ISSN 0970-2776

Volume 28 Number 2 December 2011

Journal of Oilseeds Research

Indian Society of Oilseeds Research
Directorate of Oilseeds Research
Rajendrangar, Hyderabad-500 030, India

THE INDIAN SOCIETY OF OILSEEDS RESEARCH

(Founded in 1983, Registration Number ISSN 0970-2776)

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Journal of Oilseeds Research is published biannually by the Indian Society of Oilseeds Research

JOURNAL OF OILSEEDS RESEARCH

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Review article

Recent advances in secondary and micronutrient management in safflower (*Carthamus tinctorius* L.)

I Y L N MURTHY

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

ABSTRACT

Safflower (*Carthamus tinctorius* L) is an important edible oilseed crop with diversified uses. Mostly cultivated in black clayey soils known as Vertisols in India during the winter season. Productivity of the crop is low (642 kg/ha) because of the several abiotic and biotic stresses. Among the essential nutrients, significant research was done with the major nutrient management in improving seed yield and quality. However, secondary and micronutrients have received limited attention of the researchers. In Vertisols, deficiency of these nutrients is widespread and one reason for low seed yield of safflower. Sulphur application rate of 20-45 kg/ha to safflower alone or safflower based cropping proved to be beneficial in improving seed yield. Sources of S vary depends on the soil type. Critical zinc (Zn) and boron (B) levels in Vertisol with safflower as test crop were 0.63 and 0.60 mg/kg, respectively. Among the micronutrients, Zn, Fe and B, deficiencies are reported in Vertisols and associated soils. Safflower responded significantly to the application of Zn (as $ZnSO_4$) @ 20 kg/ha, Fe (as $FeSO_4$) @ 20 kg/ha and B (as borax) @ 1.5 - 2.5 kg/ha found responsive in increasing the safflower seed yield. Intra and inter nutrient combination of S, Zn, Fe and B have shown significant seed yield responses in Vertisol and associated soils.

Keywords: Boron, Iron, Nutrient management, Safflower, Sulphur, Zinc

Safflower (*Carthamus tinctorius* L) is an ancient crop of India, cultivated during the winter season. It is grown for orange-red dye (carthamin) extracted from its brilliantly coloured florets and for much valued oil. Oil being rich in polyunsaturated fatty acid (linoleic 78%), plays an important role in reducing the blood cholesterol level. Crop cultivation under moisture and nutrient stress environment besides, poor crop managements are the major reasons for low productivity (623 kg/ha) of the crop. India occupies the second place in safflower production in the world. Currently, it grows in an area of 2.29 lakh ha. with a production of 1.42 lakh t. (2010-11). The general per hectare yield of safflower in India (642 kg/ha) is low when compared to other leading countries and world average (890 kg/ha) (Damodaram and Hegde, 2010). Conventional dry land crops can replace by sole crop of safflower in all potential areas of cultivation. Safflower is cultivated mostly in Vertisol and associated soils of Maharashtra, Karnataka and Andhra Pradesh. Black soils (Vertisols) are ideally suited for cultivation, although it is grown on other soil types. State-wise crop area, production and productivity are presented in table 1.

In this paper, a brief description of status of secondary and micronutrients in the Indian Vertisol and associated soils is discussed. Besides, the available information on secondary and micronutrient management of safflower crop is collated and presented.

Vertisols and associated soils: Vertisols are mostly concentrated in the state of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh and Karnataka, which accounts for roughly 36,23,12,10 and 9%, respectively of India's total area under black soils. Characteristically these are clayey in nature, depth-wise shallow to deep and heavy swelling on wetting and contraction on drying therefore known as swell-shrink soils. Soil reaction (pH) varies from 7.3 to 9.5. Organic carbon content varies from 0.2 to 0.7 %. Cationic exchange capacity varies between 47 to 65 cmol (p+)/kg of soil and depends on the clay type and content. Black soils in general, are deficient in nitrogen (N), low to medium in phosphorus (P) and potassium (K). Safflower is traditionally cultivated in the black soils of these states (>90% area). In safflower growing states, the percent soils deficient in most important and limiting secondary and micronutrients for the crop productivity are presented in table 1.

Sulphur (S) availability in black soils is generally sufficient. However, introduction of high yielding varieties (HYV) and hybrids, intensive cropping coupled with application of straight fertilisers to the crop lead to larger-scale depletion of this nutrient in the soils. Sulphur retention in Vertisols is difficult while in Alfisols and Oxisols it occurs due to the presence of anhydrous sesquioxides and organic matter. Mineralization of organic matter releases the S in the available form to the plants. Total S content in Maharashtra soils varied from 95 to 513 mg/kg, while organic S content and water soluble S consent varied between 54-265 mg/kg and from 6 to 54 mg/kg, respectively. (Patil and Ghonsikar, 1985). Sangammer and Rahuri tehsils of Ahmednagar district of Maharashtra black soils were found deficient in available S to the extent of 34.7% and 16%, respectively (Shinde, 2000). In intensive oilseed growing areas of Dharwad and adjacent farmers fields in Karnataka state, the range in contents of available S, $Na_2H_2PO_4$ extractable organic S and total organic S were 2.5 to 55.0 mg/kg, 26.0 to 277.5 mg/kg and 1108 to 4591 mg/kg, respectively (Venkatesh and Satyanarayana, 1999). Sulphur deficiency widely varied from 9.5% in deep Vertisols to 90% in shallow Vertisols of Madhya Pradesh. Its deficiency was highest in shallow Vertisols followed by alluvial > mixed red and black > red and yellow soils of Madhya Pradesh. (Pasricha and Fox, 1993). Vertisols of Dharwad area in Karnataka have tested less than 20% S deficiency. Widespread deficiency of S ranging from 46% in Junagadh of Gujarat to 100% in Vidisha and Devas of Madhya Pradesh was reported (Rego *et al.*, 2007). Black soils are generally alkaline in nature, have enough bases on their exchange complex and as such calcium deficiency is rare in these soils. However, strongly alkaline soils are poor in Ca. Calcium deficiency is expected where Ca saturation is less than 25% or less than 1.5 meq exchangeable Ca and pH are high. Medium black soils occupying around 65% of the area in the state of Maharashtra are bases saturated with Ca^{+2} as the dominant exchangeable cation (Patil and Ghonsikar, 1985). The conditions that favour Ca deficiency will cause Mg deficiency too. Usually soils containing less than 1 meq exchangeable Mg/100 g soil or less than 4 to 15% of CEC occupied by Mg are considered deficient (Biswas *et al.*, 1985). Zinc availability decreases with an increase in soil pH and lime content. Vertisols are normally low in available Zn, therefore needs Zn application to sustain crop productivity. Total and available Zn content in Vertisols is 63 and 0.41 mg/kg, respectively (Katyal and Sharma, 1991). Indian soils have large amounts of B, only 0.5% of total B is available. Boron deficiency reports from black soil area are limited although 33% of the soil samples in the country are deficient. Boron deficiency usually observed in deep black soils. Available B content in Vertisol of Gujarat varied from 0.03 to 3.08 mg/kg (Dangarawala *et al.*, 1983). Application of B should be done with caution since any small variation can cause toxicity. Deficiency of B to the extent of 2 to 4% was noted in Vertisols of Madhya Pradesh. In Karnataka, 32% soil samples are deficient in available B. Recently its deficiency in semi-arid soils was also reported (Sahrawat *et al.*, 2010 and Srinivasa Rao *et al.*, 2009). Availability of Fe in black soils is low because of high pH and calcareous nature of most of these soils. Soil pH influences other plant nutrients like Mn and Cu. However, they are not deficient in black soils may be due to low need of crop.

Critical nutrient levels: Critical nutrient levels found out in black soils for S may vary from 8-12 mg/kg (Tandon, 1991). Singh *et al.* (2003) suggested DTPA-Zn values of < 0.5 mg/kg for Vertisols of Gujarat, 0.7 mg/kg for red and Vertisols of Andhra Pradesh, <0.6 mg/kg for Vertisols of Madhya Pradesh and <1.2 mg/kg for red and black soils of Tamil Nadu as low or critical level. Rego *et al.* (2005) considered critical B level in SAT soils as 0.5 mg/kg. Critical S, Zn and B concentration in plant tissue (fully developed youngest leaf) for nutrient deficiencies in field crops are 0.1-0.2%, 10-20 mg/g and 5-30 mg/g, respectively (Katyal and Rattan, 2003; Rego *et al.*, 2005). The critical zinc and phosphorus: zinc ratio for safflower 'A-1' was 25.9 mg/kg and 80.2 and for 'NARI-NH-1' was 27.0 mg/kg and 81.0 at flowering stage. Similarly, critical DTPA-zinc in the black soil (Vertisol) in which the safflower genotypes were grown was also determined and was found 0.63 mg/kg for 'A-1' and 0.72 mg/kg for 'NARI-NH-1' (Murthy and Padmavathi, 2008). Critical B content in safflower shoot at flowering stage was 25 mg/kg while the critical hot water soluble B level in black soil was 0.6 mg/kg (Murthy and Padmavathi, 2010).

Crop sequestration: Safflower crop consumes on an average 43.2 kg N, 21.8 kg P_2O_5, 36.6 kg K_2O, and 12.6 kg S to produce a tonne of seed (Hegde, 1998). While micronutrient sequestration by a kg seed was 34.9 mg Zn, 48.6 mg Fe, 9.38 mg Mn, 25.4 mg Cu and 23.7 mg B (Murthy and Padmavathi 2008), besides significant quantity of Ca, Mg and Mo. Inherent fertility of black soil can sustain high crop yields. Balanced fertiliser use for crop nutrition must include application and management of all those essential nutrients which are deficient or not available to the crop in adequate amounts.

Significant research efforts were made related to the macronutrient management of safflower. However, information is sketchy on secondary and micronutrient management, which was discussed below:

Sulphur: Emergence of S deficiency in soils of various states was noticed (Table 1). Probably, this could be a reason for low yield of safflower crop. Further, remarkable S response observed with safflower, confirms its deficiency in these soils.

Sulphur application had the significant effect on seed yield and among the levels, 45 kg S/ha recorded highest seed yield (1332 kg/ha) but was at par with 30 kg S/ha (1248 kg/ha) (Patel *et al.*, 2002). Among the various sources, ammonium sulphate (AS) has recorded significantly higher seed yield (1397 kg/ha) and an additional net profit. Gypsum realized higher return per rupee invested being the low-cost input. In Dharwad, Vertisols having a low available S (7.2 mg/kg) significant increase in seed yield up to 30 kg S/ha applied through AS was observed. Oil yield also increased by 53% due to S application. The N: S ratio (8.28 in safflower seed) significantly decreased because of S application. Maximum S depletion was noted both in control and AS applied soils (Venkatesh *et al.*, 2002). While in the S deficient (4.3 mg/kg) Vertisol under rainfed conditions different sources and levels of S showed that single super phosphate (SSP) was superior to AS and gypsum but comparable to elemental sulphur (ES). The interaction effect showed the highest yield of safflower (2065 kg/ha) at 30 kg/ha applied through SSP. Net returns of ₹17, 507/ha and a B:C ratio of 3.58 was noticed (Kubsad and Mallapur, 2003).

Table 1 Safflower area, production and productivity as on 2010-11
(Area: '000 ha, Production: '000 t, Productivity: kg/ha) (Ministry of Agriculture 4th Estimates, Singh, 2000)

	Area	Production	Productivity	Per cent soil deficient			
				Zn	Fe	Mn	Cu
Andhra Pradesh	*13.0*	*7.0*	*538*	*49*	*3*	*1*	*<1*
Karnataka	57.0	41.0	719	72.8	35	17	5
Maharashtra	156.0	93.0	596	86	24	0	0
Bihar	0.17	0.14	824	54	6	2	3
Chhattisgarh	0.90	0.30	333	NA	-	-	-
Jharkhand	0.24	0.07	300	NA	-	-	-
Madhya Pradesh	0.40	0.10	250	43.9	7	1	<1
Odisha	0.75	0.44	587	54	-	-	-
All India	229.06	142.60	623	48.5	12	5	3

Safflower response to different S sources (AS, SSP, ES and gypsum) and levels (0,15,30 and 45 kg/ha) in various black soils showed that fertiliser and soil efficiency factors estimated for safflower at different locations varied from -0.027 to 0.605 and 0.010 to 0.060, respectively. A better yield response and S use efficiency by the safflower crop irrespective of sources, locations and seasons were noted under irrigated conditions. Further, lower soil efficiency values over fertilizer efficiency values is an indication the crop has drawn the S, mainly from fertiliser sources irrespective locations, S levels and conditions (Murthy, 2005).

Field studies were conducted at eight different agro-ecological regions of India for 12 years (1995-2007) under AICRP programme in Vertisols and its associated soils to find out the response of safflower to S levels (15, 30 and 45 kg/ha) and sources (AS, SSP, ES and gypsum). The pooled analysis of seed yield data showed that in Typic Haplusterts (Akola), there was a significant response up to 45 kg S/ha and SSP was the best source (Table 2). In Typic Chromusterts (Annigeri), the crop responded significantly up to 30 kg S/ha and SSP was the best source. However, in Vertic Ustochrepts (Solapur), safflower responded up to 45 kg S/ha with SSP as the ideal source. In Chromusterts (Indore), the response was significant up to 30 kg S/ha and SSP and ES were equally effective. In Chromusterts (Parbhani), safflower responded up to 30 kg S/ha and ES were the best. In Vertic Ustochrepts, (Arnej) crop responded significantly up to 45 kg S/ha and AS was the best source (Table 2). The response up to 45 kg S/ha was noticed in Chromusterts (Tandur) while in Chromusterts (Phaltan), it was limited up to 15 kg/ha and SSP was the best source at both locations (Hegde, 2008). Dashora and Sharma (2006) mentioned that safflower gave significantly higher response to earlier sowing (20th September in Rajasthan), two irrigations (one at flowering and another at grain formation) and 60 kg S/ha when compared to other treatments.

Significant response to S fertilization at most of the locations is due to the available S in soil was low or low to medium. Since oilseeds have high S needs, response to S application in S deficient soils is obvious (Hegde and Murthy, 2005). In soils having low available S content, the response was up to 45 kg S/ha. Performance of safflower with different sources of S was influenced by the soil type. In saline Vertic Ustochrepts at Arnej, AS was the best source as S from the same is easily available immediately after fertilizer application unlike with other sources. In calcareous soils, of Parbhani and Akola, ES was useful since S was available to the crop because of its application about two weeks before planting. The presence of $CaCO_3$ improves oxidation of S markedly leading to better availability (Kanwar and Randhawa, 1978). In normal soils, SSP was the best source of S, which was reported earlier by many researchers (Singh, 1999, 2000; Sudhakara Babu and Hegde, 2003). The oil content was unaffected by S sources and levels. However, there was marked increase in the harvest index (31.4) with S application (Hegde, 2008).

Field studies conducted under partial irrigated conditions to evaluate the effect of P and S on productivity of safflower in Vertisol revealed that growth, yield and yield attributing characters increased with P up to 17.6 kg/ha over the control. However, no significant difference between 17.6 and 26.4 kg/ha and 26.4 and 17.6 P kg/ha giving 19 and 14% higher seed yield over the control, respectively. Seed yield and number of branches/plant increased significantly up to 20 kg S/ha. Plant height, capitulum/plant and biomass yield were significantly better at 40 kg S/ha. No significant difference existed between 40 and 60 kg S/ha, recording 20 and 16% more seed yield over control. Phosphorus and S interaction was significant only for seed yield, 17.6 kg P with 20 kg S/ha recorded significantly higher seed yield (Table 3). Maximum additional net return of ₹ 3,650 and ₹ 3,963/ha was recorded with 26.4 kg P/ha and 40 kg S/ha respectively. Better B: C ratio was obtained at 17.6 kg P and 20 kg S/ha. Maximum additional net return of ₹ 3,963/ha was observed at 40 kg S/ha). However, the better B: C ratio was obtained at 20 kg S/ha (Mohd. Abbas *et al.*, 1995).

Different levels of P, S and B on drymatter and seed yield of safflower were quantified in Parbhani black soils (Table 4). Interaction effect was nonsignificant. Significant increase in drymatter was noted only up to 30 kg S/ha and 5 kg B/ha. However, seed yield was significantly increased up to 60 kg S/ha and 10 kg B/ha (Bhilegaonkar *et al.*, 1995).

Table 2. Effect of sources and levels of sulphur on seed yield in safflower (Hegde 2008)

Treatment	Solapur	Tandur	Annigeri	Arnej	Akola	Phaltan	Parbhani	Indore
Seed yield (kg/ha)								
Control (No Sulphur)	1115	1355	1244	897	1135	1294	1320	1432
Control Vs Rest CD (P=0.05)	144	28	210	293	174	NS	349	304
S levels (kg/ha)								
15	1179	1550	1502	1103	1339	1426	1636	1583
30	1229	1528	1563	1248	1494	1450	1823	1700
45	1389	1618	1576	1332	1546	1500	1862	1859
CD (P=0.05)	68	15	NS	83	68	NS	132	91
S sources								
AS	1233	1571	1476	1397	1464	1387	1672	1642
SSP	1386	1662	1607	1191	1611	1571	1717	1778
ES	1287	1522	1545	1194	1424	1450	1837	1796
Gypsum	1158	1507	1499	1193	1340	1432	1775	1640
CD (P=0.05)	78	16	66	105	73	90	108	105
Interaction								
CD (P=0.05)	135	28	113	NS	NS	NS	NS	NS

Table 3. Interaction effect of P and S on seed yield of safflower (Mohd. Abbas *et al.*, 1995)

Treatment	P (kg/ha)				
S (kg/ha)	0	8.8	17.6	26.4	*Mean*
0	21.29	23.05	25.21	25.62	23.79
20	24.12	25.57	28.51	31.17	27.33
40	27.72	27.69	30.12	29.14	28.66
60	24.13	27.52	28.51	29.99	27.68
Mean	24.31	25.95	27.67	28.98	
C D (P=0.05)	4.82				

The effect of S, Zn and Fe nutrition on growth, yield, nutrient acquisition and quality of safflower on Vertisol at Dharwad, showed that application of 30 kg S/ha improved the growth traits like plant height, number of leaves, number of branches and dry matter, yield components *viz.*, number of capsules (37.1), seed weight/head (0.96 g), 1000 seed weight (68.2 g) and nutrient acquisition of N, P, K, S, Zn and Fe compared to other treatments. Combined application of S with micronutrients (Zn and Fe) had a significant influence on the growth, yield, oil content, protein and nutrient uptake by safflower. Application of 30 kg S/ha + Fe + Zn foliar recorded the highest growth, yield (1765 kg/ha) and nutrient uptake compared to 30 kg S/ha, 20 kg S/ha + Fe+ Zn foliar, 10 kg S/ha + Fe + Zn foliar spray and control. The highest net returns of ₹21, 521 was recorded in 30 kg S/ha + Fe + Zn foliar spray. (Ravi *et al.*, 2008). Combinations of 30 kg/ha S along with micronutrients (Fe. Zn) spray had significant influence on the growth, yield and nutrient uptake by safflower in soils of Dharwad (Ravi and Channal, 2010).

Table 4. Effect of different levels of P, S and B on drymatter and seed yield of safflower (Bhilegaonkar *et al.*, 1995)

Treatment	Drymatter at harvest (q/ha)	Seed yield (q/ha)
P (kg/ha)		
0	51.38	13.34
40	78.35	15.85
80	65.87	14.17
SE±	3.7	0.29
C D (P=0.05)	10.3	0.69
S (kg/ha)		
0	58.81	13.73
30	67.87	14.31
60	68.71	15.28
SE±	3.7	0.29
C D (P=0.05)	10.3	0.69
Boron (kg/ha)		
0	51.2	13.22
5	64.6	14.61
10	69.8	15.48
SE±	3.7	0.29
C D (P=0.05)	10.3	0.69
Interactions	NS	NS

Safflower based cropping systems: Nitrogen and S fertilization to soybean (cv JS 71-05)-safflower (cv.JSF-1) sequence on Vertisols at Indore (MP), under rainfed conditions showed that higher and sustainable seed yield with better nutrient recovery and water-use efficiency (WUE) was realized from a combination of N, P and S @ 40, 22 and 60 kg/ha, respectively applied to soybean. Application of 40 kg N/ha to soybean gave extra 30.5% advantage in seed yield and 36.5, 47.9, 37.6 and 74.6% more recovery of N, P, K and S respectively and 29% more WUE compared to control. The safflower grown on residual nutrients gave 37% more seed yield and WUE and 46-67% increase in recovery of N, P, K and S respectively because of 40 kg N/ha applied to preceding soybean (Table 5). Application of 60 kg S/ha as agricultural grade pyrite (22% S) gave 23.7% more seed yield and 27.6, 29.6, 21.4, and 74.5% higher recovery of N, P, K and S respectively, besides 24.4% greater WUE in soybean. The residual effect of 60 kg S/ha was also obvious in safflower with high seed yield and WUE and increased acquisition of nutrients. (Sharma and Gupta, 1992). After two cropping seasons, in 30 cm soil layer, there was depletion of available N, P and K from the unfertilized plots. The plots treated with N and S showed a slight build-up of N and S (Table 6). In black clay soils of Malwa region, application of 60 kg S/ha to soybean gave maximum yield for two crop rotation in soybean-safflower system (Rathore *et al.*, 1995).

Direct and residual effect of applied S in safflower based cropping on Alfisols of Telangana showed that direct application of S at 20, 40 and 60 kg/ha as ammonium sulphate to sunflower was superior to gypsum and SSP. While, succeeding crops, greengram, safflower and sorghum showed highest yields to residual S from gypsum. All the crops succeeding sunflower gave responses only at 40 kg and 60 kg S/ha levels irrespective of the sources of S. Among the succeeding crops, while greengram showed, the higher response through drymatter production, sequestration of S was higher both by stalks and seed of safflower (Table 7) followed by sorghum. Among the three cropping, sunflower-safflower removed maximum S followed by sunflower-greengram and sunflower-sorghum (Sreemannarayana and Sreenivasa Raju, 1993). Response of S on rice, mustard, groundnut and safflower in red and lateritic soils of Odisha was studied. The dose of S varied from 20-30 kg/ha and grain yield response varied from 14.2 (rice) to 77.6% in (safflower).

Experiments in farmers' fields: The results of field experiments conducted at farmers' fields in soybean-safflower cropping at Sarola (Latur) revealed that residual effect of S on summer groundnut and safflower was significant at 45 kg S/ha in increasing pod/haulm yield of groundnut and seed/straw yield of safflower. The available S status decreased slightly in control (no S). The added S during first and second year showed a relative build up after its use by the cropping. The S uptake patterns in both the cropping increased significantly with increasing levels of S showing highest acquisition by crops receiving 45 kg S/ha directly and residually. Increasing evidence of S deficiency in oilseed growing soils stressed the need of application of S for quality farm produce and maximum production in balanced fertilization.

Thus, several studies conducted in the Vertisol and its associated soils showed the significant response of safflower to S application individually as well as with the other essential nutrients. However, the magnitude of response and source of S depended on the available soil S status and soil type, respectively.

Micronutrient studies: Although visual deficiency symptoms of micronutrients, Zn, Fe and B are not reported in safflower crop, significant responses noticed with the micronutrient application confirms the hidden hunger vis-à-vis the deficiency. Zinc, Fe and B deficiencies in soils are increasing alarmingly. Sporadic and limited information is available in the literature concern to the response of other secondary (Ca and Mg) and micronutrients (Mn, Cu and

Mo) for safflower. Obviously, the crop needs for these nutrients is either adequately met by the soil nutrient reserves or the crop needs these nutrients in low proportion.

In the Zn deficient Vertisols, an economical dose of 5 kg Zn/ha is enough to achieve higher safflower seed yield (2366.7 kg/ha). Further, Zn application showed a synergistic influence on uptake of other micronutrient cations at flowering stage of the crop. An antagonistic effect of Cu and Fe acquisition by seed with the increasing levels of Zn application suggests that lower Zn is satisfactory to meet crop Zn needs to realize best seed yield. Zinc use efficiency by the seed decreased with the increasing levels of Zn application (Murthy and Padmavathi, 2008). Micronutrient fertiliser studies conducted under AICRP on safflower in the black soils of Indore and Parbhani showed that 30 kg $ZnSO_4$/ha application gave a significant response in improving the safflower yield under irrigated condition (AICRP Safflower, 2010-11). Significant difference in see yield of safflower with application of different levels of Z and Fe micronutrients was observed. Application of ZnSO @ 30 kg/ha recorded significantly higher seed yield (210 kg/ha) when compared to all other treatments but was on pa with treating $ZnSO_4$ @ 20 kg/ha (1997 kg/ha). Applicatio of $FeSO_4$ @ 20 kg/ha recorded significantly higher see yield (2143 kg/ha) but was on par with $FeSO_4$ @ 20 kg/ha Application of $ZnSO_4$ and $FeSO_4$ @ 20 kg/ha was foun enough to achieve higher safflower seed yield unde irrigated conditions. In the Vertisols of Parbhani, build-up o Zn, Fe and S in the soils was noticed (Table 8) because o continuous application of the S, Zn and Fe to the safflowe crop. The significant responses further show the inheren deficiencies of these nutrients in the soils.

Table 5. Influence of residual N and S on yield, yield attributing characters and total uptake of nutrients by rainfed safflower grown in sequence after soybean (Sharma and Gupta, 1992)

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Capsules/plant	Seed weight/plant	Total uptake (kg/ha) N	P	K	S
N (kg/ha)								
0	1555	3324	12	13.7	57.2	4.8	24.1	17.3
20	1709	4119	13	16.1	69.1	5.9	32.0	21.9
40	2131	4566	15	18.4	83.4	8.0	36.9	25.9
CD (P=0.05)	333	878	2.0	1.0	12.5	3.1	7.5	7.7
S (kg/ha)								
0	1645	3941	12	15.2	65.5	5.5	23.7	18.0
20	1725	4037	13	15.4	67.9	6.0	29.4	20.6
40	1776	3890	13	15.9	68.4	6.1	32.0	20.9
60	1816	3986	14	16.3	70.1	6.3	34.8	22.4
80	1909	4190	14	16.6	74.4	6.6	34.9	24.3
100	1918	3976	14	16.8	73.0	7.1	31.2	23.3
CD (P=0.05)	180	NS	2	0.75	4.5	1.1	4.4	3.3

Table 6. Water use efficiency and benefit cost ratio of safflower preceded with soybean fertilized with different levels of N and S (Sharma and Gupta, 1992)

Treatment	WUE of soybean (kg/ha/mm)	B: C ratio	Available nutrient status (kg/ha) in 30 cm soil layer at termination of the study N	P	K	S
N (kg/ha)						
0	4.52	4.57	350	10.4	774	60.9
20	4.97	5.04	365	11.0	790	54.6
40	6.20	6.28	375	11.2	800	50.7
S (kg/ha)						
0	4.78	4.82	327	9.6	787	36.1
20	5.02	5.09	352	11.9	732	49.7
40	5.16	5.24	365	12.7	793	53.3
60	5.28	5.35	376	14.5	813	56.6
80	5.55	5.63	383	17.6	871	64.4
100	5.58	5.66	382	17.6	880	67.3

Table 7. Residual effect of S on stalk, seed yield, content and uptake S by safflower at maturity preceded with sunflower (Sreemannarayana and Sreenivasa Raju, 1993)

Source of S	Level of S	Drymatter (q/ha)	S uptake (kg/ha)	Seed yield (q/ha)	S uptake (kg/ha)
Gypsum	0	31.2	4.53	10.11	1.95
	20	32.71	5.06	10.83	2.29
	40	34.82	5.89	12.05	2.95
	60	35.92	6.57	12.61	2.86
Mean		33.66	5.51	11.4	2.51
A S	0	31.2	4.52	10.11	1.95
	20	32.4	4.92	10.86	2.24
	40	34.21	5.56	11.55	2.46
	60	35.31	6.18	12.39	3.07
Mean		32.28	5.37	11.22	2.50
SSP	0	31.2	4.51	10.11	1.95
	20	31.7	4.73	10.47	2.09
	40	33.8	5.15	11.43	2.59
	60	34.9	5.62	12.06	2.93
Mean		32.95	5.00	11.01	2.39

Table 8. Soil nutrient status at the end of seven years of experimentation in black clayey soils of Parbhani (AICRP Safflower Annual Report, 2010-11)

Treatment	S (mg/kg)	Zn (mg/kg)	Fe (mg/kg)
$ZnSO_4$ @ 10 kg/ha	7.58	0.56	1.56
$ZnSO_4$ @ 20 kg/ha	8.15	0.62	1.61
$ZnSO_4$ @ 30 kg/ha	8.24	0.68	1.65
$FeSO_4$ @ 10 kg/ha	7.95	0.45	2.29
$FeSO_4$ @ 20 kg/ha	8.14	0.44	2.53
$FeSO_4$ @ 30 kg/ha	8.32	0.46	2.90
Elemental Sulphur @ 1.7 kg/ha	8.38	0.46	1.49
Elemental Sulphur @ 3.4 kg/ha	8.63	0.47	1.54
Elemental Sulphur @ 5.1 kg/ha	8.94	0.47	1.65
RDF + FYM (5 t/ha)	7.81	0.45	1.68
RDF only	7.60	0.46	1.53
SEm±	0.047	0.015	0.053
CD (P=0.05)	NS	0.04	0.16

RDF: Recommended NPK (kg/ha) : 60:40:0; Initial nutrient status of soil : Zn: 0.049 mg/kg; Fe: 1.83 mg/kg, S 8.05 mg/kg

Individual and interactive effects of Zn (0, 15, 30 and 45 kgZn/ha) and S (0, 30, 45, and 60 kg S/ha) with 50 kg each of N and P_2O_5/ha on safflower for yield, quality and nutrient uptake in a swell-shrink soil showed that application of 45 kg S/ha recorded significantly high drymatter, seed yield (2.61 t/ha) and seed nutrient content (Table 9). Application of Zn recorded significant response up to 15 kg Zn/ha for seed yield (2.37 t/ha). However, significantly high straw yield (7.62 t/ha) and nutrient content in the seed and drymatter were recorded with 30 kg Zn/ha application. Increased levels of S, and Zn increased significantly the oil and protein content in seed (Table 9). Sulphur and Zn interaction was significant, and the highest seed (29.34 q/ha) and straw yield (94.23 q/ha) were obtained with the combined application of 45 kg S and 15 kg Zn/ha. (Babhulkar *et al*., 2000). Application of 45 kg elemental S and 30 kg Zn/ha had increased safflower seed yield (29.34 kg/ha), giving 92.14% increase over control (15.27 kg/ha). Further S x Zn interaction was synergistic and better in improving oil, protein contents and nutrient uptake by safflower (Dinesh Kar and Babhulkar, 1998). Interaction effects were nonsignificant with seed yield of safflower. Application of FYM @ 5 t/ha + RDF + $ZnSO_4$ @ 15 kg/ha gave the highest net returns and B:C ratio of ₹ 11,480 and 2.85, respectively, while compared to application of only FYM @ 5 t/ha + no micronutrients resulted in the lower net returns and B: C ratio of ₹ 4,630 and 1.95, respectively (Arjun Sharma *et al*., 2009). An application of FYM@ 2.5 t/ha with RDF (NPK 50:25:0 kg/ha), soil application of elemental S @ 5.1 kg/ha and $ZnSO_4$ @ 30 kg/ha resulted in producing significantly higher seed yield and better economic returns of safflower under dryland conditions of Maharashtra.(Khadtare *et al*., 2009).

Table 9. Effect of S and Zn levels on seed. drymatter yield, oil and protein content and uptake of N, P, K, S (kg/ha) and Zn (g/ha) of safflower (Babhulkar *et al.*, 2000)

Sulphur (kg/ha)	Zn level (kg/ha)				Mean
	0	15	30	45	
			Seed yield (t/ha)		
0	1.53	2.33	2.18	2.18	2.05
30	2.23	2.45	2.66	2.03	2.34
45	2.82	2.77	2.93	1.91	2.61
60	2.40	1.94	1.67	2.22	2.06
Mean	2.24	2.37	2.36	2.09	
CD (P=0.05)	S=0.26	Zn=NS	SxZn=0.54		
			Oil content (%)		
0	29.0	29.9	30.1	30.2	29.8
30	30.4	30.7	30.1	30.6	30.4
45	30.6	30.7	30.9	31.1	31.1
60	30.9	31.0	31.0	31.1	31.1
Mean	30.2	30.6	30.6	30.7	
CD (P=0.05)	S=0.70	Zn=NS	SxZn=NS		
			Protein content (%)		
0	12.9	13.2	13.4	13.5	13.3
30	13.8	14.1	14.3	14.4	14.1
45	14.5	14.7	15.0	15.0	14.8
60	15.0	14.9	14.9	14.8	14.9
Mean	14.0	14.2	14.4	14.4	
CD (P=0.05)	S=0.08	Zn=0.08	SxZn=0.14		
			Nitrogen (kg/ha)		
0	56.2	77.1	73.6	72.3	69.8
30	80.1	89.7	95.6	77.0	85.6
45	96.8	99.7	116.5	77.9	97.7
60	91.0	81.1	72.8	87.2	83.3
Mean	81.0	86.9	89.6	78.6	
CD (P=0.05)	S=6.97	Zn=6.97	SxZn=13.9		
			Phosphorus (kg/ha)		
0	15.6	20.8	20.7	19.4	19.1
30	20.9	22.9	26.2	21.0	22.8
45	25.8	26.1	32.9	20.4	26.3
60	22.8	20.5	19.0	23.4	21.4
Mean	21.3	22.5	24.7	21.1	
CD (P=0.05)	S=1.8	Zn=1.8	SxZn=3.59		
			Potassium (kg/ha)		
0	56.2	70.0	64.2	61.6	63.0
30	74.5	83.1	84.9	79.7	80.5
45	81.2	89.2	118.5	81.8	92.7
60	88.7	89.4	85.6	93.1	89.2
Mean	75.1	82.9	88.3	79.1	
CD (P=0.05)	S=6.64	Zn=6.64	SxZn=NS		
			Sulphur (kg/ha)		
0	13.6	16.4	14.7	13.6	14.6
30	19.2	21.2	22.3	19.8	20.6
45	20.7	22.4	27.3	18.5	22.2
60	20.0	18.6	17.8	19.6	19.0
Mean	18.4	19.7	20.5	17.8	
CD (P=0.05)	S=1.55	Zn=1.55	SxZn=3.10		
			Zinc (g/ha)		
0	288.5	460.3	436.7	387.1	393.1
30	427.8	506.9	541.7	466.3	485.7
45	472.8	527.2	660.9	435.4	524.1
60	446.1	147.2	435.0	481.0	452.3
Mean	108.8	485.4	578.5	442.5	
CD (P=0.05)	S=40.6	Zn=40.6	SxZn=81.4		

In the black clay soils of Solapur, significant differences were noticed with seed yield because of different levels of micronutrients application. However, differences were not noticed among graded levels of $ZnSO_4$ application. Application of $FeSO_4$ @ 30 kg/ha recorded significantly highest seed yield, which was on par with application of ES @ 5.1 kg/ha and $ZnSO_4$ @ 30 kg/ha. Application of recommended dose of fertilizer was on par with RDF + FYM @ 5 t/ha. In black soils of Phaltan, and Tandur, significant differences were not observed on seed yield. While the application of $ZnSO_4$ @ 30 kg/ha (541 kg/ha) and ES @ 3.4 kg/ha (573 kg/ha) recorded the highest seed yield (Table 10) in the black clay soils of Solapur.

Studies conducted in Vertisols to evaluate the response of safflower to graded levels of N, P, S and B on seed yield and oil content showed that S and B were effective in improving the seed and oil yield (Table 11). They each at N_{150}, P_{150}, S_{10} and $B_{2.5}$ kg/ha registered the maximum seed yield. The interaction effect of these treatments was significant. The impact of N and P, but without S and B was prominent. Further application of B @ 2.5 mg/kg without S coupled, but with N and P depressed the seed yield compared to those of S and B applied at 10 and 2.5 mg/kg respectively. Addition of B without S depressed the seed yield. However, S additions at 10 mg/kg improved the seed yield showing the essentiality of S in lipid synthesis. Oil yield of safflower was improved by treatment effects and showed a similar trend as noted in seed yield (Purvimath *et al.*, 1993). At Jalgaon, foliar sprays of 0.2% borax, 0.4% ferrous sulphate, 0.5% zinc sulphate and B + Zn at 60 and 90 DAS demonstrated the seed yields of 880, 753, 695 and 812 kg/ha, respectively compared with 635 kg/ha in control (Baviskar *et al.*, 2005).

The boron requirement was high for safflower compared to other oilseeds (Singh, 2000). In B, deficient Vertisol (0.35 mg/kg) safflower responded to 1.5 kg B/ha and gave a significantly higher seed yield (Murthy and Padmavathi, 2011).

Widespread deficiencies of S, Zn, Fe and B are reported in Vertisol and associated soils, which affect safflower productivity. Safflower alone and safflower based cropping system response to S was spectacular in Vertisols, deficient in available S. Among the sources SSP was best and the rate of application varied from 20-45 kg S/ha depending on the soil type. Among the micronutrients, Zn, Fe and B showed a significant response in improving the seed yield in Vertisols. Zinc as $ZnSO_4$ @ 20 kg/ha, Fe as $FeSO_4$ @ 20 kg/ha and B as borax @ 1.5 - 2.5 kg/ha found responsive in increasing the safflower seed yield.

Table 10. Effect of different levels of Zn, Fe and S on seed yield of safflower (AICRP Safflower Annual Report, 2007-08)

Treatment	Solapur	Phaltan	Tandur
$ZnSO_4$ @ 10 kg/ha	411	1381	1251
$ZnSO_4$ @ 20 kg/ha	420	1266	1280
$ZnSO_4$ @ 30 kg/ha	541	1287	1384
$FeSO_4$ @ 10 kg/ha	454	1093	1237
$FeSO_4$ @ 20 kg/ha	436	1404	1270
$FeSO_4$ @ 30 kg/ha	439	1243	1309
Elemental Sulphur @ 1.7 kg/ha	465	1107	1153
Elemental Sulphur @ 3.4 kg/ha	573	1174	1251
Elemental Sulphur @ 5.1 kg/ha	424	1315	1306
RDF + FYM (5 t/ha)	442	1189	1260
RDF only	454	1187	1218
SEm±	36	80	81
CD (P=0.05)	105	NS	NS

Table 11. Levels of fertilizer N, P, S and B on seed and oil yield (kg/ha) of safflower (Purvimath *et al.*, 1993)

N (kg/ha)		P (kg/ha)		S (mg/kg)		B (mg/kg)	
Seed yield (kg/ha)							
75	1422	75	1416	0	1453	0	1519
150	1659	150	1665	10	1628	2.5	1562
C D (P=0.05)	36		36		36		36
Oil yield (kg/ha)							
75	431	75	419	0	432	0	456
150	495	150	508	10	495	2.5	471
C D (P=0.05)	10.7		10.4		10.6		10.6

Future thrust areas

- Intensive and systematic studies in delineating secondary and micronutrient deficient soils have to be done.
- Soil test based secondary and micronutrient fertiliser application is essential to gain higher nutrient use efficiency.
- Refinement of critical nutrient levels of secondary and micronutrients is essential as the crop responses below and above these levels is observed.
- Identification of secondary and micronutrient efficient safflower cultivars is imperative
- Essential nutrients like Ca, Mg and Mo have received limited attention of researchers. Before they emerge as limiting nutrients for the safflower productivity, systematic studies have to be initiated on priority.

