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

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

JOURNAL OF OILSEEDS RESEARCH

Previous Issue : Vol. **34**, No. 3, pp. 119-190

Vol. **34**, No. 4 December, 2017

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GDM 4: High yielding, high oil content and bold seeded variety of Indian mustard [*Brassica juncea* (L). Czern & Coss]

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(Received: August 8, 2017; Revised: November 15, 2017; Accepted: December 7, 2017)

ABSTRACT

Extensive crop breeding efforts were made to develop high yielding, high oil content and bold seeded varieties for mustard growing area of Gujarat. As a result, the genotype SKM 301 (GDM 4) was identified and evaluated for its yield potentiality along with state and national check varieties (Varuna, GM 3 and Kranti) at various locations of Gujarat as state trial and different locations of Zone IV under AICRP on Rapeseed-Mustard trials. As compared to check varieties, the entry SKM 301 recorded higher mean seed yield 2417 kg/ha and high oil content (39.02%) and 1000-seed weight (5.70 g). Tolerant to lodging and shattering are additional features of this entry, SKM 301.

Keywords: GDM 4, Indian mustard, Oil content, Seed yield

Rapeseed-Mustard is an important edible oilseed crop in India. In the country, there was remarkable increase in production during last 30 years. The production of mustard was around 2.68 million tonnes with productivity of 650 kg/ha during 1985-86, which has been increased to 6.82 million tonnes during 2015-16 and increase in productivity was more than 1184 kg/ha (Anonymous, 2016). The mustard productivity of Gujarat was ranked second (1710 kg/ha) after Haryana with cultivated area about 2.01 lakh ha and production was 3.44 lakh tonnes during 2016-17 (Anonymous, 2017; Kumar *et al*., 2017). North Gujarat region is favourable for mustard cultivation and it covers more than 95 per cent of total mustard growing areas of Gujarat State are in the Banaskantha, Mehsana, Patan, Gandhinagar, Sabarkantha and Kutch districts which falls under the jurisdiction of S.D. Agricultural University, Sardarkrushinagar. Mustard is an important *rabi* edible oilseed crop gives good remuneration as this crop require fewer inputs like seed, fertilizer and irrigation, as compared to other *rabi* crops *viz*., wheat and potato.

Winter is very short in this region and during the end of crop season temperature start to rise early which resulted in forced maturity and reduce seed yield. Hence, short duration and high yielding varieties are the need of hours for this region. To fulfill this requirement, efforts were made which resulted in the development and release of mustard varieties, GM 1 (1989) and GM 2 (1996). Breeding endeavor in this direction was continued and the new genotype was isolated and released as GM 3 in 2005-06 (Thakkar *et al*., 2010), which was dominant variety with higher yield potential. However, enhanced production of mustard is required to fulfill the increased oil demand by enhancing mustard production. So, there is urgent need to develop a variety with high and stable yield potential, adaptable to varying climatic conditions, better seed quality with diseases and pest resistance. To develop such type of variety and considering present need, new genotype SKM 301 was developed at Castor-Mustard Research Station, SDAU, Sardarkrushinagar and released as Gujarat Dantiwada Mustard 4 (GDM 4) during the year 2011.

MATERIALS AND METHODS

The breeding efforts were initiated at Castor-Mustard Research Station, Sardarkrushinagar, the crosses were attempted between SKM 9433 and GM 2 in the year 1998-99 and segregating material handled through pedigree method of breeding, resulting the line SKM 301 has been isolated and evaluated for its yield potentiality with check varieties Varuna, GM 3 and Kranti at various 36 centers of Gujarat under State trials (31 locations of Large Scale Varietal Trial, 4 locations of Small Scale Varietal Trial as well as one location in Preliminary Yield Trial) during 2008-10. In AICRP Rapeseed-Mustard trial it was also evaluated in 13 locations (7 locations of IVT and 6 locations of AVT I) of Zone IV during the year 2008-10 along with national checks *viz.*, Varuna and Kranti. The recommended packages of practices were followed while conducting the trials to raise the healthy crop. The yield data was analyzed by methods developed by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The seed yield of mustard genotype SKM 301 was recorded and compared with three check varieties *viz.,* Varuna, GM 3 and Kranti at different locations of Gujarat. The genotype SKM 301 resulted higher seed yield (2417 kg/ha) on an average of 36 trials as compared with state and national check varieties *viz.,* Varuna (SC) 1983 kg/ha, GM 3 (SC) 2087 kg/ha and Kranti (NC) 2002 kg/ha, with corresponding increase in seed yield by 20.94, 11.1 and 24.7 per cent, respectively (Table 1). The perusal of data obtained from two trials *viz.,* IVT in 7 and AVT I during the years (2008-10) under AICRP on Rapeseed-Mustard tested at 6 different locations of Zone-IV revealed that the mustard genotype SKM 301 was produced (2026 kg/ha) 13.9 and 45.6 per cent higher yield than national check varieties Varuna (1390 kg/ha) and Kranti (1778 kg/ha), respectively (Table 2). Oil yield per ha of SKM 301 was also 11.9 and 55.7 per cent higher than Kranti (NC) and Varuna (NC) in AICRP Rapeseed-Mustard trials of Zone IV (Table 4).

