea*

Treatment	No. of saw fly larvae/plant				Average aphids/plant			
	1994	1995	1996	Average	1994	1995	1996	Average
Sowing date								
October 10-15	1.05	1.64	0.72	1.14	0.00	0.00	0.00	0.00
October 25-30	3.71	4.64	2.48	3.61	3.16	43.41	0.00	15.52
CD (P=0.05)	0.08	0.10	0.06	0.08	0.12	10.36	0.00	3.60
Spacing								
45 x 20 cm	2.40	3.25	1.68	2.44	4.01	46.93	0.00	16.98
60 x 20 cm	2.37	3.04	1.53	2.31	2.32	39.90	0.00	14.07
CD (P=0.05)	NS	NS	NS	NS	0.06	0.30	0.00	0.10
Pesticide								
Oxy-methyl-demeton @ 1/ha	2.26	3.15	1.52	2.31	2.19	29.16	0.00	10.45
Neem leaf powder @ 75 kg/ha	1.83	2.54	1.09	1.82	3.46	44.69	0.00	16.05
Dithane M-45 @ 0.25%	2.16	3.04	1.33	2.18	2.95	40.76	0.00	14.57
Control (Untreated)	3.30	3.85	2.49	3.21	4.03	59.03	0.00	21.02
CD (P=0.05)	0.09	0.06	0.09	0.06	0.12	9.11	0.00	3.14

Table 2 Impact of sowing date, spacing and pesticide application on the incidence of diseases and grain yield of mustard

Treatment	*Alternaria* disease (%)				White rust disease (%)				Grain yield (kg/ha)			
	1994	1995	1996	Average	1994	1995	1996	Average	1994	1995	1996	Average
Sowing date												
October 10-15	35.3 (36.4)	30.9 (33.8)	25.1 (30.1)	30.4 (33.5)	0.9 (5.5)	2.1 (8.4)	0.5 (4.1)	1.2 (6.2)	1760	1590	2430	1920
October 25-30	24.7 (29.8)	26.2 (30.1)	13.2 (21.3)	21.3 (27.5)	11.7 (20.0)	8.7 (17.1)	5.1 (13.1)	8.5 (16.9)	1160	1430	1950	1520
CD (P=0.05)	2.5	1.1	2.7	2.3	0.5	0.3	0.2	0.3	340	130	250	240
Spacing												
45 x 20 cm	29.9 (33.2)	28.8 (32.4)	19.9 (26.5)	26.2 (30.8)	6.2 (14.4)	5.3 (13.3)	2.8 (9.5)	4.8 (12.6)	1510	1580	2270	1970
60 x 20 cm	29.9 (33.2)	28.4 (32.2)	18.4 (25.4)	25.6 (30.4)	6.4 (14.7)	5.5 (13.6)	2.9 (9.8)	4.9 (12.8)	1420	1450	2110	1660
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	70	130	140	120
Pesticide												
Oxy-methyl-demeton @ 0.025%	30.7 (33.6)	29.1 (32.7)	20.9 (27.3)	26.9 (31.3)	5.8 (13.9)	5.4 (13.4)	2.5 (9.1)	4.6 (12.4)	1550	1570	2230	1780
Neem leaf powder @ 75 kg/ha	28.7 (32.4)	27.9 (31.9)	19.1 (25.9)	25.3 (30.2)	6.7 (14.9)	6.1 (14.3)	3.0 (10.0)	5.3 (13.30)	1430	1490	2180	1700
Dithane M-45 @ 0.25%	25.8 (30.5)	24.3 (29.5)	16.4 (23.9)	22.2 (28.1)	4.5 (12.2)	3.0 (9.9)	1.1 (5.9)	2.9 (9.7)	1540	1560	2260	1790
Control (Untreated)	34.7 (36.1)	32.8 (34.9)	20.0 (26.6)	29.2 (32.7)	8.3 (16.7)	7.1 (15.4)	4.7 (12.5)	6.7 (14.9)	1430	1420	2090	1620
CD (P=0.05)	2.8	2.7	1.3	2.5	0.2	0.2	0.2	0.2	1020	70	80	80

Figures in parentheses are angular transformed values.

Oxy-demeton-methyl proved effective to bring down the aphid population to a minimum 10.45 aphid/plant. Similarly, application of Dithane M-45 showed a marked reduction of white rust (2.9%) and *Alternaria* blight (22.2%) which ultimately resulted in increase of grain yield. Combination of oxy-demeton-methyl and nicotine sulphate has been reported by Vekaria and Patel (2000) in order to manage mustard aphid population below economic threshold level, while application of mancozeb has been found effective for the control of *Alternaria* and white rust disease and increase in grain yield of mustard (Godika *et al.*, 2001). Application of neem leaf powder in furrows played a vital role for minimizing mustard saw fly population (1.8 grubs/plant), mustard aphid population (16.1 aphids/plant), *Alternaria* blight (25.28%) and white rust (5.27%) in mustard crop. Neem leaf powder was also found effective to increase significantly the grain yield of mustard over control. Pandey *et al.* (1979) also reported high mortality of grubs from the plant-originated pesticides *viz.*, either extract of *Acorus calamus*. Neem based management *viz.*, pre-sowing application of neem cake @ 300 kg/ha, foliar application of *Azadirachtin*/neem seed kernel extract/neem oil at 9 *ml a.i./l* also have been reported effective against the mustard aphid (Chakraborti, 2001).

Thus, non-monetary inputs like planting date and spacing and low monetary input like application of neem leaf powder was found eco-friendly in the management of pest and diseases of mustard and need to be popularized for Indian farmers who are generally starved of funds for spending on costly insecticide chemicals.

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Evaluation of interspecific lines of sunflower, *Helianthus annuus* L. for disease reaction, seed yield and yield components

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Abstract

A field experiment was conducted to evaluate interspecific lines of sunflower, for disease reaction, seed yield and yield components. All the genotypes showed moderate Per cent Disease Index (PDI) at 1st stage. However, after flowering, the disease progress was very fast and all the genotypes recorded high severity at IInd stage. Although significant differences were observed for PDI at both the stages, none of the tested genotypes including interspecific lines showed high level of resistance. Highest GCV and PCV were observed for seed yield/plant followed by seeds/head and moderate variability for seed weight, oil content and head diameter. The results also indicated additive gene action for seeds/head, test weight, head diameter and plant height and non-additive gene action for seed yield and oil content. Three interspecific derived lines SAN5-01S, SAR5-05S and SARS-06F recorded significantly higher seed yield and oil content than Morden.

Key words: Sunflower, interspecific lines, *Alternaria* leaf blight, epiphytotic

Introduction

Sunflower, *Helianthus annuus* L. is one of the most important oilseed crops in India. However, the yield level of sunflower is one of the lowest in the world due to several biotic and abiotic factors affecting the crop (Hiremath *et al.*, 1990; Anon., 1997). Among biotic factors, *Alternaria helianthi* (Hansf.) is the most devastating. No varieties or hybrids resistant to the disease have been released yet. These efforts are obviously limited by the narrow genetic base of commercial sunflower, which has to be broadened by the utilization of wild relatives of the cultivated type. Moderate to high level of resistance to *A. helianthi* has been reported in *H. tuberosus*, *H. rigidus* and *H. hirsutus* (Morris *et al.*, 1983; Seiler, 1992; Sujatha *et al.*, 1997), which could be transferred to cultivated sunflower. Attempts were made to cross the cultivated and wild species in India and elsewhere leading to the development of several interspecific germplasm lines (Seiler, 1992; Sujatha *et al.*, 1997). It is required to test such interspecific derivatives for disease resistance, yield and yield components under epiphytotic conditions. In the present study attempt has been made to evaluate several promising interspecific lines, populations and germplasm accessions of sunflower against *Alternaria* disease, yield and yield components.

Materials and methods

Sixty two genotypes were selected for the study. Among them 34 were backcross derivatives involving *H. annuus*, *H. debilis*, *H. argophyllus*, *H. bolandri*, *H. diserticola*, *H. paradoxus*, *H. petiolaris* and *H. praecox* ssp. *runyanii* (Table 1) and the rest were promising breeding lines. The interspecific lines were developed at Directorate of Oilseeds Research, Hyderabad. The wild species were crossed to Morden and the F_1s or the selected F_2 plants were backcrossed to Morden (Table 1). Six interspecific lines *viz.*, EC 413060, EC 413070, EC 413075, EC 413083, EC 413086 and EC 413090 were obtained from United States, Department of Agriculture, USA. The selected genotypes were grown in Randomized Block Design with three replications during *kharif*, 1999. Each genotype was grown in a single row of 3.3 m per replication. The spacing of 60 cm between rows and 30 cm between plants in a row was followed. Along all the borders, the susceptible variety, Morden was grown to provide enough inoculum for the incidence and spread of *Alternaria* disease. All the standard agronomic practices except fungicidal sprays were followed to raise a good crop. Some of the male sterile genotypes among the interspecific derivatives were assisted through artificial hand pollination for the normal seed set. Five plants were randomly selected/replication to record observations. The observations were recorded on plant height, days to 50% flowering, days to maturity, head diameter, number of seeds/head, 100 seed weight, disease per cent indexed (PDI) at two stages *viz.*, 50% flowering (stage 1st) and PDI at physiological maturity (stage 2nd) (Mayee and Datar, 1986), oil content and seed yield/plant by following standard procedures. Dharwad is a hot spot for *Alternaria* leaf blight. The minimum RH of 76% and the maximum temperature between 24.39 °C and 30.04 °C prevailed during the crop growth period resulted in high disease incidence.

Table 1 List of interspecific lines of sunflower with pedigree

Code Number	Generation	Cross combination
SAR5-01S	BC_5F_1	234A x *H. argophyllus* x Morden
SAR5-02S	BC_5F_1	234A x *H. argophyllus* x Morden
SAR5-03S	BC_5F_1	234A x *H. argophyllus* x Morden
SAR5-04S	BC_5F_1	234A x *H. argophyllus* x Morden
SAR5-05S	BC_5F_1	234A x *H. argophyllus* x Morden
SAR5-06S	BC_4F_1	234A x *H. argophyllus* x Morden
SAR5-07S	BC_4F_2	234A x *H. argophyllus* x Morden
SAR5-08S	BC_4F_2	234A x *H. argophyllus* x Morden
SAR5-09S	BC_4F_2	234A x *H. argophyllus* x Morden
SAR5-10S	BC_4F_2	234A x *H. argophyllus* x Morden
ARSS-01F	BC_4F_2	*H. argophyllus* x Morden
ARSS-02F	BC_4F_2	*H. argophyllus* x Morden
ARSS-03F	BC_4F_2	*H. argophyllus* x Morden
PESS-01F	BC_4F_2	*H. petiolaris* x Morden
PESS-02F	BC_4F_2	*H. petiolaris* x Morden
SAN5-01S	BC_5F_1	234A x *H. annuus* (wild) x Morden
SAN5-02S	BC_5F_1	234A x *H. annuus* (wild) x Morden
SAN5-03S	BC_4F_2	234A x *H. annuus* (wild) x Morden
SAN5-04S	BC_4F_2	234A x *H. annuus* (wild) x Morden
ANSS-01F	BC_4F_2	234A x *H. annuus* (wild) x Morden
ANSS-02F	BC_4F_2	234A x *H. annuus* (wild) x Morden
SDE5-01S	BC_5F_1	234A x *H. debilis* x Morden
SDE5-02S	BC_5F_1	234A x *H. debilis* x Morden
SDE5-03S	BC_4F_2	234A x *H. debilis* x Morden
SDE5-04S	BC_4F_2	234A x *H. debilis* x Morden
ARANS-01F	BC_4F_2	*H. argophyllus* x *H. annuus* (w) x Morden
ARANS-02F	BC_4F_2	*H. argophyllus* x *H. annuus* (w) x Morden
ARANS-03F	BC_4F_2	*H. argophyllus* x *H. annuus* (w) x Morden
EC 413060	-	*H. argophyllus*
EC 413070	-	*H. argophyllus*
EC 413075	-	*H. deserticola*
EC 413083	-	*H. paradoxus*
EC 413086	-	*H. bolanderi*
EC 413090	-	*H. praecox* spp. *runyanii*
1229	-	Population
873	-	Population
180	-	Population
Morden	-	-
L101	-	-
Breeding lines	-	

Results and discussion

The season was highly favourable for disease incidence and all the genotypes showed moderate PDI values at 1st stage itself. After flowering the disease progress was very fast and all the genotypes tested recorded high disease severity at stage IInd. The mean disease incidence was as high as 75% indicating the severity of the disease during the season. The differences were highly significant for all the characters, indicating the availability of substantial variability in selected genotypes (Table 2). However, there was no high level of resistance in genotypes tested including interspecific lines. The species *H. argophyllus* was reported as resistant (Anil Kumar *et al.*, 1976; Morris *et al.*, 1983) and 18 lines derived from *H. argophyllus* were used in this study. These materials also did not show high level of disease resistance, may be due to absence of resistance in the accessions of *H. argophyllus* used for deriving these lines or less of alleles during backcrossing. Hence, it is highly essential to test the accessions of different species to *Alternaria* leaf blight before involving them in crosses. Wide differences were observed for yield and yield components. The highest GCV and PCV values were observed for seed yield/plant followed by seeds/head (Table 3). Such high variability for these characters was also reported in sunflower (Sheriff and Appadurai, 1985; Khan and Islam, 1991).

Moderate level of variability was observed for seed weight, oil content, head diameter that are major seed yield components. Hence, there is scope for selection for these traits. High heritability coupled with high genetic advance (GA) was observed for number of seeds/head, test weight and moderate heritability with moderate GA for head diameter. The results indicated that the traits *viz.*, number of seeds/head, test weight, head diameter and plant height appeared to be governed predominantly by additive gene action. These traits can be improved through selection process. High heritability with low GA was observed for oil content and seed yield confirming the earlier reports. These characters appeared to be predominantly controlled by dominant gene action (Pathak, 1975). The presence of non-additive gene action suggested the scope for exploitation of these traits through heterosis. The hybrid vigour for both seed yield and oil content has been exclusively reported and exploited in sunflower.

Twelve and seven genotypes were found to be significantly superior over Morden for seed yield and oil content respectively (Table 4). Among which three genotypes SAN 5-01S, SAR 5-01S and SARS -06F were found superior to both seed yield and oil content. San 5-01S and SAR 5-05S are the cytoplasmic male sterile (CMS) lines hence could be useful for the diversification of CMS sources. However, there is a need to test these CMS lines under varied environmental conditions for their stability. The other genotype SAR S-06F has to be tested in large-scale trails for its superiority. For disease reaction, four genotypes *viz.*, SAR 5-04S, SAN 5-01S, SARS-10F and 873-07 recorded low PDI values at both the stages. These lines are to be tested over seasons for their stability for the disease reaction. Further study is in progress at University of Agricultural Sciences, Dharwad.

Table-2 Analysis of variance for ten characters in sunflower germplasm lines

Sources	Df	Plant height (cm)	Days to 50% flowering	*Days to maturity*	Head diameter (cm)	Seeds/ *head*	100 seed *weight (g)*	PDI (Stage I[st])	PDI (Stage II[nd])	Oil content (%)	Seed yield/plant (g)
Replication	2	41.125	2.969	3.500	3.604	18488.00	0.1062	30.273	412.968	0.27344	50.453
Treatment	61	1542.38**	42.16**	93.89**	21.818**	286556.69**	1.945**	132.696**	91.351**	45.619**	930.521**
Error	122	263.99	10.569	6.019	5.127	20136.87	7.358	27.49	32.641	0.62385	50.94

* Significant at 5% level; ** Significant at 1% level

Table 3 The mean, range, phenotypic and genotypic coefficient of variance, heritability and genetic advance of different characters in sunflower

Character	Mean	Range		Genotypic variance	Phenotypic variance	GCV (%)	PCV (%)	Heritability	Genetic advance (% over mean)
		Min.	Max.						
Plant height (cm)	142.39	97.67	192.67	426.33	690.25	14.50	18.45	61.70	23.46
Days to 50% flowering	*63.67*	*56.00*	*73.67*	*10.54*	*21.07*	*5.10*	*7.21*	*49.00*	*7.41*
Days to maturity	95.78	82.00	112.33	*29.29*	*35.26*	5.65	*6.20*	*83.00*	10.59
Head diameter (cm)	18.10	11.73	23.53	5.58	10.70	13.05	18.07	52.10	19.39
Seeds/head	860.20	161.23	1958.83	88943.17	10894.29	34.64	38.37	81.50	64.43
100-seed weight (g)	5.04	3.56	7.65	0.62	0.69	15.67	16.56	89.40	30.55
PDI (Stage I[st])	30.65	18.50	43.67	35.41	62.90	19.41	25.87	56.30	30.01
PDI (Stage II[nd])	74.51	64.33	93.07	23.10	54.64	6.45	9.92	42.30	8.66
Oil content (%)	33.83	24.04	42.26	15.00	15.61	11.45	11.68	96.00	4.56
Seed yield (g)	46.55	14.83	94.98	293.19	344.17	36.78	39.85	85.20	16.79

Table 4 Promising genotypes of sunflower for seed yield and oil content

Genotype	PDI *(Stage I[st])*	PDI *Stage II[nd])*	Oil content *(%)*	Seed yield *(g/plant)*
SARS-06F	25.12	75.10	39.30	94.98
EC 413090	28.50	65.90	31.75	85.87
180-08	27.93	69.03	29.34	85.63
SAN5-01S	21.83	67.33	40.65	84.83
ANSS-01F	41.43	73.83	36.75	77.81
SAR5-02S	25.20	71.97	34.34	77.18
180-14	33.37	68.12	35.33	68.45
ARS5-03F	37.37	70.97	30.85	66.25
180-42	40.73	74.77	34.02	65.44
ARSS-01F	27.72	76.80	35.88	63.49
SAR5-05S	18.50	79.37	40.32	62.28
PESS-02F	24.80	76.73	32.32	60.52
SAN5-02S	21.13	85.47	42.26	52.62
180-31	17.53	66.97	39.29	47.31
180-12	20.80	72.63	39.47	45.45
SDES-01S	33.30	71.63	40.36	41.49
Morden (check)	24.43	71.33	37.71	47.91
CD (P=0.05)	8.39	9.14	1.26	11.52

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Short communication

Morphological characterization of Rhizoma peanut, *Arachis glabrata* Benth.

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Arachis glabrata Benth., popularly known as rhizoma peanut is a perennial tropical forage legume grown widely in Florida and the southern Gulf Coast of United States of America. Rhizoma peanut grows well under a wide range of soil types and pH levels, in well to moderately drained soil. Yields approaching 14 t/ha have been reported (French *et al.*, 1994). The potential of these wild species lies in its utilization in animal feeds and fodder and as source of resistance to various pests and diseases (Stalker, 1991). The nutritive value of *Arachis glabrata* (cv. Florigraze) and *A. pintoi* (CIAT 17434) is higher than that of most tropical legumes of commercial importance. These species have high levels of digestible energy and fermentable nitrogen (Lascano, 1994). *A. hagenbeckii* and *A. glabrata* also reported to have high leaf protein percentage (Tiwari, 1985). Reed and Ocumpaugh (1991) screened rhizoma peanut for adaptation to calcareous soils and reported that some accessions of the species could be well adapted to calcareous soil. Studies also indicated that *A. glabrata* possess high degree of shade tolerance under coconut farming system (Mullen *et al.*, 1997). Singh and Shankar (2000) formulated an ideal combination of goat pasture including *A. glabrata* as one of the components.

Twenty-three accessions of *A. glabrata* (Table 1) were grown in concrete rings of 75 cm diameter at NRCG, Junagadh, India. Observations on 17 qualitative traits and nine quantitative traits were recorded on each accessions following IBPGR (1990) descriptors list developed for characterization of wild *Arachis* species for two consecutive years 2000 and 2001 during *kharif* season. The qualitative traits included branching pattern, stem pigmentation, stem hairiness, leaflet colour, leaflet hairiness, hairiness on leaflet margin, bristles on leaflet margin, hairiness on petiole, bristles on petiole, hairiness on stipule, bristles on stipule, groove of petiole canal, leaflet shape of distal leaflet, leaflet tip of distal leaflet, leaflet shape of proximal leaflet, leaflet tip of proximal leaflet and colour of standard petal. The quantitative traits included, length of petiole, length of stipule, percentage adnation of stipule, internodal length, leaflet length, leaflet width, length of hypanthium, standard petal length and standard petal width. Both qualitative and quantitative traits were used for statistical analysis. Hierarchical cluster analysis based on average linkage method was done using squared euclidean distance as measure of distance (Sneath and Sokal, 1973).

Variation was observed for all the 17 qualitative and nine quantitative traits studied. The branching pattern was either irregular, or sequential with both reproductive and vegetative branches arising form same node. Three accessions were devoid of pigmentation on stem. Stem hairiness ranged from glabrous to sub-glabrous and moderately hairy in one accession (ICG 8154). Leaflet colour, hairiness on lamina, leaf margin, stipule and petiole and presence of bristles on leaflet, stipule and petiole also showed variation among accessions. Leaflet showed variation for shape and tip. Accession, ICG 8921 did not bear flowers. Cluster analysis based on 26 morphological traits resulted in the formation of two distinct clusters (Fig 1).

Table 1 **Passport information of *A. glabrata* accessions selected for intra-specific diversity studies**

ICG No.	Country of Origin	Province
8145	Argentina	Corrientes
8148	Brazil	---
8150	Brazil	Mato Grosso do Sul
8151	Brazil	Mato Grosso do Sul
8154	Argentina	Misiones
8156	Paraguay	Arroyo Pora
8157	Paraguay	Arroyo Pora
8159	Paraguay	Asuncion
8161	Paraguay	Mato Grosso do Sul
8165	Brazil	Mato Grosso do Sul
8166	Brazil	Mato Grosso do Sul
8167	Brazil	Mato Grosso do Sul
8169	Brazil	Mato Grosso do Sul
8170	Brazil	Mato Grosso do Sul
8171	Brazil	Mato Grosso do Sul
8173	Paraguay	Concepcion
8174	Paraguay	Concepcion
8175	Paraguay	Concepcion
8176	Paraguay	Concepcion
8177	Paraguay	Concepcion
8188	Brazil	---
8921	Argentina	Corrientes
8950	Brazil	Mato Grosso Do Sul

The first cluster comprised of all the accessions collected from Argentina and two accessions from Paraguay and three from Brazil. The only non-flowering accession (ICG 8921) found to be the last clustered accession in this group. Accessions, ICG 8150 and ICG 8161 that were collected from the same province showed minimum coefficient and probably these accessions are duplicates (Table 2). In the second cluster, accessions from Paraguay and Brazil were clustered and the distance coefficient was less among three accessions. The study revealed that intra-specific variation in *A. glabrata*is remarkable and the collection from the same province tend to cluster together indicating that wider the spread of the species may result in more variation in species.