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Gene effects of some quantitative traits in crosses of safflower, *Carthamus tinctorius* L.

D SHIVANI, CH SREELAKSHMI[1] AND C V SAMEER KUMAR

Agricultural Research Station, Tandur-501 141, Ranga Reddy Dt., Andhra Pradesh

(Received: June, 2011; Revised: November, 2011; Accepted: December, 2011)

ABSTRACT

The six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of four cross combinations of safflower (*Carthamus tinctorius* L.) *viz*., Nira x GMU 1702, HUS 305 x GMU 1946, Manjira x GMU 2914-15 and A-1 x GMU 3272 were studied for eight traits namely, days to 50% flowering, days to maturity, plant height, number of capitula/plant, number of seeds/capitula, 100 seed weight, seed yield and oil content. The mean of six generations was subjected to scaling test to determine epistasis and genetic parameters *viz*., m, d, h, I, j and l. An epistatic digenic model including all types of interactions played a major role for all the cross combinations. The study revealed the importance of additive and non- additive type of gene action for all the characters studied. Duplicate epistasis played a greater role than complementary epistasis.

Keywords: Generation mean, Gene action, Inheritance, Safflower

Safflower (*Carthamus tinctorius* L.) yield is one of the most important economic characters and is the product of multiplicative interaction of contributing characters for genetic improvement of the crop. The breeding method to be adopted depends mainly on the nature of gene action involved in the expression of the quantitative traits. Line x Tester (L x T) analysis is used to select the parents based on their combining ability but fails to detect the epistasis which remains the most complex problem and on which it is extremely difficult to obtain reliable results. The epistasis can be detected by the analysis of generation means using the scaling test, which determines the type of epistasis or whether it is additive x additive, additive x dominance and dominance x dominance type of interaction at the digenic level. After confirmation of epistasis, joint scaling test of six parameter model m,d,h,i,j and l was applied. The objective of this investigation was to obtain information on the gene effects in safflower to provide a basis of selection in a breeding programme for the improvement of safflower.

MATERIALS AND METHODS

Six generations *viz*., P_1, P_2, F_1, F_2, BC_1 and BC_2 of four cross combinations of safflower namely, Nira x GMU 1702, HUS 305 x GMU 1946, Manjira x GMU 2914-15 and A1 x GMU 3272 were raised in a randomized block design with three replications at Agricultural Research Station, Tandur during the winter season of 2007, 2008 and 2009. Ten plants were selected randomly from each of P_1, P_2 and F_1, 30 each of BC_1 and BC_2 and 50 of F_2 generations and utilized for recording the data on eight quantitative characters namely, days to 50% flowering, days to maturity, plant height, number of capitula/plant, number of seeds/capitula, 100 seed weight, seed yield and oil content. The data recorded was subjected to weighted analysis of Cavalli (1952) to know the adequacy of additive - dominance model. The presence of epistasis, the data where any of the 4, 5 or 6 parameters found adequate in the model of Jink and Jones (1968) was subjected accordingly to sequential model to obtain more precise estimate for these parameters. Significance estimates of χ^2 at (n-p) degrees of freedom would show presence of epistasis. After confirmation of presence of epistasis, joint scaling test of six parameter model m,d,h,i,j and l was applied. The adequacy of the sequential models was tested by χ^2 test, respectively

RESULTS AND DISCUSSION

The results of scaling test, indicating components of variance and interaction effects for eight quantitative traits in four crosses of safflower are presented in table 1. Simple additive dominance was inadequate for days to 50% flowering in all the crosses studied. Dominance, additive x additive gene effects were important in the crosses HUS 305 x GMU 1946 and Manjira x GMU 2914-15. Dominance x dominance gene effects played an important role in all crosses except HUS - 305 x GMU 1946. Duplicate epistasis was indicated by opposite signs of dominance and dominance x dominance type of gene effects influencing the inheritance of days to 50% flowering in the cross HUS 305 x GMU 1946 and A-1 x GMU 3272. Gupta and Singh (1990) also reported similarly.

[1] rishith_sree@rediffmail.com

Presence of non-allellic interactions was observed for inheritance of days to maturity in all cross combinations studied. Additive x additive, dominance x dominance and additive x dominance gene effects were important in the crosses Nira x GMU 1702, Manjira x GMU 2914-15. In the cross A1 x GMU 3272, dominance and additive x additive gene effects while in the cross HUS-305 x GMU 1946, additive x additive and dominance x dominance gene effects were important for inheritance of this trait. Gadekar and Jambhale (2002) reported similar results for this trait in safflower.

Presence of epistasis was detected for plant height in all the four cross combinations studied. Moreover, in addition to additive and dominance gene effects non-allelic interactions such as additive x additive, additive x dominance and dominance x dominance type of gene interactions were important for inheritance of this trait. In all the crosses duplicate epistasis was observed due to opposite signs of dominance and dominance x dominance influencing the inheritance of this trait. Present findings are in consonance with Channeshappa (1980) who reported duplicate type of gene action for plant height.

Table 1 Sealing test, components of variance and interaction effects for eight quantitative traits in four crosses of safflower

Cross/ character	Scaling test				Interaction effects					
	A	B	C	D	m	(d)	(h)	(I)	(j)	(l)
Days to 50% flowering										
Nira x GMU 1702	-4.00	-7.67	-12.32	-0.48	75.83	0.50	-7.83	0.67	1.83	11.00
HUS 305 x GMU 1946	-9.67	-6.68	-33.00	-8.45	63.50	1.83	20.50	16.67	-1.50	-0.42
Manjira x GMU 2914-15	-5.02	-10.35	-26.54	-5.62	70.68	-1.32	2.35	10.26	2.54	4.58
A1 x GMU 3272	-10.23	-10.25	-16.32	2.36	74.36	1.56	-33.86	-4.15	-0.16	24.36
Days to maturity										
Nira x GMU 1702	-4.67	-8.68	-14.12	-0.42	106.67	0.32	-10.33	0.67	2.00	12.62
HUS 305 x GMU 1946	-10.16	-7.67	-25.78	-3.12	103.50	1.83	-1.16	7.32	-1.54	11.67
Manjira x GMU 2914-15	-6.12	-11.55	-27.65	-5.32	101.56	-1.16	-0.16	10.36	2.54	6.45
A1 x GMU 3272	-4.69	-2.69	-20.22	-6.35	104.36	1.35	12.03	12.67	-1.14	-5.69
Plant height (cm)										
Nira x GMU 1702	4.33	-3.43	5.00	2.36	73.50	2.16	-0.50	-4.14	3.83	3.00
HUS 305 x GMU 1946	-19.17	-18.42	-38.33	-0.67	79.16	-1.50	-33.52	1.38	-0.51	35.67
Manjira x GMU 2914-15	-7.25	-17.21	-38.23	-6.65	67.25	-3.21	-5.23	13.25	5.56	11.32
A1 x GMU 3272	-13.68	-25.62	-33.47	2.68	80.00	-5.12	-43.25	-5.36	5.66	44.02
Number of capitula/plant										
Nira x GMU 1702	-2.00	-16.38	-9.12	4.67	31.16	1.50	-32.83	-9.34	7.17	27.67
HUS 305 x GMU 1946	-20.41	-18.76	-52.34	-6.79	10.17	4.67	-5.33	13.48	-0.61	25.36
Manjira x GMU 2914-15	-22.14	-26.47	-52.54	-2.15	25.00	-1.15	-43.21	4.02	2.33	44.67
A1 x GMU 3272	-14.12	-26.48	-50.68	-4.68	18.02	-6.00	-22.56	9.33	6.00	32.00
Number of seeds/capitulum										
Nira x GMU 1702	-5.00	-19.42	-16.67	3.64	37.33	2.67	-43.00	-7.12	7.00	31.38
HUS 305 x GMU 1946	-18.67	-5.38	-49.12	-12.67	25.33	5.38	6.17	26.12	-6.67	-1.38
Manjira x GMU 2914-15	-11.23	-25.63	-55.32	-9.15	14.26	-6.65	-0.35	18.56	7.23	18.02
A1 x GMU 3272	-25.47	-19.21	-71.48	-13.24	5.50	-1.58	14.16	26.67	-3.16	17.69
100 seed weight (g)										
Nira x GMU 1702	1.65	-1.66	-2.27	-1.13	4.67	-0.79	4.28	2.26	1.65	-2.25
HUS 305 x GMU 1946	0.18	-0.65	-1.66	-0.59	3.93	-0.14	2.30	1.19	0.42	-0.72
Manjira x GMU 2914-15	-0.26	-0.66	-1.45	-0.26	4.46	0.24	-0.11	0.52	0.20	0.39
A1 x GMU 3272	-0.41	0.30	-3.83	-1.86	4.34	0.06	6.70	3.72	-0.35	-3.61
Seed yield (kg/ha)										
Nira x GMU 1702	-80.00	-216.14	-837.33	-270.68	345.67	-34.00	833.12	541.34	68.00	-245.17
HUS 305 x GMU 1946	60.00	-489.67	-379.02	25.36	1008.8	-78.36	-518.50	-50.68	274.86	480.34
Manjira x GMU 2914-15	-395.33	-635.25	-1510.7	-240.12	503.26	-66.45	216.68	480.14	120.69	550.69
A1 x GMU 3272	-342.69	-86.69	-700.45	-135.87	845.69	42.59	140.32	270.69	-128.00	158.68
Oil content (%)										
Nira x GMU 1702	-1.30	1.50	-2.35	-1.43	20.38	1.90	7.60	2.86	-1.40	-3.06
HUS 305 x GMU 1946	-0.90	-7.60	-5.30	1.62	30.18	-1.15	-17.08	-3.20	3.35	11.70
Manjira x GMU 2914-15	3.14	12.43	0.96	-7.25	24.20	0.75	44.05	14.46	-4.71	-29.91
A1 x GMU 3272	-0.36	-3.13	0.30	1.90	25.73	0.51	-7.68	-3.80	1.38	7.30

m:Mean of the trait; d : Additive effects; h :dominance effects; I : additive x additive interaction; J : additive x dominance interaction; l :dominance x dominance interaction

In case of number of capitula/plant, presence of non-allelic interactions are important for its inheritance. Additive x additive, additive x dominance and dominance x dominance gene effects are important for inheritance of number of capitula/plant in the crosses Manjira x GMU 2914-15 and A1 x GMU 3272. Additive x dominance and dominance x dominance gene effects were important in the cross Nira x GMU 1702 while in the cross HUS 305 x GMU 1946 additive x additive and dominance x dominance gene effects played an important role. Duplicate epistasis was observed in all the four crosses influencing the inheritance of this trait. Ramachandram and Goud (1982) also reported similarly. Simple additive-dominance model was inadequate in all the four crosses for the trait number of seeds/capitula. In the cross Nira x GMU 1702, additive x dominance and dominance x dominance gene effects, whereas for the cross Manjira x GMU 2914-15 additive x additive, additive x dominance and dominance x dominance gene effects and for the cross A1 x GMU 3272, dominance, additive x additive, dominance x dominance gene effects played a major role for inheritance of this trait. Complementary epistasis was observed in the cross A1 x GMU 3272 while duplicate epistasis was observed for rest of the three crosses for inheritance of this trait. Srinivasachar and Ninganur (1990) also observed preponderance of non additive gene effects for this trait.

In case of 100 seed weight, presence of non-allelic interactions are important. In the cross Nira x GMU 1702 and HUS 305 x GMU 1946, dominance, additive x additive and additive x dominance gene effects were important for the inheritance of this trait. Additive x additive, additive x dominance and dominance x dominance gene effects were important for the cross Manjira x GMU 2914-15 whereas for the cross A-1 x GMU 3272, dominance and additive x additive gene effects are important for inheritance of this trait. Simple additive- dominance model was inadequate for all the four crosses for seed yield. Complementary type of gene action was observed in the cross Manjira x GMU 2914-15 and A-1 x GMU 3272 while duplicate epistasis was observed for the rest of the two cross combinations. These results are in agreement with the findings of Ragab (1991). Simple additive dominance model was adequate for the crosses HUS 305 x GMU 1946 and A1 x GMU 3272 for days to 50% flowering and days to maturity. Presence of epistasis was detected for oil content in the cross Nira x GMU 1702 and Manjira x GMU 2914-15 where dominance, additive x additive gene effects were important. Duplicate epistasis was observed in all the four crosses as indicated by the opposite signs of dominance and dominance x dominance. Similar results were observed by Vijayakumar and Giriraj (1985).

The present study revealed that additive and non-additive gene actions are important in the expression of the eight traits studied. The additive effects and gene interaction additive x additive (I) or other digenic complementary gene interaction can be exploited effectively by selection for the improvement of the characters. Use of reciprocal recurrent selection or biparental mating was suggested for improving the characters, when both additive and non-additive gene effects are involved in the expression of these traits. Presence of non-additive gene effects for some characters indicating that conventional selection procedure may not be effective enough for improvement of yield. Therefore, postponement of selection in later generations or intermating among the selected segregants followed by one or two generations of selfing could be suggested to break th undesirable linkage and allow the accumulation o favourable alleles for the improvement of this trait.

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Variability in growth parameters and yield of mustard genotypes [*Brassica juncea* (L.) Czern & Coss] grown under rainfed and irrigated conditions

LALLU AND MITHLESH KUMAR

Oilseeds Section, C.S. Azad University of Agriculture & Technology, Kanpur-208 002, Uttar Pradesh

(Received: November, 2010; Revised: November, 2011; Accepted: November, 2011)

ABSTRACT

Eight varieties of mustard (*Brassica juncea* L.) were studied under irrigated and rainfed field conditions to identify suitable genotype for water limited rainfed conditions. Rainfed condition caused significant reduction in different growth parameters, net photosynthetic rate, leaf water potential and seed yield in all genotypes under study. On an average seed yield reduced by 33.3% due to rainfed over irrigated condition. Reduction occurred more in different growth parameters at 60-90 days after sowing (DAS) and were noted in leaf area duration (15.6%), drymatter production rate (27.9%), relative growth rate (8.8%), net assimilation rate 28.4 and in net photosynthesis rate (21.9%) under rainfed over irrigated control. Mustard varieties 'Vaibhav' and 'Jawahar mustard' performed better and were identified suitable for rainfed as both showed minimum <15% yield reduction and value of drought susceptibility index <0.5. Study also indicated that in mustard, leaf area duration (LAD) at 60-90 DAS stage showed positive association (r=0.893) with seed yield and this growth parameter may be used as determinant to identify genotypes of mustard suited under rainfed conditions. Variety 'Varuna' produced maximum seed yield under normal situation.

Keywords: Growth parameters, Mustard, Rainfed, Seed yield

Indian mustard (*Brassica juncea* L.) is occupying 90% of the total area under rapeseed-mustard in India. It is mostly cultivated in semi-arid regions, where soil moisture stress affects crop at one or more phenological stages. Water stress is an important factor which effects growth, development and reproduction. Reduction in leaf area, cell size and intercellular volume are common under water stress. Reduction in photosynthetic activity and leaf senescence are well documented and adversely affect crop yield Gerik *et al.* (1996). Reduction in leaf area and photosynthetic activity greatly affects growth parameter of the genotype. Physiological efficiency of a genotype is determined by growth analysis. Knowledge of physiological basis of seed yield would greatly enable breeders to select donors with high physiological efficiency for seed yield improvement. Variability in the responses of Brassica cultivars to the moisture stress has been reported by Singh and Kumar (2005). Present study was an attempt to assess the variability in growth parameters, photosynthetic efficiency and yield behaviour of mustard genotypes and to identify genotype suitable for rainfed situation.

MATERIALS AND METHODS

The experiment was conducted at student instructional farm of C.S. Azad University of Agriculture & Technology, Kanpur with eight verities of mustard *viz.*, Varuna, Vaibhav, Pusa Jaikisan, Jawahar mustard, Urvashi, Ashirwad, Durgamani and Arawali, during the winter season of 2005 and 2007 in split plot design (irrigation in main plot and genotypes in sub plot) with three replications under field condition. The distance between rows and plant to plant were at 45 cm and 15 cm, respectively, in a gross plot of 3.15m x 5.50m. The two irrigations *viz.*, first at 35 days after sowing (DAS) and second at 65 DAS during both years were given only to the irrigated plots while no irrigation was given to the rainfed plots. Basal dose of 75 kg. each of N, P_2O_5 and K_2O/ha under irrigated condition and 80 kg. N and 40 kg each of P_2O_5 and K_2O/ha were applied under rainfed condition in the form of urea, DAP and muriate of potash, respectively. Nitrogen @ 75 kg/ha was applied after first irrigation only in irrigated plots. Soil moisture content (SMC) was determined under both irrigated and rainfed condition at pre- sowing and at harvest as SMC (%) = (soil fresh weight- soil dry weight)/soil fresh weight x 100). The average value of soil moisture content were 20.1% and 8.9% in normal irrigated and 8.0% and 6.0% in rainfed plots at pre-sowing and at harvest, respectively. The leaf area duration (LAD), leaf area index (LAI), relative growth rate (RGR), net assimilation rate (NAR), harvest index (HI) and drought susceptibility index were calculated. Leaf water potential and net photosynthetic rate were measured by pressure bomb technique (Model 300S plant water stress console and soil moisture equipment corporation, USA and 1-301 CO_2 gas analyzer CID, respectively).

RESULTS AND DISCUSSION

Leaf area duration and drymatter production rate increased with increasing plant age and noticed higher at 60-90 DAS stage under both conditions (Table 1). 11.4 and 15.6% reduction in LAD occurred, respectively, at 30-60 and 60-90 DAS under rainfed condition over irrigated control. In I_0 variety Vaibhav (298) showed maximum, and minimum recorded in Varuna (251) at advance stage of plant. Under I_1 condition at same stage Varuna (331) possessed higher and Arawali (303) showed lowest value of it. Reduction in DMPR occurred more (27.9%) at 60-90 DAS stage while at 30-60 DAS stage it noted less (17.9%) under rainfed over irrigated control. Under rainfed condition at early stage Durgamani proved its superiority while at advance stage Vaibhav retained its first position. Under irrigated situation Urvashi at early stage and Varuna at advance stage possessed higher value of it. Similar findings were reported by Sharma and Pannu (2007) in *Brassica* species.

Relative growth rate decreased with increased in plant age while the trend appeared reverse in case of net assimilation rate (Table 2), 7.1 and 8.8% reduction in RGR and 8.8% and 28.4% reduction in NAR occurred at 30-60 and 60-90 DAS stage, respectively, Under rainfed condition Jawahar mustard and Durgamani (67.5mg/g/d) at early stage and Vaibhav (38.6mg/g/d) at advance stage showed their superiority. Varuna at early stage and Pusa Jaikisan at later stage showed higher value of RGR under irrigated condition. Under rainfed situation Durgamani (0.89 $mg/cm^2/d$) at early stage and Arawali (6.34 $mg/cm^2/d$) at later stage possessed higher value of NAR. Under normal condition Urvashi (0.96 $mg/cm^2/d$) at 30-60 DAS and Pusa Jaikisan (8.65 $mg/cm^2/d$) at 60-90 DAS recorded higher value of NAR. Similar nature of finding was reported in Indian mustard by Piri and Sharma (2006). In general the irrigation treatment in all genotypes showed higher value of leaf area index and leaf water potential than rainfed (Table 3). Reduction in LAI occurred 15.8 and 10.8% under stress over non-stress at flowering and post-flowering stage, respectively. Under rainfed condition variety Vaibhav possessed higher LAI closely followed by Jawahar mustard at both stages. Under irrigated situation. Varuna retained their first position at both stages. Jawahar mustard (-1.14 MPa) at flowering stage and Vaibhav (-1.35MPa) at post-flowering stage possessed higher value of LWP under rainfed. Urvashi (-0.83MPa) at flowering and Varuna (-1.04MPa) at post flowering showed higher value of LWP in irrigated situation. Similar trend was also observed by Chaturvedi *et al.* (1999) in Indian mustard.

Significant reduction in net photosynthetic rate (Pn), harvest index (HI) and seed yield occurred under stress, and it was noted 21.9, 15.4 and 33.3% over normal, respectively (Table 4). Under rainfed Jawahar mustard at flowering and Arawali at post-flowering possessed higher value of Pn. Under non-stress variety Urvashi at flowering and Pusa jaikisan at post flowering showed higher rate of Pn. Variety Varuna (20.9%) in normal and Vaibhav (18.3%) in rainfed showed higher value of harvest index. Under rainfed situation, variety Vaibhav (1936 kg/ha) and Varuna (2718 kg/ha) in irrigated control produced highest seed yield. Lowest seed yield was recorded in Pusa jaikisan (1327 kg/ha) in stress and Jawahar mustard (2116 kg/ha) in normal condition. Similar reduction and variability has also been reported by Rekika *et al.* (1999) and Sharma and Pannu (2007) in *Brassica* species under soil moisture stress. Variety Vaibhav and Jawahar mustard were identified suitable for rainfed as both showed minimum <15% yield reduction under rainfed over control and value of DSI was <0.5. The seed yield has significant positive correlation with LAD at 60-90 DAS (r=0.893*), RGR at 30-60 DAS (r = 0.619*) and harvest index (r=0.892*).

Table 1 Leaf area duration (LAD) and drymatter production rate (DMPR) among mustard genotypes grown under rainfed (I_0) and irrigated (I_1) conditions *(Pooled data of two years)*

Genotype	LAD						DMPR (mg/plant/day)					
	30-60 DAS			60-90 DAS			30-60 DAS			60-90 DAS		
	I_0	I_1	Mean	I_0	I_1	Mean	I_0	I_1	Mean	I_0	I_1	Mean
Varuna	209	262	235	251	331	291	537	770	654	1294	2101	1698
Vaibhav	242	251	247	298	307	303	623	701	662	1575	1556	1715
Pusa Jaikisan	217	258	238	262	327	295	581	728	655	1276	2076	1681
Jawahar mustard	241	250	245	293	326	310	637	719	678	1523	1719	1621
Urvashi	221	260	241	265	324	295	552	789	671	1174	1846	1510
Ashirvad	223	262	242	264	303	284	615	753	684	1217	1997	1607
Durgamani	228	249	239	274	303	288	653	727	690	1436	1752	1594
Arawali	228	249	238	276	303	289	627	698	669	1520	1855	1687
Mean	226	255	241	273	316	294	603	736	669	1378	1913	1646
	(11.4)			(15.6)			(17.9)			(27.9)		
CD (P=0.05)												
Moisture levels			12.5			14.9			81.6			69.6
Genotype			NS			NS			NS			NS
M x G			NS			30.8			110.9			210.5

Data in parenthesis indicate per cent reduction in I_0 over I_1

Table 2 Relative growth rate (RGR) and net assimilation rate (NAR) among mustard genotypes grown under rainfed (I_0) and irrigated (I_1) conditions (Pooled data of two years)

Genotype	RGR (mg/g/day)						NAR (mg/cm²/day)					
	30-60 DAS			60-90 DAS			30-60 DAS			60-90 DAS		
	I_0	I_1	Mean	I_0	I_1	Mean	I_0	I_1	Mean	I_0	I_1	Mean
Varuna	62.7	72.2	67.5	37.1	41.0	39.1	0.79	0.92	0.86	5.59	8.12	6.86
Vaibhav	66.6	69.1	67.9	38.6	40.6	39.6	0.80	0.87	0.84	6.24	7.63	6.94
Pusa Jaikisan	63.7	69.3	66.5	35.6	44.7	40.2	0.82	0.89	0.86	5.50	8.65	7.08
Jawaharmustard	67.5	70.5	69.0	37.5	39.0	38.3	0.82	0.90	0.86	5.61	6.61	6.11
Urvashi	61.9	72.1	67.0	34.3	37.2	35.8	0.80	0.96	0.88	4.86	7.94	6.40
Ashirvad	65.1	71.1	68.1	33.2	40.2	36.7	0.85	0.90	0.88	4.49	8.04	6.27
Durgamani	67.5	69.2	68.4	35.6	37.8	36.7	0.89	0.91	0.90	5.55	7.31	6.43
Arawali	66.3	68.1	67.2	37.6	39.9	38.8	0.84	0.88	0.86	6.34	7.41	6.86
Mean	65.2	70.2	67.7	36.2	39.7	38.0	0.82	0.90	0.86	5.52	7.71	6.62
	(7.1)			(8.8)			(8.8)			(28.4)		
CD (P=0.05)												
Moisture			3.0			1.8			0.04			0.28
Genotype			NS			NS			NS			0.39
M x G			NS			NS			NS			0.56

Data in parenthesis indicate per cent reduction in I_0 over I_1

Table 3 Leaf water potential (LWP) and leaf area index (LAI) among mustard genotypes grown under rainfed (I_0) and irrigated (I_1) conditions (Pooled data of two years)

Genotype	LWP (-MPa)						LAI					
	Flowering			Post flowering			Flowering			Post flowering		
	I_0	I_1	Mean	I_0	I_1	Mean	I_0	I_1	Mean	I_0	I_1	Mean
Varuna	1.32	0.86	1.09	1.64	1.04	1.34	1.24	1.71	1.48	1.09	1.37	1.23
Vaibhav	1.16	1.08	1.12	1.35	1.13	1.24	1.54	1.61	1.58	1.24	1.24	1.24
Pusa Jaikisan	1.30	0.90	1.10	1.67	1.08	1.38	1.32	1.68	1.50	1.12	1.29	1.21
Jawahar mustard	1.14	1.05	1.10	1.40	1.26	1.33	1.52	1.60	1.56	1.20	1.23	1.22
Urvashi	1.28	0.83	1.06	1.50	1.15	1.33	1.37	1.69	1.53	1.10	1.34	1.22
Ashirvad	1.24	1.00	1.12	1.60	1.18	1.39	1.36	1.70	1.53	1.40	1.32	1.21
Durgamani	1.21	0.96	1.09	1.48	1.14	1.31	1.42	1.60	1.51	1.13	1.22	1.18
Arawali	1.20	1.09	1.15	1.46	1.21	1.34	1.40	1.59	1.50	1.16	1.22	1.19
Mean	1.38	0.97	1.18	1.51	1.44	1.48	1.39	1.65	1.52	1.14	1.28	1.21
							(15.8)			(10.8)		
CD (P=0.05)												
Moisture			0.04			0.12			0.08			0.51
Genotype			0.08			NS			NS			NS
M x G			0.12			0.28			0.17			0.10

Data in parenthesis indicate per cent reduction

Table 4 Net photosynthesis rate (Pn), harvest index (HI), seed yield and drought susceptibility index (DSI) among mustard genotypes grown under rainfed (I_0) and irrigated (I_1) conditions (Pooled data of two years)

Genotype	Pn (μ m CO²/m²/s)						Harvest index (%)			Seed yield (kg/ha)			DSI
	Flowering			Post-flowering									
	I_0	I_1	Mean	I_0	I_1	Mean	I_0	I_1	Mean	I_0	I_1	Mean	
Varuna	22.4	24.0	23.2	30.3	32.9	31.6	14.8	20.9	17.9	1353 (50.2)	2718	2036	1.53
Vaibhav	22.1	24.8	23.5	28.3	29.2	28.8	18.3	19.2	18.8	1936 (12.9)	2225	2080	0.33*
Pusa Jaikisan	22.2	22.7	22.5	31.7	33.3	32.5	13.9	19.9	13.5	1327 (49.7)	2636	1981	1.49
Jawaharmustard	25.7	24.4	25.1	30.9	29.6	30.3	17.5	18.7	18.0	1870 (11.2)	2116	1996	0.37*
Urvashi	22.7	26.2	24.5	27.9	29.4	28.7	16.2	19.3	17.8	1502 (41.6)	2572	2037	1.28
Ashirvad	22.5	23.8	23.2	29.5	31.7	30.6	16.9	19.5	18.2	1562 (35.9)	2438	2000	1.01
Durgamani	21.2	24.8	23.0	31.3	31.9	31.6	17.1	18.4	17.8	1673 (31.0)	2426	2049	0.94
Arawali	23.3	24.3	23.9	31.4	32.4	32.2	16.4	18.4	17.4	1725 (25.4)	2314	2019	0.84
Mean	22.7	24.4	23.6	30.2	31.3	30.8	16.4	19.3	17.9	1619 (33.3)	2430	2024	
	(7.0)			(21.9)									
CD (P=0.05)													
Moisture			0.8			7.0			0.6			109.8	
Genotype			1.4			1.7			0.9			NS	
M x G			2.0			NS			1.3			239.2	

* Tolerant genotypes showing low DSI (<0.5). Data in parenthesis indicate per cent reduction in I_0 over I_1

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Effect of integration of bio-fertilizers and farm yard manure with inorganic fertilizers on productivity of soybean (*Glycine max* L.) in farmers' fields

R K S TOMAR

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Krishi Vigyan Kendra, Tikamgarh, Madhya Pradesh

(Received: March, 2011; Revised: September, 2011; Accepted: November, 2011)

ABSTRACT

On farm trial were conducted during rainy season of 2004, 2005 and 2006 to assess the effect of integration of bio fertilizers and farm yard manure (FYM) with chemical fertilizers on productivity of soybean (*Glycine max* L.) in Bundelkhand agroclimatic zone of Madhya Pradesh. The maximum soybean yield of 1798 kg/ha was obtained with application of 75% NPK + 5 t FYM + inoculation with rhizobium + phosphate solubilizing bacteria (PSB) @ 20 g/kg seed which was 112.52 and 39.48% higher than farmers practices and 100% NPK alone, respectively. However, this treatment closely followed by 100% NPK with rhizobium + PSB inoculation (1740 kg/ha). Combined application of 100% NPK and rhizobium + PSB enhanced the yield significantly than farmer's practices and 100% NPK alone. Application 100% NPK alone also increased seed yield by 52.36% compared with farmers practices. The application of 75% NPK + 5 t FYM with rhizobium + PSB inoculation resulted in the highest net return of ₹17103/ha and benefit cost ratio of 1:2.73.

Key words: Economics, FYM, Integration, PSB, Rhizobium, Soybean, Yield

Soybean (*Glycine max* L.) a grain legume is considered as a wonder crop due to its dual qualities *viz.*, high protein (40-43%) and oil content (20%). India stands next only to china in the Asia pacific region, with respect to area (7.2 m ha) and production (8.7 m.t.). Madhya Pradesh is largest soybean producing state in the country. It is cultivated in the state in an area of 4.46 m ha; producing 3.94 m.t. with a productivity of 885 kg/ha which is covering about 60% of the total area and 55% of total soybean production in the country. Soybean has proved to be an important crop among oilseed in Tikamgarh district under Bundelkhand agro-climatic zone of Madhya Pradesh. But productivity of soybean continuous to be low. One of the critical factor for low productivity of soybean is application of injudicious use of plant nutrients.

In view of escalating prices and less availability of chemical fertilisers, there is a strong need to adopt integrated nutrient supply system by judicious combination of organic, bio and chemical fertilizers to improve soil health, crop productivity, save money and environment (Verma and Bhattacharya, 1990). Bio fertilizers mainly *Bradyrhizobium japonicum*, phosphate solubilizing bacteria (PSB) and Vesicular Arbuscular (VA) mycorrhizae (VAM) are commonly used for soybean production and they have an enormous potential to fix atmospheric N and also have capacity to solubilize and mobilizes P and micro nutrients present in non-available form in the soil. The productivity of soybean can be increased by inoculation of bio culture from rhizobium and PSB micro organism and co-inoculation of these 2 bio cultures has shown encouraging results in sustaining the crop productivity of soybean and improving soil fertility (Dubey, 1997). Use of bio fertilizers with organic manures may prove a viable option for sustaining production of soybean (Govindan and Thirumurugan, 2005). Therefore, present on farm trials was under taken to assess the effect of integration of bio-fertilizers and organic manures with inorganic fertilizers under rainfed condition on the cultivator's field.

MATERIALS AND METHODS

On farm trails were conducted at 15 farmers fields during rainy season of 2004, 2005 and 2006 on medium to heavy soils which were low in organic carbon and nitrogen, low to medium in phosphorus and medium to high in potash under soybean-wheat production system. Five highly skilled cultivators were selected for each years through PRA approach. There were four treatments comprising farmers practices (9:23:0 NPK kg/ha), 100% recommended dose of 20:60:20 NPK kg/ha, 100% NPK + rhizobium + PSB @ 20 g/kg seed and 75% NPK + rhizobium + PSB + 5 t/ha FYM. Each treatment was carried out in an area of 1000 sq.m. The five locations were considered as five replication under randomized block design for statistical analysis. The total precipitation was received during crop season (June-October) in Tikamgarh block 679, 680 and 513 mm in 2004, 2005 and 2006, respectively. The soybean cv JS-335 was sown between July 6-7 in 2004, July 21-24, 2005 and July 8-11, 2006 with a spacing of 30 cm x 10 cm at 2.5 cm depth and seed rate was 75 kg/ha. Entire dose of fertilizer was applied as basal in the form of urea, single super phosphate and muriate of potash and FYM was incorporated into the soil at the time of final field preparation. The seeds were treated with thirum @ 3 g/kg seed followed by *Bradyrhizobium japonicium* and PSB (*Bacilus megathrium*) culture @ 20 g/kg seed. Hand weeding was carried out at 30 days after sowing. First spray of Triazophos was done @ 1.2 l/ha at the time of incidence of insect pests and second spray at in 20 days interval of first spray. The crop was harvested in the first week of November.

RESULTS AND DISCUSSION

Growth attributes

Application of 75% NPK + 5 t FYM + rhizobium + PSB (20 g/kg seed) significantly increased plant height, leaves/plant, branches/plant and dry matter (g/plant) compared with farmers practices and 100% NPK applied alone. 100% NPK + rhizobium + PSB and 75% NPK + FYM + rhizobium + PSB proved equal for all these growth characters. Biological N fixation by rhizobium, greater release of P by PSB (Dubey, 1997) and synthesis of growth promoting hormones and vitamins by these microbes (Baskar *et al.*, 2000) might have favoured the plant growth characters. Application of 100% NPK alone increased plant height, leaves/plant, branches/plant and dry matter (g/plant) production by 8.92, 11.51, 28.00 and 22.83%, respectively compared with the farmers practices. The crop responded well to recommended dose of fertilizer due to low status of available plant nutrients of the initial soils (Table 1).

Table 1 Growth and yield parameters of soybean under different treatments (Average of three years)

Treatment	Plant height (cm)	Leaves /plant	Branches /plant	Drymatter (g/plant)	Pods /plant	Grain /plant	1000 seed weight (g)	Straw yield (kg/ha)
Farmers practices (9:23:0 NPK kg/ha)	56.0	19.1	2.5	16.2	25.2	64.2	116.4	1319
100% NPK (20:60:20)	61.0	21.3	3.2	19.9	36.0	71.2	131.0	2011
100% NPK + Rhizobium + PSB (@ 20 g/kg seed)	64.2	24.2	3.8	24.6	43.4	79.0	140.0	2644
75% NPK + FYM @ 5 t/ha + Rhizobium + PSB	66.4	26.1	3.9	26.1	46.2	82.0	142.5	2876
SEm±	0.9	0.7	0.1	0.5	2.8	2.1	3.1	186
CD (P=0.05)	2.7	1.9	0.5	1.6	5.2	6.2	9.3	558

Table 2 Seed yield of soybean (kg/ha), cost of production (₹/ha), net return (₹/ha), B:C ratio as affected by different treatments

Treatment	Yield (kg/ha)				Average of three years		
	2004	2005	2006	Mean	Cost of production (₹/ha)	Net return (₹/ha)	B:C Ratio
Farmers practices (9:23:0 NPK kg/ha)	916	766	856	846	8741	3949	1.45
100% NPK (20:60:20)	1410	1180	1277	1289	9799	9536	1.97
100% NPK + Rhizobium + PSB @ 20 g kg seed	2196	1331	1693	1740	10216	15886	2.55
75% NPK + FYM @ 5 t/ha + Rhizobium + PSB	2062	1488	1843	1798	9867	17103	2.73
SEm±	133	32	46	70	-	-	-
CD (P=0.05)	397	99	136	212	-	-	-

Yield attributes

Yield attributes like pods/plant, grains/plant, 1000 seed weight and straw yield of soybean was also significantly increased by the 100% NPK alone, 100% NPK + rhizobium + PSB and 75% NPK + FYM + rhizobium + PSB over the farmers practices. Biofertilizers inoculation combined with 100% NPK and 75% NPK + FYM also improved all these yield attributing character significantly compared to 100% NPK alone. However, these treatments did not differ significantly (Table 1). The benefit of biofertilizers might be ascribed to N addition through biological N fixation by rhizobium, activation of amino acids for synthesis of carbohydrates and P solubilization by PSB. Co-inoculation of biofertilizers produced heavier seeds, which might be accorded to the better translocation of photosynthetic (Kumarawat *et al.*, 1997).

Seed yield

The seed yield of soybean was significantly increased by 100% NPK alone, 100% NPK + rhizobium + PSB (@ 20 g/kg seed) inoculation and 75% NPK + FYM + rhizobium + PSB treatments over the farmers practices (local check) during all the 3 years as well as average yield data (Table 2). The mean maximum and significantly higher seed yield (1798 Kg/ha) of soybean was observed due to application of 75% NPK with 5 t/ha FYM +rhizobium + PSB (@ 20 g/kg seed), which was 112.52% higher than farmers practices (9:23:0 NPK kg/ha) and 39.48% higher application of 100% NPK alone. However, this treatment was closely followed by application of 100% NPK + rhizobium + PSB inoculation. Thus there is saving 25% chemical fertilizer through FYM, rhizobium and PSB. The application of 100% NPK with rhizobium + PSB @ 20 g/kg seed was significantly increased seed yield by 34.98% compared with application of 100% NPK alone. Application of 100% NPK alone increased the seed yield by 52.36% compared with the farmers practices. The increase in yield was due to increase in growth and yield attributes (Govindan and Thirumurugan, 2005).

Economics

The inputs and outputs prices of commodities prevailed during each year of trials were taken from calculating cost of cultivation, net return and benefit: cost ratio (Table 2). 75% NPK + 5 t/ha FYM + inoculation with rhizobium + PSB (20 g/kg seed) gave highest net return (₹17103/ha) and benefit: cost ratio (1:2.73) over other treatments followed by 100% NPK in combination with rhizobium and PSB (₹.15886/ha; 1:2.55). The application of 100% NPK alone also gave higher net return (₹ 9536/ha) and benefit ratio (1:1.97) than farmers practices (₹ 3949/ha). It can be inferred that application of 100% NPK dose of inorganic fertilizer along with biofertilizers proved to be more remunerative than 100% NPK alone. Thus, 75% NPK with 5 t/ha FYM + rhizobium + PSB may successfully be used as low cost input technology to raise the yield of rainfed soybean. The results are in agreement with finding of Pannase *et al.* (2001).

It was concluded that reduction in dose of NPK to 75% from recommended dose and supplemented with 5 t/ha FYM + rhizobium + PSB @ 20 g/kg seed can give more seed yield and monetary returns than the recommended dose of fertilizer.