The average white rust and powdery mildew disease severity was lower as compared to check varieties which indicate that this variety is tolerant to white rust and powdery mildew diseases (Table 5). The entry SKM 301 was also screened against aphid infestation under natural condition (late sown) and it was tolerant to aphid infestation (Table 6). Analysis of characteristic features of SKM 301 and two checks exhibited that it has short plant stature with higher number of branches and productive siliquae per plant as compared to both check varieties *viz.,* Varuna and GM 3 (Table 3). Previously, GM 3 variety was released in year 2007 with featuring early maturity, higher yield, bold seeded and high oil content (Thakkar *et al.,* 2010). GDM 4 exhibited superiority over GM 3. Special features of GDM 4 includes erect plant type, tolerant to lodging and shattering, suitable for timely sown irrigated condition (Zone-IV), non-shattering habit, high oil yielding, medium maturity group suitable for Indian Mustard Zone IV and II, low water requirement, raised well under rainfed area of Zone-II and stable performance

Gujarat state varietal release committee released the mustard genotype SKM 301 as new name GDM 4 (Gujarat Dantiwada Mustard 4) for large scale commercial cultivation in mustard growing area on the basis of its consistence superior yield performance, tolerance to white rust and powdery mildew diseases and aphid infestation, suitable for irrigated conditions. GDM 4 has been registered (IC No. 588756) and conserved under long term storage at NBPGR, New Delhi and also notified in the Gazette of India, Ministry of Agriculture (Department of agricultural and Co-operation), New Delhi, after consultation with Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops, ICAR, Krishi Bhavan, New Delhi, with the Notification number S. O. 1228 (E) dated 7th May, 2015.

Table 1 Mean seed yield performance of mustard genotype SKM 301 (GDM 4) under state trials at various locations in Gujarat in comparison to Varuna, GM 3 and Kranti (2003-10)

Location	Trials	Year	Mean seed yield (kg/ha)				Per cent increase over checks		
			GDM 4	Varuna	GM 3	Kranti	Varuna	GM 3	Kranti
North Gujarat (S.K.Nagar, Talod, Vijapur, Ladol)	20	2003-10	a. 2528 (20)	2081 (17)	2165 (17)	1887 (3)	21.8	9.1	32.1
			b. -	2535	2362	2491			
Middle Gujarat (Anand)	3	2005-10	a. 3123 (3)	2462 (2)	2564 (3)	2927 (1)	33.9	21.8	6.4
			b. -	3297	3149	2722			
Saurashtra and Kutch Region (Junagadh, Jamnagar, Bhachau, Amreli)	13	2004-10	a. 2084 (13)	1722 (10)	1837 (11)	1809 (3)	15.4	10.4	33.0
			b. -	1987	2028	2406			
Grand Mean			a. 2417 (36)	1983 (29)	2087 (31)	2002 (7)	20.94	11.1	24.7

*Figures in parenthesis indicates number of trials; a. Average yield kg/ha; b. Corresponding yield of SKM 301

Table 2 Seed yield performance of SKM 301 (GDM 4) under AICRP Rapesed-Mustard trials in Zone-IV (2008-10)

Location	Trials	Year	Mean seed yield (kg/ha)			Per cent increase over checks	
			GDM 4	Varuna	Kranti	Varuna	Kranti
Anand, Junagadh, Mandore, Nagpur, Talod, Sumerpur and Sardarkrushinagar	7	2008-09	1887 (7)	1390 (7)	1567 (7)	-	-
Anand, Junagadh, Mandore, Nagpur, Sumerpur and Sardarkrushinagar	6	2009-10	2212 (6)	-	2026 (6)	-	-
Weighted mean over year			2026	1390	1778	45.6	13.9

Table 3 Morphological description of GDM 4 and two checks varieties Varuna and GM 3