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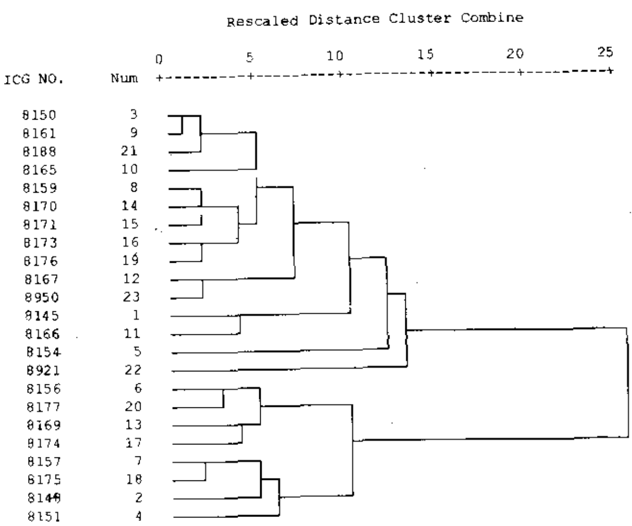

Fig 1 Dendrogram based on morphological traits of 23 accessions

Table 2 Agglomeration schedule among *A. glabrata* accessions during hierarchical cluster analysis

ICG No.	ICG No.	Coefficient
8150	8161	7.43
8159	8170	19.00
8150	8188	19.15
8159	8171	20.68
8167	8950	24.98
8173	8176	25.85
8157	8175	27.75
8156	8177	37.52
8145	8166	40.20
8159	8173	40.70
8166	8174	46.25
8150	8165	51.19
8169	8157	53.38
8156	8169	53.46
8150	8159	53.75
8148	8151	67.60
8150	5167	73.08
8145	8150	106.84
8148	8156	109.79
8177	8154	133.71
8145	8921	137.33

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Short communication

Diallel analysis for combining ability for yield and its component including oil content in Indian mustard

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Present investigation was undertaken to generate information on the nature of combining ability in the inheritance of yield and its component in Indian mustard. Ten varieties of Indian mustard *viz.*, Kranti, Pusa bold, Pusa barani, RLM-198, PHR-2, Divya, Zem1, EC-322090, EC-322092 and Domo of diverse origin were crossed in all possible combinations excluding reciprocals. The parents, 45 F_1 and 45 F_2 progenies were grown in randomized complete block design with three replications at Crop Research Centre, G.B. Pant University of Agril. & Technology, Pantnagar during *rabi* season 1998-99. The parents and F_1s were grown in single row and F_2s in four rows plots, 5 m long with the spacing of 30 x 10 cm between rows and plants. The observations were recorded on 10 randomly selected competitive plants from each plot of the parents and F_1s and 20 plants from F_2s for quantitative and qualitative traits. The character mean for each plot was used for statistical analysis. The combining ability analysis was carried out following Method-II, Model-I of Griffing (1956).

Analysis of variance for combining ability revealed significant *gca* and *sca* variances in both F_1 and F_2 generations for days to maturity, primary branches/plant, length of siliqua, seed yield/plant, harvest index and 1000-seed weight (except *sca* in F_2 generation for primary branches/plant and 1000-seed weight), indicating the presence of additive as well as non-additive gene action in parents and hybrids for these characters (Table 1). Only additive gene effects were important in the inheritance of plant height, seeds/siliqua and oil content in both F_1 and F_2 generations. These finding were in accordance with the results of Thakaral *et al.* (1995); Yadav and Yadava (1996); Luczkiewcz (1996); Sheikh and Singh (1998) and Verma (2000). Higher magnitude of *gca* variance than corresponding *sca* variance revealed predominance of additive gene actions for all these traits.

The *gca* estimates indicated that high yielding mustard variety Kranti was good general combiner for all the characters except oil content, whereas Pusa bold and Pusa barani were good general combiners for early maturity, dwarf height, length of siliqua and 1000-seed weight. Early maturing dwarf mustard strain Divya was good general combiner for early maturity, dwarf height and oil content, whereas, RLM-198 was good general combiner for early maturity, seeds/siliqua, harvest index, seed yield and oil content. Exotic accessions, Zem 1, EC-322090, EC-322092 and Domo were good general combiners for primary branches/plant. Parent PHR-2 which is *Alternaria* blight resistant was found best general combiner for oil content.

The five top crosses selected on the basis of *per se* performance revealed that performance ranking was not consistent with the estimates of *sca* effect. The *sca* effect of the cross exhibited no specific trend in cross combination between parent having good, average and poor *gca* effects. No cross combination showed *sca* effect and high *per se* performance along with parents having good general combining ability effects for all nine characters. Based on *sca* estimate and *per se* performance Kranti x Domo and Zem1 x EC-322090 were observed superior cross combinations for seed yield, whereas, the crosses Divya x Zem1, PHR-2 x EC 322090 and Pusa barani x Domo were found superior on the basis of *sca* effects only. On the basis of *sca* effects and *per se* performances, the cross Zem1 x EC 322090 was observed superior for primary branches/plant, Pusa bold x Pusa barani for early maturity, RLM-198 x Divya, Kranti x Pusa barani for dwarf height and Kranti x Pusa bold for seeds/siliqua, Kranti x Pusa bold for 1000-seed weight and RLM-198 x PHR-2 for oil content.

The crosses involving good x good *gca* parents indicated the possibility of complimentary epistasis acting in direction of additive effect of good combiners. The crosses of good x poor *gca* parents with desirable direction *sca* effects may be due to dominant x recessive interaction, excepted to produce desirable segregants in F_2 generation. However, crosses between poor x poor *gca* parents indicated that non-additive genetic variation can be exploited by heterosis breeding or multiple crosses followed by intermating among desirable segregants.

Similar results were reported by Yadav *et al.* (1992); Sheikh and Singh (1998) and Sood *et al.* (2000).

The present study resulted in the identification of Kranti, RLM-198 and Divya as good general combiners for seed yield and its components. Importance of additive as well as non-additive gene effects in the inheritance of yield and its component characters high lighted that the improvement in these attributes may be effective by biparental mating in selected F_2 on the basis of *gca* and *sca* and further selection of segregating generations or recurrent selection or diallel selective mating system.

Table 1 Estimates of general combining ability and general mean (±) of the parents

Parental lines	Genera-tion	Days to maturity	Plant height	Primary branches/ plant	Length of siliqua	Seeds/ siliqua	Seed yield/ plant	Harvest index	1000 seed weight	Oil content
Kranti	F_1	4.29**	-7.70**	-0.38**	0.24**	-0.39**	0.30*	0.25**	0.15*	0.23
	F_2	-4.04**	-11.05**	-0.54**	0.26**	0.57**	0.17	0.16**	0.10**	0.02
Pusa bold	F_1	-4.15*	-13.15*	-0.24	0.23*	0.43**	-0.05	-0.01	0.22**	0.00
	F_2	-3.48**	-10.63**	-0.17	0.25**	0.47**	-0.20	-0.03	0.26**	-0.25
Pusa barani	F_1	-2.62**	-9.97**	-0.25	0.24**	0.65**	-0.23	0.04	0.27**	-0.05
	F_2	-3.07**	-10.78**	-0.18	0.29**	0.77**	-0.06	0.03	0.25**	0.08
RLM-198	F_1	-2.51**	3.03	0.00	0.13	0.50**	0.72**	0.21**	-0.02	0.31*
	F_2	-2.34**	-1.44	-1.14**	0.06	0.66**	0.28	0.23**	0.05	0.31*
PHR-2	F_1	3.07**	4.63*	0.22	-0.10	-0.33*	-0.28	-0.03	-0.18**	0.37*
	F_2	4.36**	10.40**	0.24	-0.18*	-0.48**	0.18	0.05	-0.19**	0.28
Divya	F_1	-8.23**	-27.35**	-0.65**	0.05	0.13	-1.88**	-0.40**	-0.17**	0.74**
	F_2	-9.37**	-28.09**	-0.50**	0.12	0.02	-1.08**	-0.35**	-0.16**	0.74**
Zem1	F_1	5.18**	9.93**	0.08	-0.16*	-0.37*	0.17	0.02	-0.09*	-0.20
	F_2	3.43**	9.35**	0.10	-0.17	-0.36*	0.38*	0.01	-0.04	0.24
EC-322090	F_1	4.74**	15.24**	0.55**	-0.17*	-0.24	0.09	-0.08	-0.03	-0.13
	F_2	5.21**	20.49**	0.62**	-0.03	-0.42**	0.21	-0.06	-0.01	0.05
EC-322092	F_1	4.16**	17.03**	0.39**	-0.28**	-0.42**	-0.65**	0.06	-0.06	-0.02
	F_2	3.79**	12.31**	0.20	-0.23**	-0.59**	-0.01	-0.05	-0.06	-0.02
Domo	F_1	4.66**	8.31**	0.27*	-0.18*	-0.74**	0.51**	-0.07	-0.09*	0.25
	F_2	5.24**	9.44**	0.37*	-0.17*	-0.65**	0.13	0.00	-0.18**	-0.03
General mean	F_1	148.77± 0.90	190.02± 3.93	6.28± 0.26	3.10± 0.90	11.66± 0.29	6.95± 0.33	4.64± 0.10	3.10± 0.07	39.15± 0.23
	F_2	149.41± 0.90	188.47± 3.93	5.88± 0.26	3.06± 0.90	11.69± 0.29	5.43± 0.33	4.45± 0.10	3.12± 0.07	39.12± 0.23
SE gi	F_1	0.43	1.89	0.12	0.04	0.13	0.15	0.05	0.03	0.15
	F_2	0.43	1.89	0.12	0.04	0.13	0.15	0.05	0.03	0.15
SE (gi-gj)	F_1	0.64	2.78	0.18	0.06	0.20	0.24	0.07	0.05	0.23
	F_2	0.64	2.78	0.18	0.06	0.20	0.24	0.07	0.05	0.23

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

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Short communication

Metroglyph analysis in mustard, *Brassica juncea* (L.) Czern & Coss.

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Alternaria blight, white rust and downy mildew are three major diseases of mustard which cause substantial yield losses. In order to develop high yielding mustard genotypes which are resistant to these three major diseases, it is essential to identify resistant strains with good agronomic characteristics. In present investigation mustard genotypes having resistance to Alternaria blight, downy mildew and white rust were grouped on the basis of their agronomic characteristics using metroglyph analysis (Anderson, 1957).

Sixteen genotypes of Indian mustard [*Brassica juncea* (L.) Czern & Coss] including resistant/tolerant lines to Alternaria blight, *Alternaria brassicae* (Berk.) Sacc. and *Alternaria brassicicola* (Schw.) Wilts, white rust, *Albugo candida* (Lev.) Kunze and downy mildew, *Peronospora parasitica* (Pers ex Fr.) and two national checks *viz.*, Kranti and Varuna were grown in a randomized block design with two replications on November 27,2001 at a fertility level of 120:80:40 kg NPK/ha, respectively. Each plot consisted of 3 rows of 3 m length spaced 30 cm apart with plant-to-plant distance of 10 cm. Observations were recorded on five randomly selected plants from each plot and means of genotypes were used for important agronomic attributes for metroglyph analysis as per Anderson (1957). Yield/plot and plant height were taken as *x* and *y* axis, respectively for metroglyph depiction. The index values for these three classes of each character are represented by varying lengths of rays, i.e., low (no ray), medium (short ray) and high (long ray) (Table 1).

Analysis of variance showed significant differences among the tested genotypes for various characters. On the basis of their yielding ability genotypes were classified in to three broad groups (Fig. 1). The yield/plot of first group genotypes ranged from 120 to 178.3 g/plot (low group), second group 178.3 to 263.7 g/plot (medium group) and third group more than 236.7 g/plot (high).

The low yielding group consisted of four genotypes *viz.*, PWR 9541, PWR 9817, EC 399301-1-5 and Varuna. These genotypes were characterized by low to medium plant height, number of seeds/ siliqua and oil content, low to high number of primary branches, siliqua length, 1000-seed weight, siliquae on main shoot and length of main shoot and medium to high number of days to maturity and secondary branches/ plant.

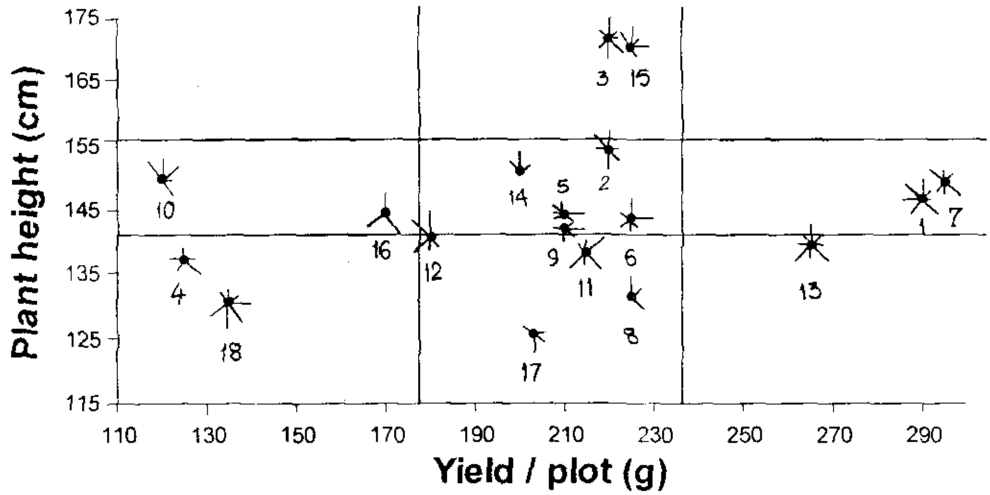
The medium yielding group, represented by eleven genotypes *viz.*, PAB 9750, EC 399294-9, PWR 9605, PWR 9714, PWR 9725, PWR 9765, PWR 9854, EC 414321, EC 399301-2, EC 399301-3 and Kranti characterized by low to high plant height, number of primary branches, oil content, siliqua length, number of seeds/siliqua, 1000-seed weight, number of secondary branches, main shoot length and siliquae on main shoot and medium to high number of days to maturity.

The high yielding group consisted of three genotypes *viz.*, PAB 9334, PWR 9724 and EC 399294-8 which were mostly dwarf to medium in height. These genotypes possessed high number of secondary branches and medium number of primary branches, low to medium siliqua length, number of siliquae on main shoot and 1000-seed weight, low to high number of seeds/ siliqua and medium to high number of days to maturity (longer duration) and length of main shoot and oil content. High positive associations between seed yield and number of secondary and primary branches were reported by Shalini *et al.* (2000). These high yielding genotypes were medium to late in maturity, whereas low yielding genotypes were early to medium in maturity. These results are in conformity with the results of Ghosh and Gulati (2001).

Most of the high yielding genotypes had medium to high length of main shoot and medium to high number of seeds/ siliqua. From correlation studies Patel *et al.*(2000) observed significant positive correlation of seed yield with length of main shoot whereas high positive association of seed yield with seeds/ siliqua was reported by Shalini *et al.*(2000). These high yielding genotypes had medium to high oil content. Similar result was reported by Ghosh and Gulati (2001).

Thus, on the basis of the present investigation it is concluded that the characters *viz.*, number of secondary branches, primary branches, days to maturity, length of main shoot and seeds/ siliqua should be given emphasis along with resistance to white rust and downy mildew for development of high yielding and resistant genotype of mustard for stabilizing and increasing production.

Fig 1 Metroglyph analysis in mustard



List of genotypes depicted in metroglyph and their number

1. PAB 9334	2. PAB 9750	3. EC 399294	4. PWR 9541
5. PWR 9605	6. PWR 9714	7. PWR 9724	8. PWR 9725
9. PWR 9765	10. PWR 9817	11. PWR 9854	12. EC 414321
13. EC 399294-8	14. EC 399301-2	15. EC 399301-9	16. EC 399301-1-5
17. Kranti (Check)	18. Varuna (Check)		

Table 1 Index value for different characters in mustard

Character	Range of means	Score 1		Score 2		Score 3	
		Value less than	Sign	Value From-to	Sign	Value more than	Sign
Days to maturity	120-133	124.3	•	124.3 to 128.7	•	128.7	•
Plant height (cm)	125.8-171.4	141	-	141 to 156.2	-	156.2	-
Primary branches/plant	4.0-8.1	5.4	•	5.4 to 6.7	•	6.7	•
Secondary branches/plant	3.9-13.3	7.1	•	7.1 to 10.2	•	10.2	•
Length of main shoot	33.8-51.1	39.5	•	39.5 to 45.3	•	45.3	•
Siliquae on main shoot	20.8-37.3	26.3	•	26.3 to 31.8	•	31.8	•
Seeds per siliqua	11.8-15.4	13	•	13 to 14.2	•	14.2	•
1000-seed weight (g)	2.9-3.9	3.2	•	3.2 to 3.6	•	3.6	•
Yield per plot (g)	120-295	178.3	-	178.3 to 236.7	-	236.7	•
Oil content (%)	36.2-38.6	37.0	•	37.0 to 37.8	•	37.7	•

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Short communication

Stability analysis in Indian mustard at Bastar plateau zone

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Mustard [*Brassica juncea* (L.) Czern & Coss] is grown under rainfed as well as irrigated conditions, after the harvest of rice, in Bastar Plateau Zone. Performance of mustard varieties under three agro-climatic conditions, depends upon their stability under varying farming situation. Further, stability is one of the most important parameters for the selection of varieties for diverse situations. Therefore, the present investigation was carried out to identify stable mustard variety(ies) for seed yield and associated characters.

The experiments were conducted with twenty Indian mustard varieties at S.G. College of Agriculture and Research Station, Jagdalpur (Bastar) in four different environments, i.e., early sown rainfed (E_1 & E_3), irrigated late sown after paddy harvest (E_2 & E_4) during *rabi*, 1999-2000 and *rabi*, 2000-01, respectively. the experiments were laid out in randomized block design with 3 replications in a 1.5 m x 5.0 m with inter and intra row spacings of 30 cm x 10 cm, respectively. The sowing dates were: E_1 (28 Sept., 1999); E_2 (07 Nov, 1999) and E_3 and E_4 (both 13 Nov, 2000). the fertilizer doses of 40N : 20P : 20 K kg/ha and 80N : 40P : 40 K kg/ha was applied under rainfed and irrigated conditions, respectively. Need based plant protection measures were applied for controlling the disease (powdery mildew) and pest (aphids) of crops. Observations on quantitative traits (5 plant basis), seed yield (on plot basis) were recorded. Stability parameters were worked out following Eberhart and Russel (1966).

Mustard genotypes differed in their response to the changes in environments as observed by the significant mean sum of squares for genotypes and genotype x environment (Linear) interaction. A large portion of this interaction was accounted for by linear regression on the environmental means, although the non-linear component was also significant indicating the possibility of prediction across environments (Table 1).

Days to 50% flowering ranged from 44.6 (Pusa Bahar) to 53.4 days (RL-1359) with the overall mean of 49.1 days. Pusa Bahar had unit regression coefficient indicating average response over varying environments. Regression coefficient was negative and significantly different than one for RH-30 suggesting its suitability of flowering under the unfavourable environment conditions. Only six varieties had non-significant deviation from regression indicating their stability in performance (Vardan, PCR-7, GM-1, PBR-91, RL-1359 and Vaibhav). The mean days to maturity was 99.8 days that varied between 87.8 to 103.4 days for B-9 and RL-1359, respectively. Pusa Bahar (1.81) and VSL-5 (-0.02) deviated significantly from the linear regression indicating their stability under favourable and unfavourable environments, respectively. More than 50% of the varieties had stability for days to maturity, which may be due to forced maturity caused by high temperature prevailing during this period. Moreover, late maturity (above average) varieties had significant deviation from regression indicating their sensitivity to the environments. Number of branches/plant varied between 2.7 (Rohini) to 3.3 (GM-2) with the average of 3.0. Rohini and RL-1359 expressed unit regression coefficient, however, PBR-91 and JM-1 were the most stable genotypes. Yellow sarson variety B-9 (71.9) recorded the least and Pusa Bahar (171.3) had the highest siliquae/plant. Seven varieties recorded the above average performance for this trait. PCR-7 (1.6) had the highest linear regression indicating its suitability for favourable climates. On the contrary, Vaibhav expressed the least (0.61) regression coefficient and non-significant deviation from regression suggesting its suitability for unfavourable conditions and stability over the environments. Vardan (27.1) and RL-1359 (31.5) also had non-significant deviation from regression indicating their stability over the environment. Kranti was reported to be stable for siliquae/plant by Patel *et al.* (1997), the present findings did not support this condition. Plant height ranges from 90.8 to 146.3 cm for B-9 and GM-1, with the mean height of 136.3 cm of variety, Pusa Bahar (1.5) exhibited significant linear regression with the above average response whereas, VSL-5 had the least (0.35) regression indicating its suitability for unfavourable conditions. Thirteen varieties had non-significantly deviation from the linear regression indicating their stability to the environment. 1000 seed weight ranged from 3.3 (B-9) to

5.2 (Varuna) with the mean test weight of 4.5 g. Pusa Bold and Rohini expressed unit regression coefficient suggesting average response over varying environment. Except four varieties *viz.*, Pusa Bold, Varuna, Kranti and Vardan, all other varieties had significant deviation from the regression indicating change in seed weight according to environments. Stability of Varuna for 1000 seed weight was also reported by Patel *et al.* (1997). Harvest index varied between 18.9 to 26.1 for Vardan and VSL-5, respectively. Above average response of RL-1359 (1.84) indicated its potential for higher harvest index under favourable management conditions, on the contrary, VSL-5 expressed the lowest (0.3) regression coefficients with highest harvest index (26.1) indicating its suitability under unfavourable conditions. Kranti (0.39), Varuna (1.41) and GM-2 (1.46) had non-significant deviation from regression hence, are stable varieties for harvest index.

The highest seed yield was recorded with Pusa Bahar 660.5 kg/ha followed by Varuna (644.8 kg/ha), Pusa Bold (630 kg/ha) and BIO-902 (629.5 kg/ha). Aruna (1.23), RN-393 (1.20) and BIO-902 (1.26) had above average response indicating their suitability under favourable environment condition. Mondal and Khajuria (1999) also reported that Varuna had above average response with the suitability for the favourable environment. B-9 had the lowest linear regression suggesting its suitability under poor environment conditions. None of the variety had non-significant deviation from regression, except PBR-91 indicating its stability with above average performance and average response for seed yield of mustard at Bastar Plateau Zone.

Pusa Bahar was the earliest in flowering with the highest siliquae/plant and seed yield suggesting that this could be a good parent for crossing aimed for development of early genotypes with high seed yield. Varuna had the highest test weight with the above average seed yield performance indicating that it could be used for developing the bold seeded genotypes under the new climatic conditions. Similarly, VSL-5 had the highest harvest index with above average seed yield performance, which indicated its suitability as parent for high harvest index with high seed yield.

Table 1 Analysis of variance for stability of eight quantitative characters in Mustard

Sources of variation	df	*Mean sum of squares*							
		Days to 50% flowering	Days to maturity	Branches/ plant	Siliqua/ plant	Plant height	1000 seed weight	Harvest index	Seed yield
Varieties	19	23.44**	40.74**	0.12**	340.49**	597.3**	0.90**	12.12**	14653.62**
Env. + (Var. X Env.)	60	6.42**	32.81**	0.41**	929.6**	397.1**	1.35**	20.27**	87429.17**
Environments	3	15.72**	520.85**	6.25**	13055.7**	6856.3**	24.19**	242.67**	1579362.3**
Var. x Env.	57	5.93**++	7.12**++	0.10**++	291.3**++	57.1**++	0.15**++	8.57**++	8906.37**++
Env. (Linear)	1	47.24**	1562.42**	18.75**	39166.8**	20568.9**	72.59**	728.0**	4738079.4**
Var. x Env. (Linear)	19	6.77**	10.83	0.12**	146.7**	60.3**	0.14**	5.05**	6365.12**
Pooled deviation	40	5.23**	5.01**	0.08**	345.5**	52.7**	0.14**	9.81**	9668.33**
Pooled error	152	1.05	1.52	0.03	62.41	42.13	0.02	2.18	1566.7

** Significant at 1% level when tested against pooled error
++ Significant at 1% level when tested against pooled deviation

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Short communication

Variability and character association among quantitative characters of sesame

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Seed yield is a polygenically controlled complex character and is determined by a number of yield components which are also quantitatively inherited. A knowledge of heritability and genetic advance of the characters indicates the scope of improvement through selection. Correlation studies provides the association of quantitative characters, especially of seed yield and its attributes will be of immense practical value in crop breeding programme. Path coefficient analysis measures the direct influence of one variable upon another and permits the separation of correlation coefficients into direct and indirect effects. The present investigation provides better understanding about the bearing of the component traits on seed yield and scope of seed yield improvement through selection in sesame.

Ninety exotic germplasm lines representing 19 countries and two indigenous released varieties as checks (RT-46 and TC-25) were grown in randomised block design with two replications during the rainy season of 1997. Each plot consisted of 2.5 m single row with a spacing of 30 cm x 15 cm between rows and plants. Data were recorded on quantitative traits on five randomly selected plants per genotype. Genotypic and phenotypic coefficient of variance were estimated as per Burton (1952) and broad sense heritability and genetic advance were estimated as per Johnson *et al.* (1955). The phenotypic and genotypic correlations and the direct and indirect effects of characters on seed yield were computed by path coefficient analysis as per Dewey and Lu (1959) using both phenotypic and genotypic correlations.