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Bio-economic feasibility of soybean (*Glycine max*) intercropped with urdbean (*Vigna mungo*) and maize (*Zea mays*) under various row proportions in rainfed situations of south-eastern Rajasthan

J P TETARWAL[1], BALDEV RAM AND D S MEENA

Agricultural Research Sub-Station, Maharana Pratap University of Agriculture & Technology, Jhalawar-326 033, Rajasthan

(Received: June, 2011; Revised: October, 2011; Accepted: November, 2011)

ABSTRACT

A field experiment was conducted at Agricultural Research Sub-Station, Aklera, Rajasthan during the rainy seasons of 2008 and 2009 to evaluate best component crop with suitable row proportion for obtaining maximum productivity of soybean (*Glycine max* L.) based intercropping system under rainfed situations of south-eastern Rajasthan. Both component crops (urdbean and maize) intercropped with soybean enhanced the soybean equivalent yield compared to sole soybean. Soybean intercropped with maize in 4:1 row ratio gave significant higher soybean equivalent yield (19.31 q/ha), net return (₹31846/ha) and B: C ratio (2.99) followed by soybean + maize (3:1 row ratio) over soybean + maize in 1:1 or 2:1 row ratio and soybean + urdbean (1:1, 2:1, 3:1, 4:1). Among the component crops, urdbean suffered maximum loss to the tune of 58.2-79.4 % irrespective of row ratio and maize was suffered minimum 39.0-58.9% over their sole crops. Maximum monetary advantage index (7081) based on LER was recorded under soybean + maize in 4:1 row ratio followed by and next was soybean + maize in 3:1 (5604) over rest of the ratios.

Keywords: Competition function, Economics, Intercropping, Maize, Row ratio, Soybean, Urdbean

South-eastern part of Rajasthan is a bowl of soybean (*Glycine max* L.) production under rainfed conditions and mostly rainfall received during the month of July and August. Of late, terminal heat at the time of crop maturity in the month of September drastically reduced the sole crop productivity. To achieve stable crop production and to provide insurance mechanism against aberrant weather situations and to mitigate abiotic stress during peak period under rainfed agriculture, intercropping is one of the best agronomical options to minimize risk lead to farmer's profit and subsistence oriented, energy-efficient and sustainable venture (Faroda *et al.*, 2007). Intercropping involves component crops having different growth pattern for extended use of resources like nutrients, water and solar radiation allowing the base crop (soybean) to feed at top layers of the soil. Moreover, spatial arrangement and plant population in an intercropping have important effect on the balance of between component crops and their productivity (Sarkar and Pal, 2004). Urdbean may be probable ideal crop for intercropping with soybean owing to its early maturity, tolerance to shade and drought and less competitiveness for soil moisture and sunlight whereas, maize is an efficient light utilizer of plant nutrients, moisture, solar radiation and trapping of insects ultimately enhanced productivity of land, nutrient and water under moisture starved condition.

Keeping this in view, the present investigation was planned to evaluate best component crop and row proportion for obtaining potential productivity of soybean based intercropping system under south-eastern Rajasthan.

MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Sub Station, Aklera, Jhalawar during the rainy seasons of 2008 and 2009. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction (pH 7.5), medium in organic carbon (6.6 g/kg), low in available phosphorus (21.4 kg/ha) and high in available potassium (305 kg/ha). The experiment consisting of eleven treatments had 3 sole crops, *viz.*, soybean (*Glycine max*), urdbean (*Vigna mungo*) and maize (*Zea mays*) and eight intercropping systems of soybean with urdbean and maize in different row ratios of 1:1, 2:1, 3:1 and 4:1. The experiment laid out in randomized block design with three replications. The rows of component crops (urdbean and maize) were adjusted to different row ratio of intercropping whereas, sole crops of soybean and urdbean were sown 30 cm and maize at 60 cm apart. Crops were sown July 18 and 20 in both the years of experimentation. The cultivars used in the study were 'JS 93-05' (soybean), 'T-9' (urdbean) and 'PEHM-2' (maize). The total rainfall received during crop period was 459 and 380 mm in 2008 and 2009, respectively. Recommended package of practices for rainfed situations was followed to grow the crop and fertilized 20 kg nitrogen and 40 kg phosphorus/ha to soybean and urdbean and 40 kg N and 15 kg P to maize, respectively. In intercropping, the

[1]E-mail: jptetarwal@gmail.com

crops received the fertilizers on the basis of proportionate area sown under each crop. Full recommended doses of P and N to soybean and urdbean and half N to maize were applied as basal in sole as well as intercropping system. Remaining half dose of nitrogen to maize was top dressed in the form of urea prior to tasseling stage on a rainy day. Urdbean and maize were harvested in the second week of October, while soybean was harvested in the fourth week of October during both the years. The various competition functions like land-equivalent ratio (LER), competitive ratio (CR), relative crowding co-efficient (RCC), aggressivity and monetary advantage index (MAI) were computed as suggested by Patra *et al.* (1999) and Area-time equivalent ratio (ATER) was calculated by formulae as proposed by Heibsch (1978). Soybean-equivalent yield was worked out by converting the yields of intercrops to the sole yield of soybean on the basis of prevailing market price of each crop. Production efficiency values were obtained by soybean-equivalent yield of system divided by yield of sole soybean crop multiplied by 100. The economics of different crops and crop combinations were computed on the basis of prevailing market rates of agro-inputs and produce. The results of both the years were showed similar trends hence, pooling of 2 years data were done and results were inferred.

RESULTS AND DISCUSSION

Productivity of main crop: Sole crop of soybean always showed higher yield attributes over intercropped soybean (Table 1). Pods/plant, seeds/pod and 1000 seed weight of soybean decreased significantly in intercropping system, depending on nature of intercrops and their spatial arrangement, but being on par with soybean + maize association in 4:1 row proportion with sole soybean owing better utilization of soil moisture from deeper layers and solar radiation compared to other row arrangements. Maximum reduction in yield attributes were recorded in soybean intercropped with either urdbean or maize in 1:1 row proportion due to more shading and intra-competition for resources in component crops with soybean. Seed yield of soybean significantly reduced in intercropping systems compared with sole soybean due to competition effect except with soybean + urdbean in 4:1 row ratio (Table 1). The average reduction in seed yield of soybean varied from 10.5 to 53.4%, depending on nature of intercrops and planting pattern. In general, the yield reduction in the intercropping pattern for soybean crop with urdbean was relatively lower compared to maize. Yield reduction of main crop with both the intercrops was maximum (44.6 and 53.4%) in 1:1 row ratio and minimum (10.5 and 21.2%) in 4:1 row ratio, respectively with urdbean and maize intercrops. Similarly, Datta and Bandyopadhyay (2006) also reported that 12.5 to 33.9% yield reduction in groundnut by intercropping with maize was due to the depressing effect of maize on groundnut. Intercropping system of soybean with either urdbean or maize in 4:1 row proportion recorded higher seed yield of soybean compared to preceding row proportions (1:1, 2:1, 3:1) on account of improvement in yield attributes of soybean due to lesser number of intercrop rows and more space occupied by soybean.

Productivity of intercrops: Sole urdbean recorded higher yield attributes and seed yield over the intercropped urdbean while, reverse trend was found in yield attributes of maize where intercropped maize recorded higher yield attributing characters as compared to the sole maize. Maize yield in intercropping system was found lesser due to their lower plant populations compared to the sole maize (Table 1). Magnitude of decrease or increase in yield and yield attributes of urdbean and maize due to intercropping with soybean varied with plant population and spatial arrangement of component species. Maximum reduction in yield attributes and yield of urdbean was recorded under 4:1 row proportion due to intense competition effect because of greater population pressure of soybean on lesser population of urdbean however, in intercropped maize maximum reduction in yield attributes and yield of were under 1:1 and 4:1 row proportion, respectively. On the other hand, urdbean suffered maximum loss (58.2-79.4%) and maize suffered minimum (39.0-58.9%) in association with soybean compared to their respective sole crops irrespective of row ratios. Maximum yield loss with urdbean might be due to reduction in plant population in intercropping, spatial and temporal competition for growth factors for a prolonged period and their susceptibility to shading effect. Minimum loss with maize might be due to its elastic response to change in plant population, less light competition effect, staggering of peak demands for growth factors and early maturing of maize (Padhi and Panigrahi, 2006). The intercrop yield reduction under 4:1 row ratio was owing to the lesser plant population of the intercrop component compared to the main crop per unit area.

Total productivity and production efficiency: All the intercropping system showed superiority to sole soybean in terms of soybean equivalent yield, except 1:1 or 2:1 row ratios with urdbean and 1:1 row ratio with maize in intercropping irrespective of intercrops (Table 2). Soybean intercropped with maize in 4:1 row ratio gave significantly higher soybean equivalent yield (19.3 q/ha) over soybean + maize row ratio of 1:1 or 2:1 and soybean + urdbean 1:1, 2:1, 3:1, 4:1 intercropping system to the tune of 10.6% over sole soybean but remained statistically on par with soybean + maize in 3:1 row ratio (18.47 q/ha). The additional yield advantage due to intercropping might be due to efficient utilization of resources, less competition between component crop species and also the higher economic value of intercrop may be accredited to higher total productivity under intercropping systems (Sheoran *et al.*, 2010). Soybean intercropped with urdbean in 1:1 or 2:1 and maize in 1:1 produced lower soybean equivalent yields compared to sole soybean and other row ratios might be owing to more inter-specific competition of component crops, resulted reduced soybean yield.

Intercropping systems were more efficient than their respective sole crops of the components except soybean + urdbean (1:1 or 2:1 row ratio) and soybean + maize (1:1 row ratio) intercropping systems and in rest of the intercropping systems, production efficiency ranged from 1.18 to 10.67 % over the sole maize (Table 2). Among the intercropping systems, soybean + maize in 4:1 row ratio seemed to be more productive, followed by soybean + maize in 3:1 row ratio recording 10.67 and 5.83 % higher production over the sole maize, respectively. However, soybean + urdbean (1:1), soybean + maize (1:1) and soybean + urdbean (2:1) row combinations were less productive by recording 15.88, 5.99 and 3.42% lower production compared to the sole maize, respectively.

Table 1 Yield components and yield of sole and intercrops as influenced by intercropping system (pooled data of 2 years)

Treatment	Soybean				Intercrop (Urdbean/maize)			
	Pods/plant	Seeds/pod	1000 seed weight (g)	Seed yield (q/ha)	Pods or cobs/plant	Seeds or grain/pod or cob	1000 seed or grain weight (g)	Grain yield (q/ha)
Sole cropping								
Soybean	86.6	3.2	116.3	17.45	-	-	-	-
Urdbean	-	-	-	-	58.7	7.6	39.9	8.74
Maize	-	-	-	-	1.16	173.1	218.2	33.21
Intercropping								
Soybean : urdbean								
1 : 1	60.7	2.0	86.0	9.66	53.6	7.1	39.0	3.68
2 : 1	63.6	2.2	90.3	13.24	50.1	6.9	38.2	2.65
3 : 1	73.2	2.6	100.3	14.52	44.4	6.2	37.1	2.30
4 : 1	76.2	2.7	105.3	15.61	40.2	5.8	36.8	1.80
Soybean : maize								
1 : 1	62.7	2.1	88.0	8.12	1.20	177.3	221.4	20.25
2 : 1	66.6	2.3	92.7	10.81	1.24	182.8	223.1	17.21
3 : 1	77.7	2.7	103.0	12.27	1.36	195.5	229.5	15.15
4 : 1	84.7	3.1	114.1	13.74	1.40	202.7	232.2	13.62
CD (P=0.05)	8.14	0.37	8.68	1.94	-	-	-	-

Table 2 Soybean-equivalent yield, production efficiency and economics of soybean intercropped with urdbean and maize (pooled data of 2 years)

Treatment	Soybean- equivalent yield (q/ha)	Production efficiency (%)	Net return (₹./ha)	B:C ratio
Sole cropping				
Soybean	17.45	100.00	27890	2.66
Urdbean	11.92	68.30	17820	2.12
Maize	13.59	77.86	20689	2.25
Intercropping				
Soybean : urdbean				
1 : 1	14.68	84.12	22742	2.38
2 : 1	16.85	96.58	27228	2.76
3 : 1	17.66	101.18	28669	2.82
4 : 1	18.06	103.52	29552	2.90
Soybean : maize				
1 : 1	16.40	94.01	26439	2.74
2 : 1	17.85	102.29	28905	2.79
3 : 1	18.47	105.83	29954	2.81
4 : 1	19.31	110.67	31846	2.99
CD (P=0.05)	1.12	-	1945	0.16

Prevailing market price of soybean, urdbean and maize @ ₹ 22.0, 30.0 and 9.0/kg, respectively

Biological feasibility: Land equivalent ratio (LER) of all the intercropping systems except soybean + urdbean in 1:1 row ratio were greater than unity indicating higher land utilization efficiency and advantage over the respective monocultures (Table 3). Intercropping system of soybean with maize in 4:1 row proportion showed the maximum biological efficiency (1.20) of the system, followed by LER of 1.16 in case of soybean + maize in 3:1 row proportion, reflecting their superiority among all the intercropping systems. This yield advantage owing to intercropping might be attributed to combined effect of better utilization of natural resources than sole cropping of companion crops, resulting in higher productivity per unit area. The association of soybean with urdbean in 1:1 row ratio gave lower LER (0.97), indicating inefficient system. Soybean proved to be the dominant ratio (CR) co-efficient than the associated urdbean in all the intercropping systems, irrespective of row ratios while, the companion crop maize appeared more competitive than soybean giving higher values for competitive ratio in all the row proportions (Table 3).

The relative crowding co-efficient indicated that it was advantageous and biologically sustainable to grow maize as intercrop with soybean in 4:1 row ratio under rainfed conditions, which was further established by the product of crowding co-efficient K (Table 3), may be due to mutual co-operation. When the values of ATER was considered to assess the yield advantages due to intercropping, it was found that all the intercropping system except that of soybean + urdbean in 1:1 or 2:1 row ratio and soybean + maize in 1:1 row proportion showed ATER values greater than unity indicating better land utilization efficiency under these systems. Highest area time equivalent (1.14) was recorded for soybean intercropping with maize in 4:1 row ratio, indicating a more efficient use of area-time by intercrop over other systems. Similarly, efficient uses of area and time by intercrop have also been reported by Datta and Bandyopadhyay (2006) in groundnut + maize in 4:2 row ratios. The aggressivity of soybean was positive in all the intercropping systems, but was negative in urdbean and maize components except soybean + maize in 4:1 row ratio where, it was negative trends in soybean and found positive in maize (Table 3). Aggressivity values of intercropping were greater than zero, indicating yield advantage over sole cropping.

Table 3 Competition function and monetary advantages of soybean intercropped with urdbean and maize (pooled data of 2 years)

Treatment	Land-equivalent ratio (LER)	Competitive ratio		Relative crowding co-efficient		Products of relative crowding co-efficient	Area-time equivalent ratio (ATER)	Aggressivity		Monetary advantage index
		CR s	CR i	K s	K i			As	Ai	
Intercropping										
Soybean : urdbean										
1 : 1	0.97	1.31	0.76	1.24	0.73	0.90	0.89	0.07	-0.07	-999
2 : 1	1.06	1.25	0.81	1.57	0.88	1.39	1.00	0.41	-0.41	2099
3 : 1	1.10	1.04	0.95	1.64	1.07	1.75	1.04	0.56	-0.56	3531
4 : 1	1.10	1.09	0.92	2.12	1.04	2.20	1.06	0.67	-0.67	3613
Soybean : maize										
1 : 1	1.08	0.76	1.31	0.87	1.56	1.36	0.98	-0.07	0.07	2673
2 : 1	1.14	0.60	1.70	0.81	2.18	1.78	1.06	0.24	-0.24	4823
3 : 1	1.16	0.51	1.95	0.78	2.52	1.97	1.09	0.41	-0.41	5604
4 : 1	1.20	0.48	2.08	0.93	2.78	2.57	1.14	0.55	-0.55	7081

CRs and CRi, Competitive ratio of soybean on intercrops and of intercrops on soybean respectively; Ks and Ki, crowding coefficient of soybean on intercrops and of intercrops on soybean respectively; As and Ai, aggressivity of soybean on intercrops and of intercrops on soybean respectively

Economic viability: Intercropping of soybean + urdbean (3:1 or 4:1) and soybean + maize (2:1, 3:1 or 4:1) row proportions gave higher net return over sole soybean (Table 2). Soybean intercropped with maize in 4:1 row ratio fetched maximum and significantly higher net return (₹ 31846/ha) and B:C ratio (2.99) over soybean + maize in preceding row ratios of 1:1 or 2:1 and soybean + urdbean (1:1, 2:1, 3:1, 4:1) as well as sole crops. The next best intercropping system were soybean + maize in 3:1 row ratio (₹ 29954/ha and 2.81) and soybean + urdbean in 4:1 row ratio (₹ 29552/ha and 2.90), respectively mainly owing to higher economic production in these system. The monetary advantage index based on LER indicated superior economic viability of soybean + maize intercropping in 4:1 row ratio by recording highest monetary advantage followed by soybean + maize intercropping in 3:1 row ratio due to higher land equivalent ratio and values of combined produce in intercrops (Table 3). Hence, it was concluded that intercropping of soybean with maize in 4:1 row ratio is biologically and economically sustainable intercropping system for rainfed situations of south eastern Rajasthan.

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Effect of integrated plant nutrient supply through organic and mineral sources on productivity of summer sesame

A K BARIK AND J FULMALI

Palli Siksha Bhavana, Institute of Agriculture, Visva-Bharati, Sriniketan-731 236, West Bengal

(Received: April, 2011; Revised: September, 2011; Accepted: October, 2011)

ABSTRACT

A field experiment was conducted during summer season of 2004 and 2005 at agricultural farm, Palli Siksha Bhavana, Visva-Bharati on sandy loam soil to study the effect of integrated nutrient management practices through organic and mineral sources of plant nutrients on growth, productivity and economics of sesame (*Sesamum indicum* L.). The use of different organic and mineral sources of plant nutrients significantly influenced the growth, yield attributes and yield as well as economics in sesame cultivation. Application of FYM showed higher growth and yield attributes, seed yield as well as gross and net returns, and return per rupee investment in sesame. This was at par with mustard cake application. Among the various levels of NPK fertilizers, application of 100% NPK fertilizers had the highest growth, yield attributes and yield of sesame, though this was at par with 75% NPK fertilizers. Gross returns and net returns in sesame were significantly higher in 100% NPK fertilizers than 75% NPK use but return per rupee investment in sesame was similar in both of the treatments. The combined use of FYM @ 10 t/ha or mustard cake @ 1.0 t/ha along with 75% recommended dose of NPK fertilizers was an efficient and economic in achieving higher yield of summer sesame.

Key words: Economics, Farm yard manure, Integrated nutrient management, Mustard and Seed yield

Edible oil demand is expected to grow by 3-4% over the next five to ten years which is estimated to be an additional requirement of 0.3 to 0.4 m.t. per annum reaching a total of 14.8 and 18.3 m.t. by the end of 2010 and 2015, respectively (Hegde, 2005). Sesame (*Sesamum indicum* L.), the second most important oilseed crop in West Bengal, is cultivated mainly during summer owing to occasional rains and higher yield potential than rainy season crop. To improve upon the productivity on a sustainable basis, integrated nutrient management approach needs to be emphasized where combined use of organic, chemical and biological sources of plant nutrients are used in a judicious and efficient manner. Keeping this in view, the present study was undertaken to find out the effect of integrated nutrient management through organic and chemical fertilizers on growth, productivity and economics of summer sesame.

MATERIALS AND METHODS

The experiment was conducted at Agricultural Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal during summer season of 2004 and 2005 on sandy loam soil with slightly acidic in reaction, low in organic carbon (0.39%), available nitrogen (110 kg/ha), phosphorus (25 kg/ha) and potassium (140 kg/ha). The experiment was laid out in factorial randomized block design consisting of 12 treatment combinations having three levels of organic sources [*viz.*, no organic manure, farm yard manure (FYM) @ 10 t/ha and mustard cake @ 1.0 t/ha] and four levels of mineral fertilizers [(*viz.*, no NPK, 50% recommended dose of NPK (25:12.5:12.5), 75% recommended dose of NPK (37.5 : 18.75 : 18.75) and 100% recommended dose of NPK (50:25:25)] with each treatment replicated thrice. Farm yard manure and mustard cake were applied and incorporated into the soil four weeks before sowing of the crop. Half of the total nitrogen (urea) and full quantity of P_2O_5 (SSP) and K_2O (MOP) were applied and mixed into the soil before sowing as per treatment and rest half of nitrogen was top dressed after first irrigation at 30 days after sowing. Sesame variety, 'Tilottama' was sown on March 20 and March 16 and was harvested on June 12 and June 14 during summer season of 2004 and 2005, respectively. The crop was grown following the recommended package of practices. The experimental data were analysed by using the standard statistical methods. The total rainfall received during the crop growing season (March to June) was 258.0 and 197.7 mm in 2004 and 2005, respectively.

RESULTS AND DISCUSSION

Growth attributes: Application of different organic manures as well as various levels of NPK fertilizers significantly influenced the growth attributes (*viz.*, plant height, number of branches/plant, leaf area index and drymatter accumulation) of summer sesame as evidenced from pooled data analyzed over two years of field experiments (Table 1). Farm yard manure performed better than mustard cake application in sesame. Organic and mineral sources of plant nutrients interacted significantly towards growth attributes of sesame. The highest plant height, number of branches/plant, leaf area index and drymatter accumulation of sesame was found in FYM application. This was significantly higher than mustard cake use in respect of plant height, leaf area index and drymatter accumulation. All the growth attributes of sesame increased with the increasing levels of NPK fertilizers. Similar findings were also reported by Mondal *et al.* (1997). Application of 100% NPK fertilizers showed significantly higher values of growth attributes in sesame except number of branches/plant.

Yield attributes and yield: A significant response was found from application of different organic and chemical sources of plant nutrients on yield attributes and yield of sesame (Table 1). Between the two organic sources, use of FYM was superior to mustard cake application in achieving higher yield attributes and yield of sesame. Singh *et al.* (1990) confirmed the superiority of combined effect of urea + FYM over urea + mustard cake application in achieving higher yield of sesame. The use of FYM @ 10 t/ha produced the highest number of capsules/plant, number of seeds/capsule, test weight, seed yield and stick yield of sesame though this was at par with mustard cake application. Increasing levels of NPK fertilizers increased the yield components and yield of sesame. Mitra and Pal (1999) and Ahamed *et al.* (2001) have reported similar findings. Though the application of 100% NPK fertilizers was superior to 75% NPK fertilizers in respect of yield of sesame, these were at par with each other.

Economics: Gross return, net return and return per rupee investment in sesame were higher in FYM application. However, this was at par with mustard cake use (Table 2). Among the different levels of NPK fertilizers, the use of 100% NPK exhibited significantly higher gross return (₹ 16,993/ha) and net return (₹ 6,638/ha) in sesame in comparison to 75% NPK. These two treatments were at par with each other in respect of return per rupee investment.

It could be concluded that application of FYM @ 10 t/ha or mustard cake @ 1.0 t/ha along with 75% recommended dose of NPK fertilizers will be an efficient and economic proposition in summer sesame cultivation.

Table 1 Effect of organic sources, NPK fertilizers and their interaction on growth, yield attributes and yield of summer sesame (pooled data over two years)

Treatment	Growth attributes				Yield attributes and yield				
	Plant height at harvest (cm)	No. of branches/plant at harvest	Leaf area index (60 DAS)	Drymatter accumulation at harvest (g/m^2)	No. of capsules/ plant	No. of seeds/ capsule	Test weight (g)	Seed yield (t/ha)	Stick yield (t/ha)
Organic manure (OM)									
No organic manure	108.1	4.6	1.4	153.1	46.2	56.9	2.8	0.6	2.3
FYM @ 10 t/ha	125.0	6.2	2.3	216.2	53.3	60.0	3.0	0.9	2.6
Mustard cake @ 1 t/ha	121.9	6.1	2.0	188.6	50.8	59.2	3.0	0.8	2.6
SEm±	1.2	0.2	0.0	3.5	0.7	0.5	0.0	0.1	0.1
CD (P=0.05)	2.9	0.8	0.1	9.9	2.0	1.7	0.0	0.1	0.1
NPK fertilizers									
No NPK	104.8	4.3	1.3	131.5	41.5	56.3	2.8	0.5	2.1
50% NPK	112.8	5.3	1.6	171.4	45.2	56.5	2.9	0.8	2.4
75% NPK	123.4	6.1	1.9	203.1	52.7	60.5	3.0	0.9	2.7
100% NPK	132.2	6.8	2.9	237.9	60.9	61.5	3.1	0.9	2.8
SEm±	1.1	0.3	0.0	4.1	0.7	0.7	0.0	0.1	0.1
CD (P=0.05)	3.3	0.9	0.1	12.0	2.3	1.9	0.0	0.1	0.3
Interaction (OM x NPK)									
SEm±	2.0	0.5	0.0	7.1	1.3	1.2	0.0	0.1	0.2
CD (P=0.05)	5.8	1.6	0.2	NS	NS	NS	0.0	NS	NS

Table 2 Effect of organic sources, NPK fertilizers and their interaction on economics of summer sesame (pooled data over two years)

Treatment	Economics			
	Gross return (₹/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	Return/Rupee investment (₹)
Organic manure (OM)				
No organic manure	11431	8465	2967	1.3
FYM @ *10 t/ha*	14961	10181	4742	1.5
Mustard cake @ 1 t/ha	14526	10316	4197	1.4
SEm±	274.5		274.5	0.1
CD (P=0.05)	805.3		805.3	0.1
NPK fertilizers				
No NPK	8425	8781	-425	0.9
50% NPK	13908	9548	4360	1.5
75% NPK	15231	9930	5301	1.5
100% NPK	16993	10355	6638	1.7
SEm±	317.0		317.0	0.1
CD (P=0.05)	929.8		929.8	0.2
Interaction (OM x NPK)				
SEm±	549.1		549.1	0.3
CD (P=0.05)	NS		NS	NS

Note: Urea = ₹ 5.5/kg; SSP = ₹ 4.5/kg; MOP = ₹ 5.0/kg; Wage of labour = ₹ 50/8 working hours; FYM = ₹ 3/kg; Mustard cake = ₹ 8/kg; Seed = ₹ 45/kg; Selling price of seed = ₹ 16/kg and Stick = ₹ 0.20/kg

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Efficacy of indigenous plant products against mustard aphid, *Lipaphis erysimi* (Kalt.) and cabbage aphid, *Brevicoryne brassicae* Linnaeus on mustard crop in Himachal Pradesh

AJAI SRIVASTAVA, ARVINDER PAUL SINGH, ARUN SUD AND VINAYIKA SINGH

CSK HPKV Rice and Wheat Research Centre, Malan-176 047, Himachal Pradesh

(Received: March, 2010; Revised: November, 2011; Accepted: November, 2011)

ABSTRACT

The studies on efficafy of indigenous plant products against *Lipaphis erysimi* and *Brevicoryne brassicae* were conducted at Malan, CSK, HPKV, Palampur, Himachal Pradesh. It was observed that application of *Pterospermuam acrifolium* (water fraction) was as effective as neem for the management of *L. erysimi* and *B. brassicae* on mustard crop.

Keywords: Cabbage aphid, Indigenous plant products, Mustard aphid

The naturally occurring, biologically active plants appear to have a prominent role for the development of future commercial pesticides not only for the increased productivity but for the safety of the environment and public health. Earlier, pyrathrins, rotenone, nicotine, lantana, ageratum, senhund, aloe and *Jatropha* species were found effective against pests and also safer to mammals and higher animals (Pandey *et al.*, 1977). In view of these, use of insecticides of plant origin is desirable. Plant extracts having the insecticidal properties are being explored as an alternative to chemical insecticides for protecting the crops due to growing awareness of harmful effects of pesticides. Hence, the present study was conducted to screen some indigenous plant products to explore the alternative management of plant sucking pests, the mustard aphid.

MATERIALS AND METHODS

Fifty gram of dried leaves of plant sample was taken in the boiling round bottom flask and extracted with methanol (400 ml). Extraction was done in rotary vacuum at the temp. 40°C (Temperature is changed according to the solvent used). Plant sample was then filtered. Filterate was distilled at the same temperature in rotary vacuum. Excess of solvent was removed with rotary vacuum and the remaining solvent is removed with the lypholizer (Freeze dryer). Finally the extract of plant sample was collected in culture tubes. Field trials were conducted at Oilseeds Research Station, Kangra and Rice and Wheat Research Centre, Malan of CSK Himachal Pradesh Krishi Visvavidyalaya, Palampur during the winter season of 2007 to 2008 and 2009 to test efficacy of different indigenous plant extracts against mustard aphid, *Lipaphis erysimi* and *Brevicoryne brassicae* on mustard, respectively. The experiments were laid out in randomized block design. The plot size was 2.4 m x 3 m. Eight treatments *viz.*, *Cnicus wallichi* (EtoAc fraction), *Agave americana* (EtoAc fraction), *Pterospermuam acrifolium* (EtoAc) fraction) and (water fraction), *Melia azedarach* (mother extract in methanol), *Jatropha* seeds (mother extract in methanol), Neem based product, Achook (Godrej @2.5ml/l) and untreated check were evaluated against mustard aphid, *Lipaphis erysimi* (Kalt.) at Oilseeds Research Station, Kangra and cabbage aphid, *Brevicoryne brassicae* Linnaeus at Rice and Wheat Research Centre, Malan. For recording the population of aphids, 10 plants/treatment were selected randomly and tagged. The number of nymphs and adults/plant was recorded on 7 days and 15 days after application.

RESULTS AND DISCUSSION

On the basis of pooled data (2007-08 and 2008) at Kangra, the treatment with neem showed minimum incidence of mustard aphid and found at par with the other treatment such as *C. wallichi*, *P. acrifolium* (water fraction) and *M. azedarach* (Table 1). The treatment with *P. acrifolium* (water fraction) also provided maximum yield (18.2 q/ha) and at par with *C. wallichi*, *A. americana*, *M. azedarach* and neem against mustard aphid (Table 1), while *P. acrifolium* (water fraction) showed superiority in yield over other treatments and and found at par with neem in the trial conducted. at Malan (Table 2). Hence, *P. acrifolium* (water fraction) followed by neem were recommended for the control of mustard aphid and cabbage aphid. Agarwal *et al.* (2005) and Bhathal and Singh (1994) also reported that efficacy of plant products against cabbage aphid. Singh (2007) reported that oxydemeton methyl and neem leaf extract were effective against mustard aphid. Singh and Arya

(2004) reported 100% mortality of both nymphs and adults of mustard aphid with 4% concentration of neem extract after 72 hr of treatment. Gaurav Kumar *et al.* (2010) reported per cent reduction of *Brevicornyne brassicae* population by neem leaf extract @ 5% (75.96), Lantana leaf extract @ 5% (75.96), Calotrophis leaf extract @ 5% (69.08), Parthenium leaf extract @ 5% (52.78) and tulsi leaf extract @ 5% (44.80) after one day of application.

Table 1 Efficacy of different plant products against *Lipaphis erysimi* (Kalt.)

Treatment	Dose	Aphid (*L. erysimi*)/10 cm shoot after 15 days of treatment			Yield (q/ha)		
		2007-08	2008-09	Pooled	2007-08	2008-09	Pooled
Cnicus wallichi (EtoAc fraction)	1g/ l	137.3(4.83)	172.00(4.81)	154.66(4.82)	16.90	17.08	15.48
Agave americana (EtoAc fraction)	1g/ l	246.3(5.47)	129.66(4.82)	188.00(5.15)	11.81	17.87	14.14
Pterospermuam acrifolium (EtoAc) fraction)	1g/ l	347.6(5.84)	115.66(4.72)	231.66(5.28)	9.02	21.02	15.25
Pterospermuam acrifolium (Water) fraction)	1g/ l	398.66(5.95)	25.66(3.18)	212.16(4.57)	11.57	26.08	18.22
Melia azedarach (mother extract in methanol)	1g/ l	207.66(5.27)	126.33(5.05)	167.00(5.04)	11.81	17.84	14.24
Jatropha seeds (Mother extracts)	1g/ l	192.66(5.20)	159.33(5.05)	176.00(5.13)	8.56	16.89	13.42
Neem (Achook)	2.5 ml/l	252.66 (5.49)	42.66 (3.53)	147.66 (4.51)	9.72	23.50	16.38
Untreated control		313.66 (5.73)	299.66 (5.69)		8.33	7.62	8.90
CD (P=0.05)		0.67	0.88		1.79	7.83	4.06

Figures in parentheses are transformed values

Table 2 Efficacy of different plant products against *Brevicoryne brassicae* Linnaeus

Treatment	Dose	Aphid/10cm shoot (7 DAS)	Aphid/10cm shoot (15 DAS)	Yield (q/ha)
Cnicus wallichi (EtoAc fraction)	1g/ l	177.00(5.11)	237.00(5.00)	11.19
Agave mericana (water fraction)	1g/ l	216.66(5.35)	500.33(5.96)	10.34
Pterospermuam acrifolium (EtoAc) fraction)	1g/ l	116.33(4.67)	292.00(5.63)	12.14
Pterospermuam acrifolium (Water) fraction)	1g/ l	89.00(4.37)	154.00(5.02)	20.27
Melia azedarach (mother extract in methanol)	1g/ l	197.66(5.25)	405.33(5.63)	11.41
Dodonea viscose (EtoAc fraction)	1g/ l	231.00(5.42)	209.33(5.24)	10.47
Neem Achook	2.5 ml l	67.66(4.20)	188.66(5.14)	17.41
Control		352.33(5.74)	802.00(6.61)	7.25
CD (P=0.05)		0.73	0.94	6.72

Figures in parentheses are transformed values

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Adoption of improved soybean production technology in Madhya Pradesh : A critique

B U DUPARE[1], S D BILLORE, O P JOSHI AND S K VERMA

Directorate of Soybean Research, Khandwa Road, Indore-452 001, Madhya Pradesh

(Received: November, 2010; Revised: November, 2011; Accepted: November, 2011)

ABSTRACT

A study was conducted to ascertain farmers' adoption behaviour of improved soybean (*Glycine max* L.) production technology in the soya state of Madhya Pradesh. The data were collected using well designed interview schedule containing psychological scales to measure different attribute. It was observed that farmers, in general, have medium levels of adoption of different production technologies. It was noticed that none of the farmer fully adopted the plant protection measure especially application of herbicide and pesticides for control of pest-disease complex. In some of the practices, an over adoption was observed as the farmers were using more than the quantity recommended or non-recommended plant protection chemicals coupled with inappropriate concentration of spray volume, while non-availability of quality seed of improved soybean varieties found a major constraint as experienced by the majority of the farmers followed by unawareness of technical know-how of soybean production technologies and non-availability of soil testing facility at local level.

Keywords: Adoption, Constraints, Farmers, Madhya Pradesh, Soybean, Technology

Soybean (*Glycine max* L.) is one of the major rainy season oilseed crops grown in Madhya Pradesh. It has occupied second position with respect to area and production among the oilseeds and is contributing significantly to the edible oil requirement of the country. The crop is being commercially cultivated in the state since last four decades of its introduction. The research and development (R&D) system has recommended package of practices (production technologies) suiting to the local agro-ecological situation way back during the sixties and since then being updated and transferred to the state department of agriculture for further dissemination to the ultimate users i.e., farmers. To bring out facts and figures on acceptance, adoption and constraints therein, a synthesis of research emanated production technology has been brought out in the following text. The out come may be of immense help for the planners and extension workers to reorient extension efforts so as to break the threshold of stagnating national soybean productivity of one tonne per hectare.

MATERIALS AND METHODS

The present study is confined to the major soybean producing regions of Madhya Pradesh, which owes maximum area (about 4.8 m. ha) under soybean (8.87 m. ha) in the country. Out of 48 soybean growing districts, 6 of them located in agro-ecological zones of Malwa plateau (Indore, Dewas and Ujjain), Satpura hills (Betul), Vindhya plateau (Hoshangabad and Vidisha) and Narmada valley (Badwani) were purposively selected on the basis of area coverage by the crop. The sample size is comprised of 117 farmers selected randomly from these districts. The data were collected through varied schedule. The adoption behaviour of a farmer was measured considering 30 practices under 7 major categories like seed-bed preparation, seed of improved varieties, sowing techniques, use of manure and fertilizers, intercultural operations, plant protection, harvesting and post-harvesting as described by the soybean R&D system (Anonymous, 2007). The respondents were evaluated on the basis of full adoption of a recommended practice which was assigned a score of 2. A score of 1 was given to partial adoption of a recommended practice whereas non-adoption of a practice was scored as 0. The adoption index score of each farmer was then worked out using the formula; total score obtained by the respondent divided by maximum score that could be obtained multiplied by 100. The data were collected through interview schedule analyzed using standard statistical tools like, mean, standard deviation, percentage and correlation coefficients.

RESULTS AND DISCUSSION

Characteristics of soybean growers vs. adoption of technology: The survey revealed that 12 characters (Table 1) have favoured in motivating farmers belonging to medium categories for adoption of technologies such as (I) age group, (ii) annual income, (iii) education level, (iv) socio-economic status, (v) size of land holding, (vi) scientific orientation, (vii) economic motivation, (viii) risk orientation, (ix)

[1]E-mail: budupare@rediffmail.com

management orientation, and (x) extension participation. Similar trend was observed with the adoption of technology by medium level category except social participation. The reason is being low number of farmers in medium category involved in social participation. Higher number of farmers (78%) participating in social event reveal higher percentage of partial adoption of technology. During participation in the social events such as religious or traditional, the farmers do exchange ideas, feelings about the technologies and impact on enhanced yields, which make them to adopt convincing technology only.