Descriptors	GDM 4	Varuna (C)	GM 3 (C)
Growth habit and Plant type	Compact	Compact	Compact
Simple/Compound	Simple	Simple	Simple
Leaves colour	Dark green	Medium green	Medium green
Pubescent/glabrous	Pubescent	Pubescent	Pubescent
Stem colour	Green	Green	Green
Flower colour	Light yellow	Light yellow	Yellow
Length of siliqua (cm)	4.50	4.33	4.24
Seed colour	Dark brown	Dark brown	Dark brown
Days to flowering	43	45	44
Days to maturity	112	112	110
Plant height (cm)	168	170	175
No. of branches/plant	18.1	17.5	16.5
Main shoot length (cm)	52	41	45
No. of siliqua/plant	299	282	284
No. of seeds/siliqua	13.5	13.5	13.3
1000 seeds weight (g)	5.70	5.45	5.74
Oil content (%)	39.02	38.06	38.46

C=Check

Table 4 Performance of mustard genotype SKM 301 (GDM 4) for oil yield (kg/ha) in IVT (2008-09) and AVT-I (2009-10) timely sown (Irrigated) trials in Zone-IV

Varieties	Oil yield (kg/ha)			Per cent increase over checks
	2008-09 IVT	2009-10 AVT-I	Weighted mean over year	
SKM 301	706 (4)	853 (5)	788	
Kranti (NC)	598 (4)	714 (5)	662	11.9
Varuna (NC)	507 (4)	-	507	55.7

Values in parenthesis indicate no. of locations; NC - National check

Table 5 Reaction of mustard GDM 4 (tested as SKM 301) against powdery mildew and white rust under natural (late sown) conditions

Year	Per cent Disease Severity (%)							
	GDM-4		GM 1 (SC)		GM 2 (SC)		GM 3 (SC)	
	White rust	Powdery mildew	White rust	Powdery mildew	White rust	Powdery mildew	White rust	Powdery mildew
2006-07	0	68	0	63	0	44	0	64
2007-08	22	0	30	0	62	0	60	0
2008-09	0	66	0	90	0	94	0	90
2009-10	0	54	0	0	0	0	0	96
Mean	5.5	47.0	7.5	38.3	15.5	34.5	15.0	62.5

SC - State check

Table 6 Reaction of GDM 4 (tested as SKM 301) to aphid under natural (late sown) condition

Variety	Alate aphid infestation index (AAII)		
	2008-09	2009-10	Mean AAII
SKM 301	1.50	1.40	1.45
GM 1 (SC)	3.65	2.00	2.83
GM 2 (SC)	2.85	1.80	2.31
GM 3 (SC)	2.70	2.00	2.35
Varuna (NC)	2.40	-	2.40
Kranti (NC)	2.40	-	2.40

NC - National check

ACKNOWLEDGEMENTS

The authors are highly thankful to the S.D. Agricultural University, Sardarkrushinagar and ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur for providing funds, facilities and guidance. The contribution of whole research team involved in testing and screening of GDM 4 is highly appreciated.

REFERENCES

Anonymous 2016. *Agricultural Statistics at a Glance,* Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India, New Delhi.

Anonymous 2017. *District wise Area, Production and Yield of Important Food and Non-Food Crops in Gujarat State.* Directorate of Agriculture, Gujarat State, Krishibhavan, Gandhinagar.

Kumar A V, Bharti V, Kumar V, Meena P D and Suresh G 2017. Hyperspectral imaging applications in rapeseed and mustard farming. *Journal of Oilseeds Research*, **34**(1): 1-8.

Panse V G and Sukhatme P V 1985. *Statistical Methods for Agricultural Workers.* Indian Council of Agricultural Research, New Delhi.

Thakkar D A, Prajapati K P, Gami R A, Parmar H D and Solanki S S 2010. GM 3: early maturing, high yielding and bold seeded variety of mustard (*Brassica juncea*) for Gujarat. *Journal of Oilseeds Research*, **27**(2): 172-173.

Western Ambar and Western Dhamaka: High yielding Spanish bunch groundnut varieties for Maharashtra

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(Received: May 26, 2017; Revised: November 11, 2017; Accepted: December 13, 2017)