Analysis of variance indicated highly significant differences among genotypes for all the characters. High magnitude of variation in the experimental material was also reflected by high values of mean and range for almost all the characters(Table 1). A close resemblance between the corresponding estimates of PCV and GCV suggested that the environment had little role in the expression of different characters. Seed yield/plant, branches/plant and capsule/plant showed high PCV and GCV estimates. There is enough scope for selection based on these characters, and the diverse genotypes can provide materials for a sound breeding programme.

The heritability estimates obtained high for seed yield, plant height, branches/plant, capsules bearing plant height, capsules/plant and oil content while moderate for days to flowering, days to maturity and 1000 seed weight.

Estimates of heritability and genetic advance in combination are more important for selection than heritability alone. High heritability combined with high genetic advance (as percent of mean) observed for seed yield, branches/plant and capsules/plant showed that these characters were controlled by additive gene effects and phenotypic selection for these characters would likely to be effective. Plant height and capsules bearing plant height indicated that improvement for these characters was also possible as these character had high heritability and moderate genetic advance as percent of mean. Oil content showed high heritability with low genetic advance. Such situation may arise due to non-additive gene action.

Seed yield/plant showed high positive correlations (phenotypic and genotypic) with all the characters studied except days to flowering and maturity. Days to flowering had significant negative correlation with capsules bearing plant height, 1000-seed weight and oil content but significant positive correlation with branches/plant. Significant positive correlation also observed between plant height with branches/plant, capsules/plant. In addition capsules bearing plant height exhibited positive correlation with capsules/plant, 1000 seed weight and oil content. Branches/plant correlated positively with capsules/plant and 1000-seed weight with oil content. In general, genotypic correlations exhibited higher than the corresponding phenotypic correlations possibly due to the modifying effect of environment association of characters at genetic level.

While correlation coefficients generally describes association between the characters in statistical terms, they are inadequate in interpreting the cause and effect relationship. Hence, correlation coefficients between various characters are partitioned into direct and indirect relationship by the path analysis. Seed yield being the complex outcome of different characters was considered the resultant variable and days to flowering, days to maturity, plant height, branches/plant, capsules bearing plant height, capsules/plant, 1000-seed weight and oil content as caused variable. A perusal of the results obtained in genotypic path analysis revealed that the maximum direct effect on seed yield was exhibited by 1000-seed weight followed by branches/plant, oil content, capsules/plant, capsules bearing plant height, days to flowering and days to maturity (Table 2). Kausal *et al.*(1974) and Gupta and Gupta (1977) had reported that capsules/plant had maximum direct effect on seed yield. The negative direct effect on seed yield was exhibited only by plant height. The positive and significant correlation coefficients between plant height and seed yield/plant may be due to high indirect effects via capsules bearing plant height, capsules/plant, branches/plant and 1000-seed weight. Correlation coefficients between branches/plant and seed yield/plant is due to high positive direct effect when compared with all characters under study. The high positive correlation between capsules bearing plant height and seed yield is due to high indirect effect of 1000-seed weight and capsules/plant; the positive and high correlation between capsules/plant and seed yield is due to high positive indirect effect of branches/plant and capsules bearing plant height; the high correlation between 1000-seed weight and seed yield/plant is due to high positive direct effect whereas, high correlation between oil content and seed yield is mainly due to indirect effects of 1000-seed weight. Thus, 1000-seed weight, branches/plant, oil content, capsules/plant and capsules bearing plant height appeared to be major components for seed yield and selection for them will lead to increase in seed yield.

Table 1 Estimates of variability, heritability and genetic advance in sesame

Character	Mean± S.E.	Range	GCV	PCV	Heritability (%)	GA	GA as % of mean
Seed yield / plant	4.60±0.2	0.67-12.32	54.6	55.0	98.4	5.1	111.5
Days to flowering	38.7±1.0	35.0-44.00	4.6	5.9	58.9	2.8	7.2
Days to maturity	82.911.1	76.0-85.0	2.6	3.2	66.7	3.6	4.4
Plant height	116.811.5	70.6-154.8	12.9	13.0	97.9	30.7	26.2
Branches / plant	4.30±0.5	1.0-7.8	27.8	31.5	77.8	2.2	50.5
Capsules bearing plant height	62.4±1.2	37.0-100.2	16.9	17.2	97.4	21.5	34.4
Capsules / plant	60.9±1.8	15.0-126.0	37.2	37.4	98.8	46.4	76.2
1 000-seed weight	2.10±0.1	1.37-2.98	16.0	18.8	72.2	0.6	28.0
Oil content	43.5±0.3	30.65-49.08	6.5	6.6	97.9	5.8	13.3

Table 2 Direct and indirect effects via various paths of eight characters on seed yield in sesame

Character	Days to flowering	Days to maturity	Plant height	Branches/ plant	Capsules bearing plant height	Capsules/plant	1000-seed weight	Oil content	Correlation with seed yield
Days to flowering	**0.1432**	0.0156	-0.0092	0.1270	-0.0393	0.0033	-0.2310	-0.0887	-0.0792
Days to maturity	0.0233	**0.0961**	-0.0041	0.0596	0.0148	0.0267	-0.1408	-0.0382	0.0375
Plant height	0.0294	0.0087	**-0.0449**	0.0834	0.1081	0.0947	0.0353	0.0069	0.3215
Branches / plant	0.0565	0.0178	-0.0116	**0.3216**	0.0036	0.1334	-0.1203	-0.0258	0.3752
Capsules bearing plant height	-0.0363	0.0092	-0.0312	0.0075	**0.1553**	0.0801	0.1429	0.0474	0.3750
Capsules / plant	0.0026	0.0142	-0.0234	0.2361	0.0685	**0.1816**	0.0120	0.0072	0.4988
1000-seed weight	-0.0733	-0.0300	-0.0035	-0.0857	0.0492	0.0048	**0.4515**	0.0846	0.3976
Oil content	-0.0661	-0.0191	-0.0016	-0.0431	0.0382	0.0068	0.1984	**0.1924**	0.3060

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Short communication

Fertilizer management in soybean, *Glycine max* L. - wheat, *Triticum aestivum* L. cropping system in Malwa Plateau of Madhya Pradesh

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Inclusion of legumes in cropping systems increased the soil fertility and consequently the productivity of succeeding crops (Singh *et al.*, 1995). Besides the effect of preceding legumes, the nutrients applied to them also have an impact on the succeeding crop (Gogoi and Sandhu, 1984). This approach allows balanced fertilizer use under resource constraints and for maintenance of fertility. When the fertilizer availability and resources of farmers are limited, it is necessary to choose appropriate yield target and fertility practice so that over seasons the twin objectives of high yields and maintenance of soil fertility could be achieved (Dev, 1997). Hence, an attempt was made to study the fertilizer management in soybean-wheat cropping system in Malwa Plateau of Madhya Pradesh.

An experiment was conducted during 1994-95 to 1996-97 in soybean (*Glycine max* L.) - wheat (*Triticum aestivum* L.) cropping system, under All India Coordinated Agronomic Research Project with an objective to grow crops with full package of practices and compare with farmers practice on farmers fields. Soybean-wheat cropping system was tested in four districts (Ujjain, Dewas, Shajapur and Biaora) in Madhya Pradesh under which six blocks (two each of Ujjain and Shajapur and one each from Dewas and Biaora) and in each block, four villages were selected where experiment was carried out. The site and the farmers' were the same for three years of experimentation. In rainy season, soybean (cv. JS-335) and in succeeding winter season wheat (cv. Loc-1) was taken in all the three years. Soybean at 80 kg seed/ha wheat with 100 kg seed/ha were sown in rainy and winter seasons with a row spacing of 30 and 22.5 cm, respectively. Yield data of four villages were added for one block and the mean value of each block (total six blocks) was used for statistical analysis. Therefore, the experiment having five treatments was replicated six times in a randomized block design. The soil was analysed before and after the completion of each season.

Soybean-wheat cropping system required the application of 100% recommended fertilizer to both crops or 100% recommended fertilizer to soybean and 75% of recommended fertilizer to wheat crop along with 25 kg/ha zinc sulphate + 3 kg/ha borax to soybean and 3 kg/ha PSB + 1 kg/ha Azotobacter to wheat crop and any reduction in the fertilizer and biofertilizers to any crop reduced the productivity of the soybean (Table 1).

Application of 100% NPK through fertilizers and $ZnSO_4$ + *borax (25 kg + 3 kg/ha) to soybean crop and 100%* NPK through fertilizers and PSB + Azotobacter (3 kg + 1 kg/ha) to wheat crop resulted in significantly higher grain yields over the farmers' practice and also considering the total productivity of the system. Singh and Singh (1995) also reported significant response to soybean yield due to S and Zn application in soybean - wheat system.

Application of biofertilizers helped to safeguard the deterioration of nutrient removal due to continuous cropping of soybean - wheat for 3 years under different doses of fertilizers to both crops. A little enrichment of organic carbon and nutrient balance were noticed when crops were fertilized with 100% to soybean and 75% fertilizers to wheat crop and along with biofertilizers (Table 2). Similar trends was also reported by Saxena and Chandel (1997).

Maximum cost benefit of 1.8 was recorded when soybean *was fertilized with 100% recommended fertiliser* + borax 3 kg/ha and wheat crop was fertilized with 75% recommended fertilizer + PSB 3 kg/ha and Azotobacter 1 kg/ha, thus, saving of 25% costly chemical fertilizers without deteriorating the fertility and profitability.

Thus, the farmers' of Malwa Plateau who followed soybean - wheat cropping system may fertilize soybean with 100% recommended fertilizer along with $ZnSO_4$ + borax (25 kg + 3 kg/ha) and 75% recommended fertilizer with PSB and *Azotobacter* (3 kg+1 kg/ha) to wheat crop.

Table 1 Effect of different treatments on grain, straw and combined yield of soybean-wheat cropping system (Pooled data of 3 years)

Treatment Fertilizer dose applied		Grain yield (kg/ha)		Total straw production (kg/ha)		Combined yield (kg/ha)	Benefit : cost ratio
Rainy season	Winter season	Soybean	Wheat	Soybean	Wheat		
Farmers' practice (3 t FYM + 9:23 kg $N:P_2O_5$/ha)	Farmers' practice (3 t FYM + 18:46 kg $N:P_2O_5$/ha)	1090	2000	3290	6010	9300	1.3
Recommended Fertilizer (RF) (25:75:20 kg $N:P_2O_5:K_2O$/ha)	Recommended Fertilizer (RF) (100:50:30 kg $N:P_2O_5:K_2O$/ha)	1850	3080	5560	9240	14800	1.6
RF + $ZnSO_4$ (25 kg/ha)	50% RF + PSB + Azotobacter (3 kg + 1 kg/ha)	1970	3230	5930	9700	15630	1.6
RF + Borax (3 kg/ha)	75% RF + PSB + Azotobacter (3 kg + 1 kg/ha)	1960	3330	5880	9990	15870	1.8
RF + $ZnSO_4$ + Borax (25 kg + 3 kg/ha)	RF + PSB + Azotobacter (3 kg + 1 kg/ha)	2190	3540	6400	10610	17010	1.7
CD (P=0.05)		40.1	26.0				

RF = Recommended fertilizer

Table 2 Total P and Zn uptake (after each crop harvest) as influenced by soybean-wheat cropping system (pooled data of 3 years)

Treatment	Initial stage			Total uptake (grain + straw)					
				OC (%)		S (ppm)		Zn (ppm)	
	OC (%)	S (ppm)	Zn (ppm)	Rainy	Winger	Rainy	Winter	Rainy	Winter
1*	0.56	7.2	0.30	0.55	0.55	5.58	7.47	0.09	0.04
2	0.56	7.5	0.32	0.55	0.55	8.11	9.75	0.11	0.12
3	0.56	7.6	0.33	0.56	0.55	6.59	10.97	0.16	0.12
4	0.56	7.7	0.34	0.57	0.56	7.45	10.47	0.13	0.23
5	0.56	7.7	0.34	0.57	0.56	7.32	10.94	0.13	0.24

* (1 to 5 as in Table 1)

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Short communication

Studies on moisture conservation practices in sesame, *Sesamum indicum* Linn. under low rainfall areas of western Rajasthan

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Sesame is a major oilseed crop of western Rajasthan, grown in *Kharif* season. The crop usually grown as rainfed experiences moisture stress at one or more stages of its growth period, which severely reduces its productivity. To mitigate moisture stress various moisture conservation practices have been proved beneficial. The adoption of any practice depends on its economics. Therefore it became pertinent to find out a low cost non monetary practice, that can easily be adopted by farmers. The wetting drying treatment (seed hardening) of seed for imparting resistance to drought and adverse conditions developed by Heneckel (1964) along with other moisture conservation practices have been tested in the present studies.

A field experiment was conducted for three *Kharif* seasons at Agricultural Research Station, Mandor. The soil was loamy sand, poor in organic carbon (0.23 %), medium in phosphorus (18 kg/ha), high in potassium (297 kg/ha) and alkaline in reaction (pH 8.1). The treatments comprised of (T_1) broad ridge and furrow (four rows of sesame at 30 cm distance in between two ridges of 15 cm height), (T_2) ridge and furrow at 60 cm interval, (T_3) opening dead furrow at five m interval, (T_4) sowing of crop with out covering furrow, (T_5) seed hardening (seed were soaked in water for 10 hours then dried in shade before sowing) and (T_6) normal drill sowing and covering the soil (control). These six treatments were replicated four times in randomized block design. The crop was sown on July 7th, 18th, and August 2nd, respectively for three years with the onset of monsoon. The 20 kg each of nitrogen and phosphorus/ha was applied as basal dose at the time of sowing and 20 kg N /ha was applied as top dressing at 30 days after sowing (DAS). Thinning was done at 15 DAS to maintain 10 cm distance between plants. Soil samples were collected from four successive soil layers of 0-15, 15-30, 30-45 and 45-60 cm depth for determination of soil moisture content by gravimetric method at sowing at seven days interval, 24-36 hours after rain and at harvest. Consumptive use of water was computed for different treatments by adding the moisture use values from sowing to harvest suggested by Dastane (1972).

During first two years of experimentation, monsoon withdrew earlier and crop experienced moisture stress at the time of pod development stage, which caused reduction in seed yield of sesame. The three seasons pooled seed yield data (Table 1) revealed that in comparison to normal drill sowing of sesame seed yield (441 kg/ha) enhanced significantly by adopting moisture conservation practices either by sowing in broad ridge and furrow (544 kg/ha) or in ridge and furrow at 60 cm (554 kg/ha). This increase in seed yield due to ridge and furrow sowing could be ascribed to better availability of moisture in soil, which directly influenced plant growth and productivity by enhancing number of capsules/plant, test weight and harvest index. Better availability of moisture enhanced nutrient availability, which indirectly helped to increase consumptive use of water and water use efficiency. Kaushik and Gautam (1991) and Kumar *et al.* (1995) reported more availability of moisture in soil due to ridge and furrow method of sowing in pearlmillet. They also observed that moisture conservation practices were beneficial only in scanty rainfall years.

Seed yield data (Table 1) further explicited that soaking seed in water and then dried before sowing (i.e. seed hardening process) produced mean seed yield (524 kg/ha) significantly superior to normal drill sowing, but at par to ridge and furrow method of sowing. The plant growth and yield attributing characters recorded under this treatment were found to be at par to those recorded with ridge and furrow sowing methods. The highest net income of Rs 8600 /ha was obtained by seed hardening treatment. Heneckel, 1964 observed that increase in seed yield due to seed soaking was due to the fact that it initiated the formation of vital biomolecules, stimulated mitochondrial activity and preserved cellular infrastructure, possibly through depression of genes which would allow plants to resist adverse edapho-climatic conditions. Although consumptive use of water (269 mm) and water use efficiency (1.86 kg/ha/mm) were low in seed hardening treatment in comparison to moisture conservation practices, but with seed hardening the crop escaped drought by maturing earlier. Similar results were obtained by Dayanand *et al.* (1972) who found that seed soaking in water hastened the germination of wheat seed by 2-3 days and enhanced grain yield. Similarly Sengupta *et al.* (1984) recorded seed yield improvement in black gram. Jain *et al.* (2000) compiled research work done on configuration and seed hardening practices in different part of India and found that seed hardening resulted in highest net returns and cost benefit ratio.

It is therefore concluded that seed hardening practice is as effective as ridge and furrow sowing method to partially mitigate the effect of drought in sesame crop.

Table 1 Effect of different soil moisture conservation practices on seed yield, yield attributes of sesame and economics (pooled)

Practice	Plant height (cm)	Primary Branches/ plant	Capsules/ plant	Test weight (g)	Oil content (%)	Seed yield (kg/ha)				Harvest index (%)	Net returns (Rs/ha)	Mean consumptive use of water (mm/ha)	Mean water use efficiency (kg/ha/mm)
						Ist	IInd	IIIrd	Pooled				
T_1*	124	4	58	2.8	47.4	374	139	1119	544	17.4	8100	280	1.91
T_2	125	5	60	2.8	47.4	376	163	1124	554	17.6	8150	292	1.91
T_3	118	4	53	2.7	47.2	311	110	951	457	16.8	6925	261	1.70
T_4	115	4	52	2.7	47.2	332	100	934	452	16.3	6800	260	1.66
T_5	122	4	59	2.8	47.6	371	119	1080	524	17.3	8600	269	1.86
T_6	116	4	52	2.7	46.9	301	102	918	441	16.3	6525	261	1.62
SEm ±	1.8	0.2	2.6	0.01	0.1	34	10	42	19	0.2	-	-	-
CD (P=0.05)	3.7	NS	7.3	0.03	0.3	NS	29	127	53	0.5	-	-	-

NS = Non significant; * Details in materials and methods.

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Short communication

Effect of moisture stress on seed yield and quality in sunflower, *Helianthus annuus* L.

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Productivity of sunflower is often affected by various stresses, of which moisture stress is the most important. Seed development and seed filling of sunflower is largely influenced by available moisture Hegde (1988). Significant reduction was reported in plant height, leaf area index and *dry matter accumulation when the crop was exposed to* moisture stress at flowering stage Chamundeshwari and Praveen Rao (1988). The scanty information available on effect of moisture stress on seed quality indicated its importance on various quality characters. Hence, it is desirable to identify and apply irrigation at correct crop growth stages to improve seed yield and quality.

The experiment with five treatments was conducted in a randomized block design with four replications during *rabi*, 2000–2001 (Table 1). The data for growth parameters i.e., leaf area index (LAI) and dry matter accumulation (DMA) were recorded at 21, 43, 65, and 87 DAS while, yield and yield components were studied at maturity (Table 1).

Table 1 Effect of moisture stress on growth parameters, yield and its components and seed quality character in sunflower

Treatment/ Character	DAS	T_1	T_2	T_3	T_4	T_5	SEm±	CD (P=0.05)
Leaf Area Index (LAI)	21	0.14	0.09	0.14	0.14	0.14	0.01	0.02
	43	1.4	1.1	1.0	1.5	1.5	0.01	0.02
	65	3.2	2.4	2.5	2.3	3.1	0.02	0.07
	87	2.4	1.7	1.9	1.7	2.1	0.02	0.06
Dry matter accumulation	21	1.32	0.83	1.29	1.32	1.36	0.03	0.08
	43	16.2	12.0	12.7	16.1	16.3	0.11	0.34
	65	99	81	86	84	99	1.2	3.7
	87	132	119	124	111	115	1.2	3.7
Capitulum diameter (cm)	-	16.9	15.7	15.7	13.5	14.3	0.07	0.21
Seed filling (%)	-	85	80	80	75	76	0.2	0.8
100 seed wt. (g)	-	4.0	3.6	3.8	3.6	3.5	0.2	0.7
Seed yield/plant (g)	-	27.5	22.9	24.3	21.4	22.2	0.2	0.6
Harvest index (%)	-	22.8	21.1	21.5	20.8	21.1	0.3	0.9
Seed recovery (%)	-	92	87	84	82	81	0.7	2.2
Oil content (%)	-	41	38	40	37	36	0.3	0.9
Kernel wt. (g)	-	3.7	3.2	3.4	3.2	3.0	0.1	0.2
Kernel to Hull ratio	-	2.7	1.8	2.0	1.7	1.5	0.1	0.2
Shelling (%)	-	73	64	67	63	60	1.5	4.6
Germination (%)	-	87	80	82	79	82	0.9	2.8
Rate of germination	-	20.7	18.6	19.1	17.8	18.3	0.2	0.7
Seedling vigour index	-	1871	1643	1704	1550	1616	13	39

DAS : Days after sowing

T_1 : No stress; T_2 : Moisture stress at vegetative stages; T_3 : Moisture stress at bud initiation stage; T_4 : Moisture stress at flowering stage; T_5 : Moisture stress at seed filling stage

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The other parameters i.e., harvest index (HI), seed recovery (%) kernel weight, kernel to hull ratio, capitulum diameter, shelling percentage and seed yield per plant were estimated after harvest. Oil content in the seeds was estimated by Nuclear Magnetic Resonance (NMR). Germination test was conducted using between the paper method (ISTA, 1985). Data on germination (%), root length and shoot length were calculated as per Abdul Baki and Anderson (1973). Rate of germination was calculated by adding the quotients of daily counts divided by number of days of germination.

There was maximum decline in LAI and DMA (28.1 and 15.2 % respectively) in plants subjected to moisture stress at flowering stage. However, with the release of stress at seed filling stage there was marginal increment in the values of various growth parameters. Similarly, the various yield attributes like capitulum diameter, seed filling %, seed yield per plant and HI were most affected when moisture stress was imposed at flowering stage (Table1). These observations are in accordance with Hegde and Havanagi (1989) and Chamundeshwari and Praveen Rao (1988). This may be attributed to reduction in LAI and inefficient photosynthetic activity leading to poor translocation of photosynthates from source to sink. The reduced seed yield may be attributed to reduction in various yield components (Stone *et al.*, 1996). However, 100 seed weight and seed recovery % (with decrease of 12.5 and 12.0%, respectively) were most affected in plants subjected to moisture stress at seed filling stage. This could be due to non-availability of moisture during critical stage of seed filling which reflected in the size of the seed.

The quality characters; oil content, kernel weight, kernel to hull ratio and shelling percentage were reduced by 12.2, 18.9, 44.4 and 17.8% respectively, when moisture stress was imposed at seed filling stage (Table 1). Germination, rate of germination and seedling vigour index declined by 9.2, 14.0 and 17.1 respectively in plants subjected to stress at flowering stage compared to no stress. Similar results were reported by Singh *et al.* (1994).

The study revealed that various growth parameters, yield attributes and quality characters showed significant reduction when moisture stress was imposed during flowering stage. The characters like 100 seed weight, seed recovery (%), kernel weight, kernel to hull ratio and shelling (%) were more effected when plants experienced moisture stress during seed filling stage. However, moisture at flowering stage had more effect on germination %, rate of germination and seedling vigour index as compared to seed filling stage.

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Short communication

Productivity of sunflower, *Helianthus annuus* L. based intercropping systems under *rabi* irrigated conditions

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India is falling short of per capita daily requirement of oilseeds, though 17 years have passed after launching technology mission on oilseeds. The shortage of oilseeds and pulses has aggravated the problem of malnutrition. In the present era of industrialization and urbanization, the scope of area expansion of oilseeds crops is limited. The solution is therefore to increase the productivity/unit area, which can be achieved through intercropping. Earlier intercropping systems were viewed in the perspective of minimizing the risk of total crop failure rather than for maximizing the yield. However, in the recent past these systems were viewed to realize the beneficial effects of the system where the production and management levels are high. Higher productivity in intercropping system depends on the selection of compatible crops (Willey, 1979).

Sunflower possesses favourable characteristic and adaptability to wide range of environment (Sindagi, 1982). Earlier studies conducted at Tirupati indicated the possibility of raising sunflower as *rabi* crop with a fair degree of success in alfisols. But the compatibility sunflower with pulses in intercropping system has not been thoroughly evaluated. Hence, this investigation has been conducted to find out suitable intercropping system of grain legumes in *rabi* irrigated sunflower.