Table 1 Characteristics of soybean growers vs adoption levels of production technology

Characteristic	No. of farmers (N=117)	Adoption levels (Mean: 26.11, SD: 7.38)		
		High (Above 34) n 21	Medium (Between 20-33) n 73	Low (Below 19) n=23
Age				
High (above 59)	18 (15.38)	4 (22.22)	11 (61.11)	3 (16.67)
Medium (32-58)	81 (69.24)	8 (09.87)	56 (69.13)	17 (20.98)
Low (up to 31)	18 (15.38)	6 (33.33)	8 (44.45)	4 (22.22)
Mean: 45.01, SD: 13.42				r 0.013
Annual income				
High (above 1,50,000)	30 (25.65)	17 (56.67)	11 (36.66)	2 (06.67)
Medium (50,000-1,50,000)	48 (41.02)	1 (02.08)	32 (66.67)	15 (31.25)
Low (up to 50,000)	39 (33.33)	3 (07.69)	30 (76.93)	6 (15.38)
Mean: 105794, SD: 80446				r = 0.0710
Education				
High (5 score)	23 (19.67)	*16 (69.57)*	9 (39.13)	0 (00.00)
Medium (Score 3-4)	63 (53.84)	4 (06.34)	41 (65.08)	18 (28.58)
Low (below 2)	31 (26.49)	1 (03.22)	24 (77.42)	6 (19.36)
Mean: 3.40, SD: 1.28				r = -0.034
Social participation				
High (above 4 score)	92 (78.64)	20 (21.74)	55 (59.78)	17 (18.48)
Medium (2 and 3 score)	8 (6.84)	1 (12.50)	7 (87.50)	0 (00.00)
Low (below 1)	17 (14.52)	0 (00.00)	11 (64.70)	6 (35.30)
Mean: 4.19, SD: 1.76				r 0.023 NS
Socio-economic status				
High (above 29)	20 (17.09)	14 (70.00)	6 (30.00)	0 (00.00)
Medium (22-28 score)	*78 (66.67)*	*6 (07.69)*	*55 (70.52)*	*17 (21.79)*
Low (below 21)	19 (16.24)	1 (05.27)	12 (63.15)	6 (31.58)
Mean: 25.07, SD: 4.03				r = 0.2193*
Land holdings				
High 4 (above 4 ha)	11 (9.40)	7 (63.63)	4 (36.37)	0 (00.00)
Medium (*2.1 ha to 4 ha*)	*81 (69.23)*	*13 (16.04)*	51 (62.96)	17 (20.98)
Low 2 (0.1 to 2 ha)	25 (21.37)	1 (04.00)	18 (72.00)	6 (24.00)
Mean: 3.18, SD: 1.07				r 0.22*
Scientific orientation				
High (above 27)	34 (29.05)	17 (50.00)	14 (41.17)	3 (08.83)
Medium (22-26)	52 (44.46)	3 (05.77)	36 (69.23)	13 (25.00)
Low (up to 21)	31 (26.49)	1 (03.22)	24 (77.43)	6 (19.35)
Mean: 24.18, SD: 3.23				r = 0.27*
Economic motivation				
High (27 and above)	10 (8.55)	6 (60.00)	4 (40.00)	0 (00.00)
Medium (23-26)	80 (68.38)	14 (17.50)	49 (61.25)	17 (21.25)
Low (up to 22)	27 (23.07)	1(03.70)	*20 (74.07)*	*6 (22.23)*
Mean: 24.74, SD: 2.40				r = -0.14*
Risk orientation				
High (above 24)	9 (7.69)	5 (55.55)	4 (44.45)	0 (00.00)
Medium (20-23 score)	95 (81.19)	16 (16.85)	62 (65.26)	17 (17.89)
Low (below 19)	13 (11.12)	0 (00.00)	7 (53.84)	6 (46.16)
Mean: 21.29, SD: 2.47				r = -0.138*
Management orientation				
High(above 17)	19 (16.25)	13 (68.42)	6 (31.58)	0 (00.00)
Medium(14-15)	88 (75.21)	8 (09.09)	63 (71.59)	17 (19.32)
Low(up to 13)	10 (8.54)	0 (00.00)	4 (40.00)	6 (60.00)
Mean: 14.98, SD: 1.53				r 0.235*
Extension contact				
High (above 4)	36 (30.77)	17 (47.22)	11 (38.89)	5 (13.89)
Medium (2-3 score)	40 (34.18)	0 (00.00)	28 (70.00)	12 (30.00)
Low (1 score)	41 (35.05)	4 (09.75)	31 (75.61)	6 (14.64)
Mean: 2.75, SD: 2.03				r 0.3889*
Extension participation				
High (above 4)	20 (17.09)	14 (70.00)	6 (30.00)	0 (00.00)
Medium (2-3 score)	55 (47.00)	3 (05.45)	34 (61.82)	18 (32.73)
Low (below 1 score)	42 (35.91)	4 (09.53)	32 (76.19)	6 (14.28)
Mean: 2.42, SD: 2.01				r = 0.594*

Figures in parentheses indicate percentage

Among the farmers with higher annual income (above ₹1.5 lakh), education (above intermediate and above), socioeconomic status, land holding (above 4 ha), scientific orientation, economic motivation, risk orientation, higher management orientation, extension contact and extension participation ensure it possible for them to go for high to medium adoption technology. Further, it reflects that it is only economically sound farmers do get attention of extension machinery operating in the fields and which needs reorientation. It appears to be logical that apart from reach of small and marginal farmers to technological developments, their low annual income forbids them to go for adoption of improved technology is one of the major impediments in enhancing the productivity of soybean. On account of their lower annual income, their entire attention is concentrated to meet the needs of the family. Moreover, these farmers are afraid of adopting monetary technology with a fear of loosing the possible benefit of inputs used on account of rainfed cultivation of crop under the uncertainty of weather conditions.

Their present levels of adoption of improved soybean production technology revealed that most of them have low to medium range of adoption index score indicating partial adoption of the technology. The mean adoption index score observed to be around 26 as against maximum of 60, which is extremely disheartening in spite of exhaustive extension efforts made by the responsible agencies in the time span of four decades of introduction of commercial cultivation of soybean.

From the table 1 it is clear that the adoption of production technology was with farmers in the medium age group ranging from 32-58 years, medium income group (₹ 0.5 to 1.5 lakh), medium education level (primary to high school), higher social participation group, medium socioeconomic group, medium land holding (2-4 ha), medium level of scientific orientation and economic motivation, medium risk orientation, medium economic orientation, medium management orientation, high extension contact and extension participation. This showed that for adoption of technology, capacity building should have a component of other traits like adequate size of land holding ® = 0.22*), scientific orientation (r=0.27*), management orientation (r=0.23*), high extension contacts (r=0.39*) and high extension participation (r=0.59**) are important factors. The combined effect of these factors in the present set of farmers could lead to medium adoption of the production technology to a large extent. Economic motivation and risk orientation negatively impacted the adoption of technology. The possible reason could be the age old tendency of farmers to get satisfied with what they get and dominance of fear of failure of crop due to uncertainty of weather.

Extent of technology adopted by the farmers: Of the 30 improved practices grouped in seven categories brought out interesting information on the level of adoption (Table 2). At seed bed preparation level, it is obvious that farmers are over enthusiastic and 83% farmers go for deep ploughing every year rather than once in three years. This leaves a scope to adopt the recommendation of deep ploughing once in three years and reduce the cost of cultivation. It is good to learn that about 90 % farmers adopt the recommendation of 2-3 cross harrowing, 74% go for application of FYM @ 10 t/ha and 55% apply phorate at the time of sowing as a measure to control insect-pests at the early stage of crop growth. Management of weeds using pre plant incorporation herbicides has been adopted only by 26 % of the farmers. It is to mention here that the weed infestation is capable of reducing the soybean seed yield levels to the extent of 77% depending on the level of infestation (Tiwari and Kurchania, 1990). A few farmers (3.4%) use the herbicides not recommended by the R&D system. However, 26% of farmers often use recommended herbicide, without stick to the required spray volume of 750-800 l/ha. It needs attention of the extension workers to show method demonstration on recommended weedicides and mode of application to achieve the desired effect of weedicides on weed management.

As far as the attention of farmers on the soybean seed being used by them is concerned, there appears to be a high level of awareness on the use of seed of improved varieties leading to 71% adoption. Remaining 29% farmers are using seed of unknown origin. Sometimes this practice may cause threat to soybean cultivation on account of possible diseas and pest infestation problems and some other risks. Sizabl number of farmers (68%) was also aware of utility c germination test to ensure optimum emergence of seedling in the field. This is one of vital non-monetary technologie needs creation of awareness among the farmers who do nc resort to germination test of seed lot before sowing Adoption of germination test will make it possible for 42% farmers who are using excessive seed rate to revert t recommended one thereby reducing the cost of cultivatio and disadvantage of over crowding of crop plants in thei fields.

About 64% farmers go for seed treatment wit bio-fertilizer (*Bradyrhizobium*/PSB) and 55% wit recommended fungicides. Attention of extension workers i drawn here to motivate farmers not adopting these practice as to reduce the field mortality of plants due to collar rot an take advantage of symbiotic nitrogen fixation/mobilizatio of native and applied phosphorus. These are low monetar inputs and have role in improving yields.

Majority of farmers (89%) are aware of the importanc of timely sowing (June last week) which yields maximur and hence they sow in time. Moreover, the delays in sowin may be there with the delay in onset of monsoon. There is need to convince the farmers to resort to adopt row to rov distance of 45 cm as recommended. Appropriate distance between rows is known to improve yields of crops and helps in minimizing the incidence of pests and diseases. Hardly 16% of farmers adopt intercropping soybean in the surveyed areas. There is a need to diversify crops for long term sustainability and enhanced productivity of crops from the same piece of land. Soybean intercropped with maize, sorghum, finger millet and pigeon pea results in land equivalent ratio of 1.2 to 1.7 (Bhatnagar *et al.*, 1995). The efforts to bring more area under soybean based intercropping are in the benefit of farmers to cover the risk of crop failure, better resource utilization and more profit. Soybean-pigeon pea intercropping is best adoptable practice in fields used to grow only one crop of soybean in monsoon and leaving fields fallow for the want of irrigation water.

Nearly half of the farmers are either not aware of significance of balanced nutrition or hesitant to invest on account of uncertainty of monsoon. Only one forth of these bothers for application of zinc or sulphur to soybean crop which is known to respond well to micronutrients application. This aspect needs special attention to sustain the soybean productivity at higher level.

Majority of farmers are traditionally used to manage weeds and to create better soil environment by manual weeding or inter-cultivation using traditional "dora". It is the best method to manage weeds, but during years receiving incessant rains at right time for weeding, it is not feasible. So they go for recommended post-emergence application of herbicide, but in sub-optimal spray concentration. Some farmers adopt non-recommended post-emergence herbicides for weed management and the practice need to be discouraged.

As far as the management of insect-pests is concerned, only partial adoption to the extent of 24 to 50% existed. A good number of farmers (8 to 47%) are using the pesticides which are not recommended for the crop. Possibly advisory from the local traders and availability of chemicals on loan might be the factor. The awareness on the use of genuine chemicals with in the expiry date should be brought among farmers. It seems that the farmers are not able to distinguish between the losses caused by insect-pests and diseases and hence not much attention on disease management is paid by them. Farmers (19%) are inclined to use bio-pesticides based on indigenous technical knowledge. The formulations available in the market are expensive than the chemical pesticides and hence do not get favour from the farmers. It is to mention here that faulty use and spurious pesticides are in vogue, leading to misconception that these are not effective. The faulty use involving under/over dose with sub-optimal quantities of water is likely to provide resistance against targeted pest.

The message to harvest on proper time (when 90% pods changing color) and use of threshers at low rpm (350) has gone well among farmers and is followed by majority of them. The scientific advice to store soybean seed under recommended conditions is also adopted by sizable number of farmers (68%). The message to remaining farmers should go so as to store seed lots using appropriate technology to ensure good germination at the time of sowing in the next season.

Constraints of soybean growers: The problems as perceived by the farmers entails that non-availability of seed of improved/newly released soybean varieties in required quantity continue to be a major constraint (Table 3). This further gets reflected in present seed replacement rate of soybean which is just around 10% (Sharma and Dadlani, 2004). In the absence of availability of certified seed from authenticated agency, the farmer resort to purchase seed from different sources or through exchange or use their farm saved seed. The certified seed supplied by the authorized outlets also do not synchronies with their liking on account of non-seriousness of responsible agencies to judge the need for farmer favoured varieties and indent them for breeder seed production in the seed chain. In addition there is varietal mismatch between indent and production of breeder seed in needed quantities. There appears to be a need to revamp the seed production system followed at present. The missing support to take the technical know-how regarding package of improved soybean practices is the second major problem expressed by (26.49%) farmers. The responsibility of dissemination of information lies with the concerned state department of agriculture which has deployed hierarchical manpower extending to the field level for the purpose. These ground level workers are inaccessible to most of the farmers because of their large working area and other non-agricultural work imposed on them. Use of latest communication technologies to out reach technologies by the agencies is needed. Unavailability of soil testing facility at local level is the third major problem expressed by 9.40% farmers. Of late, the farmers have started suspecting lowering of fertility status of their field on account of continuous cropping of the soybean since last 35-40 years. The observation has substance as the energy rich soybean crop is cultivated under most poor nutrient management conditions. During the introduction and subsequent phase of crop establishment at commercial levels, the farmers obtained more and assured yield levels with less cost of cultivation as there were less incidence of pest-disease complex, they did not even concerned to supplement soil with adequate quantity of nutrition by adopting integrated nutrient management. Further, farmers have wrong notion that there is no need to apply fertilizer for soybean crop as they apply more nutrition to subsequent crop *viz.*, potato, wheat etc., which can take care of soybean. This has further aggravated the problem of nutrient imbalance in the soils with telling effect on productivity.

Table 2 Adoption of improved soybean production technology (N=117)

Recommended practice	Full adoption	Partial adoption	Non-adoption	Over-adoption
Seed bed preparation				
Summer deep ploughing	16 (13.69)	-	4 (3.41)	97(82.90)
2-3 crisis-cross harrowing	105(89.75)	-	12(10.25)	-
Application of FYM @ 10 t/ha	86(73.52)	4(3.41)	27(23.07)	-
Application of Phorate 10G @ 10 kg/ha	65(55.55)	-	52(44.45)	-
Use of herbicide as pre-plant incorporation	-	30(25.65)	83(70.94)	4(3.41)
Seed				
Improved soybean varieties	83(70.95)	-	-	34(29.05)
Germination test	80(68.38)	-	37(31.62)	-
Use of *Rhizobium/PSB* culture for seed treatment	75(64.10)	-	42(35.90)	-
Use of fungicide for seed treatment (Thirum+carbendazim @ 3 gm/kg seed)	64(54.70)	-	53(45.30)	-
Appropriate seed rate (60-80 kg/ha depending on test weight)	68(58.11)	-	-	49(41.88)
Adequate plant population (4-4.5 lakh plants/ha)	15(12.82)	-	102(87.18)	-
Sowing				
Sowing time	104(88.88)	13(11.12)	-	-
Spacing (Line to line)	33(28.20)	76 (64.95)	4(3.41)	4(3.41)
Spacing (Plant to plant)	99 (84.62)	-	-	18(15.38)
Use of intercrop (4:2)	*19(16.23)*	-	*98(83.77)*	-
Use of pre-emergence herbicide	-	-	-	-
Nutrient management				
Application of NPKS @ 20:60:20:20 kg/ha	60(51.28)	3(2.57)	54(46.15)	-
Application of zinc sulphate	29(24.78)	-	88(75.22)	-
Application of sulphur	35(29.91)	2(1.70)	80(68.37)	-
Inter-cultural operations				
Two hoeing	115(98.29)	-	2(1.70)	-
Manual weeding	115(98.29)	-	2(1.71)	-
Plant protection				
Use of post-emergence herbicide	-	59(50.42)	45(38.47)	13(11.11)
Management of blue beetle	-	33(28.20)	29(24.80)	55(47.00)
Management of stem fly	-	37(31.62)	30(25.64)	50(42.74)
Management of girdle beetle/semilooper	-	58(49.57)	41(35.04)	9(7.69)
Management of diseases in soybean	-	-	58(49.57)	37(31.63)
Use of bio-pesticides	22(18.81)	-	95(81.19)	-
Harvest and post-harvest				
Harvesting of soybean (when 90-95 % pods changed their color)	105(89.74)	4(3.41)	-	8(6.83)
Threshing (at 350 rpm)	89(76.06)	-	28(23.94)	-
Storage	80(68.37)	-	37(31.63)	-

Figures in parentheses indicate percentage

Table 3 Constraints in adoption of improved production technology of soybean

Constraint	No. of farmers (N=117)
Non-availability of seed of improved/new soybean varieties in required quantity	68 (58.11)
Unawareness of technical know-how on package of practices	31 (26.49)
Non-availability of soil testing facility to design nutritional doses to the soil	11 (09.40)
Non-availability of remunerative local market and high transportation cost	8 (06.83)
Poor knowledge of identification of pest/disease complex	7 (05.98)
Shortage and expensive labour	6 (05.12)
Unavailability and in-efficient of extension worker	5 (04.27)
Shortage of manure/fertilizers at the time of need	4 (03.41)
Seed deterioration during in storage (poor viability)	2 (01.70)

Figures in parentheses indicate percentage

Remaining problems such as un-availability of remunerative local market and high transportation cost, poor knowledge of identification of pest/disease complex, shortage and expensiveness of labour, limited number and inaccessibility of extension worker, shortage of manure/fertilizer at the time of need, problems in storage of soybean seed (poor viability) expressed though by only few farmers, but are likely to have significant contribution towards increasing the production and productivity of the crop in the state.

Soybean is known as golden bean and is significantly contributing to oil and national economy of India from the time of its commercial introduction four decades ago. Majority of the farmers of the present study were found to have medium level of adoption of soybean production technologies which needs further scale up for higher level of adoption. Thus, a well planned strategy concentrating the attributes which favoured the adoption of improved production technology should be spread extensively at the grass root levels to bridge the technological gap. Further, using the latest technology such as information and communication technology is one of the strategies to out reach the right technology even to the unreached growers with supply of quality seed of suitable cultivars would not only enhance the adoption behaviour of farmers but also enable them to get the higher productivity.

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Impact of adoption of winter-summer groundnut (*Arachis hypogaea* L.) production technology on the livelihood of farmers

G D S KUMAR* AND V K JAIN

Directorate of Groundnut Research, Junagadh-362 001, Gujarat

(Received: April, 2011; Revised: November, 2011; Accepted: December. 2011)

ABSTRACT

This study was carried out during 2009-10 in Gujarat and Andhra Pradesh states of India to assess the extent of adoption of groundnut (*Arachis hypogaea* L.) production technologies by groundnut growers and its impact in creation of various livelihood assets and improving their livelihood outcomes. The results showed that 96% of sampled farmers in Kutch and 40% of farmers in Chittoor adopted the improved varieties of groundnut. The improved technologies such as seed treatment with bio-fertilizers (81% farmers), use of optimum seed rate (71% farmers), soil test based fertilizer application (83% farmers), application of gypsum and micronutrients (74% each) and chemical weed management (71%) were not adopted by the farmers. The adoption of improved technologies resulted in creating human, natural/physical and financial assets thereby improving the livelihood outcomes of farmers. It is very important to create awareness among farmers on improved technologies by use of appropriate extension strategies and need based training programmes.

Keywords: Adoption, Groundnut, Financial assets, Human assets, Impact, Livelihood outcomes, winter-summer

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop of India contributing about 24% and 29% to total area and production of oilseeds, respectively. About 86% of total groundnut area is sown during rainy season under rainfed conditions accounting to 78.3% of total groundnut production and remaining 14% is grown under assured irrigation conditions during winter-summer season accounting to 21.6% of total groundnut production (Damodaram and Hegde, 2010). The winter-summer productivity was higher at 1764 kg/ha as compared to rainy season (1063 kg/ha). Gujarat and Andhra Pradesh are the two most important groundnut-producing states of India contributing 60% to total groundnut area and production. The winter-summer groundnut in these states contributed 43% and 46% to total winter-summer area and production, respectively (Damodaram and Hegde, 2010). The winter-summer groundnut production is stable and less vulnerable to various stresses (biotic and abiotic) and can play an important role in increasing India's groundnut production.

The sustained research efforts of Directorate of Groundnut Research, State Agricultural Universities, ICRISAT and other institutes resulted in the development of improved varieties, production and protection technologies for winter-summer groundnut cultivation. These technologies have enormous potential of increasing the productivity of groundnut, which was evident from results of frontline demonstrations (FLDs). The winter-summer FLDs conducted in Gujarat and Andhra Pradesh during 2002-2008 indicated that the adoption of improved technologies increased the pod yield up to 30% compared to farmers' practices.

The present study was undertaken during 2009-10, winter-summer season with the objectives to assess the extent of adoption of improved technologies, its impact in creation of various livelihood assets and livelihood outcomes of farmers and farmers attributes influencing the variation in yield of groundnut.

MATERIALS AND METHODS

Two states *viz*., Gujarat and Andhra Pradesh and one district from each state *viz*., Kutch and Chittoor were, respectively selected based on significant area and production of winter-summer groundnut. Six taluks and four taluks were selected from Kutch and Chittoor, respectively based on reporting highest area of groundnut. From each taluk, 2-3 villages were selected randomly, making a total of 20 villages. From each selected village, six respondents were selected randomly, making a total sample size of 120.

For measuring extent of adoption of improved technologies, a list of improved practices (20 items) for winter-summer groundnut production was prepared in consultation with the scientists of crop improvement, production and protection. The respondents' responses were recorded as 'yes' and 'no' for each item based on adoption and non-adoption and scores were given as 1 and 0, respectively. The adoption score of each respondent was estimated by

*Senior Scientist, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 050, AP (satish_dor@rediffmail.com)

summation of scores of all items. To assess the impact of improved technologies, farmers were categorized into two groups based on mean and standard deviation of their adoption scores. Accordingly respondents were grouped into adopters with adoption score >10 and non-adopters with adoption score = or < 10. Sustainable livelihood framework (Scoones, 1998) was used. For all the variables, suitable indicators were identified and measured.

An interview schedule was developed incorporating all the indicators for measuring independent and dependent variables. It was pre-tested and standardized for data collection. The data were collected by face-to-face interviews of respondents. Apart from this, group discussions and direct observations were made to collect qualitative data. The data were analyzed using SPSS® 17.0. Descriptive statistics such as frequency, percentage and mean were calculated. Z test for unequal samples was estimated. Pearson's correlation and inter-correlations were estimated to check for multicollinearity among the indicators selected for the study by the method of Frisch's confluence analysis (Koutsoyiannis, 1977) and step-down regressions were estimated to know the effects of various livelihood assets on the livelihood outcomes.

RESULTS AND DISCUSSION

Adoption of variety and agronomic practices: The FLDs on improved varieties of groundnut under irrigated conditions showed 26% higher pod yield compared to old varieties (Venkattakumar *et al.*, 2009). But, in summer season, in Kutch, 85% of sampled farmers were growing groundnut cv. GG-2 (15 years old variety), 11% were growing western-44 and the remaining farmers were growing TATA Sumo and even J-11 (Table 1), whereas in Chittoor, 60% farmers were growing old varieties TMV-2 and/or JL-24 (30 years old varieties) and 40% were growing improved varieties *viz.*, Narayani, TPG-41 and ICGV-91114. In Kutch, few farmers (20%) were aware of the recently released varieties *viz.*, GG-5, GG-7, and GG-9. In Chittoor, many of the farmers did not adopt the improved varieties. Ingle *et al.* (1995) reported that improved varieties of groundnut (UF-70-103, TAG-24, ICGS-11) were not known to 85% farmers. The important reason for non-adoption of recently released varieties in two districts was non-availability of seed in the existing seed system.

During summer, 53% farmers in Kutch and 60% in Chittoor purchased seed from informal sources *viz.*, neighbouring farmers, farmer seed traders, private seed agencies and oil millers. In Kutch, 26% farmers used their own seed and 21% purchased from the formal sources (public sector agencies), whereas in Chittoor only 10% farmers used their own seed, while 30% purchased from formal sources. Farmers of Chittoor preferred to purchase seed from formal sources mainly to avail subsidy on the seed.

Seed treatment with fungicides and bio-fertilizers are 'low cost- no cost' technologies, which can increase seed yield by 40% and 19%, respectively as compared to farmers practice of 'no seed treatment' (Venkattakumar *et al.*, 2009). All the farmers in Kutch and 90% farmers in Chittoor followed the practice of seed treatment with fungicides (Carbendazim/Dithane M-45/Thiram) for protection against diseases. Nagaraj *et al.* (2001) reported lower adoption of chemical seed treatment. Only few farmers (18% in Kutch and 12% in Chittoor) adopted seed treatment with *Rhizobium* cultures. Many of the farmers (86% in Kutch and 80% in Chittoor) performed timely sowing, but did not care to maintain optimum spacing. The recommended seed rate was followed by only 30% farmers and conversely 70% used higher than the recommended seed rate. The seed rate used by the farmers was in the range of 150-300 kg/ha with spacing in the range of 20 cm x 5 cm to 75 cm x 5 cm. Farmers perceived that higher seed rate was required to compensate for poor germination and seedling mortality. In Kutch, sowing was done with tractor drawn seed drill by 36% of farmers and farmers with small and marginal land holding (64%) did manual sowing behind the plough, whereas in Chittoor, as high as 94% farmers adopted manual sowing behind the plough. In Kutch and Chittoor, 23% and 28% of the farmers, respectively applied organic manures. In Kutch, 17% farmers and in Chittoor, 12% farmers applied fertilizers on the basis of soil test values. A vast majority of farmers of both the districts applied higher than recommended doses of fertilizers, while only 17% farmers in Kutch and 20% in Chittoor applied recommended doses of fertilizers. Farmers perceived that higher the rate of application of fertilizer, higher the yields of groundnut.

In both the districts, farmers practised manual weeding and only 28% in Kutch and 14% in Chittoor applied herbicides. Nagaraj *et al.* (2001) reported lower adoption of herbicides. In Kutch, 26% farmers and 16% in Chittoor applied gypsum and almost an equal number of farmers adopted suitable micronutrient management practices by spraying commercially available micronutrient mixtures (Groth, Mahaphal and Mazik). These results were not in conformity with the findings of Ingle *et al.* (1995), where they had reported that gypsum and micronutrients were not adopted by farmers due to their non-availability.

Adoption of plant protection practices: Though many of the farmers believed that the insect pests and diseases were not a major problem for summer groundnut, yet they resorted to spray of insecticides and fungicides. Farmers (36% in Kutch and 32% in Chittoor) adopted appropriate spraying of insecticides. These results were not in agreement with that of Nagaraj *et al.*, (2001) where they had reported higher adoption of intercultivation practices compared to plant protection practices.

Table 1 Practise-wise of adoption of improved practices by groundnut farmers

Improved practice	Adoption	
	Kutch (n = 70)	Chittoor (n = 50)
Optimum tillage	65 (92.9)*	48 (96.0)
Suitable variety	67 (95.7)	20 (40.0)
Source of seed	-	-
I. Own	18 (25.7)	5 (10.0)
ii. Formal sources	15 (21.4)	15 (30.0)
iii. Informal sources	37 (52.9)	30 (60.0)
Optimum seed rate	20 (28.6)	15 (30.0)
Seed treatment: Fungicides	70 (100)	45 (90.0)
Seed treatment: Bio-fertilizers	13 (18.6)	06 (12.0)
Timely sowing	60 (85.7)	40 (80.0)
Depth of sowing		
I. Behind the plough in furrow	45 (64.3)	50 (100.0)
ii. Tractor drawn seed drill (Optimum)	25 (35.7)	3 (06.0)
Optimum spacing	30 (42.7)	10 (20.0)
Application of organic manures	14 (22.7)	14 (28.0)
Soil test based fertilizer application	12 (17.1)	6 (12.0)
Fertilizer management	-	-
I. Optimum	12 (17.1)	10 (20.0)
ii. Lower	4 (05.7)	15 (30.0)
iii. Higher	54 (77.1)	25 (50.0)
Weed management (chemical)	20 (28.6)	07 (14.0)
Application of gypsum	18 (25.7)	8 (16.0)
Micro nutrient management	18 (25.7)	7 (14.0)
Management of insect pests	-	-
I. Optimum	25 (35.7)	16 (32.0)
ii. Lower	12 (17.1)	14 (28.0)
iii. Higher	33 (47.1)	20 (40.0)
Management of diseases	-	-
I. Optimum	22 (31.4)	5 (10.0)
ii. Lower	8 (11.4)	16 (32.0)
iii. Higher	40 (57.1)	29 (58.0)
Timely harvesting	60 (85.7)	38 (76.0)
Optimum drying	68 (97.1)	48 (96.0)
Storage at optimum conditions	25 (35.7)	5 (10.0)

Table 2 Quantitative values of human and physical/natural assets between adopters and non-adopters

Asset	Mean			
	Pooled	Adopters (n=38)	Non-adopters (n=82)	Z value
Human asset				
Age	42.7	40.6	47.2	3.44**
Farmer education	7.3	7.5	6.8	0.87
Children education	16.8	24.8	13.1	6.64**
Household size	5.0	5.7	4.7	3.43**
Number of effective workers	2.2	2.5	2.0	2.31*
Dependency ratio	2.5	2.5	2.4	0.30
Natural asset				
Material possession	19.7	24.3	17.6	8.50**
Farm size	2.5	3.8	1.9	5.71**
Irrigated area	1.4	2.3	0.9	6.18**
Live stock	0.7	0.9	0.6	5.16**

*=significant at P=0.05; **=significant at P=0.01

Adoption of harvest and post-harvest practices: Many of the sampled farmers (86% in Kutch and 76% in Chittoor) harvested their crop at 'right maturity state'. The harvesting was done mostly by tractor in Kutch, whereas the same was done manually in Chittoor. Farmers (36%) generally followed sun-drying their produce in open fields. The threshing was done with the help of mechanical threshers in Kutch, whereas it was done manually in Chittoor. All the farmers practised collection of left over pods from the field after harvesting the crop and most farmers (68%) mixed these left over pods with main lot. Many of the farmers (85%) were not aware of aflatoxin contamination in groundnut and hence did not adopt any management practices. In Kutch, farmers (75%) stored the produce for 2-4 months in the form of pods until they could realize better market prices, whereas in Chittoor most of the farmers (73%) sold their produce immediately after harvest to traders/middlemen approaching their fields in order to repay the loans and for immediate family needs.

These results show that in both the districts, the extent of adoption was lower for practices such as use of bio-fertilizers, optimum seed rate, soil test based fertilization application, gypsum, micronutrient application and chemical weed management.

Impact of adoption of improved practices in creation of livelihood assets and outcomes: The results (Table 2) showed that there were significant differences between adopters and non-adopters in respect of livelihood assets such as *human assets*, *natural/physical* assets, financial and social assets. Adopters recorded higher mean scores than non-adopters for all the selected indicators. In case of human and physical assets, significant differences were observed in age ($Z = 3.44$, $P = <0.01$), children education ($Z = 6.64$, $P = <0.01$), household (hh) size ($Z = 3.43$, $P = <0.01$), effective workers in the family ($Z = 2.31$, $P = <0.01$), material possession ($Z = 8.50$, $P = <0.01$), farm size ($Z = 5.71$, $P = <0.01$), irrigated area ($Z = 6.18$, $P = <0.01$), and ownership of live stock ($Z = 5.16$, $P = <0.01$). However, there were no differences in the farmers' education and dependency ratio. Significant differences were observed in income from live stock ($Z = 6.34$, $P = <0.01$), which indicated that the live stock was an important component of income of the household and particularly to the adopters households and credit availed ($Z = 5.12$, $P = <0.01$, Table 3). Significant differences were also observed between adopters and non-adopters in respect of formal institutional contacts for inputs ($Z = 5.10$, $P = <0.01$) and advisory ($Z = 9.94$, $P = <0.01$) and livelihood outcomes pod yield ($Z = 21.09$, $P = <0.01$) and haulm yield ($Z = 18.24$, $P = <0.01$, Table 4). The differences in human assets *viz*., age, house hold size, number of effective workers, farm size, irrigated area and ownership of livestock indicate that the adoption of improved technologies was influenced by these factors. The mean adoption scores were 14.4 and 6.1 for adopters and non-adopters, respectively ($Z = 14.83$, $P = <0.01$, Table 3). Gowda *et al.* (2002) reported significant relationship between adoption and education, social participation, mass media use, economic motivation of big farmers and between adoption and mass media use, extension participation of small farmers.

Adoption of improved practices resulted in higher pod yield (3185 kg/ha) and income (₹ 1, 88, 078/hh) as recorded for adopters compared to pod yield (2112 kg/ha) and income (₹ 60,041/hh) recorded for non-adopters (Table 4). Adisarwanto and Muchlish (1998) reported that adoption of groundnut production technology was significantly influenced by profits and farmers' ability to purchase inputs. The increased income resulted in higher allocation for children education, which was evident from high mean score of 24.8 as compared to non-adopters (mean score=13.1). The material possession also increased in adopter households (24.3) as compared to non-adopters households (17.6).

Farmers' attributes influencing the variation in pod yield: The inter-correlation analysis among the variables (Table 5) indicated the existence of Multicollinearity between farm size and irrigated area, total income and agricultural income, livestock income, pod yield and haulm yield. Hence, only farm size and total incomes were included in fitting the multiple linear regression equation. Furthermore, based on correlation between pod yield and other variables, age and dependency ratio were also not considered, as correlation was non-significant. The step-down regression analysis indicated that various attributes such as house hold size, material possession, total income, institutional contact for advice and adoption of improved technologies significantly influenced the pod yield. The adjusted R^2 was 0.929 (Table 6) indicating that these variables accounted for almost 93% variation in pod yield. Adoption of improved technologies emerged an important variable influencing the yield of groundnut.

In Kutch, farmers adopted most of the critical practices for summer groundnut cultivation. Low adoption was observed for seed treatment with bio-fertilizers, use of optimum seed rate, soil test based fertilizer application, application of gypsum, micronutrients and chemical weed management in both the districts. It is very important to create awareness among farmers on these technologies by use of appropriate extension strategies and need based training programmes. The significant differences in livelihood assets and outcomes of the adopters indicated that improved technologies could definitely improve the livelihood of groundnut farmers. The contact of farmers with formal institutions *viz*., KVKs, agriculture departments, non-government organizations have to be increased for improving the adoption of improved technologies and thereby increasing the yield of groundnut.

Table 3 Quantitative values of financial and social assets between adopters and non-adopters

Asset	Mean			
	Pooled	Adopters (n=38)	Non-adopters (n=82)	Z value
Financial assets (₹/house hold)				
Income from agriculture	1,00,586	1,88,078	60,041	9.02**
Income from livestock	8,818	13,650	6,579	6.34**
Other income	4017	12,830	976	2.89**
Total income	1,13,421	1,19,246	43,708	8.80**
Credit availed	5,758	13,737	2,061	5.12**
Social assets				
Membership in organization	0.5	0.9	0.2	13.80**
Extension participation	0.5	0.9	0.3	7.99**
Adoption score	8.2	14.4	6.1	14.83**

*=Significant at P=0.01

Table 4 Quantitative values of formal institutional contacts and livelihood outcomes between adopters and non-adopters

Variable	Mean			Z value
	Pooled	Adopters (n=38)	Non-adopters (n=82)	
Institutional contact				
a. Inputs	0.6	0.8	0.4	5.10**
b. Advisory	0.5	0.9	0.3	9.94**
Livelihood outcome				
Pod yield (kg/ha)	2452	3185	2112	21.09**
Haulm yield (kg/ha)	3490	3975	3265	18.24**

**=significant at P=0.01

Table 5 Inter-correlation analysis among the variables

Variable	Age	Farmers' education	Children's education	House-hold size	Effective workers	Depen-dency ratio	*Material posse-ssion*	Farm size	Irrigated area	Live-stock	Agricul-tural income	*Income from livestock*	Other income	Total income	Credit availed	Organization membership	Extension partici-pation	Govt. sources for inputs	Govt. sources for advisory	Pod yield	Haulm yield
Farmers' education	-0.62	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Children's education	0.55	-0.28	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Household size	0.55	-0.33	0.67	1.00	-	-	-	-	-	-	-	-		-	-		-	-	-	-	-
Effective workers	0.51	-0.30	0.50	0.67	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dependency ratio	-0.11	0.17	-0.02	0.04	-0.55	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Material possession	0.37	-0.03	0.69	0.50	0.33	0.08	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Farm size	0.38	-0.19	0.47	0.41	0.30	0.00	0.58	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Irrigated area	0.31	-0.19	0.44	0.34	0.16	0.13	0.55	0.73	1.00	-	-	-	-	-	-	-	-	-	-	-	-
Livestock	0.44	-0.15	0.35	0.40	0.39	-0.14	0.36	0.46	0.34	1.00		-	-	-	-	-	-	-	-	-	-
Agricultural income	0.30	-0.08	0.54	0.35	0.28	-0.08	0.57	0.35	0.21	0.36	1.00	-	-	-	-	-	-	-	-	-	-
Income from livestock	0.49	-0.22	0.48	0.49	0.43	-0.08	0.51	0.65	0.53	0.71	0.48	1.00	-	-	-	-	-	-	-	-	-
Other income	0.22	-0.10	0.37	0.15	0.10	-0.01	0.36	0.41	0.41	0.16	0.31	0.38	1.00	-	-	-	-	-	-	-	-
Total income	0.38	-0.20	0.60	0.41	0.24	0.06	0.69	0.79	0.90	0.42	0.54	0.67	0.61	1.00	-	-	-	-	-	-	-
Credit availed	0.38	-0.23	0.45	0.32	0.13	0.16	0.52	0.66	0.72	0.36	0.20	0.57	0.46	0.72	1.00	-	-	-	-	-	
Organization membership	0.25	-0.10	0.46	0.25	0.11	0.11	0.59	0.39	0.48	0.25	0.62	0.39	0.23	0.61	0.36	1.00	-	-	-	-	
Extension participation	0.07	-0.02	0.33	0.18	0.12	0.02	0.44	0.30	0.40	0.22	0.32	0.34	0.14	0.46	0.35	0.50	1.00	-	-	-	
Govt. sources for inputs	0.04	0.01	0.31	0.26	0.27	-0.11	0.42	0.36	0.42	0.26	0.39	0.40	0.17	0.50	0.27	0.43	0.42	1.00	-	-	
Govt. sources for advisory	0.11	-0.05	0.40	0.30	0.19	0.04	0.49	0.25	0.37	0.24	0.40	0.34	0.20	0.48	0.33	0.57	0.77	0.38	1.00	-	
Pod yield	0.28	-0.04	0.54	0.33	0.23	0.04	0.69	0.61	0.69	0.36	0.59	0.51	0.34	0.80	0.57	0.66	0.52	0.51	0.54	1.00	
Haulm yield	0.27	-0.02	0.53	0.37	0.30	0.01	0.64	0.55	0.62	0.36	0.61	0.49	0.32	0.75	0.48	0.60	0.49	0.48	0.53	0.94	
Adoption	0.29	-0.08	0.49	0.33	0.27	-0.03	0.62	0.64	0.66	0.38	0.52	0.50	0.27	0.74	0.56	0.60	0.49	0.50	0.47	0.95	

Table 6 Step-down regression analysis of independent variables with pod yield

Variable	*b*-value	SE of *b*	*t*-value
(Constant)	1602.264	62.242	25.743**
Household size	-20.283	9.126	-2.280*
Material possession	10.397	3.845	2.704**
Total income	0.001	0.001	3.890**
Institutional contact for advisory	81.293	28.309	2.872**
Adoption	80.813	40.32	20.045**

Adjusted R^2 = 0.929; F = 313.201**; SE of estimate = 130.25; * indicates significance at $P < 0.05$; ** indicates significance at $P < 0.01$

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Productivity potentials and profitability of sunflower (*Helianthus annuus* L.) hybrid DRSH-1 under real farm situations in Andhra Pradesh

R VENKATTAKUMAR*, M PADMAIAH**, S N SUDHAKARA BABU**, S CHANDER RAO**, H BASAPPA** AND A J PRABAKARAN**

*National Academy of Agricultural Research Management, Rajendranagar, Hyderabad, Andhra Pradesh

(Received: April, 2011; Revised: December, 2011; Accepted: December, 2011)

ABSTRACT

A sunflower (*Helianthus annuus* L.) hybrid *viz.*, DRSH-1 was released to grow all over the country by Directorate of Oilseeds Research (DOR), Hyderabad. The productivity potentials and profitability of this cultivar have been demonstrated under real farm conditions by DOR in Mahabubnagar, Nalgonda and Ranga Reddy districts of Andhra Pradesh through frontline demonstrations (FLDs). The seed yield increase of sunflower hybrid DRSH-1 was ranging from 9 to 19% under rainfed and irrigated, respectively with corresponding additional returns of ₹2786 and ₹994/ha. The study concludes that the performance of this cultivar under winter-irrigated conditions is better than that of winter-rainfed situations and hence, can be very well promoted for winter-irrigated situations in Andhra Pradesh.

Keywords: Andhra Pradesh, DRSH-1, Impact, Sunflower

Sunflower (*Helianthus annuus* L.) made significant inroads into Indian vegetable oil economy since its introduction in the late sixties. In India, it is grown in an area of 18.1 lakh ha with a production of 11.6 lakh t and a productivity of 639 kg/ha (Venkattakumar and Hegde, 2010). It can be grown during any part of the year and comes up well with timely and proper management of inputs. Sunflower seed contains 38 to 40% oil. The oil is odourless with light colour and has been considered as premium due to the high level of unsaturated fatty acids and lack of linolenic acid. The cake as a feed fits well to the bovines, swine and poultry keeping. Sunflower also finds place in the industrial sector and is used in paints, varnishes and plastics. Though, sunflower is traditionally cultivated in Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu, it has gained momentum in Punjab, Haryana, Uttar Pradesh, Uttarakhand, Bihar, West Bengal and Odisha too. In Andhra Pradesh, it has been an important oilseed crop next only to groundnut, cultivated in an area of 4.2 lakh ha with 3.3 lakh t. production and 778 kg/ha productivity. The performance of winter sunflower in Andhra Pradesh is better than rainy season one with 3.3 lakh area, 2.7 lakh t. production and 815 kg/ha productivity (Damodaram and Hegde, 2010).