ABSTRACT

In groundnut, a high yield potential variety having desired combination for Spanish bunch plant habit, large pod size, higher oil content, improved oil quality and early/medium crop duration is rare. Western Ambar is a large pod mutant of popular variety TG-37A, and Western Dhamaka is a recombinant selected from a cross between TG-37A and TPG-41. Both the varieties maintained higher productivity in station, multi-locations and adaptive trials compared to check varieties in respective trial during *rabi*/summer season. Western Ambar and Western Dhamaka recorded overall an average pod yield of 4892 kg/ha and 5269 kg/ha, and exhibited superiority over the best check TG-37A (4610 kg/ha) by 6.1 and 14.3 per cent, respectively. Further, in State Agricultural Universities trials in Maharashtra, Western Ambar and Western Dhamaka recorded average yield of 3028 kg/ha and 3356 kg/ha, and showed superiority over national check TAG-24 (2645 kg/ha) by 14.5 and 26.9 per cent, respectively. Both the varieties were found tolerant to major biotic stress, and have medium crop duration, higher oil content and improved oleic/linoleic (O/L) ratio. In consideration of superiority for pod yield and their important component and quality characters; Western Ambar and Western Dhamaka have been accepted by Department of Agriculture, Government of Maharashtra to include in license for their cultivation in Maharashtra.

Keywords: Groundnut, High yield, Maharashtra, Spanish bunch variety

Groundnut (*Arachis hypogaea* L.) yields are higher in *rabi*/summer season due to controlled inputs management. High-oleate groundnut is valued by oil/food processors and health alert consumers, as it has not only better keeping quality but also provides multiple health benefits like reduced risk of cardiovascular diseases, increased sensitivity to insulin, preventive effects on tumor genesis and amelioration of some inflammatory diseases (Chao *et al.,* 2012). In India, groundnut research has been primarily emphasized on increased yield and higher oil content, and little emphasis were given for research on improved oil quality (Kavera *et al.,* 2013). Earlier significant achievements have been obtained through mutation and cross breeding (Kale *et al.,* 2000). A popular cultivar, TG-37A having Spanish plant type with erect growth habit, medium pod size and wider adaptability (Kale *et al.,* 2004a) was used for mutation breeding. Simultaneously, it was crossed with another Spanish bunch variety TPG-41 having large pod, higher oil content, improved oil quality and medium/late crop duration (Kale *et al.,* 2004b). As a result of mutation and cross breeding, groundnut varieties; Western Ambar having large pod and Western Dhamaka medium/large pod on Spanish bunch background with medium crop duration were developed.

MATERIALS AND METHODS

In mutation breeding experiment, three lots of each 150 well developed and uniform seeds of TG-37A were irradiated with 250, 350 and 450 Gy doses of gamma rays from a Co^{60} source at Bhabha Atomic Research Centre (BARC), Trombay, Mumbai. The irradiated seeds were sown during *kharif* 2007. In cross breeding experiment, reciprocal crosses were made during *kharif* 2007 season between TG-37A and TPG-41, and obtained 15 cross (F_0) seeds. The M_2 and F_1 generations were grown in 2008 *rabi*/summer (February to May) season, and thereafter subsequent generations were grown regularly in *kharif* and *rabi*/summer seasons. The variants in M_2 and segregants in F_2 were identified and advanced through pedigree method. True breeding mutants were isolated in M_3 and M_4, whereas, segregants in F_3 generations. Promising mutants and segregants were assessed in progeny row trials for pod yield, and agronomic traits were studied in comparison with local check (LC) GG-2 and zonal check (ZC) TG-37A during *kharif* and *rabi*/summer 2010 seasons. Yield potential of the most promising genotypes was examined in randomized complete block design experiment against local check GG-2 and Zonal check TG-37A in station trial during *rabi*/summer season 2011 to 2013. Among the genotypes, based on superior yield performance, mutant 40-3 and segregant 30-6 were designated as Western Ambar and Western Dhamaka, respectively. Their yield potential was confirmed in comparison with ZC TG-37A on farmers' fields in unit area of 100 m^2 (1 R) at 3 locations in Gujarat during 2012 and 3 and 6 locations in Maharashtra during 2013 and 2014, respectively, against ZC TG-37A. Further both genotypes were tested for pod yield against ZC TG-37A in 16 adaptive trials on farmers' field in unit area of 1000 m^2 (10 R); 5 in Western Maharashtra, 6 in Vidarbha, 4 in Marathwada and 1 in Konkan regions of Maharastra during *rabi*/summer 2015. Simultaneously, both the genotypes were evaluated in SAUs trials against an early maturing national check variety TAG-24 (Patil *et al*., 1995) at three locations of Mahatma Phule Krishi Vidyapeeth, Rahuri and one location of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli in Maharashtra during *rabi*/summer 2015.