A field experiment was conducted at Tirupati campus of Acharya N.G. Ranga Agricultural University on sandy clay loam under irrigated conditions during *Rabi* 1998-99. The pH and EC of the soil were 7.7 and 0.29 dS/m respectively. Groundnut (JL 24), greengram (ML 267), blackgram (LB 20), cowpea (Pusa Phalguni) and soybean (PK 471) were intercropped in sunflower at 1:1 row proportions keeping sole crops as check in a randomized block design and replicated thrice. Sole crop of sunflower was sown at 60x20 cm, groundnut, greengram, blackgram and cowpea at 22.5 x 10 cm and soybean at 30x5 cm spacings between rows x plants. In intercropping treatments 100% population was maintained for base crop (60 x 20 cm) while, 50 % for intercrops by adjusting the intra-row spacing with 7.5 cm for groundnut, greengram, blackgram and cowpea and 5 cm for soybean which were sown in between two sunflower rows. Fertilizers were applied at the rate of 80:50:40 and 30:30:30 kg of N, P_2O_5 and K_2O/ha. For sole crop of sunflower and legumes respectively. In intercropping systems, full dose of sunflower and half the recommended dose of intercrop was applied. Necessary plant protection measures were taken against pests and diseases. A total number of 12 irrigations were given to groundnut, 10 to sunflower and 9 to rest of the crops.

Size of the capitulum, total filled seeds per capitulum, filling percentage and thousand seed weight of sunflower was recorded more with SF+ GN intercropping followed by SF+ BG (Table 1). This might be due to better growth of sunflower with higher leaf area index leading to better photosynthetic efficiency as a result of less competition offered by groundnut and blackgram to sunflower confirming the findings of (Yargattikar and Sheelavantar, 1986; Sarkar and Dhara, 1992). All these yield attributes of sunflower were lower with cowpea as intercrop due to severe competition between the two. This might be due to weak growth of sunflower with lesser leaf area and photosynthetic efficiency as a result of severe competition between sunflower and cowpea.

Number of filled pods/plant of different intercrops decreased in intercropping compared to their respective sole crops (Table 2). Similar findings were reported by Shivaramu and Shivashankar (1992) and Sarkar *et al.*, (1997). Among different intercrops, relative decrease in filled pods was more in cowpea (30.2%) followed by greengram (23.5%) compared to their sole crops. The decrease in filled pods per plant in intercropping was less affected in groundnut (20.5%) followed by blackgram. Number of kernels/seeds/pod and test weight of intercrops were also of similar trend. Reduction in number of seeds/pod was relatively higher in cowpea (11.8%) while, lesser in groundnut. Similarly reduction in test weight

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among different intercrops was relatively higher with cowpea (4.5%) followed by greengram while, lesser in groundnut (1.4%) followed by blackgram (2.4%). This indicated that sunflower has offered relatively higher competition to cowpea and greengram and lesser competition to groundnut and blackgram.

Higher seed yield of sunflower was with sole cropping which was significantly higher to all intercropping systems (Table 2). Soundara Rajan and Srinivasulu Reddy (1991) and Sharma *et al.*, (1995) were also of the same view. Among different intercropping systems, SF+GN produced significantly higher seed yield of sunflower while on par with SF+BG. Lower seed yield of sunflower was with cowpea as intercrop. Reduced yield attributes of sunflower due to acute competition offered by cowpea might be the reason for poor yield in this system. Economical yield of the intercrops was higher with their respective sole crops compared to as intercrops in sunflower. The relative reduction in the yield of intercrops in intercropping systems was to the tune of 57.8% in cowpea followed by greengram compared to their sole crops. This might be due to reduced yield attributes of these crops as a result of more temporal and spatial competition offered by sunflower. Decrease in yield of intercrops in intercropping system was relatively less in groundnut followed by blackgram compared to their sole crops. Stalk and haulm yields of sunflower and intercrops followed similar trend of their seed yields.

Table 1 Yield attributes of sunflower in sole and intercropping

Treatment	Diameter of the capitulum (cm)	Total number of seed/capitulum	Number of filled seeds/ capitulum	Filling percentage	1000 seed weight (g)
Sole SF	17	1052	883	83.9	55
SF+GN	17	1047	865	82.6	53
SF+GG	16	1028	825	80.3	52
SF+BG	17	1045	843	80.7	52
SF+CP	16	975	774	79.4	52
SF+SB	16	1036	834	80.5	52
SEm±	0.2	19	12	0.2	0.2
CD (P=0.05)	0.9	NS	45	0.8	0.9

SF: Sunflower, GN: Groundnut; GG: Greengram; BG: Blackgram; CP: Cowpea; SB: Soybean.

Table 2 *Yield attributes of intercrops, yield (kg/ha), land equivalent ratio and sunflower seed equivalent yield (kg/ha) of different treatments*

Treatment	Number of filled pods/plant	Number of kernels/seeds /pod	100 pod/1000 seed weight (g)	Sunflower (kg/ha)		Intercrops (kg/ha)		Land equivalent ratio	Sunflower seed equivalent yield (kg/ha)
				Seed yield	Stalk yield	Pod/seed yield	Haulm yield		
Sole SF	-	-	-	2757	3728	-	-	1.00	2757
Sole GN	12	3	81	-	-	2469	4020	1.00	2469
Sole GG	18	9	39	-	-	1564	1998	1.00	1564
Sole BG	17	6	41	-	-	1303	1820	1.00	4954
Sole CP	14	8	75	-	-	1453	2050	1.00	1453
Sole SB	18	3	92	-	-	1385	1855	1.00	1039
SF+GN	10	2	80	2665	3706	1180	2056	1.45	3845
SF+GG	14	8	37	2496	3605	680	1040	1.33	3176
SF+BG	14	6	40	2654	3684	610	910	1.43	3569
SF+CP	10	7	72	2327	3585	624	976	1.26	2951
SF+SB	14	2	90	2504	3652	625	909	1.35	2973
SEm±	*	*	*	8	10	*	*	*	37
CD (P=0.05)				23	30				108

SF: Sunflower; GN: Groundnut; GG: Greengram; BG: Blackgram; CP: Cowpea; SB: Soybean.
*Data not analyzed statistically

Intercropping had high land equivalent ratio (LER) than crops (Table 2). Ahmed and Ibrar (1996) and Sarkar *et al.*, (1997) also reported similar findings. LER was maximum with SF+GN intercropping system (1.45) indicating 45% yield advantage over sole crop which was on par with SF+BG (1.43). Lower LER was with SF+CP intercropping system (1.26) because of reduction in yield of component crops as a result of acute competition between sunflower and cowpea. Maximum sunflower seed equivalent yield i.e., 39% higher was attained with SF+GN intercropping system followed by SF+BG which were at par. This might be due to optimum yield of component crops in these systems as a result of less competition Gajendra Giri and Blaise (1994) and Venkatakrishna and Balasubramanian (1997) also reported higher seed equivalents due to groundnut and blackgram because of their complementarity both in time and space. Lower seed equivalent yield was due cowpea as intercrop that produced only 7.04% additional seed equivalent yield.

From the results, it is concluded that groundnut followed by blackgram would be suitable to intercrop in *rabi* irrigated sunflower on sandy clay loam soils of southern agroclimatic zone of Andhra Pradesh.

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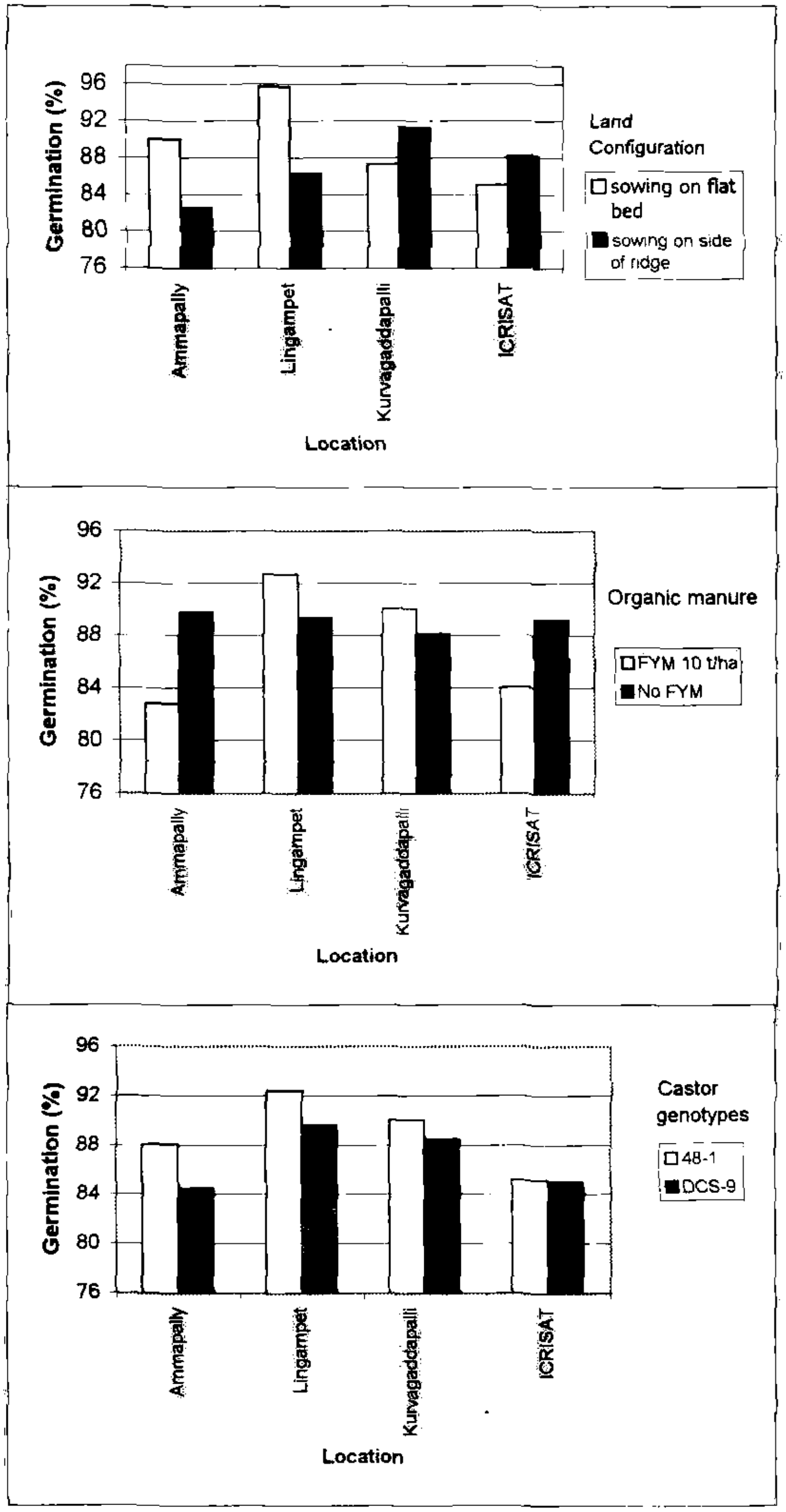

Fig 1 Germination per cent of castor as influenced by land configuration, organic manure and genotypes in sodic vertisols

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Short communication

Castor, *Ricinus communis* L. production in relation to certain agronomic measures under sodic vertisol conditions*

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In India, oilseeds are predominantly raised under rainfed ecosystem by the resource-poor farmers in arid and semi arid zones where soils are salt affected limiting their productivity. Uppal *et al.* (1961) found that castor and mustard are moderately salt tolerant, while linseed and sesame are salt sensitive crops. By and large, high exchangeable Na and high pH caused adverse effects on productivity of sunflower and safflower (Annual Progress Report, CSSRI, 1972,1973, 1974). Of the 8.6 million hectares of salt affected soils in India, about 0.46 m.ha occurs in Andhra Pradesh. The semi-arid districts of Mahaboobnagar (0.051 m.ha), Nalgonda (0.023 m.ha) and Medak (0.016 m.ha) where castor is raised as a predominant crop, deserve attention in terms of enhancing its productivity on salt affected soils, where the choice of raising other crops is limited, through the adoption of salt tolerant genotypes and agronomic management encompassing land configuration and amendments.

On-farm experiments were organized during 2000 in Mahaboobnagar district to evaluate the influence of land configuration and organic manure application on the performance of two castor genotypes as there is paucity of information on these aspects under real farm situations. For this study, the vertisols (medium deep to deep black soils) in 10 villages covering 24 farmer's fields were characterized for chemical properties like pH, EC and exchangeable Na. From these, three farmer's fields were selected. The pH of the soils ranged from 8.4-8.9, EC 0.6-1.2 dS/m and exchangeable Na 11.3 meq/100g.

One more field trial was conducted at ICRISAT, Patancheru, the soil of which is characterized by pH 8.1, EC 1.0 dS/m, available P_2O_5 17.3 kg/ha and available K_2O 840 kg/ha. The treatments comprising combination of two land configurations (sowing on flat bed and on the side of the ridges) and organic manure (FYM application @ 10 t/ha and no FYM) as main-plot treatments and two castor genotypes (48-1 and DCS-9) as sub-plot treatments were tested in split-plot design with four replications at Ammapally, Lingampet, Kurvagaddapally of Mahaboobnagar and ICRISAT, Patancheru. At Ammapally and Lingampet the crop was spaced at 90x60 cm and sown on 29th and 31st July 2000 respectively. At Kurvagaddapally it was sown on 6th October 2000 at 80 x 80 cm spacing, while at ICRISAT it was seeded on 4th October 2000 adopting 75 x 75 cm spacing. At Kurvagaddapalli and ICRISAT one life saving irrigation was provided, while at other locations it was raised as rainfed crop. The observations were recorded on growth parameters, physiological parameters like relative water content, osmotic potential, yield components and yield. The oil content in seed was estimated by Nuclear Magnetic Resonance (NMR) technique. For measurement of osmotic potential, the electrical conductivity (EC) of the saturation extract of the plant was used and the potential was calculated as:

Osmotic potential (A)=0.36 (EC x 10) where (EC x 10) is in mmhos /cm and A is in bars (USDA Hand Book 16).

The relative water content of the plant was calculated by using the formula:

$$\text{Relative water content (RWC)} = \frac{\textit{Fresh weight - dry weight}}{\text{Turgid weight-dry weight}} \times 100$$

Germination

The seed germination, a measure of salt stress tolerance in the early stages, was significantly influenced by land configuration at Lingampet and Ammapally where there was more germination in flat bed sowing as compared with sowing on ridge. During *rabi* sowing at Kurvagaddapalli and ICRISAT, seeding on side of ridge had an edge over flat bed sowing in seed germination.

Germination was not significantly influenced by application of farmyard manure at all locations barring Lingampet, where FYM @ 10 t/ha substantially enhanced germination over no FYM (Fig.1).

Among genotypes, the germination in cv.48-1 was relatively higher than in DCS-9, though the variations were not discernible. At Lingampet, application of FYM @10

* Part of the experiments conducted under NATP ROPS-16 Project funded by World Bank under rainfed agro-eco system.

t/ha has substantially improved germination of DCS-9 than no FYM, while that of 48-1 was not altered. At ICRISAT, FYM application distinctly reduced the germination of 48-1, while that of DCS-9 was unaffected (Fig.1). Reduced germination with increased salinity and differential response of castor genotypes was reported (Raghavaiah et al. 2002).

Growth

The crop growth in terms of plant stature was significantly higher when sown on ridges than flat bed only at Ammapally. Application of FYM did not induce more growth of plants. The genotype 48-1 was found significantly taller than DCS-9 at all the locations except at Lingampet. (Table 1).

The dry matter production was not influenced by land configuration. Application of FYM @10 t/ha resulted in higher dry matter production than no FYM and the genotype, 48-1 gave higher dry matter than DCS-9 at ICRISAT. Weiss (1983) observed that castor can tolerate not only higher alkalinity (up to pH 8.5) but can also withstand acidity (pH 5-6.5). Castor genotypes 48-1, DCS-9, PCS-4 were reported promising for salinity tolerance in terms of germination, shoot and root growth and their fresh weights in a laboratory study (Muralidharudu et al. 2000).

Physiological parameters

The relative water content (RWC) of plants, a measure of plant turgidity, was not influenced by land configuration, farmyard manure application and genotypes of castor at 20 DAS (Table 1). Variety DCS-9 raised without FYM application produced seedlings of distinctly higher relative water content than those grown with FYM. Like wise DCS-9 raised on flat bed possessed substantially higher RWC than that grown on ridges. However, cv.48-1 did not exhibit discernible variation in its relative water content in relation to organic manure application and land configuration at Kurvagaddapalli.

The physiological response of living cells to water stress is closely related to the free energy of water in the cells. The availability of water for physiological processes decreases as the potential lowered. The osmotic potential of the leaf tissue of the crop raised on flat bed was substantially greater than that raised on ridges at Lingampet and ICRISAT. Like wise, the osmotic potential of the plants raised without FYM was more than that of those grown with FYM. However, the genotypes did not differ in their osmotic potential. At Lingampet, the crop raised on flat bed with FYM maintained more osmotic potential than those grown without FYM. In the current experiments, lower osmotic potential was observed in plants raised on ridges and with FYM application, indicating higher water availability for physiological processes vis-a vis those grown on flat bed and with out FYM (Table 1).

Table 1 Effect of organic practices on plant height, drymatter, relative water content (RWC) and osmotic potential (OP) of castor genotypes in sodic vertisols

Treatment	Ammapally			Kurvagaddapalli			Lingampet				ICRISAT			
	Plant height (cm)	Dry-matter (g/pl) (30 DAS)	RWC (%)	Plant height (cm)	Dry-matter (g/pl) (30 DAS)	RWC (%)	Plant height (cm)	Dry-matter (g/pl) (30 DAS)	RWC (%)	Osmotic potential (-bars)	Plant height (cm)	Dry-matter (g/pl) (30 DAS)	RWC (%)	OP (-bars)
Land configuration														
Sowing on flat bed	119.0	0.17	64.5	52.5	1.05	83.3	116.0	2.16	84.3	22.1	80.8	1.97	87.0	32.6
Sowing on side of ridge	130.8	0.82	67.7	51.2	1.00	80.1	120.5	2.07	88.1	20.3	74.1	1.04	88.9	23.2
SEm±	1.7	0.1	4.2	2.0	0.2	1.4	4.6	0.1	2.2	0.2	2.2	0.02	0.9	5.6
CD (P=0.05)	7.8	NS	NS	NS	NS	NS	NS	NS	NS	1.1	NS	NS	NS	NS
Organic manure														
FYM 10 t/ha	128.5	0.58	66.7	52.6	1.08	78.6	117.7	2.25	83.5	20.3	74.8	1.67	89.8	28.9
No FYM	121.2	0.94	65.4	51.0	0.98	84.7	118.7	1.98	88.9	22.1	80.0	1.34	86.0	29.8
SEm±	2.4	0.1	5.1	2.2	0.2	2.3	2.7	0.1	1.9	0.1	2.0	0.09	2.6	0.9
CD (P=0.05)	NS	0.34	NS	NS	NS	NS	NS	NS	NS	0.37	NS	0.3	NS	NS
Genotypes														
48-1	136.8	0.91	67.9	59.2	0.98	81.8	121.6	2.39	87.2	21.4	83.1	1.87	87.3	28.7
DCS-9	112.9	0.61	64.1	44.4	1.08	81.5	114.8	1.84	85.2	21.0	71.7	1.14	88.5	30.0
SEm±	1.8	0.1	2.5	2.2	0.1	1.1	3.6	0.2	2.5	0.1	2.8	0.08	1.6	0.8
CD (P=0.05)	5.7	NS	NS	6.6	NS	NS	NS	NS	NS	NS	8.67	0.2	NS	NS

Yield and yield attributes

At ICRISAT, the crop raised on flat bed offered superior castor bean yields than that grown on ridges, though the variations were not discernible at other three locations (Table 2). This was due to non significant variations in test weight of seed. Application of FYM did not offer much yield advantage over no FYM. The genotype DCS-9 offered significantly higher yield than 48-1 at Ammapally, while they remained comparable at Lingampet and Kurvagaddapally. At ICRISAT, 48-1 provided superior yields to DCS-9. At Ammapally, DCS-9 sown on ridges resulted in substantial improvement in yield over that sown on flat bed and 48-1 sown either on ridge or flatbed (Table 3). At ICRISAT, 48-1 gave higher yield than DCS-9 without FYM, while they were comparable when grown with FYM (Table 4). The test weight of the seed was not altered due to organic manure application except at Ammapally, where FYM gave seeds of higher test weight than no FYM. The genotype 48-1 produced seeds of significantly higher test weight than DCS-9. Mass and Hoffman (1977) compiled available data on salt tolerance for 30 years and reported that salt tolerance and yield potential are independent of each other.

Oil content

The oil content of the castor seed was not altered much by different land configurations. Application of FYM improved oil content at Lingampet, while at other centers the improvement was not discernible (Table 2). At ICRISAT, the genotype 48-1 produced seeds of higher oil content than DCS-9, while at other centers the differences were not appreciable. At Kurvagaddapally, sowing on ridges along with application of FYM resulted in significant improvement in oil content than sowing on flat bed with FYM and sowing on ridge with out FYM (Table 5).

Table 2 Effect of agronomic practices on test weight, bean yield and oil content of castor genotypes in sodic vertisols in different locations

Treatment	Ammapally			Lingampet			Kurvagaddapalli			ICRISAT		
	Test weight (g)	Bean yield (kg/ha)	Oil content (%)	Test weight (g)	Bean yield (kg/ha)	Oil content (%)	Test weight (g)	Bean yield (kg/ha)	Oil content (%)	Test weight (g)	Bean yield (kg/ha)	Oil content (%)
Land configuration												
Sowing on flat bed	27.4	264.4	43.5	23.7	83.3	41.8	20.7	108.9	41.5	29.9	487.2	50.0
Sowing on side of ridge	26.5	236.5	43.8	24.5	197.6	42.0	23.1	144.1	41.1	30.1	390.1	50.1
SEm±	0.5	19.1	0.5	0.6	15.8	0.3	0.6	25.8	0.5	0.3	16.2	0.49
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	73.5	NS
Organic manure												
FYM 10 t/ha	28.3	239.0	43.2	24.1	171.7	42.4	21.2	132.0	41.7	29.9	430.5	50.2
No FYM	25.7	261.8	44.2	24.0	209.1	41.4	22.6	121.0	40.9	30.1	446.8	49.9
SEm±	0.4	22.4	1.3	0.2	24.3	0.2	0.7	18.7	0.6	0.5	32.1	0.3
CD (P=0.05)	1.51	NS	NS	NS	NS	0.91	NS	NS	NS	NS	NS	NS
Genotypes												
48-1	30.0	226.4	44.6	25.7	183.6	41.9	21.9	106.4	41.3	30.5	471.5	52.1
DCS-9	24.0	274.4	43.3	22.5	197.1	41.8	21.9	146.6	41.3	29.5	405.7	48.0
SEm±	0.7	9.0	0.3	0.5	11.8	0.3	0.5	19.6	0.8	0.3	16.7	0.2
CD (P=0.05)	2.3	27.7	NS	1.54	NS	NS	NS	NS	NS	0.9	51.6	0.9

Table 3 **Interaction effect of land configuration and genotypes on castor bean yield (kg/ha) in sodic soil at Ammapally**

Land configuration x genotypes	48-1	DCS-9	Mean
Sowing on flat bed	229	249	239
Sowing on side of ridge	224	299	262
Mean	226	274	
SEm±	12.7		
CD (P=0.05)	39.2		

Table 4 **Interaction effect of FYM and genotypes on castor bean yield (kg/ha) on sodic soil at ICRISAT**

FYM x Genotypes	48-1	DCS-9	Mean
FYM (10 t/ha)	433	427	430
No FYM	510	384	447
Mean	471	406	
SEm±	23.7		
CD (P=0.05)	73.1		

Table 5 **Interaction effect of land configuration and FYM on castor oil content (%) on sodic soil at Kurvagaddapalli**

Land configuration x FYM	FYM 10 t/ha	No FYM	Mean
Sowing on flat bed	40.05	43.02	41.53
Sowing on side of ridge	43.37	38.95	41.16
Mean	41.71	40.98	
SEm±	0.9		
CD (P=0.05)	3.5		

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Short communication

Weed management in soybean, *Glycine max* L.