The gains of impressive strides made in the production front in sunflower could not be sustained and hence there is stagnation in the production front. Although, there are several reasons contributing to the above, its cultivation has been restricted to marginal and sub-marginal lands with poor management practices, monocropping year after year, poor supplementary and complementary nutrient-related issues, lack of quality, biotic stresses, etc., are the most important ones. The researchers involved in the All India Coordinated Research Project (AICRP) (Sunflower) have addressed several of the above issues for harnessing the productivity which are easily replicable under farmers' field conditions. Several newer interventions and technologies have been emerging under the umbrella of the AICRP network suitable to specific agro-ecological situations as an answer to the problems faced in the sunflower production system. DRSH-1 is such a hybrid released by Directorate of Oilseeds Research (DOR), Hyderabad for all the sunflower growing regions of the country. The productivity potentials and performance of this cultivar under real farm situations has been analyzed in this paper.

MATERIALS AND METHODS

The DOR, Hyderabad has castor, sunflower and safflower as its mandate crops, on which the research and development activities of the Directorate are being formulated and implemented. The Directorate has three AICRPs on the mandate crops, through which agro-ecological region-specific research programmes are being coordinated. Need-based and location specific technologies are being developed by DOR and AICRPs for adoption by the farmers. In the way, the Directorate released a sunflower hybrid namely DRSH-1 for cultivation by sunflower growers all over the country. The salient features of the cultivar are as follows:

*(E-mail: venkat@naarm.ernet.in)

**Directorate of Oilseeds Research, Rajendranagar, Hyderabad-30, AP

Salient features of DRSH-1	
Year of release	2006
Yield (kg/ha)	1300-1600 (Average-1450)
Days to maturity	92-98
Oil (%)	42-44
Areas of adaptability	All India
Highlight feature	High oil content

The productivity potentials and profitability of this cultivar have been demonstrated under real farm conditions by DOR and AICRP centres at varied agro-ecological situations including that of Mahabubnagar, Nalgonda and Ranga Reddy districts in Andhra Pradesh through frontline demonstrations (FLDs). A total of 40 component technology demonstrations were organized at each one acre plots during winter seasons of 2008 and 2009 under irrigated as well as rainfed situations, out of which 5 were vitiated due to various biological and environmental factors (Table 1). The cultivars being practiced by the farmers at adjacent plots were considered as farmers' practices for control.

Interested sunflower growers were selected in consultation with the "Adarsha Rythu" of the villages as well as the concerned agricultural officers. The selected farmers were imparted pre-demonstration training through off-campus mode to impart knowledge about improved sunflower production technologies while using DRSH-1. The demonstrations were regularly supervised by a team of scientists (agronomist, entomologist, pathologist, seed specialist and social scientist). At the peak growing period, field day was organized (during 2009-10) to popularize the performance of the cultivar under real farm situations and to get the feedback from the demonstrating farmers about the cultivar. The productivity potentials and profitability of the cultivar was assessed through yield (kg/ha) and additional net returns (₹/ha).

RESULTS AND DISCUSSION

The seed yield increase of DRSH-1 over the farmers' practice under real farm situations was ranging from 15% during 2008-09 to 22% during 2009-10 under irrigated conditions (Table 2). The corresponding additional net returns accrued was ₹ 2091 and ₹ 3480/ha. The mean seed yield increase under irrigated situation was 19% with ₹ 2786/ha additional net returns. The B:C ratio was 2.3 and 2.1 with IT and FP plots, respectively. The seed yield increase of DRSH-1 over the farmers' practices was 9% under rainfed situations (Table 2). The additional net returns accrued was ₹ 994/ha. The B:C ratio was 1.5 and 1.4 with IT and FP plots respectively. The above results conclude that the performance of this cultivar under winter-irrigated conditions is better than that of winter-rainfed situations.

Exploitable yield reservoir in sunflower due to DRSH-1 in Andhra Pradesh under winter season-irrigated situations: The potential yield of the cultivar DRSH-1 has been ranging from 1300-1600 kg/ha with the average of 1450 kg/ha. It was found that the demonstration yield gap between the potential and demonstration yield was 78% (637 kg/ha) (Table 3), whereas the extension yield gap between demonstration yield and farmers' practice was (15%) (106 kg/ha). It was found that by bridging the demonstration and extension yield gaps, the sunflower production in Andhra Pradesh could have been 3.8 and 3.3 lakh t. for 2008-09, instead of actual 2.8 lakh t. for winter conditions. This exploitable yield reservoir provides scope for improving the productivity of sunflower in Andhra Pradesh by adopting recommended sunflower production technology with DRSH-1 cultivar under winter-irrigated situations.

The seed yield increase of sunflower hybrid DRSH-1 was ranging from 9 to 19% under rainfed and irrigated, respectively with corresponding additional returns of ₹ 2786 and ₹ 994/ha. The study concludes that the performance of this cultivar under winter-irrigated conditions is better than that of winter-rainfed situations and hence, can be very well promoted for winter-irrigated situations in Andhra Pradesh. The demonstration as well as the extension yield gaps of the cultivar provide the scope for improving the sunflower productivity in Andhra Pradesh under winter situations. Popularization of this cultivar for cultivation under sunflower-growing regions of Andhra Pradesh for winter situations under irrigation may bring increase in sunflower production and productivity of the state.

Table 1 Details of frontline demonstrations organized

Year	Season	Situation	Location	Type of soil	No. of FLDs organized		
					Successful	Vitiated	Total
2008-09	Winter/ summer	Rainfed	Kuruvaguda, Shabad mandal, Ranga Reddy	Vertisol	7	4	11
	Winter/ summer	Irrigated	Rayalapuram, Ramayanpet mandal, Nalgonda	Alfisol	9	-	9
2009-10	Winter/ summer	Irrigated	Shankatonupally, Amangal mandal, Mahabubnagar	Alfisol	19	1	20
Total					35	5	40

Table 2 Productivity potentials and profitability of DRSH-1 under real farm situations

Year	No. of demonst-rations	Mean seed yield (kg/ha)		% yield increase	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Additional net returns (₹/ha)	B:C ratio	
		IT	FP		IT	FP	IT	FP		IT	FP
Winter-irrigated											
2008-09	9	967	839	15	10098	9558	19217	16586	2091	1.9	1.7
2009-10	19	1139	936	22	8937	8057	24489	20129	3480	2.7	2.5
Mean	28	1053	888	19	9518	8808	21853	18358	2786	2.3	2.1
Winter-rainfed											
2008-09	7	573	525	9	8608	7950	12415	10763	994	1.5	1.4

IT=Improved technology (DRSH-1); FP=Farmers' practice

Table 3 Exploitable yield reservoir of sunflower with DRSH-1 in Andhra Pradesh under winter irrigated situation

Potential yield of the cultivar (kg/ha)	FLD average yield (IT) (kg/ha)	Average FP yield (kg/ha)	Yield gap-I (%)	Yield gap-II (%)	State average production ('000 tonnes) (2008-09)	Expected production ('000 t.)	
						EP-I	EP-II
1450	1053	888	38	19	277	382	330

IT=Improved technology; FP=Farmers' practices; Yield gap-I=Increase in potential yield over IT expressed in %; Yield gap-II=Increase in IT over FP expressed in %; EP-I=Expected production, if yield gap –I is bridged through complete adoption of improved practices; EP-II=Expected production, if yield gap-II is bridged through complete adoption of improved practices

Acknowledgements: The authors thank the Project Director for providing facilities to organize FLDs and fields days to demonstrate the sunflower cultivar DRSH-1.

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Castor hybrid seed production and marketing strategy in Andhra Pradesh

M PADMAIAH AND C LAVANYA

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

(Received: August, 2011; Revised: November, 2011; Accepted: December, 2011)

ABSTRACT

In Andhra Pradesh (AP), castor (*Ricinus communis* L.) is predominantly cultivated in Mahabubnagar, Nalgonda and Ranga Reddy districts. The productivity in AP is quite low, as its cultivation is confined to rainfed condition with low input management besides use of poor quality of seeds are some of the reasons for low yield. In the absence of pure seed, the investment on the other inputs becomes futile exercise. Keeping this in view, the castor hybrid seeds (DCH-177 and GCH-4) production through farmers' participatory approach at village level in a limited scale was initiated by Directorate of Oilseeds Research, Hyderabad in association with NGOs for timely supply of quality hybrid castor seeds at the doorstep of castor growers. Based on the experience in participatory castor seed production across the years, the methodology of castor hybrid seed production through participatory approach, economics of seed production and the various issues that contribute for success and the strategies for sustenance of seed production in castor were suggested.

Keywords: Marketing strategies and economics, Participatory castor seed production

Castor (*Ricinus communis* L.) is one of the non-edible oilseed crops grown especially in arid and semi-arid regions for its wide applications and industrial uses. India is the prime country in production and export of castor beans and oil. It produces 11.7 lakh t. of seeds from 8.7 lakh ha (Damodaram and Hegde, 2010).The crop is mainly confined to Gujarat, Andhra Pradesh and Rajasthan. It is also grown in Karnataka, Tamil Nadu, Odisha, Maharashtra, Madhya Pradesh and Haryana on a limited extent. In Andhra Pradesh (AP), it is predominantly grown in Mahabubnagar, Nalgonda and Ranga Reddy districts. Of late, it is extended to other districts *viz.*, Prakasam, Kurnool, Ananthapur, Warangal, Karimnagar, Medak and Guntur. However, the productivity in AP is only 509 kg/ha as against national average of 1152 kg/ha (Damodaram and Hegde, 2010). The reasons for less yield levels could be, grown under rainfed conditions, poor input management besides use of impure seeds and poor socioeconomic conditions of the growers. Therefore, in the absence of pure seeds, the use of other inputs becomes unproductive. This is due to a conspicuous absence of quality seed production technologies and timely delivery of quality seeds to the growers. Keeping this situation in view, the castor hybrid seeds *viz.*, DCH-177 and GCH-4 production through farmers participatory approach on a limited scale in non-traditional area was initiated with an objective of production of quality hybrid seeds and timely supply at the door step of castor growers at cheaper rate in traditional area (Padmaiah *et al.*, 2008)

MATERIALS AND METHODS

Unlike other crops, the hybrid seed production in castor involves risk and it needs continuous monitoring of the crop growth at every stage for maintaining the purity and quality. For this, a team of scientists to work in conjunction with the voluntary agencies like watershed support services and activities network (WASSAN). The NGO has been working with mandal mahaila samakyas (MMSs) and self-help groups (SHGs) and micro finance groups of Mahabubnagar district in AP. Further, the following steps were also taken to achieve the objective:

I) Formation of technical team

Seed production involves a team of experts, for this, a core team consisting scientists from each discipline *viz.*, agricultural extension, plant breeding, pathology and entomology was constituted. The team along with the staff of NGO had formulated a conceptual seed production strategy on various aspects *viz.*, social input, skills development, technical input and seed delivery involving procurement and supply of seed to the end users. The entire programme was bestowed on the NGOs and scientific team for guiding the seed growers from time to time in producing quality seeds.

ii) Location of seed production

Mahabubnagar is one of the major castor growing districts of AP and has two situations such as traditional and non-traditional castor growing areas. For the seed production, the non-traditional villages namely Challapur of Kosgi and Chennaram of Masaipalli of Daulathabad mandal of Mahabubnagar were selected especially for the reasons that they have good isolation distance and NGO has been operating for encouragement of the farmers.

iii) Selection of seed growers

The four seed growers have been selected by the MMS and SHG after thorough discussions regarding the terms and conditions like interest on seed production, irrigation facility, timely roughing, fertilizer application and other plant protection measures and price for produce.

iv) Source of parent material

Directorate of Oilseeds Research (DOR), Hyderabad, Regional Agricultural Research Station (RARS-Acharya N.G. Ranga Agricultural University)-Palem and private seed agency supplied the parent materials on payment basis to SHGs and the same seed was supplied to the seed growers with an understanding that the seed cost could be paid back at the time of seed purchase.

v) Social input of growers and staff of NGOs

The success of any programme may rest on the participation of local people and the hybrid seed production programme is also in no way different with that of any programme related to rural development. The seed producers joined together and came forward voluntarily, which facilitated in sensitizing as well as motivating them to become micro level entrepreneurs. The staff of NGO played crucial role during all the phases of seed production activities, which included delivery of seeds, in monitoring and guiding the growers to involve completely in the seed production activities from time to time especially during roughing, fertilizer application, plant protection measurers, harvesting, threshing, procurement of seeds and delivery seeds to traditional areas, etc. Without the NGO the hybrid seed production in castor could not have reaped fruits of success.

vi) Imparting skills in hybrid seed production to the growers and NGO staff

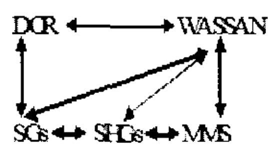
Unlike other crops castor needs special attention in hybrid seed production and this necessitates necessary skill development. The hybrid seed production activity being new to the growers (non-traditional areas), more emphasis was given to imparting skills for both women and men growers besides staff of NGO. Before onset of monsoon, a special training regarding preparatory cultivation, control of red hairy caterpillar, isolation distance, seed treatment, seeding technique, fertilizer application was arranged at the DOR. After sowing during the 2nd week of November, one more on farming training was given, with emphasis on identification of off-type plants, roughing of castor plants (of self sown seed plants, if any) around 500 m distance from seed plots, road side, FYM pits and stray plants in other crops and control of insect pests like semilooper, *Spodoptera*, sucking pests was organized at each field in the selected villages. During the spike emergence time, farmers and staff of NGOs were consulted regularly over cell phones. By and large, the skills were imparted almost at each stage of crop growth, because, all the growers and staff of NGOs were ignorant about the technique related to castor hybrid seed production. These trainings have helped in better understanding of quality hybrid castor seed production and this enabled the staff in monitoring the seed production plots, even without the presence of technical team. Modern modes of information technology used by the staff of NGOs enabled them to contact the of scientists to get clarification for the doubts and problems they came across under field conditions.

vii) Field day at the site

In order to bring about awareness among the castor growers, a field day at the field site of in Chellapur village of Kosgi Mandal was conducted. Farmers from the traditional areas and interested farmers of surrounding villages had participated and there was an interface between farmers and scientists by which all the castor growers got benefitted and the researchers got field level feedback.

Strategy for seed production and marketing

a) Seed production



b) Seed supply mode

SHGs <--> MMS (non-traditional area) <-> MMSs (traditional area) <-> SHGs-End users

viii) Seed supply mode

The seeds were procured by the SHGs from the producers by paying entire amount at a time (as per the rate of public sector agency like NSC). The seed cleaning, grading and bagging was done at SHGs level. The processed seed was shifted to the godown of MMS at mandal level. Based on demand from MMSs of traditionally castor growing mandals like Addakal and Pangal, the seeds were sent and later the seed sold to the farmers though SHGs.

ix) Benefit sharing

The MMSs of Kosgi and Daulathabad gave the advance amount to the SHGs of seed villages and the SHGs procured the raw seeds from growers by paying full amount (₹50/kg). The raw seed was cleaned, graded and made in to 2 kg bags. Later the bags were shifted to godown of MMS of above mandals. Based on the demand of seed, MMSs of traditional castor growing mandals purchased the seeds @ ₹ 140/2 kg bag. The benefit gained here was ₹40/bag, of which ₹16 has been spent towards cleaning and bagging and rest of it put in the account of MMS, later distributed the 75% benefit to the members of SHGs and rest of 25% to members of MMSs. Later the MMSs of traditional mandals sold out the seed bags @ ₹180/ bag to the end users (farmers) through non-pesticide management shops of SHGs. Here the benefit margin was ₹40/bag. Out of which, ₹16/bag spent on transportation, loading and unloading and other miscellaneous charges, The MMSs and the SHGs members shared rest of amount in 25:75 basis.

RESULTS AND DISCUSSIONS

The economics of seed production of was worked out based on the data collected regularly at various stages and worked out the cost of cultivation, gross returns includes male seeds sold in open the market, net returns and benefit cost ratio (BCR).The results in table 1 indicate that the net returns accrued due to seed production was ₹13779/ha in GCH-4, while it was ₹19868/ha in case of DCH-177. The BCR was 2.6 in GCH-4 and 3.4 in DCH-177.The over all net returns generated out of seed production in farmers field was ₹17838/ha with BCR of 3.1. It shows that the approach followed was a win-win situation in which both the producers and end users could reap benefits.

Issues and lessons learnt from participatory seed production are i) strengthening of self help and MMS groups, ii) continuous monitoring of crop, iii) one person, exclusively needed for coordinating the activities, iv) selection of farmers in clusters saves time and quality, v) announcing procurement price well in advance, vi) timely processing and bagging of seed for timely supply to end users, vii) conducting pick-wise grow-out test (GOT) or molecular test to see the purity, viii) capacity building to the growers and staff of NGO both at off and on-campus, ix) timely payment to the producers, x) timely sowing of parent materials, xii) timely fertilizer application and plant protection measures, xiii) timely irrigation, xiv) working out the economics of seed production by keeping regular track of expenditure incurred by the farmers, xv) strengthening the market strategy of seed for surplus seed, xvi) involvement of financial institutes especially nationalized banks for credit facility, xvii) demonstration of farmer produced seed *vis-à-vis* private or public sector agency produced seed, in order to create faith among the commercial cultivators on farmers produced seed, xviii) involvement of oil- millers for procurement of commercial seed.

Acknowledgement: The authors are grateful to the Project Director, DOR for his constant encouragement and guidance. Thanks are also due to Smt Bhagyalaxmi, Smt. Jaya and other field staff of WASSAN, for their support during seed production at various villages.

Table 1 Economics of participatory seed production in castor at village level

Year	Village	District	Hybrid	Area (ha)	Yield* (kg/ha)	CC (₹/ha)	GR (₹/ha)	NR (₹/ha)	B:C ratio
2006-07	Kosgi	MBNR	GCH-4	2.6	319 (F1) 346 (M)	8413	22192	13779	1:2.6
2007-08	Daulthabad	RR	DCH-177	0.8	438 (F1) 375 (M)	8550	33780	25230	1:3.9
	Kosgi	MBNR	DCH-177	1.2	250 (F1) 300 (M)	8345	22850	14505	1:2.7
	Mean		DCH-177	2.0	344 (F1) 338 (M)	8448	28315	19868	1.3.4
	Over all	Mean	(6.6)		336 (F1) 340 (M)	8436	26274	17838	1:3.1

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Scientific formula for fixing the price of oil palm (*Elaeis guineensis* Jacq.) fresh fruit bunches

P KALIDAS, C V SAIRAM AND K J PRABHAKAR RAO*

Directorate of Oil Palm Research, Pedavegi-534 450, Andhra Pradesh

(Received: August, 2011; Revised: November, 2011; Accepted: December, 2011)

ABSTRACT

Oil palm (*Elaeis guineensis* Jacq.) has been introduced crop to India to bridge the gap between demand and supply of vegetable oil requirements of the country. Fixation of price for fresh fruit bunches (FFB) on scientific formula basis is a ticklish issue causing unrest between processors and farmers. Deriving the formula based on oil extraction ratio (OER) is unrealistic as the climatic conditions of the crop growing areas vary drastically and hence have impact on the OER. Similarly the FFB that is arrived to the processing units are a mixture of both young and old plantations which again show variation in the OER. A new approach has been derived using the cost economics of the cultivation and processing to fix the price for FFBs of Oil palm. The formula was derived by taking all aspects into consideration like cost of cultivation and processing of oil palm FFB, price of crude palm oil, kernel oil and palm kernel cake, benefit cost ratio and internal rate of returns and finally net present worth. The formula being followed in Malaysia, the processors remarks on low OER during peak periods and under utilization of mill and the farmers demands of share in the other products like kernels, cake and other online products were reviewed in depth while deriving the present one.

Key words: Fresh fruit bunches, Oil palm, Price fixation

Oil palm (*Elaeis guineensis* Jacq.) is the highest vegetable oil yielding crop with an average productivity of 4-6 t. of crude palm oil/ha per year. With its large scale introduction in the irrigated tracts of the country, the crop successfully established in the states like Andhra Pradesh, Karnataka and Tamil Nadu during the last 20 years.

In India, Andhra Pradesh state stands first in both area, production and productivity of the crop followed by Karnataka. With the expansion of the cultivated area, the processing companies have also been set up for the crushing of the fresh fruit bunches (FFBs) to extract crude palm oil and thereby the other online products like palm kernels, kernel cake, empty fruit bunches, sludge, etc. So far the payment to the produce is paid based on the crude methods as no scientific formula is evolved on the lines that is being followed in Malaysia.

Presently the FFB price is fixed based on the selling price of crude palm oil by APOILFED which is a state government agency. However this does not include the other online and by products that are extracted along with CPO. This lead to demand for scientific formula from farmers on the lines of Malaysia. However in India the oil palm industry is very young with the existence of more young plantation that lead to low oil extraction rate (OER) and variation in the climatic conditions in different oil palm growing areas leading to fluctuation in OER in the FFBs. Under these circumstances bringing out of scientific formula on the basis of OER is very difficult at this juncture. Hence, the present study was taken up to bring out the scientific formula using economics of oil palm cultivation as well as processing.

MATERIALS AND METHODS

Information on cost of cultivation of oil palm in different areas from various farmers of both small and large holdings was collected and compared with the cost details submitted by National Bank for Agriculture and Rural Development (NABARD) during 1993 and the per cent increase in the cost of various aspects that are involved in cost of cultivation since then. Based on this, it is observed an increase of 35% in the labour wages (at the rate of 5% per year as obtained from the Revenue department of Govt. of Andhra Pradesh), an escalation of 32, 23 and 16%, respectively in NPK fertilizers and an increase of 35-40% price in plant protection chemicals. By taking all these into consideration, the cost of cultivation of oil palm was calculated (Annexure 4) (Kochu Babu and Prabhakar Rao, 2005). A total of 100 farmers were interviewed for this purpose to get the feed back.

Similarly, the average yields of oil palm was taken at the barest minimum as reported by Udaya Kumar (1998) though the present yielding pattern is much higher in majority of the gardens. The price of FFB that is being paid to the farmers (selling price-weighted average) was taken from the Govt. of Andhra Pradesh. The costs (latest) of palm kernel oil (PKO) and palm kernel cake (PKC) were obtained from different processing units located in Andhra Pradesh. The per cent

*Divisional Officer, APOILFED, Eluru-534 002, AP

recovery of crude palm oil was taken as 18%. The optimum mill capacity for sustainable processing has been taken as 3 mt/hr as reported by Sanjay Goenka (2006). The capacity utilization of the mill was taken as 8 hrs/day and 180 days/year which is again the barest minimum capacity of crushing. Information on cost of processing was collected from government run processing companies and the average of the same has been considered for calculation. The total economic life of both crop and processing units was taken as 25 years. In order to assess the economic viability of oil palm cultivation based on current prices, cash flow analysis was preformed using 12% as the rate of interest (opportunity cost).

While calculating the cash flow analysis of cost of cultivation, weightage to fixed costs for the farmers has been given for the first 3 years of juvenile period based on annuity approach considering 12% as the opportunity cost and calculated using the formula=Px1/(1+R)N (Table 5):

Where:

- P is the sum of cost of cultivation during the pre bearing phase (first three years).
- An amount of ₹ 3630 (excluding land value) as fixed cost per ha has been added to the total variable cost.
- R is the opportunity cost i.e. rate of interest (12%)
- N is the total economic life of the crop (25 years)

In the processing of FFB, the online / by products like PKO and PKC only have been taken for calculation. The per cent recovery of these has been taken as 2% and 3%, respectively per tonne of FFB based on information collected from different processing units. The realized values were calculated based on the existing prices of PKO and PKC. The payback period was estimated to be five years.

Cash flow analysis was carried out for both oil palm cultivation and processing. Three major investment parameters namely benefit cost ratio (BCR), net present worth (NPW) and internal rate of returns (IRR) were estimated.

While formulating the new formula, the methodology used in the previous occasions while fixing the rate since 1993 onwards was also reviewed which is as mentioned.

Initially during 1993, the price of FFB was fixed on adhoc basis as the crop was in its initial period of establishment to draw the OER based formula. In the year 1995, an OER based formula was proposed based on the lines of Malaysia but only for CPO. Since, the plantation was in its initial period and not reached to sustainability (9-18 years) it was amicably adjusted to pay 10/16 of the CPO price to the farmers (if 16% is the OER then 10% should be the farmers share). However, since the OER from the FFB started increasing beyond 16%, the formula was further adjusted as 10/16 x actual OER obtained x cost of CPO. For fixing the price based on the actual OER obtained by processing companies, the government used to collect the OER from different processing units and the average was taken into consideration. However to draw the formula on scientific lines, the present exercise has been done based on cost economics of oil palm cultivation as well as processing.

The net returns on 1 t. of FFB processing was calculated as ₹ 3300 (after the deduction of farmers share as well as cost of processing) while the net returns from one t. of production are ₹ 3599.

While working for the scientific formula the farmers' demands of consideration of gross CPO price and share in the other products like kernels, cake, EFB, sludge, etc. and processors remarks of low OER from the FFB during peak period and under utilization of mill capacity were also taken for review.

RESULTS AND DISCUSSION

The cash flow analysis of oil palm cost of cultivation and processing were calculated based on the June, 2008 rates and presented in table 1 and 2. The details on cost of processing are given in table 3. The realized values for PKO and PKC were estimated to be ₹ 1100 and 96, respectively for one mt of FFB and are taken into consideration for drawing the formula. Of this, 1/3rd of the amount was spared towards the cost of extraction and the remaining 2/3rd was shared equally between processors and farmers. While calculating the cash flow analysis for processing, a discount rate of 12% as opportunity cost was taken into consideration.

Annuity value based fixed cost for first three years: The annuity value based fixed cost during the non yielding period of oil palm cultivation was calculated by taking the cost of cultivation of the crop during the juvenile period of first three years as there is no income generation from the crop. For this purpose the net realization values, by deducting the subsidy component as well as income from intercrop, were considered. The opportunity cost which was mentioned as 12% indicates that the farmer would get at least 12% interest on the amount spent in some other venture if not in oil palm cultivation. This was continued till returns were started getting from oil palm from 4th year onwards. Similarly, the total economic life span of the crop was taken as 25 years and the same was used in the formula while calculating the annuity based fixed cost.

FFB yield/ha: The FFB yield output of oil palm was taken from the Udaya Kumar (1998) where in the pattern was mentioned as 1.5 t during 4th year, 5, 8, 11 and 15 during 5th to 8 years, respectively (Table 6). Later on stabilization in the yield output was observed from 9th to 18th year and gradually reduced thereafter to 16.5 t. during 9th and 15 t. during 20th to 25th years. These are the barest minimum yields that were recorded and visualized during 1998. Though the yield out puts are very high at present as compared to the reported one, the cash flow analysis was done using the data reported by Udaya Kumar(1998).

Costs: The details on costs involved in cultivation of oil palm from year 1 to 25 are given in the table 4. These are the average of 100 farmers' information. Of these the cost on first year was the highest as it included the establishment costs like land preparation, pit digging and seedling costs which are found only during the first year. The cost increased gradually from second year onwards till 8th year and then onwards it's stabilized in accordance with the yield stabilization.

Returns: Details on the returns that are given in the table 4 indicate that the palms pass thru the juvenile phase during the first three years and hence no returns are obtained. As the yields are started from the fourth year onwards the returns also are expected. As the yield out put of oil palm as given in the table 5 indicate the gradual increase from 4th to 8th year after planting and there on wards it stabilizes till 19th year. Accordingly, the returns were calculated based on the exiting market price of ₹ 6116/t of FFB.

Discount factor: The discount factor was calculated using the formula as given in "Discounted costs, returns and margins" and the calculations were done using the values and formulas as mentioned in table 1 and 2 . These were found essential to arrive the BCR, NPW and IRR which were essential to draw the formula on scientific lines.

BCR for oil palm cost of cultivation: Using the existing market rates for various items including costs and returns, the BCR for oil palm cultivation in Andhra Pradesh was calculated as 1.84. This infers that for every one rupee spending on cost of oil palm cultivation, the farmer is getting a profit of ₹ 0.84.

NPW and IRR: The NPW of the oil palm cultivation was found to be highly significant. Where as the IRR using the discounted margins with a guess of 25% was observed as 14% which again shows oil palm cultivation as highly economical.

Costs in processing: Details on cost of processing that are given in table 3 indicate that the cost includes both the processing cost as well as the payment made towards the purchase of FFB from farmers. As reported by Sanjay Goenka (2006) the optimum capacity of the mill for sustainable processing industry has been considered as 3 t. and run the same for one shift of 8 hrs in a day and 180 hrs in a year. Accordingly a total of 4320 t. can be processed. The processing cost of one ton of FFB as reported by APOILFED is ₹ 1090 which include the fixed costs as well as variable costs (Table 3). Similarly the price paid for FFB in way of purchasing from farmers is mentioned as ₹6116.

Returns in processing: The details on returns include the crude palm oil recovered from the total processing in a year @ 18%, PKO and PKC as online and by products of oil palm processing @ 2 and 3% respectively. The cost of CPO, PKO and PKC was calculated based on the existing market price. All the other aspects like discount factor, discounted costs, discounted returns and discounted margins were calculated as done in case of cash flow analysis of cultivation.

BCR for oil palm processing: The benefit cost ratio for oil palm processing in Andhra Pradesh was calculated as 1.39. This indicates that for every one rupee spent by the company in way of processing the FFB, it is getting a profit of ₹ 0.39. In the present case, the BCR of oil palm processing 1.39 seems to be very profitable and indicates more sustainability of the industry. Similarly, the net project worth of the processing also shows significant at the current price. The net project worth when calculated based on the existing price seems to be very high which indicates the worthiness of industry for sustainability.

It is also observed that the rate of change is uniform in both the cases i.e. cultivation and processing even if the CPO price increases or reduces.

Formula on scientific basis: From the above calculations, the below mentioned scientific formula using the BCR of oil palm cultivation and processing, is brought with an increase of 6.66% over the existing formula considering the increase in cost of cultivation, etc. which holds good for both the farmers and processors for their sustainability.

Price for 1 tonne of FFB =	SP CPO x 12% + (SP RV PKO + SP RV PKC) x 33%
SP CPO =	Selling Price of one tonne of crude palm oil of the montl or quarter obtained from any Govt. agency
SP RV PKO =	Selling price of one ton of realized values of the palm kernel oil
SP RV PKC =	Selling price of one tonne of realized values of palm kernel cake

Table 1 Cash flow analysis of oil palm cost of cultivation

Year	Cost (₹)	Returns (₹)	DF	Dis. cost (₹)	Dis. ret. (₹)	Dis. mar.
1	32860	0	0.89	29339	0	-29339
2	24672	0	0.80	19668	0	-19668
3	27150	0	0.71	19325	0	-19325
4	29560	9174	0.64	18786	5830	-12956
5	28080	30580	0.57	15933	17352	1419
6	28080	48928	0.51	14226	24788	10562
7	28080	67276	0.45	12702	30432	17730
8	29080	91740	0.40	11745	37052	25307
9	29080	110088	0.36	10487	39699	29212
10	29080	110088	0.32	9363	35445	26082
11	29080	110088	0.29	8360	31648	23288
12	29080	110088	0.26	7464	28257	20793
13	29080	110088	0.23	6664	25229	18565
14	29080	110088	0.20	5950	22526	16576
15	29080	110088	0.18	5313	20113	14800
16	29080	110088	0.16	4744	17958	13214
17	29080	110088	0.15	4235	16034	11798
18	29080	110088	0.13	3782	14316	10534
19	29080	100914	0.12	3376	11717	8340
20	29080	91740	0.10	3015	9510	6496
21	29080	85624	0.09	2692	7925	5234
22	29080	73392	0.08	2403	6065	3662
23	29080	67276	0.07	2146	4964	2818
24	29080	67276	0.07	1916	4432	2516
25	29080	67276	0.06	1711	3957	2247
Average	28876.88	76083.04		225344	415251	189907
		13.115504				
		2201.7362	BCR	1.842739		
			NPW	189907		
			IRR	14%		

DF= Discount factor = 1/(1+R)^n
DIS CST= Discounted cost
DIS RET= Discounted returns
DIS MAR= Discounted margin

R= Rate of interest (12%)
n=Corresponding year

Table 2 Cash flow analysis of oil palm processing

Year	Cost (₹)	Return (₹)	DF	Dis. cost (₹)	Dis. ret. (₹)	Dis. mar. (₹)
1	31458240	44026000	0.89	28087714	39308929	11221214
2	31458240	44026000	0.80	25078316	35097258	10018941
3	31458240	44026000	0.71	22391354	31336837	8945483
4	31458240	44026000	0.64	19992280	27979319	7987039
5	31458240	44026000	0.57	17850250	24981535	7131285
6	31458240	44026000	0.51	15937723	22304942	6367218
7	31458240	44026000	0.45	14230110	19915127	5685016
8	31458240	44026000	0.40	12705456	17781363	5075907
9	31458240	44026000	0.36	11344157	15876217	4532060
10	31458240	44026000	0.32	10128711	14175194	4046482
11	31458240	44026000	0.29	9043492	12656423	3612931
12	31458240	44026000	0.26	8074547	11300378	3225831
13	31458240	44026000	0.23	7209417	10089623	2880206
14	31458240	44026000	0.20	6436979	9008592	2571613
15	31458240	44026000	0.18	5747303	8043386	2296083
16	31458240	44026000	0.16	5131520	7181594	2050074
17	31458240	44026000	0.15	4581715	6412138	1830423
18	31458240	44026000	0.13	4090817	5725123	1634306
19	31458240	44026000	0.12	3652515	5111717	1459202
20	31458240	44026000	0.10	3261174	4564033	1302859
21	31458240	44026000	0.09	2911762	4075029	1163267
22	31458240	44026000	0.08	2599788	3638419	1038631
23	31458240	44026000	0.07	2321239	3248589	927349
24	31458240	44026000	0.07	2072535	2900525	827990
25	31458240	44026000	0.06	1850478	2589755	739277
				246731353	345302043	98570690
			BCR	1.399506139	(DIS RIT/DIS CST)	
			NPW	98570690		
			IRR	----		

FFB in MT	4320	(180*3*8)		
Products	Realized values			
CPO	38880000	(4320*0.18)*50000		
PKO	4730000	(86*55000)	2% of FFB	
PKC	416000	(130*3200)	3% of FFB	
Total	44026000			
	10191.2			

DF Discount factor = 1/(1+R)^n
DIS CST= Discounted cost
DIS RET= Discounted returns
DIS MAR= Discounted margin

R= Rate of interest (12%)
n=Corresponding year

Annexure 3: Cost of processing of 1 mt. of Oil palm fresh fruit bunches (Collected from M/s APOILFED, Andhra Pradesh)

Item	Cost (₹)
Variable costs	
Power	115
Labour	160
Spares	52.5
Maintenance	52.5
Administration	10.5
Total	390.5
Fixed costs	
Interest on investment	217
Interest on working capital	73
Salaries	165
Insurance	18
Depreciation	223
Total	696
Grand total	1086.5

Table 4 Actual cost of cultivation and expected returns (as per the feedback from the farmers of Andhra Pradesh)

Item of expenditure	I Year (₹)	II Year (₹)	III Year (₹)	IV Year (₹)	Total (₹)	V Year (₹)	VIII Year (₹)
Cost of seedlings @ ₹55x143	7865	0	0	0	7865	0	0
Gap fillings @ ₹7	0	385	0	0	385	0	0
Saplings transport @ ₹ 7	1001	49	0	0	1050	0	0
Manures (FYM, organic, composts)	750	1200	1500	1750	5200	2250	02750
Fertilizers	2200	3700	5240	6098	17238	6098	6098
Plant protection	250	400	550	550	1750	550	550
Inter crop	1200	1200	0	0	2400	0	0
Land preparation	1500	0	0	0	1500	0	0
Lining and pitting	750	0	0	0	750	0	0
Inter culture	750	750	1500	1500	4500	1500	1500
Basin making/twice/year	715	858	1001	1287	3861	1430	1430
Pruning	250	250	500	500	1500	750	750
Labour for irrigation	1000	1250	1500	1750	5500	2000	2000
Electricity power and maintenance (including depreciation)	2000	2000	2000	2000	8000	2000	2000
Harvesting	0	0	375	750	1125	1250	1500
Collection and transportation	0	0	350	750	1100	1250	1500
Misc. Watch and ward, etc.	9000	9000	9000	9000	36000	9000	9000
Total (A)	29231	21042	23516	25935	99724	28078	29078
Subsidy on seedlings	6750						
Fertilizer	1545	3097	5220	5220	21832		
Total subsidy (B)	8295						
A-B	20936	18945	21796	24125	77892		
Income from intercrop ©	4500	4500	3000				
Income from FFB (D)				20500		28700	73800 (18t)
Net realisation	-16436	-14444	-18796	-3625		+622	+44722

Table 5 Annuity value based fixed cost for first four years after subsidy

Particulars	Year								
	1	2	3	4	5	6	7	8	9
Total variable cost (₹)	29230	21040	23510	25930	28080	28080	28080	29080	29080
After subsidy (₹)	20940	18950	21800	24130	28080	28080	28080	29080	29080
Net realization	-16440	-14440	-18800	-3620	620	15000	30000	44720	
(C:F5-3630)	*-20070*	*-18070*	*-22430*	*-7250*					
Formula: P X (1/(1+R)^N	(C4+D4+E4)*(1)/((1.12)*25)								
Value	3628.81								
Rounded off to	3630								

P=Sum of variable costs during juvenile period of first three years after deducting the subsidy; R Rate of interest; N Economic life of the crop in years

Table 6 Yield (fresh fruit bunches) output of oil palm

Year	Yield (t/ ha)
1	0
2	0
3	0
4	1.5
5	5
6	8
7	11
8	15
9-18	18
19	16.5
20-25	15

The above formula was derived based on the cash flow analysis carried out for both cultivation and processing. From the BCRs it is found that the above formula holds good for both farmers as well as processors as both are in a win-win situation. However the claim of farmers on both online / by products of FFB processing is well justified and hence, the above formula is projected with an equal share in the profits (after deducting the processing cost) of online as well as by products for both farmers and processors. Hence, it is recommended to add 33% of the realized values of the online/by products of Oil palm FFB processing i.e. PKO and PKC to the formula so that the remaining 33% will be the share of processors. Hence, the realized values obtained from these online/by products are divided into three parts of which one part i.e. 33% of realized values can be attributed towards the cost of processing and the remaining two parts i.e. 66% can equally be shared between farmers and processors. The same formula may be added to the other value added products, if any, in future.

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Studies on combining ability and heterosis in Indian mustard, *Brassica juncea* L. Czern & Coss.

R K YADAV, RAMAKANT AND L SINGH

Department of Genetics and Plant Breeding, C.S. Azad University of Agril. & Technology, Kanpur-208 002, Uttar Pradesh

(Received: October, 2009; Revised: June, 2011; Accepted: September, 2011)

ABSTRACT

Combining ability and heterosis were studied in six parent half diallel cross for eleven quantitative characters in order to identify suitable parents/ crosses, which could be utilized in Indian mustard (*Brassica juncea* L.) for further improvement programme. The analysis of variance of the data obtained on ten randomly taken plants revealed that both *gca* and *sca* variances were significant for all the characters indicating the importance of both additive and non- additive genetic components in controlling the expression of these traits. Average degree of dominance reflected the pre-dominance of over dominance in these characters expression. The parents, Varuna and Vardan for seed yield; RK-104 and Rohini for oil content were judged as good general combiners. The cross combinations, Vardan x RK-114, Varuna x Rohini, Vardan x Rohini and RK-114 x Maya were identified as potential ones based on their *sca* and heterotic effects, which had involved either HXL or LXL general combiners and confirms the validity of average degree of dominance values.