Crop duration of both the WRG varieties was judged on the basis of maturity symptoms, and ancillary observations in respect to yield component characters were recorded as reported earlier by Kale and Patel (2012). Data on reaction to biotic stress were collected simultaneously. The representative seed samples of test varieties and check varieties were collected from SAUs trials and adaptive trials for oil content and its quality parameters analysis. The oil content and fatty acids profile analysis was done at Gujarat Laboratory, Ahmedabad by following IS: 3579-1966 solvent extraction and AOAC 18th Edition 999.06 method, respectively. The results on fatty acids profile are presented in a manner as reported by Ahmed and Young (1982) and Nordan *et al*. (1987). A combination of oleic and linoleic acids is expressed as Oleic Linoleic ratio (Ming *et al*., 2015).

RESULTS AND DISCUSSION

The data presented in Table 1 show that among the gamma rays irradiation treatments, the treatment 450 Gy had a detriment effect on seeds with very low germination (6.0%). There was no survival of plants at harvest indicating it could be a lethal dose for TG-37A. Other treatments, 250 Gy and 350 Gy had decreased percentage of germination (66%) and (45.3%) in comparison to control (95.3%), respectively. It could be because of disparity dose effect of gamma rays on seeds. Among the 3068 and 1744 plants population in M_2, 88 and 11 variants were identified in 250 Gy and 350 Gy treatments, respectively, on the differences for morphological characters such as plant height, leaflet size and shape, pod size, type and shape and kernel colour. Out of these, 23 and 2 variants bred true for their mutated characters in 250 and 350 Gy, respectively in M_3 and M_4 generations. Among the true breeding mutants, mutant 40-3 from 250 Gy dose of gamma rays exhibited increased pod size compared to the source variety, and leaflets having oblong shape with curved margin which bred true in M_4 generation for leaflet and pod size characteristics (Table 2). The mutant 40-3 was designated as Western Ambar.

Whereas, in F_2 generation of a cross of TG-37A and TPG-41, variation was observed mainly for pod size, shape and type. Total 64 segregants were identified for increased number of pods and intermediate pod size of both the parents. Among the true breeding segregants, segrgant 30-6 was identified as desirable recombinant in respect to intermediate pod size with slight pod constriction as in TG-37A and medium reticulation as in TPG-41 (Table 2). It bred true in F_3 generation onward. The recombinant was designated as Western Dhamaka.

Yield performance: In station trials (Table 3a), Western Ambar produced mean pod yield of 4993 kg/ha and out yielded LC GG-2 (4505 kg/ha) and ZC TG 37A (4795 kg/ha) by 10.8 and 4.1 per cent, respectively. During 2012 its pod yield (5290 kg/ha) was statistically higher than GG-2 (4807 kg/ha). Whereas, variety Western Dhamaka produced an average pod yield of 5484 kg/ha, and surpassed the yield of both check varieties GG-2 (4505 kg/ha) and TG-37A (4795 kg/ha) by 21.7 and 14.4 per cent, respectively. It significantly out yielded both the checks during 2011 and 2012. On farmers fields (Table 3b) across the locations Western Ambar and Western Dhamaka showed consistent superior performance for pod yield over check variety TG-37A in Gujarat during 2012 and in Maharashtra during 2013 and 2014. The mean pod yield of Western Ambar (4766 kg/ha) and Western Dhamaka (5379 kg/ha) across the locations was higher by 6.4 and 20.0 per cent than TG-37A (4481 kg/ha), respectively. In adaptive trials on farmers' field at 16 locations (Table 3c), Western Ambar and Western Dhamaka produced mean pod yield of 4967 kg/ha and 5147 kg/ha, which was 6.3 and 10.2 per cent higher over TG-37A (4672 kg/ha), respectively. On an average of 31 trials (Table 3d), which includes station, multi locations and adaptive trials, mean pod yield of Western Ambar (4892 kg/ha) and Western Dhamaka (5269 kg/ha) was higher as compared to TG-37A (4610 kg/ha) by 6.1 and 14.3 per cent, respectively. In SAUs trials conducted at 4 locations (Table 4), Western Ambar (3028 kg/ha) and Western Dhamaka (3356 kg/ha) established superiority for pod yield by 14.5 and 26.9 per cent over national cheek TAG-24 (2645 kg/ha), 5.9 and 17.4 per cent against local check varieties (2858 kg/ha), respectively. Western Ambar and Western Dhamaka varieties showed significant yield superiority over national check TAG-24 at K. Digraj, whereas, at Jalagaon Western Dhamaka significantly out yielded both national and local checks.