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Soybean is known as a potential yielder, but its productivity has been low due to several factors, the foremost among them being the menace caused by weeds, which deplete large amount of nutrients and moisture. Weeds cause a loss of about 29-87 % of the total soybean yield (Mishra *et al.*, 1990). The competition from weeds is severe, especially during early stages of crop growth, as the initial growth of the crop is slow. Among the several practices to control the weeds, hand weeding is the traditional method which is widely followed even today. Hand weeding is not feasible at all the times, often it becomes ineffective as it is time consuming and constrained by less labour availability during peak periods of weeding. Sometimes incessant rains also make hand weeding difficult. In this context, control of weeds through use of combinations of herbicides and cultural practices can be viable at farmers level. Maintaining suitable crop stands coupled with application of pre-emergence herbicide mixtures can provide greater scope for effective and timely weed management.

A field experiment was therefore conducted at S.V.Agricultural College Farm, Tirupati during *rabi* 1999-2000 on soybean cultivar, JS-335 under irrigated condition. The crop was sown on 19-12-1999 and harvested on 8-3-2000. An amount of 74.4 mm rainfall was received in 5 rainy days. The experiment was laid out in a split-plot design with crop stands as main plot and weed management practices as sub-plot treatments. The treatments were replicated thrice with three levels of crop stands and five weed management practices (Table 1). The crop received a total of six irrigations during the crop season. Need based plant protection measures were taken. Observations on weed density, weed dry weight, seed and haulm yields were recorded.

The predominant weed species in the experimental fields were *Dactyloctenium aegyptium, Chloris barbata, Cyperus rotundus, Cleome viscosa, Trianthema portulacastrum* and *Eclipta alba*. The results revealed that adopting a closer spacing of 15 x 10 cm recorded the lowest weed density and dry weight (Table 1). This might be due to early canopy coverage, which caused smothering effect on weed growth and development. Pre-emergence application of oxyfluorfen (0.125 kg/ ha) or metolachlor (0.5 kg/ ha) along with pendimethalin (0.5 kg/ ha) resulted in significant reduction of weed density and dry weight at early stages. However, observations at harvest showed that hand weeding was found to be a superior method of weed management to any of the herbicide combinations. This might be due to gradual decomposition of herbicide compounds with time. The findings of the present study are in accordance with those of Balasubramaniam and Arumugam (1996).

The seed yield (Table 2) increased due to the increase in plant stand from 3.33 to 4.44 lakh/ha, and a further increase in stand to 6.66 lakh/ha (15x10 cm) led to drastic yield reduction, due to competition among plants for sunlight, space, nutrients and moisture and to over come the competition, plants grew taller and prolonged the vegetative phase. This resulted in excess crop dry mass production, thus led to considerably lower yields. Zaric (1994) also opined that the seed yield beyond a plant population of 4 lakh/ ha reduced to a considerable extent. Seed yield recorded with a spacing of 22.5 x 10 cm was significantly higher and more remunerative than wider spacing of 30 x 10cm. These results are in conformity with the reports of Agarwal *et al.*, 1996; Dubey, 1998. The haulm yield (Table 2) was significantly higher with the closer spacing of 15x10 cm than the other spacings.

Pre-emergence application of oxyfluorfen @ 0.125 kg a.i./ha+pendimethalin @ 0.5 kg a.i./ha offered significantly higher seed yield than the rest of the treatments. Metolachlor @ 0.5 kg a.i./ha+pendimethalin @ 0.5 kg a.i./ ha and hand weeding twice were the next best treatments. The highest seed and haulm yields were due to effective suppression of weeds in the early stages, which was evidenced from maximum growth parameters and yield attributes recorded. Similar findings were reported by Ved Prakash *et al.* (1991). Seed yield of pre plant incorporation of fluchloralin @ 0.5 kg a.i./ ha+pendimethalin @ 0.5 kg a.i./ha was significantly inferior to other weed management practices, as fluchloralin was highly volatile, this was evident from higher weed count and weed dry matter recorded. The results are in accordance with Jat *et al.* (1998) and Mehar Singh *et al.* (1996). Un checked weed

Table 1 Weed density and dry weight as influenced by drop stand and weed management practices in soybean

Treatment	Weed density (number/m²)								Weed dry weight (g/m²)							
	30 x 10 cm	22.5x10 cm	15x10 cm	Mean	30 x 10 cm	22.5x10 cm	15x10 cm	Mean	30 x 10 cm	22.5x10 cm	15x10 cm	Mean	30 x 10 cm	22.5x10 cm	15x10 cm	Mean
Weedy check	210 (14.5)	185 (13.6)	161 (12.7)	185 (13.6)	490 (22.1)	436 (20.9)	359 (19.0)	428 (20.7)	34 (5.8)	33 (5.7)	31 (5.5)	32 (5.7)	171 (13.1)	159 (12.6)	138 (11.7)	156 (12.5)
Hand weeding at 20 x 40 DAS	206 (14.4)	179 (13.4)	160 (12.7)	182 (13.5)	59 (7.7)	46 (6.8)	33 (5.7)	46 (6.8)	33 (5.7)	31 (5.5)	31 (5.5)	31 (5.6)	20 (4.5)	16 (4.0)	15 (3.8)	17 **(4.1)**
Metolachlor 0.5 kg a.i./ha + Pendimethalin 0.5 kg a.i./ha	28 (5.3)	19 (4.4)	30 (5.5)	25 (5.0)	113 (10.6)	91 (9.5)	66 (8.1)	90 (9.5)	5 (2.2)	4 (2.1)	4 (1.9)	4 (2.1)	53 (7.3)	39 (6.3)	29 (5.3)	**40 (6.3)**
Oxyfluorfen 0.125 kg a.i./ha + Pendimethalin 0.5 kg a.i./ha	27 (5.2)	24 (4.9)	18 (4.2)	23 (4.8)	105 (10.3)	85 (9.2)	65 (8.1)	85 (9.2)	3 (1.8)	3 (1.7)	3 (1.7)	3 (1.7)	39 (6.3)	31 (5.5)	24 (4.9)	**31 (5.6)**
Fluchlorlin 0.5 kg a.i./ha + Pendimethalin 0.5 kg a.i./ha	46 (6.8)	40 (6.3)	34 (5.8)	40 (6.3)	178 (13.3)	139 (11.8)	126 (11.2)	147 (12.1)	6 (2.5)	6 (2.4)	6 (2.4)	6 (2.5)	88 (9.4)	73 (8.6)	64 (7.9)	**75 (8.6)**
Mean	103 (9.2)	89 (8.5)	80 (8.2)	-	189 (12.1)	159 (11.6)	129 (10.4)	-	16 (3.6)	15 (2.5)	15 (3.4)	-	74 (8.1)	64 (7.4)	54 (6.7)	-

Figures in parenthesis are square root transformed values.

	Weed density				Weed dry weight			
	At 20 DAS		At harvest		At 20 DAS		At harvest	
Source	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
C	**0.12**	0.48	0.11	0.43	0.03	**0.12**	0.03	**0.12**
W	**0.13**	0.37	0.11	0.33	0.02	**0.07**	0.07	**0.20**
W at C	**0.22**	0.65	0.19	**0.57**	0.04	**0.12**	0.12	0.35
C at W	**0.26**	0.84	0.23	**0.75**	0.04	**0.13**	**0.08**	0.25

C = Crop stand W = Weed management practices

Table 2 Yield and economics as influenced by crop stand and weed management practices in soybean

Treatment	Seed yield (kg/ha)				Haulm yield (kg/ha)				B:C ratio			
	30x 10cm	22.5x 10cm	15x 10cm	Mean	30x 10cm	22.5x 10cm	15x 10cm	Mean	30x 10cm	22.5x 10cm	15x 10cm	Mean
Weedy check	274	304	268	282	465	527	608	533	0.64	0.67	0.52	0.61
Hand weeding at 20 & 40 DAS	945	1046	922	971	960	1051	1275	1096	1.67	1.74	1.41	1.60
Metolachlor 0.5kg a.i./ha + Pendimethalin 0.5kg a.i./ha	967	1071	943	994	1069	1173	1411	1218	1.78	1.84	1.49	1.70
Oxyfluorfen 0.125kg a.i./ha + Pendimethalin 0.5kg a.i./ha	1013	1142	999	1051	1093	1207	1433	1245	1.76	1.89	1.51	1.72
Fluchlorlin 0.5kg a.i./ha + Pendimethalin 0.5kg a.i./ha	805	924	786	838	1054	1184	1391	1210	1.47	1.60	1.23	1.43
Mean	801	897	783		928	1028	1224		1.46	1.55	1.23	

	Seed yield		Haulm yield	
Source	SEm ±	CD (P=0.05)	SEm ±	CD (P=0.05)
C	16	64	18	74
W	8	[illegible]	14	43
W at C	10	33	19	56
C at W	7	25	15	46

C: Crop stand; W : Weed management practices
B:C ratio was not analysed statistically

growth reduced seed yield by 75 % as compared with hand weeding twice. These results are in agreement with the earlier findings of Kumar (1998).

A spacing of 22.5x10 cm along with pre-emergence application of oxyfluorfen (0.125 kg/ ha) + pendimethalin (0.5 kg/ ha) was found effective and economical for higher yields in soybean.

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Short communication

Productivity and quality of soybean, *Glycin max* (L.) Merrill as influenced by integrated methods of weed management

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Severe weed competition is mainly responsible for low productivity in soybean. Being a *Kharif* season crop, congenial soil moisture conditions coupled with suitable temperature (30-35° C) as well as better nutrient availability to weeds to appear simultaneously with crop plants, leading to heavy competition for nutrients, light, moisture and space. Bandiwaddar and Itnal (1998) reported 63.4 % reduction in soybean yield due to weed competition. Weeds can be managed in soybean with a well-planned programme that involves a through analysis of the field situation and use of a combination of cultural practices coupled with herbicides.

An experiment in split-plot design was laid out during *Kharif* 2001 at Crop Research Center of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The date of planting (optimum, 5th July, delayed, 20th July) and row spacing (30 cm and 60 cm) were kept in main plots and different weed management practices (Meteibuzin @ 1.0 kg/ha, Alachlor @ 2.5 kg/ha pendimethelin @ 1.5 kg/ha, weed free and weedy check) in sub plots were replicated four times. Soybean variety PK-1024 was planted using 80 kg seed/ha. Experimental soil was silty clay loam in texture, medium in organic carbon (0.96 %), phosphorus (18 kg/ha) and potassium (125 kg/ha) having pH-7.3. Data on weed dry matter and density was subjected to log transformation.

Echinochloa colonum, Eluesine indica, Dactyloctenium aegyptium, Brachiaria mutica, Commelina benghalensis, Celosia argentea, Cleome viscosa and Cyperus rotundus were dominating weed species, which infested the experimental field. The data in Table 1 revealed that at 60 days stage, highest weed dry matter (4.07 g/m^2) was recorded in delayed planting and wider row spacing (3.88 g/m^2) as also reflected by weed index. All the weed management methods significantly reduced the weed dry matter as compared to weedy check. Metribuzin @ 1.0 kg/ha recorded significantly lower weed dry matter (3.61 g/m^2) as compared to other weed management practices. Plant dry matter was significantly higher in timely planted crop as compared to delayed one. Dry matter of crop planted was also significantly lower in weedy check over rest of the treatments.

In general higher grain yield was recorded in optimum planting date (3049 kg/ha) as compared to delayed planting (2390 kg/ha). Similar results were also reported by Raghuvanshi *et al* (1988) and Madhavi *et al* (1997). Narrow row spacing also recorded higher yield than wider row spacing. However the grain yield was not influenced significantly due to row spacing. Under different weed control treatments highest grain yield (3343 kg/ha) was recorded in weed free treatment which was at par with Metribuzin @ 1.0 kg/ha (3219 kg/ha) and significantly higher as compared to other weed control treatments. This might be due to production of higher growth and yield parameters in these treatments. Protein content of soybean grain was not significantly influenced by date of planting, row spacing and different weed management practices. Oil content was also not significantly influenced by date of planting and row spacing. However significantly higher oil content was recorded in weedy check treatment as over rest of the treatments. Different weed management methods followed negative relationship between oil and protein content.

Table 1 Effect of various treatments on grain yield, oil and protein content of soybean dry matter of weeds

Treatment	*Grain yield* (kg/ha)	*Weed index* (%)	*1000-grain* wt. (g)	*Oil content* (%)	*Protein* content (%)	*Plant dry* matter (g/m^2)	*Dry matter of weeds* (g/m^2) 60 DAS
Date of planting							
Optimum (July 5th)	3049	30.3	113.2	20.5	40.4	11.7	3.6 (113.9)
Delayed (25^{th})	2390	30.8	116.6	20.3	40.2	2.6	4.1 (158.1)
SEm ±	382	-	1.79	0.1	0.2	1.09	0.16
CD (P=0.05)	NS	-	NS	NS	NS	3.48	0.51
Row spacing (cm)							
30	2821	30.3	116.5	20.1	40.3	7.3	3.8 (126.9)
60	2629	30.9	113.4	20.4	40.3	6.9	3.9 (145.1)
SEm ±	382	-	1.79	0.1	0.15	1.09	0.16
CD (P=0.05)	NS	-	NS	NS	NS	NS	0.51
Weed management practices							
Metribuzin 1.0 kg/ha	3219	15.4	113.8	20.0	40.2	7.4	3.6 (53.1)
Alachlor 2.5 kg/ha	2662	32.0	112.3	20.3	40.4	8.1	5.1 (182.6)
Pendimethalin 1.5 kg/ha	2744	26.3	114.1	20.3	40.1	6.4	4.8 (151.7)
Weed free	3343	0.0	121.9	20.1	40.0	8.8	0.0 (0.0)
Weedy	1659	53.0	112.5	20.5	40.1	4.8	5.6 (292.7)
SEm±	146	-	1.50	0.1	0.2	0.79	0.16
CD (P=0.05)	415	-	4.28	0.3	NS	2.24	0.46

Original data in parenthesis

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Short communication

Response of castor, *Ricinus communis* L. to sulphur application in alfisol

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Castor is one of the important non-edible oilseed crops cultivated in red '*chalka*' soils (Alfisol) of Andhra Pradesh under rainfed conditions. These soils are in general, low in soil fertility and available sulphur (Saharan *et al.*, 1989), which is an essential nutrient for improving oil quantity and quality. Sulphur is one of the limiting nutrients in reducing the castor seed yield in these soils and its application will increase the S bioavailability. Average critical S level of soil reported with $CaCl_2$ extractant was 13 mg/kg for oilseed crops (Tandon, 1991) and these crops were known to respond up to certain S level. Under such conditions, determining critical nutrient level is imperative. Realizing the importance of S needs, the present investigation was attempted to study the response to S application and its critical limits for castor as test crop on red soil (Alfisol).

A green house experiment with red sandy loam (Alfisol) soil was conducted during *rabi* 2001. Physico-chemical properties of the soil were as follows: pH 6.2, E.C. 0.23 dS/m, organic C 0.36 %, available N (210 kg/ha), P (15.3 kg/ha) and K (120 kg/ha). Available S (sulphate - S) was 12.2 mg/kg. Experimental design was completely randomized, with three replications. Five kg soil was taken into a polyethylene lined earthen pots and graded doses of S (elemental S) *viz.*, @ 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 and 110 kg/ha were applied. N, P and K were applied as per recommended doses (40:40:0 kg/ha) to all the pots. Two plants per pot of castor cv. DCS-9 were maintained and irrigated with deionized water. Above ground plant parts, shoot with leaves were harvested on 90^{th} day. They were oven dried and digested in 1:2 $HClO_4$-HNO_3 acid mixture (Johnson and Ulrich, 1959). Sulphate-S in initial and post harvest soils were extracted with 0.15 % $CaCl_2$ (Williams and Steinbergs, 1959). The S content in plant and soil extracts was determined by turbidimetric method (Chesnin and Yien, 1950). Dry matter yield of plants, sulphur content and uptake in shoots were recorded. Critical S limits in castor and soil were determined by Cate and Nelson (1965) scatter diagram technique and applying a simple mathematical model (Sharma, 1991).

Graded levels of sulphur application increased significantly the dry weight of castor shoot at harvest (Table 1). This might be due to higher requirement of S in these light textured soils, as sulphate is often subject to leaching and only a limited quantity of applied S is available for plant utilization. Increase in dry matter yield of oilseed crops like sunflower and toria due to increased levels of S application, for different soil types was reported (Sreemannarayana and Sreenivasa Raju, 1994; Raj *et al.*, 1994). Sulphur content in the shoot ranged from 0.016 to 0.410 per cent among the treatments and was found to vary significantly. Sulphur uptake also showed similar trend (Table 1). Ganeshamurthy (1996) reported an increase in S content and uptake, with increased levels of S application to rainfed Soybean.

Available sulphur status of soil after crop harvest varied from 12.1 to 30.5 mg/kg and its content increased with increasing levels of S application (Table 1) which indicated that applied and native S was less utilized by plant. Available S status varied significantly over control at higher levels of S application, which may be attributed to low S status of the soil. Addition of fertilizer S known to increase available S status of soils as cropping without S input will decrease (Intodia and Sahu, 1999).

Critical limits of S

Critical S limits determined by scatter diagram technique for red sandy loam soil and castor shoot were 20 mg/kg and 0.22% respectively. The critical S values computed by simple mathematical model were found to be 22 mg/kg for soil and 0.44 per cent for plant parts (Table 2). Critical S limits ranged from 0.14 to 0.36% in oilseed crops at different growth stages in various plant and its parts (Tandon, 1991). The soil critical S limit determined, was nearly same by both the methods. However, a slightly greater S value observed for plant parts compared to graphical method was in corroboration with the results reported in different crops, with various essential nutrients (Sharma, 1991). Since critical nutrient levels are influenced by several plant and soil factors, the levels determined in pot studies should always be reconfirmed under field conditions before being put into practice.

Table 1 Effect of S levels on castor plant dry matter, sulphur concentration, uptake and soil available S (90 Days after sowing)

S levels (kg/ha)	Shoot			Soil available S (mg/kg)
	Dry matter (mg/plant)	S concentration (%)	S uptake (mg/plant)	
0	18.36	0.16	0.029	12.1
10	21.15	0.18	0.039	12.3
20	21.58	0.21	0.045	12.8
30	22.25	0.22	0.050	13.3
40	23.19	0.24	0.056	14.0
50	25.20	0.26	0.067	15.0
60	25.29	0.29	0.074	20.8
70	27.03	0.31	0.085	21.8
80	27.25	0.35	0.095	27.1
90	27.21	0.36	0.099	28.2
100	28.18	0.39	0.109	28.9
110	28.25	0.41	0.116	30.5
LSD (P=0.05)	1.99	0.01	0.006	9.9

Table 2. Estimated parameters and critical S levels

Nutrient	Pertain to	α	β	γ	Critical levels	
					Graphical	Mathematical model
S (mg/kg)	Soil	8.11	0.16	0.94	20	22
S (%)	Castor shoot	0.19	10.00	0.83	0.22	0.44

α, β and γ are average rate constant, base value and (maximum yield-minimum yield)/maximum yield respectively.

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Short communication

Effect of pre-sowing seed treatment on establishment and seed yield of sunflower

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The seedling emergence and their establishment are two important factors affecting yield potential in sunflower. Under good field stand with vigorous plant growth one can expect the desirable level of crop yield. Seed invigoration treatment helps to improve the germination and vigour of the seed and ultimately it establishes a good field stand and yields higher. Ray (1982) reported that seed treatment greatly reduced physiological deterioration and finally resulted in better field performance and gave higher seed yield in sunflower.

The above information indicated that use of different chemicals may help in improving plant stand by way of invigorating the seed. Therefore, the present investigation was carried out to find out the effect of pre-sowing seed treatment for the better establishment and yield of less vigorous seed lot of sunflower.

A field experiment was carried out in randomized block design replicated four times at Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to find out the effect of per-sowing seed treatment for better crop establishment and yield of sunflower. Seed lot (cv. Modern) selected for study was low in germination (55%). The seeds of sunflower were subjected to the ten pre-sowing treatments along with control (Table 1). The seeds were treated in laboratory for 16 hr. and used for sowing. The sowing was done during *kharif* season of 1998. The crop was grown as per agronomic practices and observations on morphological characters and yield attributes were recorded from five representative plants, which were previously selected randomly and labeled from each treatment per replication.

The treating dry seeds with *Trichoderma harzianum, hydration and seed treated with Thiram as well as hydration with 0.5% KCl and 0.5% $MnSO_4$ solution had* beneficial effect on plant stand establishment as well as germination. The plant height and functional leaves at initial stage were significantly more in GA_3 treatment because cell elongation is the property of GA_3, which resulted in increased plant height but at later stage its effect was reduced and became normal. However, significantly more plant height was reported in Thiram treatment, whereas, significantly low in Thiourea (0.5%) treatment.

Table 1 Effect of different treatments on yield of sunflower

Treatment	Disc size (sq.cm)	Number of filled seeds	Number of filled seeds	Per cent filled seeds	100 seed weight (g)	Seed yield (kg/ha)
T_0 : Control	318	481	106	81.9 (9.07)*	4.1	1276
T_1 : KCL	325	501	103	83.0 (9.14)	4.2	1484
T_2 : KH_2PO_4	321	486	206	82.1 (9.08)	4.1	1435
T_3 : $MnSO_4$	324	492	101	82.9 (9.13)	4.3	1578
T_4 : KNO_3	321	487	104	82.3 (9.11)	4.1	1378
T_5 : Thiourea	301	440	97	81.9 (9.07)	4.1	527
T_6 : GA_2	324	494	110	81.7 (9.07)	4.2	1460
T_7 : Kinetin	335	493	106	82.3 (9.11)	4.1	1407
T_8 : Hydration	322	490	102	82.7 (9.12)	4.1	1410
T_9 : Hydration + Thiram	330	490	102	82.7 (9.12)	4.2	1461
T_{10} : Thiram	367	504	106	82.3 (9.11)	4.2	1527
T_{11} : *Trichoderma harzianum*	368	515	105	82.4 (9.11)	4.1	1657
SEm±	2.3	6.1	2.6	0.019	0.02	20.14
CD (P=0.05)	6.8	17.8	7.4	0.05	0.06	56.59

* Figures in parenthesis are square root transformation values.

The maximum yield of 1657 kg/ha was recorded with the treatment *Trichoderma harzianum* followed by $MnSO_4$ (1578 kg/ha), Thiram (1527 kg/ha), KCL (1484 kg/ha), hydration + Thiram (1461 kg/ha) and GA_3 (1460 kg/ha). It is obvious that these treatments have a better invigoration effect on seed and which was shown on initial and final plant stand in field. In addition to better plant stand some treatments had persistent effect on plant growth and yield parameters. The highest yielding treatment *Trichoderma harzianum* and Thiram also had more plant height, large disc size, maximum number of seed/head, maximum number of filled seed/head, and yield/plant. *Trichoderma harzianum* is the antagonistic agent, which suppresses the growth of many fungi found on seed and in soil. The protection given by *Trichoderma harzianum* helped in germination of poor vigour sunflower seeds Alagarsamy *et al.* (1987). However, Windham *et al.* (1986) reported that *Trichoderma harzianum* increased growth by production of a growth stimulating factor. The treatment with $MnSO_4$ had large flowers, maximum filled seed (%), increased 100 seed weight and yield/plant (Kannadasan *et al.*, 1982) also reported increased seed yield in bajra by $MnSO_4$ treatment. A large flower size with significantly high per cent of filled seeds were found in KCl treatment, it also increased 100 seed weight which might have helped in increasing seed yield. In case of GA_3 treatment, the increased 100-seed weight had just pushed the yield per plot to the level of significance. Dave and Gaur (1972) also reported slight increase in grain production in crop plant by pre-sowing seed treatment with 50 ppm GA_3.

From the study, it is concluded that seed treatment with KCl (0.5%), $MnSO_4$ (0.5%), GA_3 (50ppm), hydration + Thiram, Thiram treatment to dry seeds and *Trichoderma harzianum* to dry seeds, were the treatments increasing seed yield significantly higher than untreated control.