Key words: Combining ability, Heterosis, Indian mustard

Rapeseed-mustard (*Brassica juncea* L.) group of crops plays an important role in the oil seed economy of our country. India is a second largest rapeseed-mustard growing country in the world and has rank third next to Canada and China in production. Its productivity (1056 kg/ha) is much lower than the world average (1511 kg/ha). Thus received a great attention of breeders for genetic improvement, as it has shown greater production potential under varying environments. For the success of any breeding programme the basic need is selecting proper parents for hybridization. The study of heterosis shows the percentage as increase or decrease of the F1 over the economic parents or over better parents but it fails to identify the possible causes for the superiority of hybrid. Combining ability analysis provides information related to gene action controlling the quantitative characters and helps the breeder in the choice of suitable parents. The present investigation was undertaken to study the nature and magnitude of heterosis and analysis of combining ability in Indian mustard using diallel mating design.

The experimental material comprising six diverse lines of Indian mustard *viz.*, Vardan, Varuna, RK 104, Rohini, Maya and RK 114 were selected. These parents were crossed in diallel fashion during winter season of 2004. The resulting 15 hybrids and their six parents were evaluated in randomized block design with three replications during winter season of 2005 at Oilseed Research Farm, Kalyanpur, of C.S. Azad University of Agriculture and Technology, Kanpur. Each entry was sown in single row of two meters length spaced at 45 cm apart keeping 15 cm distance between plant to plant. All recommended agronomic practices were adopted for growing good crop. The observations were recorded on ten randomly selected plants from each line for eleven characters *viz.*, days to 50% flowering, plant height (cm), number of primary branches/plant, number of secondary branches/plant, length of main raceme (cm), number of siliquae on main raceme, days to maturity, number of seeds/siliqua, 1000 seed weight (g), seed yield/plant (g) and oil content (%). Combining ability analysis was done according to the method of Griffing (1956) Method II model I. Heterosis over economic parents and better parent was estimated by standard procedures.

The analysis of variance because of GCA and SCA (Table 1) were significant for all the characters indicating the importance of both additive and non-additive genetic components of variation in expressing these traits. The average degree of dominance was more than unity, suggesting to involve over dominance in inheriting these traits. The findings are in agreement with the earlier repots of Ghosh *et al.* (2003) and Parmar and Patel (2003).

Two top desirable parents and three crosses selected on the basis of *per se* performance with respective GCA and SCA effects for all the eleven characters have been presented in table 2 and table 3, respectively. The comparison of GCA effects with *per se* performance of parents revealed positive association for most of the characters. Based on *per se* performance along with estimate of GCA effects, good general combiners were Rohini and Maya for days to flowering, RK 104 for plant height; Vardan and Maya for number of primary branches/plant; RK 104 and Vardan for secondary branches/plant; Vardan and Maya for length of main raceme and number of siliquae on main raceme; RK 104 and Varuna for days to maturity; Varuna and RK 114 for number of seeds/siliqua; RK 104 ad Rohini for oil content. Thus, the parents can be considered in formulation of breeding programme for improving seed yield. The best specific combiners were Varuna x RK 104, Vardan x RK 114 and Vardan x Rohini for days to flowering, Vardan x Varuna, Rohini x Maya and Maya x RK 114 for days to maturity, Rohini x RK 114, RK 104 x Rohini and Varuna x Maya for 1000 seed weight and Vardan x Maya, Varuna x Maya and Maya x RK 114 for oil content, respectively.

Table 1 Analysis of variance for combining ability in Indian mustard

Source of variation	d.f.	Date to flowering	Plant height	Number of primary branches/plant	Number of secondary branches/plant	Length of main raceme	Number of siliquae on main raceme	Date to maturity	Number of seeds/siliqua	1000 seed weight	Seed yield/ plant	Oil content
GCA	5	23.71**	37.06**	1.58**	1.07**	17.95**	7.51**	30.32**	1.77**	0.15**	4.91**	4.36**
SCA	15	24.43**	24.82**	0.77	3.43**	21.87**	7.65**	18.92**	2.89**	0.14**	4.49**	2.13**
Error	40	1.43	1.89	0.12	0.30	1.75	1.86	1.98	0.38	0.03	0.76	1.29
$\delta^2 g$		2.78	4.39	0.18	0.10	2.03	0.70	3.54	0.17	0.02	0.52	0.38
$\delta^2 s$		23.00	22.93	0.65	3.13	20.12	5.70	16.94	2.51	0.11	3.76	0.84
$\delta^2 g/\delta^2 s$		0.12	0.19	0.28	0.03	0.10	0.12	0.21	0.07	0.18	0.14	4.45
$(\delta^2 S/\delta^2 g)$ 0.5		2.87	2.28	1.90	5.59	3.15	2.85	2.18	3.84	2.35	2.69	1.49

*, ** significant at 5 and 1% level, respectively

Table 2 General combining effects of parents in Indian mustard

Character	Parents	*Per se* performance	*gca* effects
Days to 50% flowering	Maya	42.67	-1.22**
	Rohini	45.33	-2.53**
Plant height	RK 104	126.93	-2.45**
	RK 114	126.67	-2.97**
Number of primary branches/plant	Vardan	9.69	0.70**
	maya	7.53	0.30**
Number of secondary branches/plant	RK 104	13.87	0.53**
	Vardan	13.57	0.29*
Length of main raceme	Vardan	58.03	1.90**
	Maya	58.30	1.20**
Number of siliquae on main raceme	Vardan	32.27	1.14**
	Maya	29.60	0.34*
Days to maturity	RK 104	120.67	-2.54**
	Varuna	127.33	-1.42**
Number of seeds/siliqua	Varuna	14.47	0.63*
	RK 114	10.67	0.45*
1000 seed weight	RK 104	4.53	0.20*
	Maya	4.44	0.08
Seed yield/plant	Varuna	14.53	0.87*
	Rohini	13.64	0.06
Oil content	RK 104	40.12	0.91*
	Rohini	39.42	0.16

*, ** significant at 5 and 1% level, respectively

The SCA effects and *per se* performance were not always considered together. Top ranking crosses involved high, medium and low combiners as parents Singh *et al.* (2006) also reported involving high, medium and low combiners in superior crosses for seed yield/plant and its components in Indian mustard. The cross combinations with good results on account of low x low GCA status of their parents specially for oil content may be explained because of the main role of non-additive gene action. High x high general combiners showed additive x additive gene action for these characters and may be exploited through pedigree method of selection. The crosses showing maximum heterosis for seed yield/plant were short listed in table 4. The magnitude of heterosis over economic parents ranged from 4.06 to 27.47% over respective check Varuna. The cross Varuna x RK 104 showed highest heterosis over economic and better parents (27.47**) and (21.47**), respectively. Similar higher values of heterosis over economic parents were reported by Singh and Lallu (2004). The highest and positive heterosis over check Varuna was recorded in hybrid Vardan x RK 114, Varuna x Rohini, Vardan x Rohini and RK 104 x Maya. The heterosis observed in these crosses justifies the development of commercial hybrid involving parents with either H x L and L x L general combiners in Indian mustard. Therefore, it is worthwhile to see superior crosses showing high level of heterosis for seed yield/plant. This would enable the breeders to concentrate on few promising cross combinations for further crop improvement.

Table 3 Superior cross combination based on SCA effects in Indian mustard

Character	Parents	*Per se* performance	*sca* effects	*gca* effects
Days to 50% flowering	RK 104 x Maya	43.3	-7.51**	L x A
	Vardan x Varuna	43.0	-4.76**	A x A
	Vardan x Rohini	42.0	-3.93**	A x H
Plant height	Vardan x RK 104	120.3	-1.49**	L x H
	Vardan x RK 114	127.6	-1.19**	L x H
	RK 104 x Maya	132.7	-1.07**	H x L
Number of primary branches/plant	Maya x RK 114	7.3	0.83*	H x L
	Varuna x Maya	7.4	0.81*	L x H
	RK 104 x Rohini	6.8	0.60*	L x L
Number of secondary branches/plant	RK 104 x Maya	14.2	1.97**	L x H
	Vauna x Rohini	14.2	2.68**	L x H
	RK 104 x Rohini	13.1	1.99**	H x H
Length of main raceme	RK 104 x RK 114	59.0	6.20**	H x L
	Varuna x Maya	53.0	4.22**	H x L
	RK 104 x Rohini	53.4	3.36**	H x L
Number of siliquae on main raceme	Maya x RK 114	32.0	4.03**	L x L
	Varuna x RK 104	30.3	3.05**	H x L
	Varuna x Rohini	30.4	2.50*	L x H
Days to maturity	Vardan x Varuna	119.6	-6.22**	L x H
	Rohini x Maya	123.3	-6.51**	L x A
	Maya x RK 114	123.6	-5.51**	H x L
Number of seeds/siliqua	Varuna x RK 104	15.1	2.73**	L x H
	Vardan x RK 104	14.3	2.47**	H x L
	Rohini x RK 114	14.3	1.98**	L x L
1000 seed weight	Rohini x RK 114	5.0	0.85**	L x A
	RK 104 x Rophini	4.8	0.33*	H x L
	Varuna x Maya	4.8	0.39*	A x A
Seed yield/plant	Varuna x RK 104	17.6	4.04**	A x L
	Vardan x RK 114	16.4	3.47**	A x A
	Vardan x Rohini	16.2	1.74*	A x L
Oil content	Vardan x Maya	39.0	0.95	L x L
	Varuna x Maya	38.8	0.94	L x L
	Maya x RK 114	38.7	0.74	L x L

*, ** significant at 5 and 1% level, respectively

Table 4 Crosses exhibited higher heterosis over economic and better parent for seed yield in Indian mustard

Crosse	*Per se* performance	Heterosis percentage		Desirable significant heterosis for other traits
		Over EP	Over BP	
Varuna x RK 104	17.65	24.47**	21.47**	PH, PB, SB, SMR, DM, 1000-SW
Vardan x RK 114	9.23	12.66**	25.63**	DF, SB, DM
Varuna x Rohini	16.23	11.70**	11.70**	DF, PB, SB, SMR, SPS, 1000-SW
Vardan x Rohini	15.12	4.06**	10.85**	DF, PB, SB, SMR
Vardan x Maya	12.68	12.73**	15.90**	DF, PB, SB, LMR, DM, SPS, 1000-SW, OC

PH : Plant height; DF : Days to flowering; PB : Number of primary branches/plant: SB : Number of secondary branches/plant; LMR : Length of main raceme; SMR : Number of siliquae on main raceme: DM : Days to maturity, SPS : Number of seeds/siliqua; 1000-SW : 1000 seed weight; OC : Oil content; BP : Better parent; EP : Economic parent

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Inheritance of yield and its component traits in Indian mustard, *Brassica juncea* L. Czern & Coss.

R K YADAV RAMAKANT AND L SINGH

Department of Genetics and Plant Breeding, C.S. Azad University of Agril. & Technology, Kanpur-208 002, Uttar Pradesh

(Received: October, 2009; Revised: June, 2011; Accepted: September, 2011)

ABSTRACT

The generation mean analysis was carried out involving six basic populations namely, P_1, P_2, F_1, F_2, BC_1 and BC_2 of three crosses namely Varuna x Vardan, Varua x RK 104 and Rohini x Maya of Indian mustard, *Brassica juncea* L. to estimate gene effects for 11 quantitative characters. Significance of scaling test for different traits was observed in almost all crosses showing the presence of digenic or higher order interactions. The results showed that most of the characters were mainly governed by dominance gene action and duplicate type of epistasis. These results suggested that substantial gain in seed yield/plant may be achieved through recurrent selection and heterosis breeding in Indian mustard.

Key words: Generation mean analysis, Indian mustard, Yield components

Rapeseed-mustard group of crops plays an important role in oilseed economy of our country. To increase the present yield level and to overcome yield stagnation of Indian mustard, *Brassica juncea* L., it is essential to reshuffle the gene complex through hybridization. For this, it is necessary to identify gene actions involved in expressing various yield contributing characters. Generation mean analysis is a simple and a useful technique for characterising gene effect. The knowledge on the nature of gene effect in inheriting yield components would be useful for development of better cultivars by formulation of suitable breeding method.

The present investigation was carried out with six populations namely, P_1, P_2, F_1, F_2, BC_1 and BC_2 of three crosses namely Varuna x Vardan, Varuna x RK 104 and Rohini x Maya in randomized block design with three replications during winter season of 2005 at Oilseed Research Farm Kalyanpur of C.S. Azad University of Agriculture and Technology, Kanpur. The plot size was kept of single row for parents, F_1s and two rows for F_2s, BC_1 and BC_2 of 3m length with distance of 45 cm between rows and 20 cm within row. Ten plants each from parents and F_1s and 20 plants each from F_2s, BC_1 and BC_2 were randomly selected for recording the observations on eleven metric traits *viz*., days to flowering, plant height, number of primary branches/plant, number of secondary branches/plant, length of main raceme, number of siliquae on main receme, days to maturity, number of seeds/siliqua, 1000 seed weight, seed yield/plant and oil content. Data were subjected to different biometrical techniques like scaling test (Mather, 1949) and generation mean analysis following six parameter model of Hayman (1958). Significance of scaling test for almost all the characters was observed in all three crosses indicating presence of digenic or higher order interactions. Estimates of gene effects and interactions for the best fit model for all traits studied in three crosses of Indian mustard are given in table 1. The inheritance pattern varied with crosses and characters under consideration. Means of F_1s for days to flowering, plant height and days to maturity were either intermediate or closer to desirable lower parent, showing dominance of gene for early flowering, dwarf plant type and early maturity. Similar results were reported by Sachan *et al.* (2006) for all the three traits. F_1s means for 1000 seed grain weight were intermediate occasionally approaching to higher parent suggesting balancing effects of negative and positive alleles for higher test-weight. F_1s means for grain seed yield were higher than those of the higher parent. Other characters also displayed differential between F_1s mean and their parental values. Means of BC_1 and BC_2 for seed yield/plant were invariably higher than those of the parents and F_1s suggesting the accumulation of favourable alleles resulting back cross in the present material.

In general, additive effect (d) was more pronounced in desirable direction for inheriting days to flowering, plant height and days to maturity. Among the interactions additive x dominance (J) and dominance x dominance (l) for days to flowering, plant height and days to maturity were important. Similar interactions were reported by Sheikh and Singh (2004) for days to flowering.

Table 1 Estimates of gene effects and interaction for eleven characters in Indian mustard

Character	Cross	m	d	h	l	j	I	Type of epistasis
Days to flowering	Vardan x Varuna	45.67**	-5.00**	17.67**	8.67	2.67	24.67**	C
	SEm±	1.45	1.52	6.66	6.57	1.79	8.72	
	Varuna x RK 104	43.67**	-6.00**	2.99	9.33	-1.33	11.33	C
	SEm+	1.20	0.81	5.25	5.08	1.05	6.39	
	Rohini x Maya	55.00**	5.33**	12.67	6.67	-6.67*	-45.33**	D
	SEm-	1.53	1.33	6.87	6.67	1.42	8.49	
Plant height (cm)	Vardan x Varuna	136.40**	-7.27**	28.02**	23.73**	-12.60**	-8.33	D
	SEm+	1.46	1.67	6.80	7.57	1.99	9.33	
	Varuna x RK 104	130.57**	3.40*	28.29**	6.19	2.53	-49.39**	D
	SEm+	1.68	1.73	7.78	5.49	1.98	10.32	
	Rohini x Maya	129.83**	-13.73**	-02.21	2.60	-18.82**	-20.37**	D
	SEm=	1.16	1.98	5.69	1.77	1.74	8.08	
No. of primary branches/plant	Vardan x Varuna	5.80**	0.23	1.80	-6.80**	1.80*	-0.53	D
	SEm±	0.31	0.64	1.89	1.89	0.81	3.51	
	Varuna x RK 104	7.60**	0.93*	-8.83**	3.07	-1.03	9.93**	D
	SEm±	0.42	0.45	1.98	1.58	0.64	2.71	
	Rohini x Maya	6.86**	-0.13	-2.95	3.47	-0.15	1.90	D
	SEm±	0.26	0.59	1.65	2.82	0.64	2.77	
No. of secondary branches/plant	Vardan x Varuna	11.43**	5.13**	5.29	-21.06**	3.39**	-1.67	D
	SEm±	0.64	0.60	5.96	2.95	0.69	3.84	
	Varuna x RK 104	15.37**	0.93	-23.75**	-09.33**	0.48	27.77**	D
	SEm±	0.61	0.69	2.88	2.64	0.74	3.94	
	Rohini x Maya	15.07**	3.80**	-12.26**	-8.53	3.20**	5.60	D
	SEm+	0.52	0.82	2.67	5.67	0.86	4.00	
Length of main raceme (cm)	Vardan x Varuna	46.30**	-5.87**	-9.42	42.27**	10.22**	46.03**	D
	SEm-	1.69	1.81	7.78	7.44	1.93	10.22	
	Varuna x RK 104	43.70**	6.47**	36.68**	-15.53**	0.12	-57.50**	D
	SEm=	1.59	1.94	7.65	5.70	2.14	10.63	
	Rohini x Maya	55.03**	-13.37**	-9.28	19.13**	-15.98**	14.57	D
	SEm+	1.15	1.69	5.89	5.10	1.88	8.69	
No. of siliquae on main raceme	Vardan x Varuna	22.57**	7.77**	17.45**	19.13**	5.25	-6.90	D
	SEm±	0.94	1.73	5.28	5.10	2.02	8.32	
	Varuna x RK 104	32.37**	7.10**	-11.27	-7.27	8.23**	-4.93	C
	SEm=	1.71	1.09	7.36	7.19	1.32	8.71	
	Rohini x Maya	35.27**	-4.33**	-32.30**	-32.13**	-7.33**	34.87**	D
	SEm±	0.58	1.43	3.97	3.69	1.49	6.85	
Days to maturity	Vardan x Varuna	35.27**	-4.33**	-32.30**	-32.13**	-7.33**	34.87**	D
	SEm±	0.58	1.43	3.97	3.69	1.49	6.85	
	Varuna x RK 104	129.33**	0.67	18.17	21.33**	-0.83	49.67**	C
	SEm±	6.67	0.98	15.26	6.59	3.68	9.06	
	Rohini x Maya	124.33**	2.99**	7.47	9.99	7.17**	-22.99**	D
	SEm±	0.88	1.89	5.39	5.16	2.72	8.90	
No. of seeds/siliqua	Vardan x Varuna	15.23**	0.03	-4.80	-3.40	2.23**	-7.87	C
	SEm±	0.62	0.78	3.39	2.92	0.86	5.26	
	Varuna x RK 104	16.10**	2.80**	15.47**	-16.4**	3.10**	11.73*	D
	SEm±	0.96	0.74	4.13	4.12	0.87	5.04	
	Rohini x Maya	10.27**	0.37	22.03**	21.27**	0.53	-90.07**	D
	SEm±	0.37	0.46	1.86	1.75	0.61	2.69	
1000 seed weight (g)	Vardan x Varuna	4.96**	-0.35	-3.12**	-2.72**	-0.65	2.98	D
	SEm±	0.13	0.49	1.10	1.09	0.49	2.03	
	Varuna x RK 104	4.51**	1.03**	0.24	-0.15	1.17**	0.63	C
	SEm±	0.40	0.20	1.64	1.64	0.22	1.79	
	Rohini x Maya	4.81**	40.90**	-1.56	-1.//*	-0.63	1.03	D
	SEm=	0.14	0.41	1.04	0.99	0.46	1.84	
Seed yield/plant (g)	Vardan x Varuna	14.34**	-1.41	-9.73**	-7.36*	-0.05	5.29	D
	SEm±	0.52	0.99	2.97	2.89	1.14	4.71	
	Varuna x RK 104	14.87**	-0.40	-1.05	-5.63	-1.88	13.20*	D
	SEm±	0.90	1.26	4.62	4.41	1.40	6.79	
	Rohini x Maya	11.70**	5.01**	6.19	8.11*	4.88**	12.84**	D
	SEm=	0.82	0.90	3.86	3.76	1.20	5.20	
Oil content (%)	Vardan x Varuna	38.81**	-0.63	-4.60**	-2.84*	-1.07	3.99*	D
	SEm±	0.21	0.37	1.12	1.12	0.37	1.71	
	Varuna x RK 104	34.49**	0.32	4.78**	4.61**	0.14	-8.29**	D
	SEm±	0.17	0.42	1.11	1.09	0.42	1.88	
	Rohini x Maya	40.02**	1.98**	2.31**	1.39*	0.40	-9.79**	D
	SEm=	0.08	0.32	0.74	0.73	0.34	1.39	

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

Negative sign of significant effects showed the genes for early flowering, reduced plant height and early maturity were dominant over the genes for late flowering, tallness and late maturity. Inadequacy of additive-dominance model in almost all the three crosses suggested either gene interactions or linkage or both are playing an important role in the expression of these characters.

Additive effects were more important for the inheritance of number of primary branches/plant and number of secondary branches/plant. Additive x dominance (j) was important interaction component being significant and desirable. Verma *et al.* (1992) reported similarly for these characters. So, selection for more number of primary branches/plant and secondary branches/plant would be more fruitful in later generations. Opposite sign of h and l components showed duplicate epistasis for both the characters. Inadequacy of additive-dominance model for both characters in all three crosses, showed presence of gene interaction or linkage or both in expressing these traits.

Additive and dominance effects were important for the inheritance of length of main raceme and number of siliquae on main raceme. These findings are in conformity with Singh and Singh (1985) results. Additive x additive (I) as well as additive x dominance (j) components of interaction were important being desirable positive significant in different crosses. This suggested that selection for longer length of raceme and more number of siliquae on main raceme would be rewarding, if selection is delayed till dominance component is reduced. Opposite sign of h and l components showed the presence of duplicate epistasis, which would hinder the progress in selection. Presence of gene interactions or linkage or both was indicated by inadequacy of additive-dominance model for these traits.

Additive effect (d) was the important for number of seeds/siliqua and 1000 seed weight being higher in magnitude and in desirable direction. Similar results were given by Malkhandale (1993). Among the interactions, additive x dominance (j) was relatively more important component being significant and in desirable direction for both the traits. Sign of h and l components indicated presence of both duplicate and complementary epistasis in various crosses for these traits.

Additive as well as dominance effects were important in the expression of seed yield/plant and oil content with predominant of additive effect. These results are in agreement with the findings of Yadav *et al.* (1993). Among the interactions as additive x additive (i) and dominance x dominance (l) were important. Duplicate epistasis was indicated by the opposite sign of h and l for both the characters. Inadequacy of additive -dominance model was found in all crosses for both the characters.

It can be inferred from discussions that grain yield/plant could be improved through recurrent selection followed by pedigree method or heterosis breeding method.

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Genetic variability, heritability and genetic advance for yield and yield components in sunflower (*Helianthus annuus* L.) genotypes

G VINAY KUMAR, J SURESH, S SUDHEER KUMAR, P SAIDAIAH AND B RAGHU

Department of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar-500 030, Andhra Pradesh

(Received: March, 2011; Revised: September, 2011; Accepted: December, 2011)

ABSTRACT

The present investigation was carried out in 63 sunflower (*Helianthus annuus* L.) inbreds including 3 hybrids during the winter season of 2007 at College Farm, College of Agriculture, Rajendranagar, Hyderabad. Variability parameters were estimated for yield and yield component characters. Seed yield/plant recorded highest phenotypic coefficient of variability (PCV) value (31.61%) followed by number of unfilled seeds/head (21.06%) and the lowest value of 2.58% was recorded by days to maturity. Highest genotypic coefficient of variability (GCV) values were recorded for seed yield/plant (28.07%) followed by number of unfilled seed (21.06%), number of filled seeds (20.86%) and test weight (16.57%). The highest heritability was recorded by oil content (96.60%) followed by days to 50% flowering (90.20%) and test weight (80.70%). The genetic advance as per cent of mean was highest for seed yield (65.83%) followed by oil content (49.59%), test weight (39.30), number of filled seeds/head (35.67%), head diameter (32.69%), number of unfilled seeds/head (29.92%), plant height (26.17%) and number of leaves/plant (26.03). The character number of filled seeds revealed high variability, high heritability and high genetic advance as per cent of mean.

Key words: Genetic advance, Heritability, Sunflower, Variability, Yield

Sunflower (*Helianthus annuus* L.) is an important oilseed crop cultivating for its premier oil for manifold uses. Sunflower competes in the world oilseed scenario with the other three major oilseed crops *viz*., soybean, groundnut and rapeseed. Sunflower requires assessment of various heritable traits. Genetic variability is the most important feature of any population and variability present in the population is the prerequisite in response to selection for any crop improvement programme. Selection of superior varieties will be possible only when adequate variability exists in the gene pool. Hence, the insight into the magnitude of variability of present in a gene pool of a crop species is of utmost importance to plant breeder for initiating a judicious plant breeding programme. The coefficient of variation expressed in phenotypic and genotypic levels are used to compare the variability observed among different characters. A wide range of variation has been reported for seed yield and seed number (Velkov, 1980) and other important components of yield (Virupakshappa and Sindagi, 1988). The heritability estimates aid in determining the relative amount of heritable portion in determining the relative amount of heritable portion in variation and thus help the plant breeder in selecting the elite inbreds from a diverse population. Therefore, the present study was undertaken for assessing the extent of genetic variability, heritability and genetic advance in sunflower germplasm lines. A field experiment consists of 63 inbred lines including three hybrids of sunflower were sown in randomized block design with two replications at College Farm, College of Agriculture, Hyderabad, during the winter season of 2007. Each genotype was sown in three rows of 4.5 m in row length with a spacing of 60 cm x 30 cm. Recommended agronomic practices were followed to grow a good crop. Observations were recorded on five randomly selected plants for each genotype in each replication. The characters studied were, days to 50% flowering, days to maturity, plant height, head diameter, number of unfilled seeds/head, number of filled seeds/head, 100 seed weight, oil content, seed set under self pollination and seed yield/plant. Analysis of variance and estimates of genotypic and phenotypic coefficient of variation, broad sense heritability and expected genetic gain were worked out following conventional methods. (Falconer. 1981). The data were subjected to analysis of variance (Panse and Sukhatme, 1985). The genotypic and phenotypic coefficient of variability were calculated as Burton and DeVane (1953). Heritability in broad sense was estimated using the formula of Allard (1960), while genetic advance was worked out as per Johnson *et al.* (1955).

The analysis of variance indicated high and significant variation for all the characters under study. The phenotypic coefficient of variability (PCV) was greater than genotypic coefficient of variability (GCV) for all the characters studied showing the environmental effect for all the characters (Table 1).

The analysis of variance revealed significant difference for all the traits studied (Table 1). The range of variation was maximum for the characters *viz.*, plant height (108.2 to 177.0 cm), number of leaves/plant, days to 50% flowering, days to maturity, head diameter, number of filled seeds/head (283 to 711.2), number of unfilled seeds/head (129.3 to 280.0), oil content (21.2 to 44.0) and seed yield/plant (6.3 to 39.6g), while it was lowest in the case of test weight (2.0 to 6.9g) (Table 1). In general, PCV values were marginally higher than GCV. Investigation also showed moderate to low PCV and GCV values for some of the characters. Among the characters studied, seed yield/plant recorded highest PCV value (31.61%) followed by number of unfilled seeds/head (21.06%) and the lowest value of 2.58% was recorded by days to maturity. While, PCV values were moderate for other characters *viz.*, number of filled seeds/head (20.86%), oil content (19.44%), test weight (18.44%) and head diameter (16.44%). These results are in accordance with the results of Sujatha *et al.* (2002). Moderate values of PCV and GCV were obtained for the plant height, number of leaves/plant and head diameter. Similar results were reported by Sujatha *et al.* (2002). However low values were obtained for days to 50% flowering and day to maturity, similar results were obtained by Rao *et al.* (2003) and Sujatha *et al.* (2002).

However, high variance values alone are not the determining factors of the expected progress that could be made in quantitative traits (Falconer, 1981). It was suggested that the GCV together with the high h2 estimates would give a better picture of the extent of genetic gain to be expected under selection. In the present investigation, all the characters expressed high heritability estimates ranging from 53.8 to 96.6%. The genetic advance was very high for number of filled seeds/head (157.9) followed by an number of unfilled seeds/head (157.9) followed by number of unfilled seeds/head (58-91) and plant height (37.17), while other characters recorded low genetic advance.

The genetic advance as per cent of mean was highest for seed yield (65.83%) followed by oil content (49.59%), test weight (39.30), number of filled seeds/head (35.67%), head diameter (32.69%), number of unfilled seeds/head (29.92%), plant height (26.17%) and number of leaves/plant (26.03). While, rest of the characters recorded medium to low genetic advance as per cent of mean. The character head diameter exhibited low variability, high heritability and medium genetic advance as per cent of mean of GCV. The character number of filled seeds revealed high variability, high heritability and high genetic advance as per cent of mean. Komuraiah (2002), Thirumala Rao (2002) and Rajeswari (2004) reported similar results earlier.

The character, test weight showed high heritability and genetic advance as per cent of mean. This trait was less influenced by environment, similar results were observed by Komuraiah (2002) and Rao *et al.* (2003). Seed yield and oil content are two important characters in sunflower. It is desirable to evolve hybrids with high seed yield coupled with high oil per cent. Among the inbred lines GP9-472-7-5, GP9-290-5-3, GP2-2035 and GP9-38-2-1 and the checks KBSH-1, KBSH-44 and DRSF-108 were found to be superior for seed yield. It is interesting to note that seed yield recorded high heritability coupled with high genetic advance as per cent of mean indicating the improvement of seed yield can be achieved by adopting simple selection procedures with which additive genes can be pyramided and will be gaining in the selection process. Similar results were also reported by Thirumala Rao (2002) and Rajeswari (2004). The expression of traits is unstable. Hence, breeder should not rely on the estimates of heritability alone.

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

Character	Minimum	Maximum	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	Heritability broad sense (h^2)	Genetic advance	GA as per cent mean
Days to 50% flowering	56.60	69.60	7.10	6.41	4.34	4.12	90.20	6.34	10.35
Head diameter (cm)	8.45	17.75	4.81	3.62	16.44	14.27	75.30	4.35	32.69
Number of leaves/plant	15.70	31.0	14.13	9.58	14.54	11.97	67.80	6.73	26.03
Plant height (cm)	108.2	177.0	327.50	254.86	12.74	11.23	77.80	37.17	26.17
Days to maturity	88.2	98.10	5.67	4.27	2.58	2.24	75.40	4.74	5.15
Number of unfilled seeds /head	129.33	279.99	1720.14	925.58	21.06	15.45	53.80	58.91	29.92
Number of filled seeds /head	282.99	711.16	8530.67	5524.73	20.86	16.79	64.80	157.91	35.67
Test weight (g)	2.04	6.85	0.73	0.59	18.44	16.57	80.70	1.83	39.30
Seed yield/plant (g)	6.34	39.59	41.86	33.02	31.61	28.07	78.90	13.47	65.83
Oil content (%)	21.2	44.15	39.38	38.05	19.44	19.11	96.60	16.00	49.59

Heritability in broad sense : Below 25 (Low); 25-50 (Medium) and above 50 (High)

Table 2 ANOVA for seed yield and yield attributes in sunflower

Character	Mean sum of squares		
	Replications	Treatments	Error
Days to 50% flowering	1.34	13.52**	0.69
Head diameter (cm)	1.14	8.43**	1.18
Number of leaves/plant	22.12	23.72**	4.55
Plant height (cm)	1038.31**	582.36**	72.64
Days to maturity	1.20	9.94**	1.39
No. of unfilled seeds/head	7.31	2645.72**	794.56
No. of filled seeds/head	637.33	14055.41**	3005.93
Test weight (g)	0.13	1.33**	0.14
Seed yield/plant (g)	0.99	74.88**	8.84
Oil content (%)	29.92*	77.44**	1.33

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

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Character association and path analysis for yield and yield components in sunflower (*Helianthus annuus* L.)

G VINAY KUMAR, J SURESH, S SUDHEER KUMAR, P SAIDAIAH AND B RAGHU

Department of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar-500 030, Andhra Pradesh

(Received: March, 2011; Revised: October, 2011; Accepted: December, 2011)

ABSTRACT

Sixty three sunflower (*Helianthus annuus* L.) inbreds including three hybrids were analyzed for character association. It revealed strong positive association of seed yield with number of filled seeds/head followed by test weight, head diameter, plant height and number of leaves/plant. Non significant positive correlation was recorded with number of unfilled seeds/head, days to 50% flowering and days to maturity. Path coefficient analysis indicated number of filled seeds/head exerted the highest positive direct effect on seed yield followed by test weight, while oil content, number of leaves for plant and days to 50% flowering displayed low positive direct effects on seed yield. On contrary, low negative direct effects on seed yield were registered through plant height, number of unfilled seeds/head, days to maturity and head diameter.

Key words: Correlation, Genotypes, Path analysis, Sunflower, Yield parameters

The cultivated sunflower, *Helianthus annuus* L. has emerged as one of the major edible vegetable oilseeds crop in the world, ranking second in its importance after soybean. The estimation of genetic correlation coefficients between yield and its component characters has been of immense value for the indirect selection of desired plant ideotype. Expression of various characters is greatly changed with the changing breeding material and environment. Therefore, it is important to know the character association between the traits themselves and with the yield for breeding material which is subjected to selection for high yielding genotypes. According to Fonseca and Patterson (1968), it is the correlation coefficient that measures the magnitude of relationship between various plant characters and determines the component character based on which selection can be done for improvement of yield. The phenotypic and genotypic correlation coefficient estimates provide a basis for identifying traits for an ideal plant type of indirect selection.

Path analysis divides correlation coefficient into direct and indirect effects. With this, the breeder can determine the magnitude of direct and indirect effects of different characters on seed yield. Hence, to a better insight into the cause and effect relationship between different pairs of character, study of correlation in conjunction with path analysis is essential.

Sixty three inbred lines including three hybrids were grown in a randomized block design with two replications at College Farm, College of Agriculture, ANGRAU, Hyderabad, during the winter season of 2007. Each genotype was grown in three rows of 4.5 m length with a spacing of 60 cm x 30 cm. Recommended agronomic practices were adopted to grow the healthy crop. Quantitative observations were recorded on five randomly selected plants for each genotype in all the replications. The characters studied were days to 50% flowering, days to maturity, plant height, head diameter, number of leaves/plant, number of unfilled seeds/head, number of filled seeds/head, 100 seed weight, oil content, seed set under self-pollination and seed yield/plant. The correlation coefficients were calculated as per the method suggested by Johnson *et al.* (1955). Path analysis was worked out followed by the method of Dewey and Lu (1959).

$$\text{Seed set under self-pollination condition} = 100 \times \frac{\text{No. of filled seeds under self-pollination}}{\text{Total No. of seeds under self-pollination (filled+unfilled)}}$$

The phenotypic and genotypic correlations among grains yield and yield component characters in sunflower are presented in table 1. The genotypic and phenotypic correlations were on par with each other suggesting the negligible role of environment on the genotypic expression. Correlation studies revealed that the traits number of filled seeds/head, test weight, head diameter, plant height and number of leaves/plant had significant and positive correlation with the number of filled seeds/head followed by test weight, head diameter, plant height and number of leaves/plant on seed yield. However, non-significant positive correlation was recorded with number of unfilled seeds/head, days to 50% flowering and days to maturity. The significant positive association was observed for number of filled seeds/head, head diameter, test weight and seed yield. The findings are in conformity with the earlier findings of Sridhar *et al.* (2005); Vidhyavathi *et al.* (2005) and Ravi *et al.* (2006) in sunflower.

The study of inter-character association between the yield component characters revealed significant positive association of day to 50% flowering with days to maturity and plant height. Head diameter showed significant positive correlation with seed yield/plant, oil content, number of filled seeds/head, plant height, test weight and number of leaves/plant. Number of leaves/plant recorded significant positive correlation with plant height, number of unfilled seeds/head, seed yield/plant and test weight. Number of filled seeds/head revealed significant positive correlation with seed yield/plant, test weight and oil content (Table 1). The test weight recorded significant positive correlation with seed yield/plant and oil content. Test weight showed positive association with seed yield, plant height and number of leaves/plant. These results are similar with the findings of Sridhar *et al.* (2005) and Ravi *et al.* (2006). Number of unfilled seeds/head showed significant positive association with oil content. The positive non-significant phenotypic association seed yield/plant, number of filled seeds/plant and test weight. Autogamy has positive association with seed yield/plant, number of number of filled seeds/plant and test weight. Autogamy has positive association with yield contributing characters except unfilled seeds/head.

The path analysis indicated that, the character number of filled seeds/head exerted the highest positive direct effect on seed yield followed by test weight, whereas oil content, number of leaves for plant, days to 50% flowering displayed low positive direct effects on seed yield (Table 2). On the contrary, low negative direct effects on seed yield were registered through plant height, number of unfilled seeds/head, days to maturity and head diameter (Table 2). Except number of unfilled seeds/head, days to 50% flowering and days to maturity, other characters had positive and significant correlation with seed yield. Thus it indicates, these traits had maximum influence on yield. The highest direct positive effect was revealed by the number of filled seeds/head followed by test weight and oil content with seed yield. Hence, direct selection will be rewarding for these traits for the improvement of the seed yield. The results are in consonance with the earlier reports (Madhavilatha *et al.*, 2004 and Ravi *et al.*, 2006).

The negligible role of environment on the genotypic expression was evident from the higher magnitude of genotypic correlations than that of phenotypic correlations. On the other hand, number of filled seeds/head, test weight oil content number of leaves/plant and days to 50% flowering exhibited maximum direct effect as well as indirect effect through many other characters on seed yield. So, simultaneous selection based on number of filled seeds/head, test weight and oil content which had highly significant association with yield as well as maximum direct and indirect effects through other traits will be promising the seed yield in sunflower.