Oil and fatty acid profile analysis: The oil content and fatty acids profile analysis results of all varieties were consistent across the testing research stations and farmers' fields, which suggest that those have been less influenced by environments. The varieties Western Ambar and Western Dhamaka had mean oil content of 52.71 and 52.78 per cent, respectively, which were higher than mean oil content of TAG-24 (48.91%) and TG-37A (50.37%). In regards to fatty acids profile, Western Ambar and Western Dhamaka had 55.38 and 46.78 per cent mean oleic acid content and 25.52 and 32.69 per cent mean linoleic acid content, respectively and showed superiority in terms of oil quality compared to TAG-24 (oleic acid 39.10% and linoleic acid 39.88%) and

TG-37A (oleic acid 39.10% and linoleic acid 39.88%). An oleic acid to linoleic acid ratio of Western Ambar was 2.18 and that of Western Dhamaka was 1.44, which were impressively higher than adapted varieties TAG-24 (0.98) and TG-37A (1.06) (Table 5).

Reaction to pests and diseases: The observations recorded for diseases incidence and insect pests damage revealed that both varieties showed tolerance to major diseases, such as tikka, rust and peanut bud necrosis; whereas, damage caused by thrips and caterpillars was very less, and comparable with TG-37A (Table 6).

Table 1 Effect of gamma rays on seed viability and plant population of TG-37A

Generation	M1 (*Kharif* 2007)			M2 (*Rabi*/summer - 2008)			M3 (*Kharif* 2008) & M4 (*Rabi*/summer 2009)
Dose	Seeds sown	Germinated (%)	Survival at harvest	Progenies grown	Seeds sown	Variant identified	Mutants identified
Control	150	143 (95.3%)	135	--	100	--	--
250 Gy	150	99 (66.0%)	84+0 *	84	3068	88	23
350 Gy	150	68 (45.3%)	57+3 *	57	1744	11	2
450 Gy	150	9 (06.0%)	--	--	--	--	--

*Figures indicate sterile plants

Table 2 Morpho-physiological comparison of Western Ambar and Western Dhamaka with parents

Characters		TG-37A	TPG-41	Western Ambar	Western Dhamaka
Plant	Habit	Erect	Erect	Erect	Erect
	Height	Medium	Medium	Medium	Medium
Flowering on	Stem	Present	Present	Present	Present
	Branches	Valgaris	Sequential	Valgaris	Valgaris
Leaflet	Size (cm)	Medium 6.3 x 2.9	Medium 6.7 x 2.8	Medium 6.7 x 3.0	Medium 7.0 x 2.8
	Shape	Elliptical	Elliptical	Oblong, curved margin	Elliptical
	Colour	Dark green	Dark green	Dark green	Dark green
Pod	Size L x B (cm)	Medium 2.84 x 1.26	Large 3.58 x 1.42	Large 3.63 x 1.42	Medium/Large 3.05 x 1.32
	Constriction	Slight	Medium	Medium	Slight
	Reticulation	Slight	Medium	Slight	Medium
Kernel	Size L x B (cm)	Medium 1.36 x 0.91	Large 1.64 x 1.05	Large 1.66 x 1.06	Medium/Large 1.43 x 0.98
	Testa	Uniform	Uniform	Uniform	Uniform
	Testa Colour	Rose	Rose	Rose	Rose
	Shape	Roundish	Spheroid	Spheroid	Spheroid
	Fresh seed dormancy (days)	20	25	25	25
	Protein (%)	27.17	26.56	25.60	26.08

Table 3a Comparative performance of Western Ambar and Western Dhamaka for pod yield (kg/ha) - Station trials (*Rabi*/summer season)

Year	Location	Western Ambar	Western Dhamaka	GG-2 (LC)	TG-37A (ZC)	SE±	CD at 5%	CV%
2011	WASL, Gandhinagar	5227	5542 **++	4437	4633	364.88	773.50	7.70
2012		5290 *+	6370 **++	4807	5213	83.01	170.03	1.86
2013		4461	4539	4272	4539	108.29	217.74	3.23
Mean (3)		4993	5484	4505	4795	-	-	-
% increase over GG-2		10.8	21.7	-	-	-	-	-
% increase over TG37A		4.1	14.4	-	-	-	-	-

*+= significant superiority over one cheek variety; **++ = significant superiority over both cheek varieties

Table 3b Comparative performance of Western Ambar and Western Dhamaka for pod yield (kg/ha) - Multi location trials (*Rabi*/summer season)

Year	State	No. of locations	Pod yield (kg/ha)		
			TG-37A	Western Dhamaka	Western Ambar
2012	Gujarat	3	2998	3340	3105
2013	Maharashtra	3	6475	7668	6919
2014	Maharashtra	6	4224	5254	4520
Over all mean		12	4481	5379	4766
% increase over TG-37A			--	20.0	6.4

Table 3c Comparative performance of Western Ambar and Western Dhamaka for pod yield (kg/ha) - Adaptive trials (*Rabi*/summer season)