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Short communication

Performance of sunflower intercropped with *Tamarindus indica* under different levels of fertility

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In recent years, arable farming has become unremunerative owing to poor management practices and weather aberrations. Monocropping with high inorganic inputs like fertilizers and pesticides and their continuous and indiscriminate use has brought plethora of environmental problems. Proper crop rotations and cropping systems are not being practiced to sustain the soil health and returns. System approach is one domain for such problems. Agroforestry, a method of tree plus crop integration is the best system approach to maximize returns specially from rainfed agriculture. Agri-Horticulture system has proved beneficial (Gupta and Mohan, 1984; Syed Ismail *et al.*, 1993) under rainfed conditions.

Therefore, a field experiment to assess the advantage of tamarind plus sunflower Agri-Horticulture system was carried out at students' farm during *kharif*, 2001. Four years old tamarind (PKM-1) plantation spaced at 6 x 4 m was selected for study along with control (open area). The experimental treatments were tamarind plus sunflower and sole cropping of sunflower in main plots and seven N and P combinations of N_0 P_0, N_{40} P_{20}, N_{40} P_{40}, N_{40} P_{60}, N_{80} P_{20}, N_{80} P_{40} and N_{80} P_{60} in sub-plots. The design selected was split-plot with three replications. Organic carbon and available nitrogen were low while P and K were found medium in the experimental soil. The plot size was 6 x 4 m in tamarind and 4 x 4 m in open area. The sunflower variety Morden was sown on 7[th] July, 2001 in tamarind and open area at a spacing of 45 x 20 cm. N and P fertilizers were applied as per treatments. The sunflower crop was harvested on 2[nd] October, 2001. Since tamarind had not came to fruiting yields and returns were taken for calculation of gross return in the system.

Growth and yield: Cropping systems and fertilizer doses influenced the drymatter production, crop growth rate (CGR) and seed yield significantly (Table 1). Mean drymatter production of 7740 kg/ha, CGR of 7.9 g/m^2/day and seed yield of 662 kg/ha of sunflower was recorded under sole cropping as compared to intercropping with tamarind (4965 kg/ha, 6.3 g/m^2/day and 470 kg/ha). Competition for the growth resources might have reduced the growth and yield of sunflower in association with tamarind. Earlier, reduction in sunflower seed yield grown in association with ber (Syed Ismail *et al.*, 1993) has also been reported.

Fertilizer levels significantly influenced the growth and yield of sunflower. Application of N_{80} P_{60} produced higher drymatter (7666 kg/ha) CGR, (9.7 g/m^2/day) and seed yield (687 kg/ha) followed by N_{80} P_{40} and N_{80} P_{20}. However, N_{40} P_{60} produced equally comparable seed yields as that of N_{80} with 20, 40 levels of 'P' indicating synergic effects of both the nutrients and nitrogen dose can be reduced by increasing 'P' dose upto optimum level. Minimum growth and seed yields were recorded in the control treatment (N_0 P_0).

Interaction effects were found significant. Under both the cropping systems, increase in fertilizer dose increased the growth and yield of sunflower and the increase was much higher under sole cropping. Fertilizer application to sunflower under tamarind did not result in substantial increase in growth and yield due to the fact that the trees might have taken certain percentage of nutrients indicating additional requirement of nutrients in agroforestry. Similar results were reported by Tomar *et al.* (1988) from an Agri-Horticulture system.

Economics: Benefit cost ratio differed significantly due to cropping systems with a value of 1.26 under intercropping and 0.76 under sole cropping. The reason being additional returns from the trees. Reddy and Sudha (1988) have also reported that Agri-Horticultural system was more profitable than sole cropping or horticultural system alone.

Application of N and P fertilizers at different levels also influenced the B:C ratio significantly. B:C ratio of 1.33 was observed at N_{80} P_{60} which was found superior to other combinations. Increased availability of nutrients and higher seed yields were the reasons ascribed for more B:C ratio at N_{80} P_{60}.

Interaction effects of treatments under study also influenced the B:C ratio. Intercropping with N_{80} P_{60} had higher B:C ratio of 1.59 followed by N_{80} P_{40} (1.49) and N_{80} P_{20} (1.43) and all were found superior to N_{40} with different levels of P under sole cropping at different levels of N and P combinations. Lower B:C ratios were observed indicating sole cropping of sunflower is unremunerative.

From the results of the study, it can be concluded that intercropping of sunflower with tamarind proved remunerative under rainfed conditions.

Table 1 Drymatter, CGR and seed yield of sunflower as influenced by cropping systems and fertilizer levels

Treatment/ Fertilizer level	Drymatter (kg/ha)			CGR (g/m^2/day)			Seed yield (kg/ha)			B:C ratio		
	Intercrop	Sole crop	Mean	Intercrop	Sole crop	Mean	Intercrop	Sole crop	Mean	Intercrop	Sole crop	Mean
N_0 P_0	3562	5036	4299	2.9	4.1	3.5	290	493	391	0.75	0.31	0.53
N_{40} P_{20}	3825	7184	5505	4.8	6.6	5.7	394	576	485	1.05	0.53	0.79
N_{40} P_{40}	5114	8296	6705	5.9	8.2	7.1	420	666	543	1.23	0.77	1.05
N_{40} P_{60}	5262	7740	6501	6.7	8.1	7.4	490	691	590	1.30	0.84	1.07
N_{80} P_{20}	5318	8258	6788	7.4	8.3	7.9	539	705	622	1.43	0.88	1.15
N_{80} P_{40}	5562	8444	7003	7.8	9.2	8.5	558	727	642	1.49	0.94	1.21
N_{80} P_{60}	6110	9221	7666	8.8	10.7	9.7	597	778	687	1.59	1.07	1.33
Mean	4965	7740	-	6.3	7.9	-	470	662	-	1.26	0.76	-
CD (P=0.05)												
Main		963			0.689			51.9			0.19	
Sub		453			0.886			50.9			0.11	
Main x Sub		640			1.253			72.0			0.16	

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Short communication

Establishing critical soil fertility limit of available P for sunflower crop

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Soil testing for available nutrients is a well known practice for efficient use of fertilizers. However, there have been instances where phosphatic fertilizer dose given on the basis of existing fertility class did not result in desired response. This could be due to increased intensity of cultivation, use of high yielding varieties etc. and hence there is a need to have a relook on the critical limits governing the availability of nutrients in soil for crop growth, more so in the case with phosphorus. Dhillon *et al.* (1987) have emphasized the need of revising the existing soil fertility categories depending on the local agro-climatic conditions. Several workers (Bansal and Nayyar, 1994; Ghosh and Mukhopadhyay, 1996; Ganeshamurthy, 1996) have established critical limits of different nutrients for different soils and crops. Since the information on establishment of critical limit of P in sunflower crop in Vertic ustochrepts of Rangareddy district (Andhra Pradesh) is lacking in literature, the present experiment, therefore was undertaken to establish critical level of available P for sunflower.

Pot culture study was conducted during 1999 with phosphorus deficient Vertic ustochrepts (available P_2O_5, 11.65 kg/ha) collected from Directorate of Rice Research farm, Rajendranagar, Hyderabad. Varied levels of P (0, 30, 60, 90, 120, 150, 180 and 210 kg P_2O_5/ha) were added through KH_2PO_4 to the pots replicated thrice. The soil was non-saline having pH of 7.7, the organic carbon 5 g/kg soil and available K was 357 kg/ha. Polyethylene lined pots were filled with 4 kg soil. Normal recommended doses of N and K at 75 and 30 kg/ha, respectively were applied taking into account of K coming from KH_2PO_4. Five plants of sunflower (hybrid KBSH-1) were grown per pot. The crop was harvested at maturity, air dried and seed and stover yields were recorded. The plant samples collected at harvesting stage were digested and analyzed for P concentration. Similarly, initial soil P concentration was estimated (Olsen *et al.*, 1954). Scatter diagram as suggested by Cate and Nelson (1965) for correlation of soil test data with crop response was plotted by taking Bray's percent yield on Y-axis and initial soil P concentration on X-axis (Fig. 1).

Phosphorus application to the soil with different levels of P increased the seed yield and shoot dry weight of sunflower. The response to applied P was more pronounced at lower doses as compared to higher doses of applied P. Increase in seed and stover yields was observed upto 150 kg P_2O_5/ha and similar trend was observed in P concentration and P uptake also (Table 1). It was found that the critical level of P in soil was 9 kg/ha and plant concentration of P 0.12 % below which response of P to sunflower could be predicted in these soils of Ranga Reddy district.

Table 1 **Effect of phosphorus application on shoot and seed yield and P uptake by sunflower**

Level of P_2O_5 applied (kg/ha)	Shoot dry wt (g/plant)	P content in shoot (%)	P uptake (mg/plant)	Seed yield (g/plant)
Control	1.0	0.06	0.66	0.4
30	1.6	0.08	1.30	0.7
60	1.8	0.07	1.25	0.9
90	1.8	0.10	1.81	1.3
120	2.0	0.10	1.96	1.4
150	2.2	0.12	2.60	1.4
180	1.6	0.06	0.95	0.7
210	1.4	0.03	0.38	0.6
CD (P=0.05)	0.6	0.01	0.83	0.4

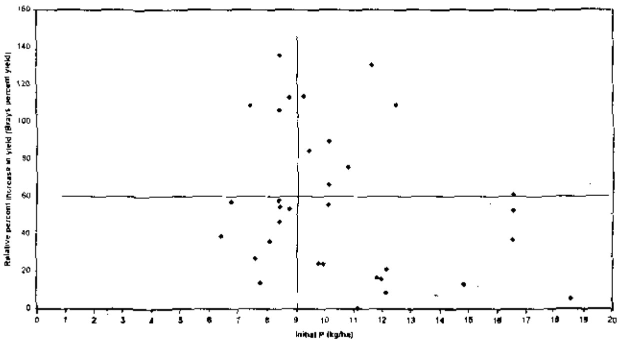

Fig 1 Critical limit of P in black soil (Vertic ustrochrepts)

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Short communication

Influence of date of sowing and row spacing on the incidence of *Nomuraea rileyi* (Farlow) Samson on *Spodoptera litura* (F.) in groundnut

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Biological pest suppression specialists need to be increasingly concerned with the environmental and cultural manipulations, particularly to conserve encourage natural enemy complex. Entomogenous fungi can be a useful bioagents, but their dependency on specific environmental conditions limit their applicability (Smits, 1997). *Nomuraea rileyi* (Farlow) Samson as like many other fungus, requires high relative humidity and optimum temperature for its epizootic (Vimala Devi *et al.*, 1996) and these are the possible factors that have strained its practical utility and commercial success. Under natural conditions wide spread occurrence of *N. rileyi* has been noticed on several insect pests in transitional belt of Karnataka and coastal Andhra Pradesh (Sridhar and Devprasad, 1996; Lingappa *et al.*, 2000; Patil, 2000). As groundnut crop is ideal niche for multiplication of entomopathogenic fungi, a study was taken-up to know the influence of time of sowing and alteration in plant geometry to enhance the early epizootic in nature.

The investigation was carried out under field condition at Main Research Station, University of Agricultural Sciences, Dharwad during *kharif*, 2001. The experiment was laidout in split plot design with date of sowing as main plot and spacing as sub-plot treatment with four replications. The plot size maintained was 5 m x 3 m. The groundnut variety used was JL-24. The seeding was done by using marker and rope. All the recommended package of practices were followed except plant protection for the pest management. The same plant population was maintained in different spacings by varying inter and intra row spacing.

Table 1 Effect of date of sowing and spacing on larval population and mycosis due to *N. rileyi* on *S. litura* in groundnut ecosystem

Treatment	45 DAS			60 DAS			75 DAS		
	Total No. of larvae/m row	Mycosed larvae/m row	Mycosis (%)	Total No. of larvae/m row	Mycosed larvae/m row	Mycosis (%)	Total No. of larvae/m row	Mycosed larvae/m row	Mycosis (%)
Date of sowing									
D_1	10.3a	1.3b	12.5b	12.6a	3.0b	23.3b	7.9a	4.1a	51.6a
D_2	8.2ab	1.6ab	18.5ab	9.7ab	3.7a	35.7a	4.7b	2.2b	44.8a
D_3	7.0b	1.7a	22.7a	7.9b	2.8b	34.2a	3.8b	0.9c	21.3b
Spacing									
S_1	10.5a	2.5a	24.1a	11.8a	4.5a	39.6a	6.3a	3.2a	48.2a
S_2	8.4ab	1.4b	17.6b	9.5b	3.1b	31.8b	5.7ab	2.4b	39.4b
S_3	6.6b	0.7c	12.1c	9.0b	1.9c	21.7c	4.6b	1.6c	30.1c
Interaction									
D_1S_1	11.7a	2.0d	16.8c	14.2a	4.2b	29.5cd	8.4a	5.2a	61.7a
D_1S_2	10.3a	1.2c	11.7e	12.3ab	2.8d	22.7ef	7.8a	4.0b	51.5b
D_1S_3	8.9a	0.8f	8.9f	11.4bc	2.0e	17.6f	7.9a	3.2c	41.7c
D_2S_1	9.8a	2.5b	25.4b	11.1bcd	5.0a	45.0a	5.6b	3.0c	53.8b
D_2S_2	8.6a	1.5e	17.4c	9.9be	3.8c	38.3ab	5.1bc	2.4d	47.2bc
D_2S_3	6.3b	0.8f	12.7e	9.3cde	2.2e	23.7de	3.6de	1.2ef	33.4d
D_3S_1	10.0a	3.0a	29.9a	9.9be	4.4b	44.3a	4.8bcd	1.4e	29.2d
D_3S_2	6.4b	1.5e	23.6b	7.5ef	2.6d	34.4bc	4.1cd	0.8ef	19.4e
D_3S_3	4.5b	0.7f	14.7d	6.4f	1.5f	23.9de	2.6e	0.4g	15.4e

D_1 = Early sowing (II[nd] fortnight of June) S_1 = Closer spacing (22.5 cm x 13 cm)
D_2 = Normal sowing (I[st] fortnight of July) S_2 = Normal spacing (30 cm x 10 cm)
D_3 = Late sowing (II[nd] fortnight of July) S_3 = Wider spacing (45 cm x 6 cm)
DAS = Days After Sowing Means followed by same alphabet in a column do not differ significantly (P=0.05) by DMRT

Observations were made from 45 DAS at 15 days interval. The total number of *S. litura* healthy and mycosed larvae in each meter row length at five randomly selected spots in each treatment was recorded and was converted into per cent disease incidence. Leaflet damage was assessed by visual damage grade (Wightman and Ranga Rao, 1994). Pod yield at harvest was also recorded.

At 45 DAS, early sown crop (D_1) recorded significantly higher number of 10.3/m row larvae while least number of larvae (7.0 larvae/m row) were noticed in late sown crop (D_3) (Table 1). Among different spacings, closer spacing (S_1) recorded significantly higher larval population (10.5/m row) followed by S_2 and lowest larval population (6.6/m row) was noticed in wider spacing (S_3) (Table 1).The interaction effect was also found significant with date of sowing and spacing. Significantly higher larval population (11.7/m row) was recorded in D_1S_1 and least larval population (4.5/m row) was recorded in D_3S_3 and was on par with D_3S_2 and D_2S_3 (Table 1).

Significantly higher number of mycosed larvae (1.7/m row) and mycosis (22.7 %) was noticed in late sown crop and least number of mycosed larvae (1.3/m row) and mycosis (12.5 %) was noticed in early sown groundnut crop. As the spacing increased from 22 cm to 45 cm, the larval population, mycosed larvae and disease incidence decreased significantly (Table 1).

Closer spacing recorded significantly higher number of mycosed larvae (2.5/m row) and disease incidence (24.1%), whereas, wider spacing recorded significantly lower number of mycosed larvae (0.7/m row) and disease incidence (12.1%) respectively. Interaction effect between date of sowing and spacing was found significant. Significantly higher number of mycosed larvae (3/m row) and disease incidence (29.9%) was noticed in D_3S_1. Whereas, least number of mycosed larvae (0.7/m row) and disease incidence was recorded in D_3S_3. The similar trend was continued with respect to larval population, mycosed larvae/m row and per cent mycosis due to *N. rileyi* with higher magnitude at 60 and 75 days after sowing.

Significantly higher and lower leaflet damage was noticed in early (D_1) and late sowing (D_3) crops at all the three observations, 45, 60 and 75 DAS respectively (Table 2). Considerably, closer spacing (S_1) recorded significantly higher leaflet damage irrespective of date of sowing whereas, least leaflet damage was recorded in wider spacing (S_3). Date of sowing and spacing had significant interaction effect on leaflet damage. Early sowing crop with closer spacing recorded significantly higher leaflet damage at 45, 60 and 75 DAS respectively whereas late sown crop with wider spacing (D_3S_3) recorded significantly lesser leaflet damage at all three observations (Table 2).

The normal sown crop (D_2) recorded significantly higher mycosis (35.7%) at 60 DAS and early sown crop at 75 DAS (51.6%) where the environmental conditions were favourable for epizootic of the entomopathogen. During this period, canopy cover was more compared to late sown crop which therefore, provided ideal niche for the pathogen to cause epizootic. Lingappa *et al.* (2000) and Patil (2000) have reported that August and September months were found ideal for *N. rileyi* to cause epizootic under Dharwad condition. In Dharwad during crop growth period the temperature ranges between 26-28 °C with more than 85% relative humidity. This condition is congenial for the pathogen to multiply itself in the nature of its hosts and to cause epizootic.

Closer spacing recorded significantly higher disease incidence (39.6% and 48.2%) at 60 and 75 DAS, respectively. This might be due to the favourable effect of microclimatic condition under thick canopy cover. In addition to existing favourable environment, under close and dense canopy, there was decrease in temperature by 2 to 3 °C and increased relatively humidity by 3-4% compared to open field might have created suitable condition for fungal pathogen to cause more mycosis on host insects. Not much variation in temperature and relative humidity recorded above and below the canopy of groundnut in wider spacing was observed. In addition, direct exposure of the few dead cadavers to sunlight might have affected the sporulation, viability and further spread of pathogen. These results are in accordance with the findings of Sprenkel *et al.* (1979) who reported that higher percentage of mortality of the larval population due to *N. rileyi* was more in narrow rows at higher seeding rate in soybean ecosystem. Further, Berleigh and Katayama (1983) found that infection by *N. rileyi* was significantly greater in *Helianthus* species in closed canopy variety (Deltapin-216) that in open canopy variety (Lousiana okra leaf) of cotton.

Significantly higher leaflet damage was recorded in early sown groundnut as compared to other advanced date of sowing. This is due to the more larval population on early sown crop compared to late sown crop. These findings are in confirmity with the findings of Patil *et al.* (1996) who observed that, the groundnut crop suffered more damage due to *S. litura* in crop sown on 15th June compared to 30th July sown crop. Lesser build up of inoculum of *N. rielyi* in early sown crop probably failed to suppress the pest. In late sown crop pest activity could have been lower due to early build up inoculum hence the lesser leaflet damage.

The maximum yield was recorded in normal sown crop (1867 kg/ha) and was significantly higher than late sown crop (1410 kg/ha). The significant reduction in yield of late sown crop might be due to lack of moisture during critical stage of crop growth period. In early sown crop, though it has received maximum pest load and less incidence of *N. rileyi*, it recorded on par yield with normal sown crop. The probable reason might be availability of moisture at critical stage of crop, which inturn could make up for the foliage loss due to the pest damage.

Table 2 Effect of date of sowing and spacing on leaflet damage due to *S. litura* and its influence on yield (groundnut)

Treatment	Leaflet damage (%)			Yield	Shelling
	45 DAS	60 DAS	75 DAS	(kg/ha)	(%)
Date of sowing					
D_1	20.7a	28.9a	31.7a	1826a	68.3a
D_2	18.4ab	20.7b	25.5b	1867a	66.8a
D_3	13.5b	14.7c	20.9b	1410b	64.8a
Spacing					
S_1	19.8a	24.3a	28.9a	1699a	66.4a
S_2	17.9a	21.2b	25.3ab	1768a	67.2a
S_3	14.8b	18.8b	23.9b	1635a	66.3a
Interaction					
D_1S_1	23.2a	32.4a	32.4a	1775b	68.2a
D_1S_2	20.9ab	28.6b	31.7a	1927a	68.7a
D_1S_3	17.8bc	25.7bc	31.0a	1776b	68.0a
D_2S_1	19.8cd	24.5c	29.2ab	1934a	66.6a
D_2S_2	18.8bc	20.3d	24.9bc	1924a	67.9a
D_2S_3	16.4cd	17.3e	22.5cd	1743b	66.0a
D_3S_1	16.3cd	15.9ef	25.1bc	1391c	64.6a
D_3S_2	14.1d	14.7fg	19.4d	1452c	65.0a
D_3S_3	10.3e	13.0g	18.3d	1386c	64.8a

D_1 = Early sowing (IInd fortnight of June)
D_2 = Normal sowing (Ist fortnight of July)
D_3 = Late sowing (IInd fortnight of July)
S_1 = Closer spacing (22.5 cm x 13 cm)
S_2 = Normal spacing (30 cm x 10 cm)
S_3 = Wider spacing (45 cm x 6 cm)
DAS = Days After Sowing
Means followed by same alphabet in a column do not differ significantly ($P=0.05$) by DMRT

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Short communication

Biochemical changes in relation to white rust development in Indian mustard

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White rust, *Albugo candida* (Pers. ex Lev.) Kuntz is an important disease of *Brassica juncea* (L.) Czern. & Coss (Kolte,1985). The pathogen infects both the vegetative and flowering parts of the plant resulting in 17-32% yield loss (Bains and Jhooty, 1979). Screening of germplasm against the disease has emanated the identification of resistant sources (Saharan, 1992). Resistance in the cultivars may be governed by various biochemical constituents present in it. Some changes in these constituents may occur as a result of infection. Present study was undertaken to determine the status of important biochemical parameters *viz.*, sugars and phenols in the resistant, moderately resistant and susceptible cultivars of Indian mustard in relation to white rust disease.

Five cultivars of Indian mustard *viz.*, JM-1 and ZEM-1 (resistant), PHR-1 and KBJ-78 (moderately resistant), Varuna (susceptible) were raised at the experimental farm of Oilseeds Research Station, Kangra in 3.0 m X 1.5 m plots with recommended package of practices. For analysis of biochemical parameters, ten healthy leaves were sampled from the middle portion of ten randomly selected plants at 60 days after sowing in each cultivar before appearance of disease. White rust inoculum was sprayed in the plots with high volume knapsack sprayer after sampling for pre-infectional biochemical analysis. Inoculum was prepared by soaking white rust infected leaves in water to get fungal sporangia. The sporangial suspension was kept for 4-5 hours in BOD incubator at 15°C to obtain sporangial germination. The concentration of zoospores was adjusted to 2.5 x 10^4/ ml of inoculum. Leaf samples were collected again after disease development on 80 days after sowing for analysis of biochemical parameters. For disease scoring on leaves 0-5 scale (AICORPO, 1988) was used. Disease index (%) was calculated as per Wheeler (1969). Total sugars were estimated by the method of Dubios *et al.* (1951) whereas, estimation of total and ortho-dihydroxy phenols was done as per Bray and Thrope (1954) and Mahadevan (1966).

Results indicated that susceptible cultivar Varuna showed highest disease followed by moderately resistant cultivars PHR-1 and KBJ-78 (Table 1). The resistant cultivars ZEM-1 and JM-1 recorded least disease. At the pre-infectional stage, total phenols were highest (3.0%) in the resistant cultivars JM-1 and ZEM-1 and least in Varuna (2.6%) susceptible check. The moderately resistant cultivars *viz.*, PHR-1 and KBJ-78 showed an intermediate value of 2.9% and 2.8%, respectively. Almost similar trend was observed for ortho-dihydroxy phenols. There was an increase in total and ortho-dihydroxy phenolic content in all the cultivars as a result of infection. However, the increase in the total phenols was more in the resistant (20.0%) cultivars JM-1 and ZEM-1 than moderately resistant KBJ-78 and PHR-1 (3.6% and 10.3% respectively) or susceptible cultivar Varuna (7.7%). In contrast to total phenols, susceptible and moderately resistant cultivars exhibited greater increase in the ortho-dihydroxy phenols than the resistant cultivars. In spite of this increase, the level of ortho-dihydroxy phenols in susceptible and moderately resistant cultivars did not match with that in resistant cultivars. Resistance in mustard against white rust may be attributed to the presence of higher level of phenols. Dhavan *et al.* (1981) and Singh (2000) have also reported higher amount of total phenols in the white rust resistant varieties of rapeseed-mustard. Singh *et al.* (1998) have reported higher level of flavonoids in addition to phenols in the white rust resistant genotypes of mustard. Before white rust infection, total sugars were more in the susceptible cultivar Varuna (9.2%) in comparison to resistant cultivars JM-1 (7.1%) or ZEM-1 (7.2%). The moderately resistant varieties showed an intermediate range of total sugars. As a result of infection total sugar content was observed to decrease in all the cultivars. However, this decrease was slightly more in the resistant cultivars in comparison to moderately resistant or susceptible cultivars. Dhavan *et al.* (1981) have reported more sugars in white rust susceptible varieties of mustard. Phenolic metabolism is energy demanding and more decrease in sugars of resistant cultivars may be because of more synthesis of phenolics by them.