Table 1 Correlations (phenotypic and genotypic) between seed yield and yield components in sunflower

Character		Head diameter (cm)	No. of leaves/plant	Plant height (cm)	Days to maturity	No. f unfilled seeds/head	No. of filled seeds/plant	Test weight (g)	Seed yield/plant (g)	Oil content (%)
Days to 50% flowering	P	0.077	0.062	0.195*	0.676**	0.007	0.168	0.133	0.177	-0.016
	G	0.088	0.068	0.213*	0.764**	0.061	0.238**	0.144	0.219*	-0.008
Head diameter (cm)	P	1.000	0.349**	0.573**	-0.152	0.209	0.578**	0.430**	0.606**	0.587**
	G	1.000	0.546**	0.723**	-0.269	0.158	0.526**	0.555**	0.610**	0.691**
Number of leaves/plant	P		1.000	0.641**	0.082	0.253**	0.158	0.217*	0.234**	0.586**
	G		1.000	0.778**	0.029	0.371**	0.264**	0.319**	0.331**	0.735**
Plant height (cm)	P			1.000	0.090	0.295**	0.283**	0.373**	0.375**	0.624**
	G			1.000	0.103	0.426**	0.348**	0.445**	0.437**	0.722**
Days to maturity	P				1.000	-0.030	0.138	0.045	0.107	-0.136
	G				1.000	-0.072	0.164	0.057	0.129	-0.151
Number of unfilled seeds/head	P					1.000	0.186	0.148	0.188	0.352**
	G					1.000	0.068	0.264**	0.246**	0.489**
Number of filled seeds/ head	P						1.000	0.368**	0.854**	0.318**
	G						1.000	0.517**	0.885**	0.411**
Test weight (g)	P							1.000	0.778**	0.407**
	G							1.000	0.842**	0.440**
Seed yield/plant (g)	P								1.000	0.442**
	G								1.000	0.499**

**=significant at 1% level; *=Significant at 5% level; P = Phenotypic; G = Genotypic

Table 2 Phenotypic and genotypic path coefficient of yield and other component characters in sunflower

Character		Days to 50% flowering	Head diameter (cm)	No. of leaves/plant	Plant height (cm)	Days to maturity	No. of unfilled seeds/head	No. of filled seeds/head	Test weight (g)	Oil content (%)	Correlation with seed yield/plant (g)
Days to 50% flowering	P	**0.0094**	-0.0010	0.0018	-0.0080	-0.0094	-0.0002	0.1137	0.0721	-0.0005	0.1779
	G	**0.0187**	-0.0028	0.0001	-0.0066	-0.0116	-0.0022	0.1458	0.0791	-0.0006	0.2199*
Head diameter (cm)	P	0.0007	**-0.0133**	0.0102	-0.0234	0.0021	-0.0122	0.3903	0.2329	0.0196	0.6068**
	G	0.0017	**-0.0317**	0.0005	-0.0224	0.0041	-0.0129	0.3214	0.3040	0.0456	0.6102**
Number of leaves/plant	P	0.0006	-0.0043	**0.0293**	-0.0262	-0.0011	-0.0076	0.1068	0.1178	0.0195	0.2345**
	G	0.0013	-0.0173	**0.0009**	-0.0241	-0.0004	-0.0134	0.1616	0.1750	0.0485	0.3319**
Plant height (cm)	P	0.0018	-0.0076	0.0188	**-0.0408**	-0.0012	-0.0088	0.1910	0.2020	0.0208	0.3759**
	G	0.0040	-0.0229	0.0007	**-0.0310**	-0.0016	-0.0154	0.2126	0.2434	0.0477	0.4375**
Days to maturity	P	0.0063	0.0020	0.0024	-0.0037	**-0.0138**	0.0009	0.0935	0.0246	-0.0045	0.1077
	G	0.0143	0.0085	0.0000	-0.0032	**-0.0152**	0.0026	0.1004	0.0315	-0.0100	0.1290
No. of unfilled seeds/head	P	0.0001	-0.0055	0.0074	-0.0121	0.0004	**-0.0299**	0.1281	0.0885	0.0117	0.1888
	G	0.0012	-0.0114	0.0003	-0.0132	0.0011	**-0.0361**	0.1641	0.1086	0.0323	0.2469**
No. of filled seeds/head	P	0.0016	-0.0077	0.0046	-0.0116	-0.0019	-0.0146	**0.6745**	0.1992	0.0106	0.8547**
	G	0.0045	-0.0167	0.0002	-0.0108	-0.0025	-0.0097	**0.6106**	0.2830	0.0271	0.8858**
Test weight (g)	P	0.0012	-0.0057	0.0064	-0.0152	0.0006	-0.0104	0.2485	**0.5405**	0.0135	0.7781**
	G	0.0027	-0.0176	0.0003	-0.0138	-0.0009	-0.0204	0.3159	**0.5469**	0.0291	0.8423**
Oil content (%)	P	-0.0002	-0.0078	0.0172	-0.0255	0.0019	-0.0105	0.2146	0.2200	**0.0333**	0.4429**
	G	-0.0002	-0.0219	0.0006	-0.0224	0.0023	-0.0177	0.2511	0.2411	**0.0660**	0.4991**

Residual effect (P) = 0.1386; P=Phenotypic; G=Genotypic; Residual effect (G) = 0.1103

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Genetic divergence in sesame (*Sesamum indicum* L.)

E MURUGAN, S JULIET HEPZIBA AND N SUDHAKAR

Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai, Tamil Nadu

(Received: January, 2011; Revised: October, 2011; Accepted: November, 2011)

ABSTRACT

Mahalanobis D^2 statistics was used to study the genetic diversity among 42 genotypes of sesame (*Sesamum indicum* L.) grown during summer 2008. Observations recorded on eight characters revealed the wide genetic diversity. By adopting Tocher's technique, the 42 genotypes were grouped into six clusters. The average intra cluster distance revealed that the genetic diversity among the genotypes in cluster II was minimum (2.68) followed by cluster III (3.00). The maximum intra cluster distance was observed in the cluster V (7.56). Selection within this cluster might be exercised with emphasis on high mean values for the desirable traits. The relative divergence of each cluster from other clusters (inter cluster distance) indicated high order of divergence between cluster II and V (7.85) followed by cluster I and V (7.47) and cluster V and VI (7.37). Selection of parents from these clusters would help to achieve novel recombinants in future hybridization programmes. *Per se* performance had maximum contribution (49.94 %) followed by days to maturity (43.32 %) towards the divergence. Genotypes VS 9510, Si 115, Varasam patty local, CO_1, Cordeborgea, TMV 4, Multilocule and SVPR 1 were found to be desirable for inclusion in the improvement of the sesame breeding programme.

Key words: Cluster, D^2, Genetic divergence, Sesame

Sesame (*Sesamum indicum* L). is an important oilseed crop of tropical and sub tropical region. India ranks first in the world in sesame cultivation (27.7% area), but its productivity is quite low (368 kg/ha) as compared to the world average (489 kg/ ha) (www.fao.org). It is one of the nine major oil seed crops and referred as queen of oilseed crop because of its good oil quality having many anti-nutritional factors. According to Van Rheenen (1981), India is a rich source of different forms of cultivated sesame. The success of any crop improvement programme essentially depends on the nature and magnitude of the genetic variability present in the crop. The knowledge of nature and magnitude of genetic variability is of immense value for planning efficient breeding programme to improve the yield potential of the genotypes. Improvement in yield is normally attained through exploitation of the genetically diverse parents in breeding programmes. Genetic divergence among parents is essential as divergent parents throw heterotic crosses and also more variability could be expected in the segregating generations. For identifying such diverse parents for crossing, multivariate analysis using Mahalanobis D^2 statistic (1936) has been used in several crops. This is a valuable tool to study genetic divergence at inter varietal and sub-species level in classifying the crop plants. The present study was carried out to ascertain the nature and magnitude of genetic divergence among the 42 sesame genotypes.

Fourty two genotypes of sesamum consisting of local types, released varieties, advanced cultures were collected from TNAU, Coimbatore and ARS, Vriddachalam. The entries were grown during the rainy season 2008 at Agricultural College and Research Institute, Madurai in randomized block design with two replications. Each genotype was sown in rows of 3 m length at a distance of 40 cm between the rows and 20 cm between the plants. Recommended agronomic practices were followed to grow a healthy crop. Observations were recorded on the plant height (cm.), number of branches/plant, number of capsules/plant, number of seeds/capsule, capsule length (cm.), 1000 grain weight (g), seed yield/plant (g) and maturity (days). Multivariate analysis was done as per Mahalanobis D^2 statistics described by Rao (1952) and the genotypes were grouped into different clusters following Tocher's method. Contribution of each character for genetic divergence was estimated from the number of times each character appeared in first rank. The intra cluster distance was calculated by taking the average of the component genotypes. Inter cluster distance was arrived at by considering of all the component D^2 values possible among the members of the clusters. The values of the genetic distance between the clusters were arrived by taking the square root of the average D^2 values.

The fourty two genotypes were grouped into six clusters based on D^2 values such that on an average, the genotypes belonging to same cluster had smaller D^2 value than those belonging to different clusters (Table 1). Out of six, clusters formed, cluster I and VI is the largest group with 16 genotypes, followed by cluster V with four genotypes. While clusters, II, III and IV had two genotypes each.

The clustering pattern indicated that there was no relationship between geographic distribution and genotypic diversity as the genotypes from different geographic origin were grouped into the same clusters. It is an indication for the absence of relationship between genetic diversity and geographic diversity. Swain and Dikshit (1997) and Priti Rodge *et al.* (2003) reported similarly. Murty and Arunachalam (1966) stated that genetic drift and selection in different environments could cause greater diversity than geographic distance. Inclusion of maximum genotypes in clusters I and VI showed that the genotypes did not have wider diversity.

Table 1 Grouping of 42 genotypes of sesame into different clusters

Cluster	No. of genotypes	Genotype
I	16	PAIYUR 1, TMV 5, VRI 1, TNAU 120, KS 95010, Sankaralingapuram, Kalugasalapuram, Chinthalikarai 1, VS9701, TVS 0011, OSSEL 253, ORM 14, RT 125, RAMA, Si 1650 and Multilocule I
II	2	Varasampatty local and CO 1
III	2	Vs 9510 and Si 1115
IV	2	TMV 1 and NIC 7957
V	4	TMV 4, SVPR 1, Cordeborgea and Multilocule
VI	16	TMV 3, TMV 6, VRI 1, TNAU 165, TNAU 118, Ettayapuram local, Kallurani, Varasam patty -1, ORM 7, UMA, NIC7937, VS 9701, Cianno 13/10, TKG 22, AVTS 02-10 and URM 17

The average intra and inter cluster distances (Fig 1) revealed that the genetic diversity among the genotypes in cluster II was minimum (2.68) followed by cluster III (3.00). The maximum intra cluster distance was observed in the cluster V (7.56). Selection within this cluster might be exercised with emphasis on the high mean for the desirable traits. The relative divergence of each cluster from other clusters (inter cluster distance) indicated high order of divergence between cluster II and V (7.85) followed by cluster I and V (7.47), V and VI (7.37). Selection of parents from such clusters in the future hybridization programme would help to recover novel recombinants. Hybridization between genetically diverse genotypes in sesame to generate promising breeding material has been suggested by Alarmelu and Ramanathan (1998). Hybridization between the genotypes falling in divergent clusters *viz.*, cluster V (TMV 4, SVPR 1, Cordeborgea. and Multilocule) and cluster II (Varasampatty local and CO 1) could result in high hybrid vigour and may eventually give rise to desirable recombinants.

The contribution of individual characters towards the divergence (Table 2) indicated that seed yield/plant (49.9 %) contributed the maximum followed by days to maturity (43.3%). The other characters *viz.*, 1000 grain weight (g), number of capsules/plant, plant height, capsule length and number of seeds/capsule recorded negligible contribution. Similar observations have been recorded by Alarmelu and Ramanathan (1998) and Sudhakar *et al.* (2006). The cluster mean for different traits indicated considerable differences between the clusters for all traits (Table 3). Cluster II had highest mean values for number of capsules/plant, plant height, days to maturity, seed yield/plant, number of branches/plant, and 1000 seed weight. Cluster V exhibited lowest means for days to maturity, number of capsules/plant, seed yield/plant, number of branches/plant and 1000 grain weight. Crosses among diverse parents are likely to yield desirable recombinants. The greater the distance between two clusters, the wider the genetic diversity among the parents to be included in hybridization programme.

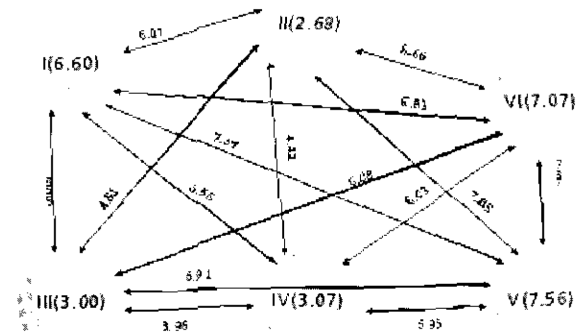

Fig. 1. Cluster diagram depicting the genetic distance

Table 2 Contribution of different characters to divergence

Character	No. of first rank	Contribution (%)
Plant height	10	1.1
No. of branches/plant	0	0.0
No. of capsules/plant	17	1.9
Capsule length	9	1.0
No. of seeds/capsule	4	0.5
Days to maturity	373	43.3
1000 grain weight	18	2.2
Seed yield/plant	430	49.9
Total	861	100

The genotypes Varasampatty local and CO 1 of cluster II and the genotypes TMV 1, NIC 7937 of the cluster IV would give promising seed yield segregants in segregating generations as these genotypes were found to possess higher cluster mean values for yield. The genotypes TMV 4, SVPR 1, Cordeborgea and Multilocule forming cluster V would produce early maturing segregants as these genotypes were found to possess lower cluster mean values for days to maturity. In general, *per se* performance and days to maturity are the important traits and hence, Varasampatty local, CO1 (cluster II) and Cordeborgea, TMV 4, Multilocule and SVPR 1(cluster V) were found to be desirable for inclusion in the sesamum breeding programme.

Table 3 Cluster mean values for eight characters towards genetic divergence in sesame

Cluster	Plant height (cm)	No. of branches/plant	No. of capsules/plant	Capsule length (cm)	No. of seeds/capsule	Maturity (days)	1000 grain weight(g)	Seed yield/ plant(g)
I	128.9	7.1	63.0	2.5	51.5	84.5	2.8	8.0
II	131.5	9.7	144.7	2.5	70.5	89.5	3.1	15.4
III	114.5	9.7	99.5	2.6	72.7	84.7	3.0	13.7
IV	131.5	7.0	98.7	2.6	54.8	85.0	2.8	14.0
V	116.5	4.9	61.3	3.0	54.6	77.3	2.6	6.6
VI	110.5	8.3	91.8	2.7	60.1	82.3	3.0	6.9

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Genetic divergence for seed yield and other characters in sesame, *Sesamum indicum* L.

P VENKATESH, M BHARATHI, N SREEDHAR AND M GANESH

Department of Genetics and Plant Breeding, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

(Received: February, 2010; Revised: June, 2011; Accepted: September, 2011)

ABSTRACT

Studies on the genetic divergence of 53 genotypes of sesame, *Sesamum indicum* L. for 13 characters led to their grouping into eight clusters. Grouping of genotypes into different clusters was not related to their geographic origin. The genotypes from different geographic locations were grouped into one cluster while genotypes of the same geographic origin showed genetic diversity. The diversity among the genotypes, measured by intercluster distances was adequate for improvement by hybridization and selection.

Key words: D^2, Genetic divergence, Sesame, Variability

Sesame (*Sesamum indicum* L.) an ancient traditional oilseed crop of India is better known as "Queen of oilseeds" by virtue of its oil quality. The crop has a large diversity in cultivars and cultural systems in India. It is grown throughout the country and round the year. Collection and evaluation of germplasm is a basic requirement for any crop improvement programme for building up a basic population of wide genetic diversity. The choice of suitable parents is of paramount importance for a planned and successful hybridization programme. Hence, efforts have to be made to identify the best parents with wide genetic divergence from germplasm pool for the characters of economic importance, so as to utilize them in hybridization programme. The present study has been undertaken with 53 sesame germplasm lines to study the nature and magnitude of genetic divergence and the characters contributing to genetic diversity by using D^2 statistics.

The materials for the study comprised of 53 sesame genotypes representing diverse eco-geographic origin. The experiment was conducted at college farm, College of Agriculture, Rajendranagar during the rainy season of 2006 in a randomized block design with three replications. Each genotype was sown in a single row of 4 m length at a distance of 30 cm between the rows and 10 cm between the plants. Five plants in each row were selected at random and the data on 13 characters were recorded. Multivariate analysis was done as per Mahalanobis (1936) D^2 statistics as described by Rao (1952) and the genotypes were formed into clusters following Tocher's method as described by Rao (1952).

The pooled divergence for all the characters withing the lines, tested by the Wilk's criterion, was significant. Hence, the analysis of genetic divergence among genotypes used in the study was considered relevant. Based on the relative magnitude of D^2 values, the 53 genotypes were grouped into eight clusters (Table 1). Cluster VI consisted of 14 genotypes followed by cluster V (12), cluster IV (11), cluster I and cluster VII (4), cluster II and cluster III (3) and cluster VIII had two genotypes. The results indicated that genetic divergence is not related to geographical diversity corroborating with earlier findings of Thangavelu and Rajasekaran (1983).

Genotypes within the same cluster diverge little from one another as the aggregate of characters is measured. Statistical distances represent the index of genetic diversity among clusters. Intra cluster distance was minimum for cluster V (15.54) and maximum for cluster II (68.52). The inter cluster distances were greater than intra cluster distances (Table 2), revealing that considerable amount of genetic diversity existed among the genotypes studied. Inter cluster distance is the primary criterion for selection of genotypes using D^2 analysis. Genotypes belonging to the clusters with maximum inter cluster distance are genetically more diverse and hybridization between genotypes of divergent clusters are likely to produce wide variability and desirable segregants (Bhatt, 1970). The maximum inter cluster distance was recorded between cluster II and VIII (7194.33) while, it was least between cluster IV and V (82.67) showing close relationship and similarity for most of the characters of the genotypes.

There was a wide range of variation in the cluster mean values for most of the characters under study (Table 3). The genotypes grouped in cluster VIII and VI were earliest to flower and mature while, the genotypes in cluster I and III were late in flowering and maturity. Cluster II had highest mean value for number of effective primaries/plant, plant height, effective capsules/plant, number of seeds/plant, 1000 seed weight, seed yield/plant and with less phyllody count. Similar results were reported by Sudhakar *et al*. (2006).

Table 1 Distribution of fifty three genotypes of sesame in different clusters

Cluster No.	No. of genotypes	Genotype
I	4	Rajeshwari, GM-IS-349-1, YLM-66, GM-NIC-8202
II	3	YLM-11, YLM-17, Swetha Thil
III	3	JCS-402, Madhavi, GM-NIC-8254
IV	11	TKG-308, Rama, JCS-9426, EC-310439, GM-NIC-16146, IS-101-2-14, GM-NIC-16332, GM-NIC-7909, GM-NIC-913, GM-SI-1260, ES-44
V	12	TKG-22, MT-111, Chandana, EC-101936, Uma, GM-NIC-8361, NIC-8263, KMR-17, GM-NIC-16330, NIC-8394, SI-157, GM-NIC-16226
VI	14	RT-103, MT-32, TKG-307, TMV-3, IS-113, GM-NIC-8252, SI-205, GM-ES-3196, Kayamkulam-1, NIC-16214, RT-46, RT-125, Krishna, GM-NIC-8394
VII	4	KIS-282-2, IS-14, IS-419, IS-421-B
VIII	2	GM-SI-3064, ES-146-1-84

Table 2 Intra (diagonal) and intercluster average of D^2 and D (parenthesis) values of fifty three genotypes of sesame

Cluster No.	I	II	III	IV	V	VI	VII	VIII
I	C 55.88 (7.47)	M 263.76 (15.39)	M 266.43 (16.32)	M 589.79 (24.29)	H 1028.26 (32.06)	H 1708.32 (41.33)	H 2606.21 (51.05)	H 4931.18 (70.22)
II		C 68.52 (8.28)	H 944.28 (30.72)	H 1500.78 (38.74)	H 2173.42 (46.62)	H 3127.09 (55.92)	H 4308.02 (65.64)	H 7194.33 (84.82)
III			C 17.40 (4.17)	C 88.51 (9.41)	M 284.66 (16.87)	M 675.61 (25.99)	H 1275.68 (35.72)	H 3008.73 (54.85)
IV				C 23.45 (4.84)	C 82.67 (9.09)	M 321.42 (17.93)	M 755.72 (27.49)	H 2172.02 (46.60)
V					C 15.54 (3.94)	C 104.71 (10.23)	M 380.19 (19.49)	H 1489.33 (38.59)
VI						C 21.80 (4.67)	C 114.03 (10.68)	M 864.20 (29.40)
VII							C 15.68 (3.96)	M 384.01 (19.59)
VIII								C 29.12 (5.40)

C = Closely related; M = Moderately divergent; H = Highly divergent

Table 3 Cluster means for twelve characters in fifty three genotypes of sesame

Cluster No.	No. of days to 50% flowering	No. of days to maturity	No. of effective primaries/ plant	Plant height (cm)	No. of effective capsules/ plant	Capsule length (cm)	No. of seeds/ capsule	1000 seed weight (g)	Seed yield plant (g)	Oil content (%)	Chlorophyll content (SPAD units)	Phyllody count (%)
I	34.75	92.08	4.80	102.64	99.23	3.10	75.34	2.84	8.56	52.60	62.56	19.39
II	33.11	88.00	5.25	115.03	131.29	3.68	79.75	3.21	12.21	54.37	65.71	9.03
III	34.22	92.88	4.27	97.79	74.09	2.85	68.52	2.33	6.46	51.39	55.37	20.00
IV	33.18	87.45	4.15	97.02	70.96	2.96	71.95	2.51	6.14	50.67	56.38	21.79
V	33.08	87.66	3.96	95.16	63.85	2.86	68.94	2.56	5.30	50.14	55.34	26.53
VI	33.07	85.09	3.69	86.95	58.43	2.77	64.80	2.36	5.01	49.52	53.39	21.31
VII	32.58	88.00	3.91	97.91	68.68	2.79	64.61	2.39	6.11	48.32	51.39	22.63
VIII	30.50	85.83	2.84	109.85	46.38	2.71	53.69	2.08	3.24	44.06	43.04	37.13

Hence, the genotypes belonging to cluster II could be exploited for hybrid vigour and desirable recombinants in future breeding programmes.

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Variability, heritability and genetic advance in sesame (*Sesamum indicum* L.)

S V S GANGADHARA RAO

Agricultural Research Station, Peddapuram-533 437, East Godavari District, Andhra Pradesh

(Received: March, 2011; Revised: November, 2011; Accepted: December, 2011)

ABSTRACT

An investigation was carried out to assess the variability, heritability and genetic advance for six characters *viz.*, plant height (cm), number of branches/plant, number of capsules/plant, 1000 seed weight (g), duration (days) and seed yield/plant (g) in 76 sesamum (*Sesamum indicum* L.) genotypes during the year 2007. High genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV) were observed for the characters number of capsule/plant, 1000 seed weight and seed yield/plant. The characters number of capsules/plant, 1000 seed weight and seed yield/plant exhibited high heritability accompanied by high genetic advance.

Key words: Genetic advance, Heritability, Sesame, Variability

Sesame (*Sesamum indicum* L.) is an important oilseed crop grown since ancient times for its rich source of oil. The presence of antioxidants *viz.*, sesamin and sesamolin in the oil increase the shelf life and imparts resistance to the human body. No other vegetable oil contains these antioxidants, hence its quality is unique and it is known as queen of oil seed crops. It contains 50 to 55% oil and rich in vitamin 'E' Genetic variability is a key for any crop improvement and pre-requisite for initiating a breeding programme. Therefore knowledge on variability is important in the selection of superior plant types. To know the nature and magnitude of the variability present in the population, an attempt was made to estimate the genetic variability in 76 genotypes of sesame collected from different sources.

The experiment was conducted at Agricultural Research Station, Yellamanchili, Visakhapatnam District, Andhra Pradesh during the rainy season of 2007. Seventy six genotypes of sesamum from different parts of the country were evaluated in the study. The germplasm was evaluated by growing in randomized block design replicated thrice. Each genotype was sown in two rows of 6m length with a spacing of 45cm. between the rows and 15cm. between the plants. The package of practice followed were as recommended by a Acharya N.G. Ranga Agricultural University. Observations were recorded on ten randomly selected plants for six characters *viz.*, plant height (cm), number of branches/plant, number of capsules/plant, 1000 seed weight (g), duration (days) and seed yield/plant (g). The genotypic and phenotypic co-efficient of variation were worked out as per the formula suggested by Burton (1952). Broad sense heritability was computed according to the formula given by Robinson (1966) and genetic advance was worked out based on the formula given by Johnson *et al.* (1955).

In the present study, the variation among genotypes was estimated as coefficient of variation (Table 1). It was evident from the study that significant differences exhibited among the genotypes in all the characters studied.

Table 1 Magnitude of variability, heritability and genetic advance for characters in sesame

Character	GCV (%)	PCV (%)	Heritability in broad sense %	Genetic advance	Genetic advance as % mean
Plant height (cm)	6.98	7.60	0.84	16.54	13.19
No. of branches/plant	13.13	25.55	-0.26	0-0.55	-13.89
No. of capsules/plant	28.86	29.79	0.93	23.91	57.59
1000 seed weight (g)	17.39	17.72	0.96	0.81	35.16
Duration (days)	2.54	2.92	0.75	3.26	4.55
Seed yield/plant (g)	37.63	39.16	0.92	4.36	74.49

Phenotypic coefficient of variation ranged from 2.92 to 39.16. Highest PCV was recorded by seed yield/plant, while least was recorded in duration. GCV followed the same trend as PCV and it ranges from 2.54 in duration to 37.63 in seed yield/plant. Highest variability for seed yield/plant was already reported by Kumaresan *et al.* (2001)

and Senthil Kumar and Sasivannan (2006). The difference between GCV and PCV for all the characters studies were low indicating that these characters were less influenced by environment. Therefore, all the characters except duration were amenable to crop improvement. All the characters except number of branches/plant studied showed high heritability (Table 1). The maximum value was recorded by 1000 seed weight while the minimum was recorded by the number of branches/plant. Solanki and Gupta (2000) and Senthil Kumar and Sasivannan (2006) reported high heritability for most of the characters in sesame. Genetic advance was high (23.91) for the number of capsules/plant moderate (16.54) for plant height and low (-0.55) for number of branches/plant.

Heritability is the ratio of genotypic variance to the phenotypic variance or total variance. Heritability is the heritable portion of phenotypic variance. It a good index of the transmission of characters from parents to their offspring (Falconar, 1981). Although heritability helps the plant breeder in selection of elite genotypes, it does not provide any indication of the amount of genetic progress that would result in selecting best individual, but depends upon the amount of genetic advances. The highest value of genetic advance (23.91) was recorded in the number of capsules/plant. The characters number of capsules/plant, 1000 seed weight and seed yield/plant recorded high heritability followed by high genetic advance as per cent of mean. Mohan (2002) also reported high genetic advance in sesame. Therefore, clearly these characters were less influenced by the environmental changes and the improvement in these traits would be more effective through selection despite their additive gene effects.

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Genetic divergence in selected germplasm of safflower (*Carthamus tinctorius* L.)

R K MURKUTE AND S N DESHMUKH

Department of Agricultural Botany, Post-Graduate Institute, Dr. PDKV, Akola-444 104, Maharashtra

(Received: September, 2010; Revised: September, 2011; Accepted: October, 2011)

ABSTRACT

A set of 150 germplasm lines and five checks of safflower (*Carthamus tinctorius* L.) were subjected to Mahalanobis D^2 analysis to access genetic diversity among them. All these genotypes were grouped into nine clusters with maximum inter-cluster distance between cluster II and cluster IX (77.55) and the minimum inter-cluster distance was observed between cluster V and cluster VI (15.79). The clustering pattern also revealed that genetic diversity is different from that of geographical diversity. Among the eleven characters studied height of insertion of first primary branch contributed maximum towards genetic divergence (33.49%) followed by plant height *(19.46%) and seeds/capitulum (16.38%).*

Key words: D^2 analysis, Genetic divergence, Safflower

Safflower (*Carthamus tinctorius* L.) is one of the important oilseed crops grown in winter season on residual soil moisture. The genetic diversity which is the basis of crop improvement is produced due to inherent genetic differences in plant species and hence, it is necessary to evaluate extent of genetic divergence in breeding lines. There are many approaches for selection of parents for hybridization programme *viz.*, selection of parents based on *per se* performance, ecogeographic diversity, regression analysis, multivariate analysis and combining ability. But, Mahalanobis D^2 analysis has ability to estimate genetic *divergence and to access the relative contribution of each* character towards genetic divergence. Bhatt (1973) has demonstrated the usefulness of D^2 statistics for choosing parents in wheat. The study of genetic divergence among genotypes will, therefore, help to plan hybridization programme to develop varieties or hybrids with high yield and high oil percentage.

One hundred and fifty safflower germplasm accessions from different geographical regions with five standard checks *viz.*, A-1, Bhima, Manjira, HUS-305 and JSF-1 were grown in the field of Oilseeds Research Unit, Dr.PDKV, Akola during the winter season of 2009. The experimental material was sown in an augmented block design, in a single row plot of four meter length. The experimental design consists of five blocks with each block containing 30 germplasm accessions and five checks. Checks were common for all block. The spacing of 45 cm x 20 cm was maintained and recommended cultural practices were followed to grow good crop. Among 150 germplasm accessions 138 were from Varanasi, six from China and remaining six were exotic. The data were recorded on five randomly selected plants for eleven quantitative traits i.e., days to 50% flowering, days to maturity, plant height (cm), height of insertion of first primary branch from ground level (cm), number of primary branches/plant, number of capitula/plant, capitulum diameter (mm), number of seeds/capitulum, 100 seed weight (g), oil content (%) and seed yield/plant (g). Oil content was estimated by NMR technique and capitulum diameter was measured by vernier caliper. The genetic divergence was estimated by Mahalanobis D^2 as described by Rao (1952) and the genotypes were grouped into different clusters by Tocher's method.

Analysis of variance has shown highly significant differences for plant height, number of capitula/plant, height of insertion of first primary branch, number of *seeds/capitulum, capitulum diameter, seed yield/plant, oil* content and number of primary branches/plant, showing the presence of wide genetic variability for these characters among the germplasm. The contribution to total divergence was maximum by height of insertion of first primary branch from ground level (33.49%). This was followed by plant height (19.46%), seeds/capitulum (16.38%), days to maturity (11.19%), number of capitula/plant (10.36%), days to 50% flowering (5.92%) and oil content (1.6%), while 100 seed weight did not have any contribution towards genetic divergence in the present study.

All 155 genotypes were grouped into nine clusters by Tocher's method. Cluster I was the largest involving 88 genotypes originated from different geographic regions. In this cluster, three checks *viz.*, HUS-305, JSF-1 and Manjira were included. The next largest cluster was cluster II (26 genotypes) followed by cluster III (24 genotypes), cluster VII (12 genotypes) while clusters IV, V, VI, VIII and IX contain only one genotypes each (Table 1). National check A-1 and local check Bhima were included in cluster III. The average inter-cluster distance was maximum between clusters II and IX (77.55) followed by cluster I and IX (68.47), cluster V and IX (67.97), cluster III and IX (67.50), cluster VII and IX *(60.62), cluster VI and IX (57.84), cluster V and* VIII

(51.74), showing that genotypes in these cluster are much diverse and can be successfully used in hybridization programme. Cluster VII recorded the highest intra cluster distance, which included 12 genotypes. This was followed by cluster III (20.99), which has 24 genotypes along with check A-1 and Bhima.

Overall study of cluster means for all 11 characters indicated that cluster IX showed maximum values for characters *viz.,* plant height, capitulum diameter, seeds/capitulum and oil content. The cluster VIII exhibited the highest cluster values for seed yield/plant and 100 seed weight while cluster V showed the highest cluster values for days to 50% flowering and days to maturity (Table 2). The results of canonical analysis revealed that 54.03% was covered in first two phases. It is clear from Canonical vector that seeds/capitulum, capitulum diameter, days to maturity, days to 50% flowering and plant height were important sources of variation and the same results were confirmed contribution of each character towards genetic divergence. These results are in conformity with that of Agarwal *et al.* (1982), Patil *et al.* (1984) and Rao *et al.* (1980). The results showed that the genotypes grouped in cluster II, IX, I and V shall produce potential transgrets if used in hybridization programme.

Table 1 Grouping of genotypes into different clusters

Cluster	*No. of genotypes*	*Genotype*
I	88	GMU-3279, 3314, 3316, 3317, 3322, 3315, 3268, 3391, 3427, 3376, 3320, 3258, 3401, 3299, 3276, 3417, 3382, 3280, 3281, 3336, 3344, 3345, 3300, 3346, 3393, 3331, 3330, 3282, 3426, 3422, 3338, 3373, 3301, 3394, 3388, 3275, 3296, 3302, 3328, 3261, 3297, 3366, 3324, 3277, 3289, 3295, 3350, 3283, 3415, 3284, 3372, 3397, 3339, 3262, 3326, 3313, 3306, 3353, 3272, 3377, 3340, 3364, 3374, 3385, 3311, 3257, 3265, 3378, 3253, 3354, 3266, 3286, 3292, 3315, 3319, 3322, 3333, 3355, 3367, 3396, 3304, 3408, 3409, 3410, 3390, HUS-305, JSF-1, Manjira
II	26	GMU-3341, 3347, 3375, 3356, 3361, 3349, 3278, 3305, 3304, 3358, 3273, 3371, 3384, 3399, 3303, 3418, 3405, 3343, 3329, 3264, 3359, 3413, 3402, 3416, 3428, 3287
III	24	A-1, Bhima, GMU-3325, 3365, 3369, 3351, 3332, 3421, 3386, 3256, 3411, 3383, 3368, 3294, 3263, 3387, 3363, 3310, 3342, 3323, 3381, 3403, 3327, 3395
IV	1	GMU-3285
V	1	GMU-3400
VI	1	GMU-3290
VII	12	GMU-3270, 3352, 3269, 3429, 3348, 3423, 3367, 3259, 3309, 3307, 3412, 3414
VIII	1	GMU-3260
IX	1	GMU-3420

Table 2 Cluster means for eleven characters

	Days to 50% flowering	Days to maturity	Plant height (cm)	Height of insertion of first primary branch	No. of primary branches/ plant	No. of capitula/ plant	Capitulum diameter (cm)	Seeds/ capitulum	100 seed weight (g)	Oil content (%)	Seed yield/plant (g)
Cluster I	69	108	54	23	8	13	18	23	3	27	7
Cluster II	66	103	48	15	10	15	17	19	3	27	6
Cluster III	73	112	60	16	11	19	19	25	3	27	12
Cluster IV	69	117	61	39	7	11	16	22	3	29	4
Cluster V	83	118	63	35	8	13	17	18	3	26	4
Cluster VI	76	118	50	32	6	8	20	31	3	31	8
Cluster VII	74	111	56	39	5	7	19	29	3	26	5
Cluster VIII	72	113	65	18	11	23	19	60	4	28	25
Cluster IX	81	116	70	39	6	7	32	83	3	30	11

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Improved yield and quality in groundnut, *Arachis hypogaea* L. with spent wash application

P KALAISELVI AND S MAHIMAIRAJA

Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu

(Received: December, 2010; Revised: July, 2011; Accepted: September, 2011)

ABSTRACT

Distillery spent wash is used in agriculture as a source of plant nutrients and irrigation water. Being plant originated, the spent wash contains all plant nutrients and organic matter. The effect of different levels and methods of spent wash application on yield of groundnut (*Arachis hypogaea* L.) was examined in 2007 through a field experiment at Research and Development Cane Farm, The Salem Co-operative Sugar Mills Ltd., Mohanur, Namakkal District. The different levels of spent wash was applied to the field in one time and split doses of application. Among the spent wash applied plots, the plot which received spent wash @ 120 m^3/ha along with NP recorded the maximum yield. Similar to yield, increase in the rate of application increased the protein and oil content significantly. A maximum kernel yield and oil content of 1641 kg/ha and 44.2 %, respectively was obtained with the application of split doses of spent wash @ 120 m^3/ha plus recommended dose of NP fertilizers. Application of split doses of spent wash was found better than one time basal application.

Key words: Groundnut, Oil content, Protein, Spent wash, Yield attributes

The distillery spent wash is a nutrient rich liquid organic waste obtained from molasses based distillery industries after biomethanation process. Currently, about 40.72 million m^3 of spent wash is generated annually from Indian distilleries. The distillery spent wash is used as a source of plant nutrients, and organic matter for various agricultural crops (Mahimairaja and Bolan, 2004). Agricultural utilization of distillery spent wash offers a low cost alternative. The presowing irrigations with distillery effluent has been reported to have no adverse effect on the germination but improved the growth and yield (Singh and Raj Bahadur, 1995). In doing so, the manurial and irrigational potential of distillery spent wash invariably have a considerable economic value in the context of present energy and fertilizer nutrient crisis. It is also important that the environmental impact of the spent wash should be identified and efforts are needed to minimize such deleterious effects on plants, soil and environmental quality. The current study was, therefore, aimed at examining the impact of spent wash application on groundnut (*Arachis hypogaea* L.) yield, yield attributes and quality parameters.

The biomethanated distillery spent wash sample was collected from the Salem Co-operative Sugar Mills Ltd, Mohanur, Namakkal District, Tamil Nadu. Spent wash pH was 7.1 and N, P and K contents were 420, 40 and 9097 mg/l. A field experiment was conducted during rainy season 2007 with groundnut (*Arachis hypogaea* L.) as a test crop to examine the effect of spent wash on nutrient dynamics at Research and Development Cane Farm, The Salem Co-operative Sugar Mills Ltd., Mohanur, Namakkal District. During the experimental period (31 August to 11 December, 2007) a rainfall of 79 mm was received by the crop. The experimental soil was sandy loam in texture; taxonomically the soil belongs to the family Typic Rhodustalfs. A representative soil sample, at 0-15 cm depth, was collected from the experimental plot to determine the initial fertility status of the soil. The soil was medium in mineral-N (201.6 kg/ha), high in $NaHCO_3$-P (18.1 kg/ha) and high in NH_4OAc-K (278.0 kg /ha) status.

There were 16 treatment combinations in field experiment. The main plots comprised one time application (M_1) and split doses of application of spent wash (M_2). There were 8 treatments of spent wash in the sub plot. T_1 - Control; T_2 - Recommend dose (RD) of NP (17-34-0); T_3 - Spent wash @ 40 m^3/ha; T_4 - Spent wash @ 40 m^3/ha + RD of NP; T_5 - Spent wash @ 80 m^3/ha; T_6 - Spent wash @ 80 m^3/ha + RD of NP; T_7 - Spent wash @ 120 m^3/ha; T_8 - Spent wash @ 120 m^3/ha + RD of NP. The plot size was 15 m^2 and a split-plot design with 3 replications was followed.

The different levels of spent wash was applied to the field uniformly as per treatments by spraying manually to each plot 15 days before sowing for main plot treatment. In the second main plot treatment (M_2), the spent wash was applied in three equal splits along with irrigation water. The first split dose of spent wash was applied 15 days after sowing. The crop was applied with N (as urea) and P (as SSP) fertilizers, as per the treatments at the RD of 17 and 34 kg/ha, respectively. The K was entirely supplied through the spent wash.

Groundnut variety TMV 7 was sown with a spacing of 30 cm x 10 cm. All other cultural operations in vogue were followed. Pod and haulm yield were recorded. The oil content in groundnut kernels was determined using Nuclear Magnetic Resonance Spectrometer (Sagare and Naphade, 1983). The seed samples were analysed for total N by *microkjeldhal method. The N content of the seed was* multiplied by the factor 6.25 to find out the crude protein content of the seeds.

Both the levels and methods of application of spent wash had significant impact on pod, kernel and haulm yield of groundnut (Table 1). Successive increase in the rate of spent wash application progressively increased the groundnut yield. The pod, kernel and haulm yield varied from 1333 to 2296 kg/ha; 896 to 1641 kg/ha and 2491 and 4478 kg/ha, respectively. The highest yields were recorded in T_8 (spent wash @ 120 m^3/ha + NP) which was closely followed by T_6 (spent wash @ 80 m^3/ha + NP). The pod yield increased with increase in the rate of spent wash up to 120 m^3/ha. Irrespective of methods of application, addition of recommended dose of NP fertilizers along with spent wash significantly improved the pod yield. There was a marked *difference in the yield between the two methods of spent* wash application where the continuous application of split doses of spent wash resulted in significantly higher pod, kernel and haulm yield than one time application. The interaction effect of methods of application and different levels of spent wash on pod and kernel yield was found significant and the highest pod yield was recorded in M_2T_8 and the lowest pod yield was recorded in M_1T_1 (Table 1). Highest haulm yield was recorded in M_2T_8 and the lowest haulm yield was recorded in M_2T_1.