Year	Division of Maharashtra	No. of locations	TG -37A (check)	Western Dhamaka	Western Ambar
2015	Western Maharashtra	5	5289.4	5751.0	5459.4
	Vidarbha	6	4666.0	5258.5	5208.3
	Marathwada	4	3655.0	3992.5	3832.5
	Konkan	1	5690.0	6075.0	5595.0
Over all mean		16	4672.1	5146.9	4967.0
% increase over TG-37 A		-	-	10.2	6.3

Table 3d Summery of performance for pod yield (kg/ha) of Western Ambar and Western Dhamaka

Year	Location	No. of trials	Western Ambar	Western Dhamaka	GG-2 (LC)	TG-37A (ZC)
Station trials						
2011	Gandhinagar	1	5227	5542**++	4437	4633
2012		1	5290*+	6370**++	4807	5213
2013		1	4461	4539	4272	4539
Multilocation trials						
2012	Gujarat	3	3105	3340	-	2998
2013	Maharashtra	3	6919	7668	-	6475
2014	Maharashtra	6	4520	5254	-	4224
Adaptive trials						
2015	Maharashtra	16	4967	5147	-	4672
Over all mean		31	4892	5269	-	4610
% increase over TG37A			6.1	14.3	-	-

* + indicate significant superiority over one check variety; ** ++ indicate significant superiority over both check varieties

Table 4 Performance of Western Ambar and Western Dhamaka in SAUs trials (Maharashtra) - Pod yield (kg/ha)

Year	Location	Western Ambar	Western Dhamaka	TAG-24 (NC)	LC*	SE±	CD at 5%	CV%
2015	Jalgaon	1805	2461 **++	1772	1758	132.8	390.7	16.3
	Rahuri	4380	4636	3676	3917	354.8	1015.7	16.1
	K-Digraj	3427 *+	3640 *+	2829	3113	203.6	574.3	11.1
	Shiragaon	2499	2685	2303	2645	166.7	513.6	12.6
Mean (4)		3028	3356	2645	2858	-	-	-
% increase over TAG24		14.5	26.9	-	-	-	-	-
% increase over LC		5.9	17.4	-	-	-	-	-

*+ : Local check variety varied over the locations; *+ : Statistically superior over national check TAG-24; **++ : Statistically superior over both national and local checks

Ancillary data: Western Ambar and Western Dhamaka had medium crop duration as both took 111 to 120 days for pods maturity, which were similar to GG-2 (111 days), TG-37A (111 days) and TAG-24 (122 days). Their shelling out turn was around 70 per cent, equivalents to GG-2 (69.9%), TG37A (68.9) and TAG-24 (70.8%). The hundred kernel weight (HKW) values of all varieties varied, which could be due to varied ecosystems and crop inputs management. However, variety Western Ambar depicted 79g HKW value at one of the research centers in SAUs trials in Maharashtra; whereas, for Western Dhamaka the highest value was 58.0g in station trials at WASL Research Farm, Gandhinagar. In station trial high mean HKW value of Western Ambar (68.0g) and Western Dhamaka (54.3g) confirmed large and medium/large kernel size, respectively (Table 7).

Groundnut varieties having high yield potential on Spanish plant type with erect growth habit and early to medium maturity are largely accepted by farmers, whereas, oil industries, food processors and consumers prefer variety having large pod, bold kernels, higher seed oil content and improved oleic/linoleic ratio. Under present groundnut scenario in India, Spanish bunch variety TG-37A with medium pod size is popular among the farmers. Another Spanish bunch variety TPG-41 with large pod size is mostly preferred for confectionary purpose. The use of variety TG-37A in mutation breeding and a cross between TG-37A and TPG-41 resulted in development of Western Ambar and Western Dhamaka, respectively. Western Ambar showed superiority for pod yield compared to local check variety GG-2 and national check variety TAG-24; whereas it was comparable with the most popular variety TG-37A. Besides, it has large pod size, higher oil content and improved oil quality. Other variety Western Dhamaka has higher pod yield potential compared to all three check varieties, medium/large pod size, more seed oil content, improved oil quality. Both the varieties showed tolerance to major biotic stress.

Based on higher pod yield and improvement in economical and oil content and quality characters; the Department of Agriculture, Government of Maharashtra has accepted Western Ambar and Western Dhamaka to include in license for seed production and distribution for general cultivation in Maharashtra. The large scale cultivation on farmers' field will not only benefit to the farmers in regards to economical gain but to the consumers to maintain good health.