Table 1 Biochemical constituents in leaves of *Brassica juncea* cultivars in relation to white rust infection

Cultivar	Disease index* (%)	Total phenols (%)			Ortho-dihydroxy phenols (%)			Total sugars (%)		
		Healthy	Infected	% increase (+) over healthy	Healthy	Infected	% increase (+) over healthy	Healthy	Infected	% decrease (-) over healthy
JM-1	2.4 (9.0)**	3.0 (9.9)	3.6 (10.9)	+20.0	0.7 (4.9)	0.9 (5.4)	+28.6	7.1 (15.4)	6.0 (14.1)	-15.5
ZEM-1	1.6 (7.1)	3.0 (9.9)	3.6 (10.9)	+20.0	0.6 (4.4)	0.9 (5.5)	+50.0	7.2 (15.5)	6.3 (14.4)	-12.5
PHR-1	16.8 (24.1)	2.9 (9.8)	3.2 (10.2)	+10.3	0.5 (3.9)	0.8 (5.1)	+60.0	8.7 (17.2)	8.0 (16.4)	-8.0
KBJ-78	10.4 (18.7)	2.8 (9.5)	2.9 (9.9)	+3.6	0.4 (3.6)	0.7 (4.7)	+75.0	8.1 (16.5)	7.4 (15.8)	-8.6
Varuna	35.2 (36.3)	2.6 (9.3)	2.8 (9.5)	+7.7	0.3 (3.3)	0.6 (4.4)	+100.0	9.2 (17.6)	8.3 (16.8)	-9.8
CD (P=0.05)	(2.9)	(0.3)	(0.7)		(0.5)	(0.4)		(0.2)	(0.3)	

* Values are the mean of four replicates ** Values in parenthesis are the means after arc sine transformation

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Short communication

Effect of sowing date, varieties and fungicides on the incidence of Alternaria blight of mustard

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Indian mustard [*Brassica juncea* (Linn.) Czern & Coss.] is an important oilseed crop, which occupies about 90% area of total hectarage under rapeseed-mustard group in India (NRCRM, 1999). Alternaria blight is an important disease of mustard among the foliar diseases which appears at juvenile stage of the crop and affects all above ground parts of the plants inflicting great loss (Chahal and Kang, 1979). Appearance of the disease on siliquae is more important than on leaves because it directly influence the grain yield as well as quantity and quality of oil. Due to the introduction of new cropping patterns like early, normal and late sowings and non-availability of resistant donors against Alternaria blight, management of the disease has become a problem. Therefore, the present study was undertaken to identify better fungicide and sowing time for managing Alternaria blight of mustard.

A field experiment was conducted at the Oilseeds Farm of C.S. Azad University of Agriculture and Technology, Kanpur during two consecutive years in post-monsoon (*rabi*) of 1999-2000 and 2000-2001. The experiment was laid out in a factorial design with three replications in a plot of 5m x 3m. The trial was constituted with combinations of two dates of sowing (D_1 and D_2) two varieties (V_1 and V_2) and four other treatments, two fungicides (CH_1 and CH_2) use of recommended practices {seed treatment with Apron @ 6g/kg, NPK (120:60:60 kg/ha), spraying of Mancozeb (0.2%) at 50, 70 and 90 days after sowing (DAS)} and local practices (without seed treatment, fertilizer and management as a control]. The disease severity was recorded at the maturity stage as per the scale suggested by Conn *et al.* (1990). Seed yield of each plot was also recorded.

All the treatments gave better response in minimizing the disease intensity and increased the seed yield of mustard over control in all the combinations (Table 1). Disease intensity and seed yield were significantly affected by date of sowing during both the years. Early sowing (20, October) significantly reduced the disease intensity and enhanced the seed yield in both the years in comparison to late sown crop (20, November). The minimum disease intensity, 16.7% and 15.6% was recorded in 1999-2000 and 2000-2001, respectively in $D_1V_2CH_1$ combination while the maximum seed yield 2866 kg/ha and 3221 kg/ha was observed in D_1V_1RP combination during both the years. Howlider *et al.* (1989) have reported that the mustard crop sown on 2nd November or a week earlier, developed the least infection of *A. brassicae* in field and gave the highest seed yield, whereas, delay in sowing caused the higher disease incidence. Similarly, Kolte *et al.* (1987) and Dasgupta *et al.* (1991) have also reported increase in disease intensity and loss in yield due to delay in sowing of mustard crop.

Alternaria disease intensity of 19.0%, 16.2%, 21.2% and 24.1% was observed with CH_1 combinations followed by RP combinations which exhibited 21.2, 20.9, 22.4 and 25.3% disease intensity (Table 1). Among all the combinations, significantly minimum disease intensity (16.2%) was observed in Varuna variety sown on 20th October with two sprays of Ridomil at 50 and 70 days of sowing and one spray of Mancozeb (0.25%) at 90 days after sowing ($D_1V_1CH_1$). However, the maximum yield (30.44 kg/ha) was recorded in D_1V_1RP combination which might be due to the fertilizer included in recommended practice combination. Mancozeb (0.25%) was the most efficient fungicide against *Alternaria brassicae* as reported by Barbu and Denescu (1969), however, in the present study, two sprays of Ridomil (0.2%) at 50 and 70 days and one spray of Mancozeb (0.25%) provided the effective control of Alternaria blight as compared to spraying of Mancozeb (0.25%) alone in RP combination.

Variety Varuna gave 12.8% higher seed yield in comparison to Rohini in the 1st date of sowing (20 October) while in 2nd date of sowing, Rohini gave 10.60% higher yield than Varuna. The combination of $D_1V_2CH_2$ which recorded 28.1% disease intensity was found ineffective to check the disease and was at par to the control combination (29.9%). Disease intensity and seed yield with regards to the varieties were found statistically non-significant. Therefore, the present investigation exhibited that the sowing of mustard (*Brassica juncea*) around 2nd and 3rd week of October and application of two sprays of Ridomil MZ (0.2%) at 50 and 70 days and one spray of Mancozeb (0.25%) at 90 days after sowing reduced the Alternaria disease intensity and provided *higher seed yield.*

Table 1 Effect of date of sowing, varieties, fungicides and recommended practices on the disease intensity and seed yield

Treatment	Disease intensity (%)			Yield (kg/ha)		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
$D_1V_1CH_1$	19.0	19.0	19.0	2800	3110	2955
$D_1V_1CH_2$	30.4	24.1	27.2	2711	2910	2810
D_1V_1RP	21.7	20.6	21.2	2866	3221	3044
D_1V_1(Con.)	38.0	26.8	32.4	2177	2711	2444
$D_1V_2CH_1$	16.7	15.6	16.2	2333	2688	2511
$D_1V_2CH_2$	31.4	24.8	28.1	2266	2677	2472
D_1V_2RP	21.4	20.5	20.9	2422	2866	2644
D_1V_2 (Con.)	32.2	27.5	29.9	1844	2488	2166
$D_2V_1CH_1$	20.5	21.9	21.2	1588	1544	1566
$D_2V_1CH_2$	34.7	24.0	29.4	1533	1555	1544
D_2V_1RP	22.5	23.0	22.7	1822	1622	1722
D_2V_1(Con.)	40.9	38.1	39.5	1210	1110	1160
DV_2CH_1	26.8	21.3	24.0	1710	1888	1800
$D_2V_2CH_2$	31.8	31.0	31.4	1777	1510	1644
D_2V_2RP	27.6	23.0	25.3	1655	1733	1694
D_2V_2 (Con.)	37.9	35.1	36.5	1066	1444	1283
CD (P=0.05)						
Fungicide	4.84	1.78	3.61	1.13	1.61	NS
Date of sowing	3.42	1.26	2.55	0.80	1.14	2.72
Variety	NS	NS	NS	0.80	NS	NS

D_1 = 1st date of sowing (20, October); D_2 = 2nd date of sowing (20, November); V_1 = Varuna variety; V_2 = Rohini variety
CH_1 = Two spray of Ridomil MZ (0.2%) at 50 and 70 days and one spray of Mancozeb (0.25%) at 90 DAS
CH_2 = One spray of Ridomil (0.2%) at 50 days and two sprays of Mancozeb at 70 and 90 DAS
RP = Recommended practice (seed treatment with Apron @ 6 g/kg of seed+N_{120}:P_{60}:K_{50} kg/ha + Spraying of Mancozeb (0.25%) at 50, 70 and 90 DAS)
Con. = Control

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Short communication

Pathogenicity of *Beauveria bassiana* and *Metarhizium anisopliae* to different development stages of castor spiny caterpillar, *Ergolis merione* L.

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The entomopathogenic fungi *Beauveria bassiana* (Balswamo) Vuillemin and *Metarhizium anisopliae* (Metschnikoff) Sorokin have been widely tested against many Lepidopteran pests and the pathogenicity has already been established against a number of insect pests belonging to different orders both in the field and laboratory (Prasad *et al.*, 1989). The castor spiny caterpillar, *Ergolis merione* L. is getting prominence recently due to its high defoliating ability (David and Kumaraswami, 1988). Though, different chemical and microbial products were tested against this pest (Pawar and Thombre, 1990) none has reported the efficacy of entomogenous fungi against *E. merione*. Keeping this in view, the present investigations were undertaken with selected strains of *B. bassiana* and *M. anisopliae* against *E. merione* to study their virulence using bio assay.

The fungal isolates MUCL 38502 of *B. bassiana* and MUCL 8237 of *M. anisopliae* obtained from Belgian Coordinated Collection of Microorganisms, Belgium were used in the present study. These isolates were multiplied on Sabouraud dextrose agar medium enriched with 5% yeast extract for 10 days and the conidia were harvested from the petriplates. The viability of conidia was examined before carrying out the bioassay using the microculture method (De La Rosa *et al.*, 1997). Conidia concentrations were measured and adjusted to 1×10^6 conidia/ml using a haemocytometer. The microcultures were inoculated with 0.3 ml aliquots and viability was determined by examination of a minium 200 conidia from each of three replications. A spore was considered viable if germ tube was greater than 0.3 mm in length (Inglis *et al.*, 1997).

Bioassays were conducted with newly moulted 2nd, 3rd, 4th and 5th instar larvae of *E. merione* to determine their age related susceptibility to *B. bassiana* and *M. anisopliae*. To determine the mean lethal concentration (LC_{50}), different conidial concentrations ranging from 10^4 to 10^9 conidia/ml were prepared in sterile distilled water containing 0.02% Tween 80R for both the fungi and twenty larvae from each instar were taken separately in a petriplate lined with sterilized filter paper were sprayed directly with 2 ml conidial suspension of different concentrations. Three replications were maintained for each concentration. The control insects were treated only with sterile distilled water containing 0.02% Tween 80R. These larvae after air drying were carefully transferred to individual sterile round plastic vials containing fresh pieces of disinfected castor leaves and maintained in an incubator at 25±2 °C and 90±5 % RH. Observations were recorded at every eight hour interval until the eighth day for the strains under evaluation. While, a determine the mean lethal time (LT_{50}) the larvae were sprayed directly with *B. bassiana* and *M. anisopliae* conidial concentrations standardized at 5 x 107 conidia/ml. The observations were recorded at 24 h interval upto eighth day and cumulative mortality data was used for the probit analysis.

Mean lethal concentration (LC_{50})

The results indicate that the larval instars showed differential susceptibility to fungal infections (Table 1). An inverse relationship was observed between *E. merione* larval instars and susceptibility to the entomogenous fungi. The second instar was the most susceptible which is evident from the LC_{50} values recorded with *B. bassiana* (3.6×10^5 conidia/ml) and *M. anisopliae* (9.8×10^5 conidia/ml). The LC_{50} values for *B. bassiana* increased 3.02, 5.63 and 12.56 folds during 3rd, 4th and 5th instars, respectively whereas the same with *M. anisopliae* was 1.94, 4.15 and 8.54 folds, respectively. This result is not uncommon because younger instars often are more susceptible to entomogenous fungi (Prasad *et al.*, 1989; Legaspi *et al.*, 2000). The possible reasons for greater susceptibility of early instar larvae may be the greater conidial concentration per unit body weight which decreased with the age of the larvae and hence the lower mortality of the later instars. Among the two fungi, *B. bassiana* was found more virulent than *M. anisopliae* and this study indicated that the susceptibility of the insect decreased with increase in age of larvae.

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The χ^2 test showed the homogeneity of the test populations in all the bioassays indicating the good fit of the observed and expected response. The dose dependent responses in the present study were not well pronounced as evidenced in lower slope values (Table 1). Shallow dose mortality responses seem to be typical for fungus insect interactions (Rombach and Gillespie, 1988). The differential susceptibility of the pest to the different pathogenic fungi could be attributed to the inherent variation in the susceptibility of the host to the fungal pathogens. As envisaged by Boman (1981), the chemical constituents vary as the larvae advance in age resulting in progressive hardening of the cuticle and increased humoral defense mechanism to the microbial infection. This seems to be a probable reason for the lesser susceptibility of the later instars to the fungal infection. Earlier Loc (1995) reported that in Bihar hairy caterpillar, the thickness of hairs acted as a physical barrier for the spores to fall on the integument and subsequently germination. This was also true with castor spiny caterpillar which has branched spine like hairs on the body.

Mean lethal time

The results of the probit analysis of time mortality data from bioassays of the indicated LT_{50} values (at 5 x 10^7 conidia/ml) of *B. bassiana* and *M. anisopliae* on *E. merione* larval stages ranged from 4.07 to 6.09 days (Table 2). The 2nd instar larvae recorded the lower LT_{50} with *B. bassiana* (4.07d) and *M. anisopliae* (4.32 d) than the 3rd, 4th and 5th instars. Among the two fungi tested, *B. bassiana* was the most virulent against *E. merione* larvae. The LT_{50} increased 1.09, 1.25 and 1.39 folds during 3rd, 4th and 5th instars, respectively when treated with *B. bassiana* and the same with *M. anisopliae* was 1.10, 1.27 and 1.41 folds.

Table 1 virulence of *B. bassiana* and *M. anisopliae* against different instars of *E. merione (dose mortality)**

Fungus	*E. merione* (Larval instars)	χ^2	LC_{50} (95% CI) (x10^5 conidia/ml)	Slope (±SE)	a
B. bassiana	II	0.08	3.60 (0.57-22.63)	0.1872 (0.04)	4.8958
	III	0.04	10.87 (2.08-56.64)	0.1902 (0.04)	4.8030
	IV	0.12	20.28 (4.09-100.63)	0.1908 (0.04)	4.7050
	V	0.05	45.23 (9.05-226.16)	0.1895 (0.04)	4.6863
M. anisopliae	II	0.39	9.80 (2.07-46.37)	0.2037 (0.04)	4.7981
	III	0.21	19.01 (4.10-88.10)	0.2001 (0.04)	4.7441
	IV	0.12	40.71 (8.94-185.43)	0.2012 (0.04)	4.6761
	V	0.26	83.73 (13.67-512.69)	0.1718 (0.03)	4.6696

* @ 360 larvae/bioassay

Table 2 virulence of *B. bassiana* and *M. anisopliae* against different instars of *E. merione (time mortality)**

Fungus	*E. merione* (Larval instars)	χ^2	LC_{50}#(95% CI) (x10^5 conidia/ml)	Slope (±SE)	a
B. bassiana	II	3.62	4.07 (3.62-4.58)	3.2645 (0.49)	..0097
	III	2.28	4.45 (3.99-4.97)	3.0900 (0.48)	2.9960
	IV	0.53	5.08 (4.76-5.64)	2.9723 (0.49)	2.9018
	V	0.70	5.68 (5.06-6.37)	2.7293 (0.48)	2.9453
M. anisopliae	II	3.63	4.32 (3.87-4.84)	3.2019 (0.49)	2.9650
	III	3.23	4.75 (4.22-5.34)	2.7147 (0.48)	3.1635
	IV	1.06	5.49 (4.84-6.23)	2.4392 (0.47)	3.1965
	V	0.35	6.09 (5.28-7.02)	2.3397 (0.48)	3.1645

* @ 360 larvae/bioassay; # at 5 x 10^7 conidia/ml

A positive relationship between the LT_{50} value and the age of the larvae was observed with both the fungi indicating the lower susceptibility of older larvae than the early instars. Similar findings were reported earlier in larval instars of *S. obliqua* (Patel, 1997) and *S. litura* (Prasad *et al.*, 1989). Slopes of the regression varied considerably from the instar to instar (Table 2). The results revealed that the virulence of the fungi decreased with the age of the larvae. According to Boucias and Pendland (1987) a complex protease inhibitors activity detailed in the haemolymph of 6^{th} instar larvae of *Anticarcia gemmatalis*, inhibited both conidial germination and germ tube development of *Nomuraea rileyi*, which was attributed to the lesser susceptibility of the aged larvae to the fungal infection. The present findings are in accordance with the above reports. Thus, from the above results it is concluded that entomogenous fungi like *B. bassiana* and *M. anisopliae* being the potential microbial agents can be utilized in the integrated management of *E. merione*.

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Short communication

Assessment of yield losses caused by *Antigastra catalaunalis* (Dup.) in different genotypes of sesame under agroclimatic conditions of Haryana

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Sesame is attacked by an array of insect-pests throughout the crop season (Nayar *et al.*, 1976., Rai, 1976., Singh and Yadava, 1985) of which sesame leaf roller and capsule borer, *Antigastra catalaunalis* (Dup.) is a very serious and regular pest in India (Bhattacharjee and Lal, 1962). The severity of losses caused by this pest has compelled the farmers to grow sesame as mixed crop. In the present investigation efforts were made to determine the losses caused by this pest and to relate the losses with resistance in some genotypes of sesame.

Forty genotypes of sesame (Table 1) were sown in a plot size of 10 rows x 4 m, keeping 30 cm row to row and 10-15 cm from plant to plant spacing , in a field with basal application of 37.5 kg nitrogen/hectare. There were three replications of each genotype under two sets of conditions i.e., protected and unprotected. The protected set was sprayed with carbaryl 50 WP 0.15% at 25, 40 and 55 days old crop, whereas, in the unprotected set no spraying was done. The yield of the respective plots was recorded after harvest and computed as q/ha and percent avoidable losses worked out.

The yield of different genotypes under protected and unprotected conditions and avoidable yield losses are presented in Table 1. The avoidable yield losses due to this pest were 15.62 and 17.29 % in RAUSS-17-4 and B-67, respectively, as against the highest losses to the tune of 66.83 % in CST-785. In general, the losses in rest of the genotypes were high ranging from 20.34 (CST-782) to 64.65% (L-38). The losses in two released varieties i.e. Pb. Til No. 1 and HT-1 for Haryana, were also quite high i.e., 34.00 and 57.38 % respectively. Deshpande and Singh (1969) and Singh (1983) reported the yield loses of 3.35 to 71.53 % among different sesame genotypes due to *A. catalaunalis* (Dup).

The avoidable yield losses in genotype RAUSS-17-4 and B-67 were low, therefore, these genotypes appeared to be armoured with some features to fight with the pest. Hence, these genotypes may be used as resistant sources for bringing out new high yielding varieties coupled with resistance to *A. catalaunalis*. However, the yield potential

Table 1 **Avoidable losses in some sesame genotypes caused by *Antigastra catalaunalis* (Dup.)**

Genotype	Seed Yield (kg/ha)		Percent avoidable
	Unprotected*	Protected	loss
TC-171	480	890	45.8
JLT-9	680	830	17.6
JLT-2	370	690	45.4
TNAU-10	340	760	56.0
BS-129	190	350	44.0
RCR-4	400	830	51.6
ST-7	4.40	840	47.7
RT-4	190	340	43.5
AT-7	500	750	33.8
AT-5	600	830	27.7
HT-6	640	1380	53.5
Kanke-white	430	890	51.3
CST-783	490	890	44.5
TC-25	650	860	24.1
Pb. Til No.1	580	890	34.0
JLT-3	640	800	19.8
BS-5-18-6-G	560	720	22.4
CST-782	450	560	20.3
B-67	350	420	17.3
TC-151	610	1090	43.9
PDP-2	400	860	53.2
TC-289	570	730	22.9
CST-781	610	1270	52.4
AT-4	220	460	53.6
JLT-8	480	660	27.3
RCR-1	810	1360	40.5
RCR-2	380	590	35.6
RAUSS-17-4	260	300	15.6
TC-229	630	1060	40.4
TNAU-11	340	630	45.9
HT-1	530	1250	57.4
TC-17	650	850	23.8
JLT-1	410	760	46.9
CST-785	450	1370	66.8
RCR-3	480	820	41.4
AT-8	250	420	41.8
JLT-7	310	630	51.4
L-38	340	970	64.7
TC-167	680	1220	43.9
AT-3	230	350	34.0
SEm ±	130	110	-
CD (P=0.05)	360	300	-

* Sprayed thrice with carbaryl 0.15% at 25, 40 and 55 days after sowing.

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of these two genotypes, under protected condition, was very low i.e., 419 (B-67) and 302 kg/ha (RAUSS-17-4). Hence, these genotypes should not be recommended for general cultivation. The yield potential of HT-6, TC-151, CST-781, RCR-1, HT-1, CST-785 and TC-167 was 1384, 1085, 1272, 1355, 1246, 1369 and 1218 kg/ha respectively.

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Short communication

Constraints and suggestions in transfer of oilseeds technology : A critique

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The system of technology transfer has three main components such as technological knowledge transfer, supply of inputs and agricultural services including credit, veterinary services etc. In this each component was taken care of by the separate agency. Among them, the agency engaged in dissemination of technical knowledge was very important while rest of them mostly taken care by the users (clients) themselves. Despite strong network of extension mechanism for transfer of technical know-how operating in the country, yet a wide gap was existed between transfer of oilseed technology and adoption by farmers. In fact, the oilseeds are next to cereals to their economic viability and future potentiality, so if the gap is narrowed, the oilseed production can be increased by 43% than the existing farmers level production of 973 kg/ha (Ramanjaneyulu *et al.*, 2000). Hence, it was felt necessary to know whether the extension personnel engaged in public and private sectors encountering any constraints in the transfer of oilseeds technology. So, a study was undertaken with the objective of eliciting constraints encountered by the extension personnel engaged in transfer of oilseed technology and their suggestions for effective dissemination of technical know-how.

A total of 72 trainee representatives of Subject Matter Specialists, Agricultural Officers and Researchers from Tamil Nadu (16), Andhra Pradesh (15), Karnataka (12), Maharashtra (10), Madhya Pradesh(8), Uttar Pradesh (6) and Haryana (5), who had undergone trainings in Oilseed production technology, Integrated pest management and Hybrid seed production technology at Directorate of Oilseeds Research and National Plant Protection Training Institute, Hyderabad during 2000-2001. were formed the clientele for the study. The data were collected through questionnaires. The date were analyzed, tabulated and interpreted with suitable statistical tools.

The frequency distribution of personal characteristics is presented in Table 1. It could be seen from the table that overwhelming majority (84.72%) of the extension personnel were in the middle age group followed by young age (13.89%), 68.05% of them had graduation, while others (31.84%) were completed post graduation and above. The data on service experience clearly indicated that 50% of them were belonged to medium experience in service followed by low experience (34.75%) and high experience (Table 2). Further, the results indicated that the average number of trainings underwent in oilseeds and other crops by the individuals of different experience groups was as highest as 2.66 and 8 times in high experience group as against 1.98 & 4.89 and 0.8 & 2.92 times by medium and low experience groups respectively.