Table 1 Effect of different methods and levels of spent wash application on the pod, kernel and haulm yields of groundnut

Treatments	Pod yield (kg/ha)			Kernel yield (kg/ha)			Haulm yield (kg/ha)		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
T_1 - Control	1333	1407	1370	896	936	916	2640	2491	2566
T_2 - NP alone	1481	1556	1519	1000	1054	1027	2815	2831	2823
T_3 - Spent wash @ 40 m^3/ha	1704	1852	1778	1156	1290	1223	3066	3519	3293
T_4 - Spent wash @ 40 m^3/ha + NP	2000	2074	2037	1397	1468	1432	3755	4148	3952
T_5 - Spent wash @ 80 m^3/ha	1778	1926	1852	1210	1345	1278	3413	3717	3565
T_6 - Spent wash @ 80 m^3/ha + NP	2074	2222	2148	1463	1585	1524	3941	4355	4148
T_7 - Spent wash @ 120 m^3/ha	1926	2074	2000	1317	1454	1386	3700	4024	3862
T_8 - Spent wash @ 120 m^3/ha + NP	2074	2296	2185	1473	1641	1557	4086	4478	4282
	SEd	CD (P=0.05)		SEd	CD (P=0.05)		SEd	CD (P=0.05)	
Level of spent wash (T)	33.05	70.90		31.93	68.48		70.04	150.23	
Method of application (M)	3.86	8.19		8.11	17.19		9.45	20.04	
T x M	33.94	72.76		35.81	76.62		72.54	155.48	
M x T	10.93	23.16		22.93	48.61		26.73	56.67	

M_1 = One time application; M_2 = Continuous application

The distillery spent wash is essentially a plant extract containing large quantity of plant nutrients. Spent wash application not only adds plant nutrients, but also favoured the nutrients (N, P, S, etc.,) mineralization in soil. Increases availability of these nutrients probably facilitated uptake of nutrients by groundnut which was reflected on better growth, development and yield of the crop. The results corroborates with the findings of Ramana *et al.* (2002) who reported that the distillery effluents significantly increased the seed yield in groundnut over the control. A maximum kernel yield of 1641 kg/ha was achieved with the continuous application of *120 m^3 of spent wash in split doses + RD of NP fertilizers.* It was significantly greater (11% more) than the yield observed with the same treatment (T_8) but applied in single dose as one time application. At all levels, the spent wash applied continuously in split doses had resulted in significantly higher yield than its one time application. This might be the result of relatively higher uptake of nutrients (N, P, K, Ca, Mg, S, etc.) made possible under continuous application of spent wash. Devarajan *et al.* (1998) reported higher yield of groundnut when spent wash was applied at 50, 40 and 30 times dilution. Irrespective of the methods of application, the pod, kernel and haulm yield increased linearly up to 120 m^3/ha both with and without NP fertilizers. In several studies, it has been found that the optimum dose of spent wash for achieving the maximum yield was 100 m^3/ha, beyond which reduction in yield was observed. However, in this study, the crop response up to 120 m^3 of spent wash could be due to the difference in the chemical constituents and nutrients content of the spent wash used, and the characteristics of the experimental field. Hence, the distillery spent wash may safely be used up to 120 m^3/ha for groundnut in the dryland region.

The protein and oil content of groundnut seeds improved significantly due to the application of spent wash. In the control (T_1) the seed protein content was only 22.3 to 22.4% while with spent wash application, it was improved up to 25.1%. The seed protein content markedly increased with increase in the levels of spent wash, and at a rate of 120 m^3/ha + NP fertilizers resulted in the highest seed protein content with one time application (24.6 %) and continuous application (25.1 %). Though not always significant, addition of RD of NP fertilizers further improved the protein content. Significant difference was not observed between the methods of application where the continuous application of spent wash (M_2) resulted in relatively higher protein content than one time application (M_1).

The oil content of groundnut seeds ranged from 37.1 to 42.9%. The different levels of spent wash and its methods of application had remarkable influence on the oil content. The lowest oil content was recorded in control (T_1) followed by NP fertilizer alone (T_2). The spent wash @ 120 m^3/ha + NP fertilizers (T_8) applied continuously in split doses recorded the highest oil content of 44.2%; followed by one time application of spent wash (42.9%). The two methods of application differed significantly in affecting the oil content. The crop applied with 120 m^3 of spent wash with NP fertilizers had higher amount of protein and oil content, however, it was not statistically different from the crop that received spent wash alone. There was only a small increase in seed protein and oil content due to the application of NP fertilizers alone (T_2). This shows that the improvement in protein and oil content was mainly due to the application of spent wash.

The N and S nutrition might have favoured the synthesis of higher amounts of protein and oil content. Devarajan *et al.* (1993) also reported on improvement in seed protein, and oil content in groundnut (var. TMV 7), due to the application of 40 and 50 times diluted spent wash.

ACKNOWLEDGEMENT

The authors thanks the Salem Cooperative Sugar mills Ltd., Mohanur, Namakkal District, Tamil Nadu, for financial assistance.

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Effect of moisture stress on yield and yield related parameters in sunflower (*Helianthus annuus* L.) genotypes

A GEETHA, A SIVA SANKAR, LAKSHMI PRAYAGA, J SURESH AND G ANURADHA

Department of Plant Physiology, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

(Received: January, 2011; Revised: November, 2011; Accepted: December, 2011)

ABSTRACT

Twenty nine genotypes of sunflower (*Helianthus annuus* L.) were evaluated during the winter season of 2008 to study genotypes yield and yield related parameters response to water stress. All the yield related parameters were reduced under water stress condition in all the genotypes examined. These traits are suggested to be used as selection criteria for higher yield/plant under water stress situation. Genotypes SH-491, RSF-107 and DSF-111 maintained higher capitulum weight, capitulum diameter, seed yield, total dry weight, harvest index with moderate drought susceptible index compared to remaining other genotypes hence considered as promising lines . These lines may be utilized in different drought related studies.

Keywords: Drought susceptibility index, Genotypes, Harvest index, Plant yield, Sunflower, Water stress

Producing greater harvestable yield is the ultimate purpose of growing crops. The crop genotypes show great differences for harvestable yield under drought stress.. In early plantings of sunflower (*Helianthus annuus* L.), the yield increase was associated with both an increase in achene number and in individual achene weight (Soriano *et al.*, 2002). The partitioning of dry matter to the head is critical in the process of yield determination in water stressed sunflower (Vijay, 2004). The effect of water deficits on the harvest index of sunflower is complex due to the interactions between the timing and intensity of the stress relative to the developmental processes that determine the components of yield. Exposure of sunflower plants to drought stress at bud initiation stage was more detrimental to seed and biological yield than at seed filling stage.

Water stress reduced the head diameter, 100 achene weight and yield/plant in sunflower (Reddy *et al.*, 2003). Water stress for longer than 12 days at grain filling and flowering stage of sunflower (grown in sandy loam soil) was the most damaging in reducing the achene yield in sunflower (Reddy *et al.*, 2004). In this context, the present investigation was carried out to know the effects of water stress on yield and yield related characters of sunflower genotypes and identify relatively tolerant genotypes.

The experiment was laid out in factorial random block design with two main treatments/factors and 29 sub (factors) treatments replicated thrice during the winter season of 2008 at College Farm, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad. The main two treatments were control and water stress and 29 genotypes were used as sub treatments. Controls plots were irrigated at 10 day intervals throughout the crop growth period whereas, in stress treatment plots irrigation was withheld from 40 days after sowing (DAS) to 60 DAS, which coincides with flower bud initiation stage. Each genotype was sown in two rows of 5.1 m length with spacing of 60 cm x 30 cm. Thinning was done two weeks after sowing to retain one seedling per hill. Recommended package of practices were followed to grow a healthy crop. In each entry, five plants were tagged randomly and data was recorded. For total dry matter accumulation (g/plant), five plants were harvested from each treatment for all genotypes. The component of harvested plants were separated in stem, leaf, petiole and capitulum and dried to a constant weight in hot air oven at 80°C for 48 hours and weighed in grams. Harvest index (HI) was calculated as the ratio of seed yield to total plant weight/plot. It was estimated as the proportion of total drymatter (TDM) production partitioned to economic parts expressed (%). Drought susceptibility index (DSI) was calculated according to Fischer and Maurer (1978).

Drought imposed at flower bud initiation stage caused significant reduction (21%) in TDM compared to control (Table 1). Similar results are found by researchers (Agele, 2003; Turhan and Baser, 2004). Diminished biomass due to water stress was observed in almost all genotypes of sunflower (Tahir *et al.*, 2002). However, some genotypes showed better stress tolerance than the others. Genotypes M-1029 exhibited the highest total dry weights in stress condition and interaction at harvest while lowest dry weight was recorded by DSF-114 in control, stress and interaction. The reduction in TDM under stress is due to reduced leaf area, plant height, capitulum weight, shoot dry weight.

Capitulum diameter was significantly reduced when drought was imposed at flower bud initiation stage. When

[1]E-mail: Geethagri_100@yahoo.co.in

compared to non-stress treatment, stress treatment recorded 32% reduction in capitulum diameter (Table 1). At harvesting, genotype SH-491 followed by DSF-111 and RSF-107 under control condition and RSF-107 and TSF-103 under stress condition showed higher capitulum diameter. In combined effect, RSF-107 recorded highest capitulum diameter followed by DSF -111, SH-491, while ASF-104 recorded lowest capitulum diameter. Teama and Mahmoud (1994) also reported decrease in capitulum diameter due to stress. The reduction of capitulum diameter under stress treatment was due to reduction in leaf area which is source of photo assimilates required for development of head.

Capitulum weight was highly reduced when drought was imposed at flower bud initiation stage (Table 2). Maximum capitulum weight was recorded in control (75g) and was significantly superior to stress treatment (53 g). Genotype DK-3849 and SH-491 recorded higher capitulum weight under control treatment, whereas SH-491 recorded highest capitulm weight both in control and the interaction of two main factors and the same genotypes were superior over other genotypes. While DSF-114 recorded lowest capitulum weight in both the treatments and interaction effect of main factors. Results are supported by findings of Andrich *et al.*, (1996). Poor photosynthetic performance due to water stress and reduction in assimilatory structure leads to carbohydrates and mineral deficiency which cause abortions of ovaries, pollen sterility leading to production of less achenes results in reduction in capitulum weight (Rauf and Sadaqat, 2008). Water stress resulted in 28% reduction in seed yield compared to control (Table 2). Significant variation was noticed among the genotypes with respect to seed yield. SH-491 followed by DK-3849 under control and SH-491 under stress recorded significantly superior seed yield in comparison to rest of the genotypes. However, genotype x treatments data revealed that SH-491 recorded highest seed yield and significantly superior over the rest of the genotypes. Similar findings were obtained by Rauf and Sadaqat (2008).

Table 1 Total drymatter weight at harvest, capitulum diameter/plant of sunflower genotypes as influenced by moisture stress

Genotype	Total drymatter weight (g/plant) at harvest/plant				Capitulum diameter (cm)/plant			
	Control	Stress	Mean	% decrease	Control	Stress	Mean	% decrease
RSF-101	203.7	170.0	186.9	16.6	15.3	11.0	13.2	28.3
TSF-103	308.3	234.7	271.5	23.9	28.0	19.6	23.8	29.9
ASF-107	242.8	198.3	220.5	18.3	26.3	19.3	22.8	26.6
DSF-114	144.1	114.8	129.4	20.3	10.7	6.2	8.4	42.2
SH-177	348.2	292.0	320.1	16.1	26.7	11.7	19.2	56.0
DSF-104	207.9	187.1	197.5	10.0	19.3	14.0	16.7	27.6
RSF-106	159.0	123.5	141.3	22.3	13.7	8.7	11.2	36.6
DSF-111	359.2	299.2	329.2	16.7	30.7	19.3	25.0	37.0
RSF-107	319.4	252.7	286.0	20.9	30.0	21.3	25.6	29.1
ASF-104	251.7	215.3	233.5	14.5	9.7	5.9	7.8	38.6
TSF-106	292.0	257.3	274.6	11.9	21.7	19.3	20.5	10.8
SH-491	484.5	346.9	415.7	28.4	31.7	18.0	24.8	43.2
M-1029	544.8	414.0	479.4	24.0	30.7	15.2	22.9	50.5
GP-812-5	233.7	187.7	210.7	19.7	14.2	10.7	12.4	24.7
GP-247-4	184.6	156.8	170.7	15.1	21.0	15.6	18.3	25.6
GP4-2605	214.9	187.3	201.1	12.8	11.3	9.1	10.2	19.7
GP-69	293.6	255.0	274.3	13.1	14.7	11.9	13.3	19.1
GP4-2935	368.7	324.2	346.4	12.1	25.7	16.3	21.0	36.4
GP-978	224.9	171.7	198.3	23.7	14.9	9.6	12.3	35.5
DK-3849	504.6	319.5	412.1	36.7	28.8	13.3	21.1	53.8
GP9-515-7-3	306.2	240.0	273.1	21.6	23.7	18.1	20.9	23.5
GP4-2885	177.1	147.2	162.1	16.9	13.6	11.0	12.3	18.7
RHA-274	183.4	147.0	165.2	19.9	10.9	8.0	9.5	27.1
GP4-187	224.1	183.2	203.6	18.3	13.5	11.2	12.3	17.3
GP-2793	293.2	230.7	262.0	21.3	16.2	13.1	14.7	18.9
GP4-2704	221.5	196.0	208.7	11.5	15.3	11.1	13.2	27.4
EC-512690	279.1	249.6	264.4	10.6	18.7	12.9	15.8	30.9
GP9-846-4-4	249.0	189.7	219.3	23.8	16.4	13.4	14.9	18.7
GP9-38-C-2-1	241.3	188.3	214.8	22.0	13.9	9.7	11.8	30.5
Mean	279.3	220.1	249.7	21.2	19.6	13.3	16.4	32.2
CD (P=0.05) for treatments		3.0				0.5		
CD (P=0.05) for genotypes		11.3				1.8		
CD (P=0.05) for T x G		15.9				2.6		

Table 2 Capitulum weight/plant and seed yield/plant of sunflower genotypes as influenced by moisture stress

Genotype	Capitulum weight (g)/plant				Seed yield (g)/plant			
	Control	Stress	Mean	% decrease	Control	Stress	Mean	% decrease
RSF-101	48.7	39.0	43.8	19.9	25.2	15.0	20.1	40.5
TSF-103	83.0	59.2	71.1	28.7	44.9	40.1	42.5	10.8
ASF-107	81.9	40.7	61.3	50.3	40.0	23.0	31.5	42.5
DSF-114	38.7	19.0	28.8	50.9	11.4	8.4	9.9	26.8
SH-177	101.7	83.3	92.5	18.1	66.5	32.7	49.6	50.8
DSF-104	60.6	50.1	55.3	17.3	24.6	20.4	22.5	17.2
RSF-106	44.5	32.6	38.6	26.7	19.3	15.3	17.3	20.6
DSF-111	105.0	84.7	94.8	19.4	87.2	67.0	77.1	23.2
RSF-107	105.4	82.0	93.7	22.2	67.7	59.7	63.7	11.8
ASF-104	41.7	31.4	36.6	24.8	19.3	15.6	17.4	19.0
TSF-106	73.0	62.3	67.7	14.6	38.0	32.0	35.0	15.8
SH-491	131.3	85.7	108.5	34.8	102.0	81.0	91.5	20.6
M-1029	120.4	71.0	95.7	41.0	95.2	51.0	73.1	46.4
GP-812-5	56.7	40.3	48.5	28.8	35.4	15.3	25.4	56.7
GP-247-4	60.6	41.7	51.2	31.3	33.0	23.6	28.3	28.5
GP4-2605	61.6	52.3	57.0	15.0	25.7	23.5	24.6	8.6
GP-69	51.3	41.3	46.3	19.5	54.7	48.5	51.6	11.3
GP4-2935	91.3	68.0	79.6	25.5	66.2	40.2	53.2	39.3
GP-978	69.7	52.0	60.8	25.4	54.3	49.3	51.8	9.2
DK-3849	133.6	74.0	103.8	44.6	100.3	48.8	74.5	51.3
GP9-515-7-3	91.3	69.7	80.5	23.7	47.3	21.3	34.3	54.9
GP4-2885	53.5	38.7	46.1	27.7	23.7	14.3	19.0	39.4
RHA-274	41.3	31.7	36.5	23.4	9.9	8.5	9.2	14.8
GP4-187	58.5	42.3	50.4	27.6	35.7	33.3	34.5	6.7
GP-2793	78.3	56.0	67.2	28.5	45.1	36.3	40.7	19.6
GP4-2704	75.4	48.0	61.7	36.4	41.8	38.3	40.0	8.4
EC-512690	76.3	45.0	60.7	41.1	37.8	33.3	35.5	11.9
GP9-846-4-4	63.7	46.3	55.0	27.2	31.0	24.0	27.5	22.6
GP9-38-C-2-1	69.7	40.7	55.2	41.6	30.3	28.7	29.5	5.5
Mean	74.8	52.7	58.9	42.5	45.3	32.7	39.0	27.8
CD (P=0.05) for treatments				1.0			0.8	
CD (P=0.05) for genotypes				3.8			3.1	
CD (P=0.05) for T x G				5.3			4.3	

The decrease in yield might be due to decreased sink size (mainly number of seeds) and seed weight. It may be related with decreased photosynthetic efficiency by degradation of chlorophyll, lower production and translocation of organic material from source to sink (Amrutha *et al.*, 2007). Harvest index is a useful trait in discrimination between drought sensitive and tolerant lines. There was 27% reduction in harvest index compared to non stress treatment (Table 3). Significant differences among genotypes were observed for HI (%). GP4-2704 followed by ASF-107 and RSF-107 in control and GP-247-4 and RSF-107 in stress showed higher HI over rest of other genotypes. However, in genotype x treatment interaction, RSF-107 recorded maximum HI, which was significantly superior over other genotypes. Whereas, lowest HI was recorded by ASF-104. The results are in accordance with findings of Reddy *et al.* (2003) and Rauf and Sadaqat (2008). Exposure of sunflower plants to drought stress at bud initiation stage was more detrimental to seed and biological yield than at seed filling stage (Prabhudeva *et al.*, 1998). Higher HI was obtained due to better translocation of photosynthates to the reproductive part under drought stress (Rauf and Sadaqat, 2008).

Among the genotypes there were significant differences in DSI values (Table 3). Genotype GP-812-5 recorded higher DSI value followed by GP9-515-7-3, SH-177, DK-3849 and M-1029, while genotype GP9-38-C-2-1 recorded lowest DSI. A higher value of susceptibility index indicates higher susceptibility of a genotype to the stress. Similar findings were also reported by Rauf and Sadqat (2008). Higher DSI of a genotype under water stress situation is due to higher yield reduction caused due to poor defensive mechanism against water stress.

Based on the above results, the genotypes SH-491, DSF-111, M-1029 and DK-3849 showed promising results for yield and yield related parameters under drought condition and these lines may be utilized in breeding for drought tolerance and marker studies.

Table 3 Drought susceptibility index (DSI) and harvest index (HI) of sunflower genotypes as influenced by moisture stress

Genotype	Harvest index (%)				DSI
	Control	Stress	Mean	% decrease	
RSF-101	24.0	23.0	23.5	4.2	1.47
TSF-103	26.9	25.2	26.1	6.3	0.38
ASF-107	33.7	20.5	27.1	39.2	1.53
DSF-114	26.9	16.6	21.8	38.1	1.01
SH-177	29.3	28.6	28.9	2.4	1.85
DSF-104	29.2	26.8	28.0	8.3	0.63
RSF-106	28.1	26.5	27.3	5.8	0.75
DSF-111	29.2	28.3	28.8	3.2	0.85
RSF-107	33.1	32.5	32.8	1.7	0.43
ASF-104	16.6	14.6	15.6	11.9	0.69
TSF-106	25.0	24.3	24.6	3.0	0.55
SH-491	27.1	24.7	25.9	8.9	0.75
M-1029	22.1	17.2	19.7	22.5	1.68
GP-812-5	24.3	21.5	22.9	11.5	2.06
GP-247-4	33.0	26.6	29.8	19.3	1.03
GP4-2605	28.7	28.0	28.3	2.6	0.24
GP-69	17.5	16.2	16.9	7.5	0.33
GP4-2935	24.8	21.0	22.9	15.1	1.4
GP-978	31.0	30.4	30.7	2.0	0.33
DK-3849	26.5	23.2	24.8	12.5	1.84
GP9-515-7-3	29.8	29.1	29.4	2.5	1.98
GP4-2885	30.3	26.3	28.3	13.1	1.38
RHA-274	22.6	21.6	22.1	4.2	0.54
GP4-187	26.1	23.1	24.6	11.6	0.21
GP-2793	26.8	24.3	25.5	9.4	0.72
GP4-2704	34.1	24.5	29.3	28.2	0.29
EC-512690	27.4	18.0	22.7	34.1	0.45
GP9-846-4-4	25.6	24.4	25.0	4.6	0.83
GP9-38-C-2-1	29.0	21.6	25.3	25.7	0.2
Mean	26.8	19.5	23.2	27.1	0.91
CD (P=0.05) for treatments	0.5				-
CD (P=0.05) for genotypes	1.8				0.52
CD (P=0.05) for T x G	2.6				-

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Effect of zinc levels on nickel and other micronutrient cations in the leaves of castor (*Ricinus communis* L.) genotypes

I Y L N MURTHY AND CH V HARIPRIYA

Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

(Received: October, 2010; Revised: March, 2011; Accepted: September, 2011)

ABSTRACT

Two separate field experiments were conducted during the rainy season of 2005 with castor (*Carthamus tinctorius* L.) variety DCS-9 and hybrid DCH-32 to study the influence of graded levels of zinc (Zn) on nickel (Ni) and other micronutrient cationic content in the recently matured leaves (RML). Nickel content in the leaves of DCS-9 and DCH-32 varied from 15.6 to 64.5 mg/kg and 27.3 to 69.7 mg/kg, respectively among the graded doses of Zn. Micronutrient ratios computed for Zn/Ni, Fe/Ni, Mn/Ni and Cu/Ni in RML of castor genotypes has shown an increasing trend with the increased levels of Zn application. Higher levels of Zn application resulted in higher Zn and lower Ni content in leaves irrespective of variety or hybrid.

Key words: Castor, Micronutrient cations, Nickel, Zinc

Plant species vary in their capacity to remove and accumulate heavy metals, *viz.*, cadmium (Cd), lead (Pb), chromium (Cr) and nickel (Ni) (Zurayk *et al.*, 2001). Castor (*Ricinus communis* L.) crop is known to be a hyper accumulator of Ni element hence, few researchers (Vwioko *et al.*, 2006; Malarkodi *et al.*, 2008) have tried in bioremediation of contaminated soils. Even though the heavy metal like Ni content in the soil may be found within the safe limits, but they are toxic to life when transmitted even at very low concentrations. The safe limits for heavy metals like Cd, Pb, Cr and Ni in irrigation waters and soils as per international standards are 0.05, 2.0, 1.0 and 2.0 mg/l and 3.0, 300, 120 and 75 mg/kg, respectively (IIHR web site). Nickel was considered as an essential element for the growth of higher plants (Brown *et al.*, 1987). Heavy metals like Ni known to bind certain proteins and essential elements, thereby exhibiting normal functions in metabolism. Similarly, Zn is a well established essential micronutrient for the crop growth. Castor crop response to Zn application was reported recently by several researchers in the soils of the semi-arid tropical region (Murthy, 2007; Murthy and Padmavathi, 2007; Rego *et al.*, 2007). Nickel content may vary between the soil types and Ni concentration in plants is affected by many factors such as soil properties, climatic conditions, plant species and cultivars, etc. In most plants, Ni content in vegetative organs is in the range of 1-10 mg/kg dry weight (Marschner, 1995). Nutrient interactions also play a key role in the nutrition of crop. Hence, an attempt was made to study the influence of graded levels of Zn on Ni and other micronutrient cationic content *vis-à-vis* the optimum Zn level and the nutrient ratio in the RML of castor genotypes. Two separate field experiments were conducted during the rainy season of 2005 at Directorate of Oilseeds Research, Rajendranagar experimental farm with castor variety DCS-9 and hybrid DCH-32. Physico-chemical characteristics of the red sandy loam soil are as follows, pH: 7.1; E.C. 0.3 dS/m; organic carbon: 3 g/kg, available nitrogen, phosphorus and potassium were 178, 8.0 and 240 kg/ha, respectively. Available Zn (DTPA-Zn), Ni (DTPA-Ni), Fe (DTPA-Fe), Mn (DTPA-Mn) and Cu (DTPA-Cu) in soil were 0.40, 0.15, 4.2, 2.5 and 0.4 mg/kg, respectively. A randomized block design was followed and treatments were replicated thrice. Twenty one plots (each plot size 3.6 x 4.0 Sq.m) under the variety and another 21 plots under hybrid received graded doses of Zn (zinc oxide) *viz.*, @ 0, 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 kg/ha. Nitrogen, phosphorus and potassium were applied to all the plots as per recommended doses (60:40:0), respectively. Recently matured leaf (RML) samples from the top of main stem were collected at primary spike initiation stage, washed with tap water followed by 1% hydrochloric acid and distill water. Then shade and oven dried at 60°C and powdered in stainless steel Wiley mill. The samples were acid digested with triacid mixture [nitric:perchloric (HNO_3:$HClO_4$) in 9:4 ratio; Tandon, 1995] and the extract was used for analysing Zn, Fe, Mn, Cu and Ni concentration by using Atomic Absorption Spectrophotometer, GBC 933.

In general, at primary spike initiation stage of the crop, Zn content in the RML of castor increased with an increased dose of Zn irrespective of variety and hybrid (Table1). However, the Zn content in the leaves was relatively higher in hybrid than in the variety. Similar trend was observed in other micronutrient Fe, Mn, Cu and Ni contents. Iron and Mn content in the RML of both the variety and hybrid has shown statistically significant variation among the Zn treatments whereas Zn and Cu have shown non-significant variation. Nickel content varied significantly among the Zn treatments both in variety and hybrid. Among the Zn treatments as the Zn content in RML increased, the Ni content has decreased in both the DCS-9 and DCH-32 genotypes (Table 1). Korner *et al.* (1987) found that both Ca^{+2} and Mg^{+2} inhibited Ni^{+2} uptake noncompetitively by an unknown mechanism, whereas Cu^{+2}, Zn^{+2} and Co^{+2} all competitively inhibited Ni^{+2} absorption. They suggested that all four divalent cations were transported via the same mechanism, based on their similar ionic radii. Some minor variation in trend with Zn levels was noticed in other micronutrients in both the genotypes. The Ni removal by leaves was not equal in castor genotypes. Nickel uptake and concentration in plant foliage can differ markedly between species even in the same soils (Vwioko *et al.*, 2006). In general, more than 50 mgNi/kg on the dry weight basis was considered as critical toxicity level for moderately tolerant plants (Marschner, 1995). Recently, Malarkodi *et al.* (2008) reported that Ni accumulation in various plant parts of castor plant follows the order: root > leaf > stem > petiole. This might be due to the direct and continuous contact with roots in the contaminated soil.

Table 1 Influence of Zn levels on Ni and other micronutrient cations in recently matured leaves of castor genotypes at primary spike initiation stage

Zinc levels (kg/ha)	Zn	Fe (mg/kg)	Mn	Cu	Ni	Zn/Ni	Fe/Ni	Mn/Ni	Cu/Ni
Castor variety DCS-9									
0	99.4	475.8	113.3	55.0	64.5	1.54	7.37	1.76	0.85
2.5	100.3	572.5	119.6	52.9	61.5	1.63	9.30	1.94	0.86
5.0	101.8	586.3	150.8	54.2	53.3	1.91	10.99	2.83	1.02
7.5	109.6	514.6	135.4	57.1	43.7	2.51	11.77	3.10	1.31
10.0	109.0	607.9	162.5	57.1	35.2	3.10	17.27	4.62	1.62
12.5	108.5	478.8	155.0	55.4	23.3	4.65	20.52	6.64	2.38
15.0	110.2	362.5	155.8	52.9	15.6	7.06	23.24	9.99	3.39
SEm+	12.8	59.6	14.2	6.7	1.79				
CD (P=0.05)	NS	183.8	43.7	NS	5.53				
Castor hybrid DCH-32									
0	109.4	523.4	124.7	60.5	69.7	1.57	7.51	1.79	0.87
2.5	110.3	629.8	131.5	58.2	71.9	1.53	8.75	1.83	0.81
5.0	112.0	644.9	165.9	59.6	65.7	1.70	9.81	2.52	0.91
7.5	120.5	566.0	149.0	62.8	58.4	2.06	9.69	2.55	1.08
10.0	119.9	668.7	178.8	62.8	46.7	2.57	14.33	3.83	1.35
12.5	119.3	526.6	170.5	61.0	38.7	3.08	13.60	4.40	1.57
15.0	121.2	398.8	171.4	58.2	27.3	4.45	14.62	6.29	2.13
SEm+	13.5	65.8	15.6	7.7	1.64				
CD (P=0.05)	NS	202.8	48.0	NS	5.04				

Micronutrient ratios computed for Zn/Ni, Fe/Ni, Mn/Ni and Cu/Ni in RML of castor genotype DCS-9 varied from 1.54 to 7.06, 7.37 to 23.24, 1.76 to 9.99 and 0.85 to 3.39, respectively. Similarly, in RML of castor genotype DCH-32 the Zn/Ni, Fe/Ni, Mn/Ni, and Cu/Ni ratio varied from 1.57 to 4.45, 7.51 to 14.62, 1.79 to 6.29 and 0.87 to 2.13, respectively. These ratios in both the genotypes have shown an increasing trend with the increased levels of Zn application (Table 1). The nutrient ratios were often less affected by plant age than nutrient concentration based on the dry matter. Ratio of nutrient element concentrations is often better indicators of nutrient deficiency/sufficiency than single nutrient element concentrations. In general, when a ratio is low, a response to the element in the numerator will be obtained if it is limiting (Tisdale *et al.*, 1985). Quadratic equation is fitted between the micronutrient ratio and the Zn rate to find out the optimum dose of Zn for both DCH-32 and DCS-9. Optimum rate of Zn for DCH-32 was found as 2.26 kg/ha and the corresponding optimum ratio of Zn/Ni, Fe/Ni, Mn/Ni and Cu/Ni in the RML leaves was 1.52, 8.7, 1.89 and 0.83, respectively. Similarly, for DCS-9 the optimum dose was found as 2.52 kg/ha and the corresponding optimum ratio of Zn/Ni, Fe/Ni, Mn/Ni and Cu/Ni in the RML leaves was 1.50, 8.91, 1.84 and 0.82, respectively.

Thus, castor genotypes are mining some amount of Ni besides the essential micronutrient cations and its content in the RML of castor hybrid DCH-32 was higher than in the variety DCS-9 at primary spike initiation stage. Higher levels of Zn application resulted in higher Zn and lower Ni content in leaves irrespective of variety or hybrid. Role of Ni in castor as an essential nutrient or as a phytoextractor of contaminants from the soil needs further studies.

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Studies on growth analysis of linseed, *Linum usitatissimum* L. varieties under different sowing dates

F G SHAIKH, D N GOKHALE, N K KALEGORE, B S ROKADE AND B D THAKUR

Department of Agronomy, College of Agriculture, Latur-413 512, Maharashtra

(Received: August, 2011; Revised: September, 2011; Accepted: November, 2011)

ABSTRACT

The growth parameters and linseed (*Linum usitatissimum* L.) yield were influenced by different dates of sowing. The early sowing of linseed in the 40[th] and 41[st] meteorological weeks (MW) was significantly superior over sown conditions. Among the varieties, 'Garima' was found significantly superior to 'Kiran' and RLC-4 in different growth parameters and yield of linseed.

Keywords: Dates of sowing, Linseed, Varieties

Linseed (*Linum usitatissimum* L.) is a source of drying oil used in the industries. India is a leading producer of linseed in the world. Linseed occupies an area of about 525.5 lakh ha in India with an annual production of 211.9 lakh t. and average productivity of 403 kg/ha. The area under linseed in Maharashtra was 87 lakh ha. with an annual production of 22 lakh t. and average productivity was 253 kg/ha (Agropedia, 2010). Seed yield/ha of this crops is very low in India, therefore, it is necessary to analyse the causes for low yield and the measures to increase it. Systematic analysis of the cause of variations is imperative. Techniques of growth analysis have become a very useful tool to the research workers in answering the variation in yield and this study of growth analysis is gaining importance in all the field crops. There is a need to develop or identify high yielding varieties and to find out optimum sowing time for the region.

A field experiment was conducted at Agriculture College Farm, Latur, Marathwada Agricultural University during winter season of 2007. Experimental soil was a Vertisol with good drainage. The soil was clayey in texture, low in available nitrogen (265.2 kg/ha), medium in available phosphorus (15.7 kg/ha), high in available potassium (941.9 kg/ha) and slightly alkaline in reaction (pH 7.4). The field was fallow in rainy season. The experiment was laid out in split plot design with three replications, with 18 treatment combination of date of sowing (D_1=40 MW, D_2=41 MW, D_3=42 MW, D_4=43 MW, D_5=44 MW and D_6 46 MW) in main plot and three varieties (V_1=Kiran, V_2=Garima and V_3=RLC-4) in sub-plot. Sowing of linseed crop was done by dibbling method as per the treatments. The gross and net plot size of experimental unit was 6.4 m x 3.6 m and 5.4 m x 2.4 m, respectively with a row spacing of 30 cm and plant spacing of 10 cm. Basal dose of NPK @ 50:25:0 kg/ha in the form of urea, single super phosphate and muriate of potash were applied uniformly to all the plots at the time of sowing. The leaf area index (LAI) was worked out by dividing the leaf area/plant by the land area occupied by the plant.

The sowing of linseed crop in first (D_1) date of sowing at 40[th] MW produced significantly higher seed yield (889 kg/ha), straw yield (2109 kg/ha) and oil yield (349 kg/ha) as compared to subsequent delayed sowings (Table 2). Also the drymatter production was significantly higher when the crop was sown in 40[th] MW (D_1), which might be because of the higher leaf area/plant through out the growth period. This has provided greater photosynthetic surface, enabling the plant to produce higher seed yield. Similar trend was observed regarding LAI. These results are in line with Arjun Sharma and Gururaj Hunsigi (1997). The absolute growth rate (AGR) and crop growth rate (CGR) was observed maximum when sowing of linseed was undertaken at 40[th] MW as compared to other dates of sowing. The maximum value of AGR and CGR was recorded between 45-60 DAS. The drymatter accumulation continued to be higher level with increase in the life of crop except at harvest. It is worth noting that the functional leaf area and LAI were progressively increased gradually from 30 DAS and declined after 90 DAS in all dates of sowing (Table 1).

The increased seed as oil yield in variety Garima (656 kg/ha) was attributed to growth component such as the functional leaf area, LAI, AGR and CGR. The functional leaf area and LAI was recorded maximum in variety Garima than other variety. Leaf area and leaf area index was increased gradually from 30 DAS, attained the highest value at 60 DAS and declined sharply after 90 DAS in all varieties. Similar trends were also observed by Arjun Sharma and Gururaj Hunsigi (1997). The maximum value of CGR was recorded in variety RLC-4 followed by variety Garima and Kiran. The CGR was highest in variety Garima followed by variety RLC-4 and Kiran. The drymatter accumulation was significantly higher in variety Garima at all stages of crop growth except at harvest followed by RLC-4 and Kiran. Higher seed yield, straw yield and oil yield was recorded in variety Garima than other varieties. Similar results have been reported by Samui and Pintoo Bandopadhyay (1991). The higher seed yield was ascribed to the higher CGR and the AGR. Reddy (1983) opined that synthesis, accumulation and translocation of photosynthates depends on the building up of the efficient photosynthetic super structure in the early phase of the crop growth cycle.

Table 1 Leaf area, leaf area index, absolute growth rate and crop growth rate of linseed as influenced by date of sowing and varieties at various crop growth stages

Treatment	Leaf area (cm^2/plant) (DAS)			Leaf area index (DAS)			Absolute growth rate g/plant/ day			Crop growth rate (g/dm^2/ day		
	30	60	90	30	60	90	31-45	46-60	61-75	31-45	46-60	61-75
Date of sowing (MW)												
40	66.2	320.8	108.3	0.22	1.06	0.36	1.02	0.84	0.06	0.06	0.07	0.05
41	62.5	183.4	102.9	0.21	0.61	0.34	0.91	1.12	0.52	0.04	0.05	0.04
42	55.2	180.8	100.6	0.18	0.60	0.33	1.07	0.91	0.50	0.04	0.01	0.04
43	42.0	141.5	97.8	0.14	0.47	0.32	1.03	0.89	0.11	0.01	0.03	0.01
44	27.1	122.1	87.0	0.09	0.40	0.29	1.01	1.11	0.04	0.02	0.02	0.01
45	39.0	83.1	78.2	0.13	0.27	0.26	1.03	0.63	0.10	0.03	0.02	0.00
SEm±	1.1	5.8	2.1	0.00	0.12	0.00	0.02	0.02	0.00	0.00	0.00	0.00
CD (P=0.05)	3.7	18.4	6.7	0.01	0.40	0.02	0.07	0.06	0.01	0.00	0.00	0.00
Variety												
Kiran	44.3	164.8	95.1	0.14	0.54	0.21	1.00	0.91	0.22	0.04	0.04	0.04
Garima	50.8	205.5	103.4	0.16	0.68	0.34	1.00	0.93	0.18	0.05	0.05	0.04
RLC-4	45.9	145.3	88.6	0.15	0.44	0.29	1.00	0.96	0.25	0.04	0.04	0.04
SEm±	1.12	3.9	2.2	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00
CD (P 0.05)	3.5	12.8	7.1	0.01	0.04	0.02	0.07	0.02	0.01	0.00	0.00	0.00

Table 2 Total drymatter accumulation/plant at different growth stages and seed, straw and oil yield (kg/ha) as influenced by date of sowing and varieties

Treatment	Total drymatter accumulation (g/plant) (DAS)				Seed yield (kg/ha)	Straw yield (kg/ha)	Oil yield (kg/ha)
	30	60	90	At harvest			
Date fo sowing (MW)							
40	0.48	2.3	5.3	2.3	889	2109	349
41	0.26	1.4	4.3	2.0	823	1999	332
42	0.25	1.4	2.7	2.1	654	1999	266
43	0.41	1.2	2.5	1.7	543	1540	217
44	0.35	2.0	2.7	1.3	473	1582	188
45	0.05	0.9	1.5	1.0	334	979	134
SEm±	0.06	0.0	0.1	0.0	7.3	10.5	5.4
CD (P =0.05)	0.02	0.0	0.3	0.0	23.1	33.1	17.2
Variety							
Kiran	0.19	1.5	2.8	1.7	613	1619	248
Garima	0.21	1.7	3.5	2.0	656	1773	258
RLC-4	0.20	1.6	2.9	1.8	588	1712	237
SEm±	0.00	0.0	0.0	0.0	6.4	6.8	3.6
CD (P= 0.05)	0.01	0.0	0.0	0.1	19.9	19.9	10.5

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Ph : (040) 24016141/24015345; Fax : (040) 24017969
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Computer Typesetting : **Sasi Graphics**, Rajendranagar, Hyderabad Printed by **M/s Progressive Press Pvt. Ltd**, Hyderabad