It could be inferred that the training underwent by the individuals during their service was considerably low, so giving trainings more number of times enable them become proficiently competent besides helps in transfer of technology effectively.

The constraints encountered by the extension personnel engaged in transfer of technology were given in Table 3. It could be seen from the table that, non-availability of quality inputs in time was ranked 1st followed by poor conveyance facility for extension personnel and private companies are often exploiting the farmers which led to a problem in convincing the farmers for adoption of public sector hybrids and varieties ranked IInd and IIIrd. Unstable market price for oilseeds, import of oils affected the oilseed growers, high cost involved in improved methods and lack of latest technical know-how for the extension personnel were ranked IVth, Vth, VIth and VIIIth respectively. It could be inferred that the constraints listed had effected the transfer of technology which directly or indirectly effected in shifting of oilseeds to other crops. Similar findings were also identified by Narendra Prakash and Ram Bahal, 2001.

Further, the extension personnel were also offered some of the suggestions in order to over come the constraints faced by them for effective transfer of technology (Table 4). It could be observed from the data that, timely supply of quality seed and other inputs locally by the department ranked 1st followed by training to extension personnel for improving professional competency, conveyance facility for extension personnel and organization of more demonstrations and use of mass media for propaganda ranked IInd, IIIrd and IVth respectively. The other important suggestions given by them were retention of trained extension personnel in the same post, ban on entry of truthfully labled seed into the market, *encouragement of self help groups ranked VIth* and VIIth respectively. The suggestions offered by them, if considered to overcome the constraints in the transfer of oilseed technology, would help in enhancing rate of adoption by farmers.

Table 1 Distribution of extension personnel according to their age and education

Factor	Respondents	
	Fre. No.	(%)
Age (Years)		
Young (upto 30)	10	13.9
Middle (31-55)	61	84.7
Old (>55)	1	1.4
Education		
Graduation	49	68.1
Post-graduation and above	23	32.0
Total	72	100

Table 2 Distribution of extension personnel according to their experience and trainings underwent

Category	Frequency No.	(%)	Training on		Total No. of trainings
			Oilseeds*	Other crops*	
Low experience (upto 10 years)	25	34.74	0.80	2.92	3.72
Medium experience (upto 20 years)	35	48.60	1.98	4.88	6.86
High experience (> 20 years)	12	16.60	2.66	8.00	10.66
Total	72	100.00	3.54	14.80	22.24

* Average number of trainings

Table 3 Constraints as perceived by the extension personnel in transfer of oilseeds technology

S.No.	Constraints	Fre. No.*	(%)	Rank
1.	Non-availability of good quality inputs (seeds, pesticides, fertilizer etc.)	50	69.4	I
2.	Poor conveyance facility	47	65.5	II
3.	High cost of improved seed to extension personnel	13	18.1	VII
4.	Farmers often refuse to remove stray plants in seed production plots instead prefer good quality breeder seed	12	16.6	VIII
5.	Unstable market price for oilseeds causes for shifting to other crops	24	33.3	IV
6.	Large number of farmers having an apprehension about new varieties and hybrids under rainfed situation	12	16.6	VIII
7.	Lack of latest technical know-how to the extension personnel	13	18.1	VII
8.	*Private companies often exploiting the farmers, hence facing problem in convincing* the farmers for adoption of public sector hybrids and varieties	27	37.5	III
9.	High cost involved in improved methods	17	23.6	VI
10.	Poor linkages between research, extension and farmers	12	16.6	VIII
11.	Import of oils affected the oilseed growers hence shifting to other crops	20	27.8	V
12.	*Electricity problem in the spring/summer hampering the oilseed production*	17	23.6	VI
13.	Occurrence of pests in castor and sunflower led to shift of oilseeds for other crops	8	11.1	IX

** Multiple responses*

Table 4 Suggestions as offered by extension personnel for effective transfer of technology in oilseeds

Sl. No.	Particulars	Fre. No.*	%	Rank
1.	Timely supply of quality seed and other inputs locally by the department	30	41.70	I
2.	Organisation of IPM on large scale basis, helps in adoption of more technologies	10	13.90	VIII
3.	Announcement of minimum support price before commencement of season	5	6.94	X
4.	Training to extension personnel from time to time for improving professional competency	29	40.28	II
5.	Retention of trained extension personnel in the some posts after trainings	15	20.83	V
6.	Organisation of more number of rhythu melas and use of mass media for wide publicity.	24	33.33	IV
7.	More no. of demonstrations at the field level	10	13.90	VIII
8.	Use of mass media for wide publicity on oilseed crops	17	23.6	VI
9.	Discourage on entry of truthful lable seed into the market	14	19.44	VI
10.	Conveyance facility for extension personnel	25	34.73	III
11.	Encouragement of self help groups	12	16.67	VIII
12.	Training for input deals for better utilization of Transfer of Technology at village level	9	12.3	IX

* Multiple responses

Conclusion

From the results, it could be observed that all of the extension personnel were graduates and above having more experience, but the number of trainings underwent by the individuals in oilseeds was less, indicated the need of professional competency. Hence, all the extension personnel who deals with TOT at field level should be provided subject matter trainings from time to time besides improvement in conveyance facility, supply of quality inputs and good local market for the produce to accelerate the transfer of oilseed technology thereby high rate of adoption of improved technology by the farmers.

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Short communication

Yield and economics of niger, *Guizotia abyssinica* Cass. as influenced by new technologies on the farmers' fields

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Niger is a major oilseed crop and contributes 3 % of Indian oilseeds production and has great export potential, particularly on account of being free from pesticides residues in seed and oil. It is mostly growing on infertile and sub-marginal lands of tribal areas and is highly drought tolerant crop. The productivity of niger in Madhya Pradesh is low (258 kg/ha) due to non-adoption of improved technologies i.e. suitable high yielding varieties, proper method of sowing, recommended balanced fertilizers and weed control etc. However, the yield of niger can be enhanced by 93 to 155% with adoption of recommended package of practices (Das *et al.*, 1998; Anonymous, 2000). Therefore, it was decided to demonstrate the improved technologies of niger crop to farmers in the Satpura plateau of Madhya Pradesh under front line demonstration programme.

A total 85 front line demonstrations were conducted during *kharif* season of 1996 to 2001 at farmers' fields in Chhindwara district of Satpura plateau of Madhya Pradesh. The plot size ranged between 0.4 to 0.6 ha in sandy and gravelly soils. The recommended package of practices in demonstration plots included niger varieties Chhindwara-1, Ootacmund and IGP-76 were sown in rows at 30 cm apart with a seed rate of 5 kg/ha. The recommended dose of nutrients included N, P_2O_5 and K_2O at 20, 20 and 10 kg/ha respectively. Half dose of nitrogen (Urea) full dose of phosphorus (Single super phosphate) and potash was drilled two days before sowing at depth of 5-6 cm and the remaining 50% nitrogen was top dressed at 35 days after sowing. Seeds were treated with thiram at 3 g/kg seed for protection against root rot (*Rhizoctonia bataticola*). Niger was sown between 27 July to 12 August and harvested between 20 November to 4 December. One hand weeding was done at 20-25 days after sowing.

Variety IGP-76 produced the highest seed yield (375 kg/ha) followed by Chhindwara–1 (314 kg/ha). Variety IGP-76, Ootacmund and Chhindwara-1 recorded 134, 118 and 112 % respectively higher grain yield under recommended package of practices over local varieties with farmers' practices (Table-1). Earlier Das *et al.* (1998) and ICAR (2001) also reported that niger varieties IGP-76 and Ootacmund gave higher yield than local variety. The results are in close conformity with the earlier reports.

The highest grain yield of niger (382 kg/ha) was recorded under recommended practices with the productivity ranging from 268 to 420 kg/ha. Higher grain yield of niger could be obtained with improved technology as compared to local practices to the extent of 90 to 148% (Table 2). The reason of higher yield of niger could be attributed to adoption of improved varieties, line sowing with 30 cm row spacing, fertilizer management and weed control.

The economic analysis made on the basis of prevailing market rates showed that the demonstration gave higher net returns and cost benefit ratio as compared to local practices in the corresponding years (Table 3). It is concluded that cultivation of niger varieties *viz.*, IGP-76 and Ootacmund under improved management practices including proper seed rate, line sowing with 30 cm spacing, recommended fertilizer and weed control proved more remunerative than that grown with traditional practices.

Table 1 Performance of improved varieties of niger against local varieties on farmers' fields

Variety	Yield (kg/ha)		Yield of local checks (kg/ha)	Per cent increase in yield over local check
	Highest	Average		
Chhindwara-1	348	314	148	112
Ootacmund	392	336	154	118
IGP-76	440	375	160	134

Average of 5 years

Table 2 Recommended and local practices affected niger seed yield on farmers' field

Year	Area (ha)	No. of farmers	Yield (kg/ha)				Increase in yield over local check (%)
			Highest	Lowest	Average	Local Check	
1996	10	24	357	272	315	165	91
1997	5	12	320	268	294	144	104
1998	10	25	385	297	337	160	111
1999	5	12	345	295	320	140	129
2000*	-	-	-	-	-	-	-
2001	5	12	420	360	382	154	148

** The plant population was recorded very low due to early termination of rains thus yields were not included.*

Table 3 Economics of niger cultivation under improved and local management practices

Year	Cost of cultivation (Rs/ha)		Net return (Rs/ha)		Addl. Cost of cultivation (Rs/ha)	Addl. Net returns (Rs/ha)	Incremental benefit cost ratio
	Demonstration	Local check	Demonstration	Local check			
1996	1235	725	2545	1255	510	1290	2.52
1997	1310	795	2585	1113	515	1472	2.85
1998	1632	978	3254	1342	654	1912	2.92
1999	1893	1140	3227	1100	753	2127	2.82
2001	2112	1275	4764	1497	837	3267	3.90

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Short communication

Economic aspects of processing of oil palm

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India is the third largest edible oil economy in the world after USA and China. India holds a premier position in the global oilseed scenario accounting for 19% of the total area and 9% of production. However, the productivity in India is only 935 kg/ha as compared to the world level of 1632 kg/ha. Oil palm is the highest oil yielding crop i.e., about six tonnes of oil/ha/annum. At present, India is importing palm oil as palmolein to bridge the gap in production and consumption. It accounts for 80% of total edible oil imports. It is therefore necessary to encourage oil palm cultivation and processing as well to bridge the supply demand gap and reduce the financial burden on edible oil imports.

In India, 8.11 lakh ha were identified as potential area for oil palm cultivation of which Andhra Pradesh and Karnataka were found to possess the maximum potential with identified areas of 4.1 lakh ha and 2.5 lakh ha, respectively.

Nellore district in Andhra Pradesh was purposively selected for the study as it has considerable area (2766 ha) in the year 1998-99 under oil palm and ranked fourth in the cultivation of oil palm in the state. Multistage stratified technique was used for selecting sample farmers. Three mandals were selected based on the maximum area under oil palm. From the three mandal, six villages were selected based on the same criterion. All the farmers in the selected villages growing oil palm were divided into two groups *viz.*, prebearing orchards upto the age of four years and bearing orchards with the age above four years. An ultimate sample 60 (30+30) oil palm growers covering the above two groups was chosen randomly. The lone oil palm processing unit existing in the study area was selected for the study. The relevant data from the farmers and processing unit were collected by personal interview with the help of pretested schedules.

Processing aspects of oil palm: The common method of oil palm processing is knows as 'Dry process' wherein the oil is extracted mechanically by the hydraulic process or continuous screw process. The minimum size of oil processing mills available was 3 tonnes of Fresh Fruit Bunches (FFB)/hour. A minimum of 200 ha plantations were required to make such a unit economically viable. Simhapuri Agro Products Pvt. Ltd., the processing unit in Nellore district was established with a capacity of 5 tonnes/hour. The processing consisted of the following aspects *viz.*, sterilization, stripping, digestion, pressing or oil extraction, clarification, oil purification, drying and separation of nuts from fibre.

Costs and returns from oil palm processing: The processing costs including variable costs and fixed costs incurred in producing one tonne of palm oil by the mills were worked out and are furnished (Table 1).

Table 1 Costs and returns from oil palm processing (Rs./tonne)

Particulars	Amount	Percentage
Variable costs		
Cost of raw material	16176.5	85.8
Incidental charges	153.7	0.81
Wages for casual labour	380.9	2.02
Power charges	38.6	0.21
Lubricant charges	2.6	0.01
Fuel charges	57.9	0.31
Miscellaneous charges	30.9	0.16
Interest on working capital	5.7	0.03
Total variable costs	16846.7	89.35
Fixed costs		
Depreciation on buildings		
Factory building	174.6	0.93
Administrative building	30.2	0.16
Workshop	1.5	0.01
Depreciation on		
Machinery	328	1.74
Effluent treatment plant	45.6	0.24
Tractors and Accessories	30.6	0.16
Drum (250 lit Capacity)	5.1	0.03
Fire extinguisher and fixers	1.1	0.01
Generators	4.2	0.02
Opportunity cost of land	29	0.16
Repairs and maintenance	57	0.3
Insurance charges	38	0.2
Taxes	74	0.4
Salaries for permanent staff	97	0.5
Interest on fixed capital	1092	5.79
Total fixed costs	2007	10.65
Total costs	18854	100
Returns		
Returns from one tonne of oil (CPO)	36000	92.45
Returns from kernels	2940	7.55
Gross returns	38940	100
Net returns from one tonne of oil	20086	
Input-output ratio	2.07	
Benefit cost ratio	1.07	

The total cost incurred to produce one tonne of oil was Rs. 18854.29. The variable costs and fixed costs were Rs. 16846.74 and Rs. 2007.55 accounting for 89.35 and 10.65% of the total cost, respectively. Among variable costs, cost of raw material was the major item amounting to Rs. 16176.47 and accounting for 85.80% of the total cost/tonne of oil produced by the oil mills. Next to raw material wages incurred towards casual labour accounting for 2.02%, miscellaneous charges (0.16%), interest on working capital (0.03%) and lubricant charges (0.01%). The labour intensive operations were loading and unloading of raw material, separation of pulp from mesh, separation of oil from water, waste bunches disposal and firewood shifting to boiler. Incidental charges in the form of telephones and records were incurred. Fuel charges were higher than the power charges because of utilization of generators.

The total fixed costs accounted for Rs. 2007.55 per tonne. Interest on fixed capital was the major item of fixed costs accounting for 5.79% of the total cost. Next to interest on fixed capital, depreciation formed the other item of expenditure in fixed costs which accounted for 3.3%, salaries for permanent staff worked out to be 0.50%/tonne of oil produced followed by taxes (0.40%), repairs and maintenance (0.30%), insurance charges (0.20%), and cost of land (0.16%).

Returns for one tonne of palm oil: It is observed that on an average, palm oil mill crushed 5.88 tonnes fresh fruit bunches of oil palm to obtain one tonne of oil which was valued at Rs. 36,000 and 0.588 tonnes kernels as by product valued at Rs. 2,940 (Table 1). Thus, the gross and net returns were worked out to be Rs.38,940 and Rs.20,086.01/tonne of palm oil, respectively. Thus, the value addition as a result of processing activity stood at Rs. 20,086.01/ tonne of oil. The benefit cost ratio and the input output ratios were 1.07 and 2.07, respectively. So, the investment on oil palm processing unit was economically feasible.

A sizable return indeed, but there were some constraints in the area such as shortage of power supply, non-availability of raw material (FFB) throughout the year and scarcity of labour during peak periods of work. In the light of these facts, an integrated approach is a must to meet the target production of oil palm.

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Short communication

Studies on mechanical expression of *Simarouba glauca* kernels

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Simarouba glauca kernel has oil content of 58-60% and total lipid of 67% (Sahoo *et al.*, in press). With a potential to produce about 2 tonnes of oil/hectare, *S. glauca* can become a future source of edible oil and help in bridging the demand and supply gap (Rao, 2001). With increasing concern for presence of traces of residual solvent in edible oils, mechanical expression of oils from high oil containing seeds like *S. glauca* attains special significance. In the mechanical means of expelling of oil from the seeds, the seeds are compressed or squeezed. Different devices available are hydraulic presses, *Ghanies*, low pressure and high-pressure expellers. Since *Simarouba* is a very high oil-containing kernel, its processing should be considered accordingly.

Shukla *et al.* (1992) reported that is not much difficulty in expelling of whole seeds when the hulls constitute only a small percentage of the seed. However, since *glauca* seed contains about 70% hull by weight and the hull is very hard to crush, it is very difficult and not advisable to crush *Simarouba* seeds in a mechanical oil expeller either under hot or cold processing. Studies on expelling of different oilseeds such as linseed (Singh and Bargale, 1990) sunflower (Srivastava and Gupta,1992) and safflower (Gupta and Srivastava, 1994) have been reported. These authors reported that choke settings, pretreatment and the moisture content influence the capacity, percentage of oil recovery and thickness of the cake. The compression ratio of screw press is the ratio of volume displaced per revolution of the shaft at feed section to the volume displaced per revolution of the shaft near end of the plug section. The shaft should be axial and compression ratio of about 10:1 required for seeds of high oil content, while low oil containing seeds require higher compression ratio (Singh *et al.*, 1990). So far no reports on the expelling of *Simarouba* kernels have been reported. We describe here the effect of different pretreatment on oil recovery from *S. glauca* kernels. This is the first report on crushing characteristics of *S. glauca* kernels.

We have carried out the initial expeller performance studies in a Rosedown type screw press of 20 kg/hour capacity. The detail of the expeller used are given below :

Table 1 Details of expeller used for studies

Barrel	Cylindrical barrel having a number of chamfered holes at the feed end side. Length 125 mm and internal ID 75 mm
Worm shaft	Diameter of the worm shaft at feed end - 50mm and at discharge end - 73mm
compression ratio	10
rpm of the main shaft	90-100 through gear and belt
Drive	3 H.P motor

Hard seed materials like cotton seed, coconut, castor, etc., required more power than soft materials like mustard, groundnut and *Simarouba* kernels. Published literature suggested that a pressure of 100 Kgf/cm^2 was required to compress and expel oilseeds containing 25-40% oil content. At a compression ratio of 10:1, for a 20 kg/hour seed crushing capacity, with the chosen barrel dimension, a 3 H.P. motor with 970 rpm was chosen.

Taking the above parameters into considerations, components of oil expeller was procured (Fig 1). The cage bar system was replaced with the barrel fabricated in the workshop. After assembling the system and trial runs, the performance of the oil expeller was evaluated.

Simarouba glauca seeds were supplied by State Forest Department, Govt. of Orissa and the kernels were obtained by manual decortication. Proximate analysis of kernels was carried out as per procedure given in Indian Standard (IS-543 : 1986). The seed had 25-30% kernel and 70-75% shell. While the moisture content of kernel was 8.5%, the shell had 6.2%. Soxhlet extraction with hexane gave 57-60% oil, but on extraction with chloroform : methanol (2:1), total lipid extracted was 67-68%. The deoiled cake had >50% protein and only 4.2% fibre.

For the expression of oil, the following pretreatment was given to seeds:

(i) Size reduction prior to feeding to the expeller; (ii) instant addition of water to raise the moisture content and putting the sample in the air tight polythene bag to attain uniform moisture content and (iii) mixing predetermined amount of *Simarouba* cake with kernels prior to expelling.

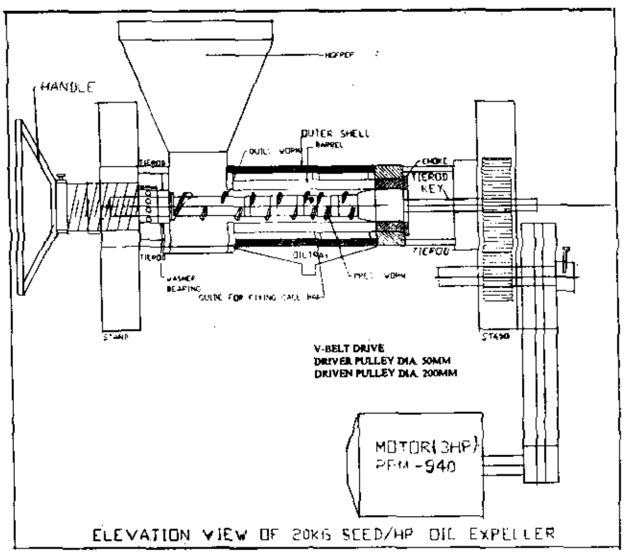

Fig 1 Elevation view of 20 kg seed/hour oil expeller

The kernel was ground and sieved to obtain material in the 2-3 *mm and below* 2 *mm size which was used for* crushing. From the performance data, the expeller capacity and efficacy were calculated using standard formulae. The oil obtained from the expeller as well as solvent extraction (Table 2) was analysed for free fatty acid content and lipid composition as per Christie (1982), IS:543 (1986), Hemavathy and Prabhakar (1990).

Table 2 Lipid composition of the *Simarouba glauca* fat

Lipid/Fat	Neutral lipid (%)	Glyco lipid (%)	Phospho lipid (%)	Free fatty acid (%)
Total lipid (67-68%)	83.3	16.2	1.6	-
Expeller fat (48-52%)	91.8	6.2	1.5	3.5
Hexane extracted fat (56-58%)	87.5	10.7	1.5	1.5
Total lipid from Hexane extracted cake (11-12%)	44.3	43.4	8.7	3.5
Total lipid from expeller cake (18-20%)	54.7	36.9	9.1	7.5

It may be seen that *Simarouba* kernels have high oil and low fiber, but the cake has high protein content (Table 2). Thus, expelling *S. glauca* kernels directly resulted in the formation of semi-solid plastic mass which simply rotated in the barrel without forward movement resulting in no oil recovery. The *Simarouba* fat has higher melting point and needed some amount of heat for expelling. This problem was overcome in two steps: in the first step of expelling, the kernels were fed along with groundnut hulls or rice husk and cake generated. From the second step onwards, the kernels were admixed with *S. glauca* cake. Increasing the moisture content of *Simarouba* kernels by instant water addition did not have any specific advantage. Similarly, size reduction of kernels did not have any additional advantage in expression since the soft *Simarouba* kernels easily got crushed during the first pass. The heat generated during the 2nd and 3rd passes perhaps helped coagulation of the protein in the cake and allowed easy passage of the oil from the capillaries.

It is observed that oil recovery varied from 72% to 89% depending upon cake content in the feed (Fig 2). Semi-solid paste was obtained without any oil yield upto 10%

cake. The maximum recovery of more than 85% oil was obtained when 40-50% cake and kernel mixture was used. The crushing capacity at maximum oil recovery was found at 10 kg seed/hr, where as energy consumption varied from 0.20 to 0.26 kwh/kg of feed depending upon cake content i.e., 20% to 50% in the feed. Increasing the press cake though has not changed the oil recovery drastically, however, the effective capacity of the expeller was reduced.

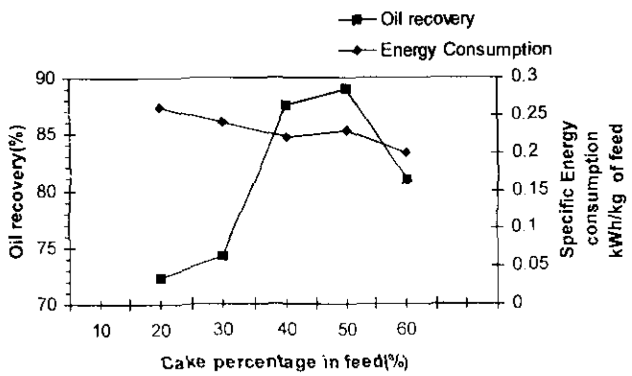

Fig 2 **Variation in oil recovery and specific energy consumption with cake percentage in feed**

A nine bolt commercial expeller also performed without any difficulty with *Simarouba* kernels. As the kernels have adequate moisture of 8.5% it needed no or slight addition of water (2% by weight) before starting expelling. The moisture helped in cooking of the cake in the barrel facilitating easy flow of oil and controlling the oil and cake temperature.

Conclusion

The oil from the soft *S. glauca* seed kernel can be expelled in modified table as well as commercial expellers when the kernel is admixed with 40-50% of press cake. This provided sufficient roughage for easy movement of the seeds through the kernel and oil recovery was more than 85%.

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