Table 5 Comparison of mean oil per cent and major fatty acids profile (*Rabi*/summer 2015)

Variety	Locations	% Oil	Major unsaturated fatty acids		
			Oleic	Linoleic	Ratio
Research centers					
TAG-24	WASL, Gandhinagar, GS	48.88	38.78	41.67	0.93
	MPKV, Jalagaon, MS	49.62	39.62	38.87	1.02
	BSKKVShiragaon, MS	48.23	38.91	39.10	1.00
	Mean	48.91	39.10	39.88	0.98
Western Ambar	WASL, Gandhinagar, GS	52.58	58.36	23.41	2.49
	MPKV, Jalagaon, MS	52.43	53.51	27.39	1.95
	BSKKV, Shiragaon, MS	52.45	54.11	25.82	2.10
	Mean	52.49	55.37	25.54	2.18
Western Dhamaka	WASL, Gandhinagar, GS	53.28	48.12	31.74	1.52
	MPKV, Jalagaon, MS	53.88	45.33	32.72	1.39
	BSKKV, Shiragaon, MS	52.10	47.23	32.19	1.47
	Mean	53.09	46.89	32.22	1.46
Farmers' field					
TG-37A	Devapar, Kuch, GS	50.81	39.44	41.15	0.96
	Neral, Raigadh, MS	50.09	42.85	37.99	1.13
	Wai, Satara, MS	49.23	40.99	38.58	1.06
	DahegaonYawatmal, MS	51.36	41.90	38.41	1.09
	Mean	50.37	41.30	39.03	1.06
Western Ambar	Devapar, Kuch, GS	52.56	56.78	25.33	2.24
	Neral, Raigadh, MS	52.18	55.14	25.69	2.15
	Wai, Satara, MS	53.86	54.89	25.49	2.15
	Dahegaon,Yawatmal, MS	52.89	54.89	25.49	2.15
	Mean	52.87	55.43	25.50	2.17
Western Dhamaka	Devapar, Kuch, GS	53.17	47.28	31.08	1.52
	Neral, Raigadh, MS	51.71	48.17	31.95	1.51
	Wai, Satara, MS	53.14	45.15	35.11	1.29
	Dahegaon,Yawatmal, MS	52.15	46.21	34.01	1.36
	Mean	52.54	46.70	33.04	1.42
TAG-24 (3)	Pooled mean	48.91	39.10	39.88	0.98
TG-37A (4)		50.37	41.30	39.03	1.06
Western Ambar (7)		52.71	55.38	25.52	2.18
Western Dhamaka (7)		52.78	46.78	32.69	1.44

Table 6 Disease incidence and insect pests damage (2011 to 2013)

Variety	Disease						Pests/insect damage			
	Tikka (*Kharif*) *		Rust (*Kharif*) *		PBND (*Rabi*/summer)		Thrips (*Rabi*/summer)		Caterpillar (*Rabi*/summer)	
	% incidence	Score	% incidence	Score	% incidence	Score	% incidence	Score	% incidence	Score
GG-2	14.9	1-3	7.5	0-1	5.4	0-1	17.8	1-2	11.4	1-2
TG-37A	12.7	1-2	4.2	0-1	4.6	0-1	15.2	1-2	7.5	0-1
Western Ambar	10.7	1-2	3.5	0-1	4.2	0-1	13.3	1-2	6.7	0-1
Western Dhamaka	9.84	0-1	2.2	0-1	4.1	0-1	11.8	1-2	6.6	0-1

*Tikka and Rust diseases did not appear in *Rabi*/summer; hence data recorded in *Kharif* are presented

Table 7 Ancillary observations (*Rabi*/summer trials)

Year	Western Ambar	Western Dhamaka	GG-2	TG-37A
	Station trail (Mean)			
	Days to maturity			
2011 to 2013	111 (109 - 113)	111 (109 - 113)	111 (109 - 113)	111 (109 - 113)
	Shelling out turn (%)			
	70.2 (68.8 - 72.3)	69.3 (67.8 - 71.2)	69.9 (68.6 - 71.6)	68.8 (68.0 - 70.5)
	Hundred Kernel weight (g)			
	68.0 (66.0 - 71.0)	54.3 (50.0 – 58.0)	40.3 (38.0 – 43.0)	44.3 (41.0.- 48.0)
	SAUs Trials (4 locations) (Mean)			
Year	Western Amber	Western Dhamaka	Local checks	TAG-24
	Days to maturity			
2015	120 (105 - 128)	119 (121 - 129)	129 (122 - 133)	122 (115 - 128)
	Shelling out turn (%)			
	69.9 (64.4 - 73.8)	69.1 (66.5 - 71.8)	68.4 (65.0 - 71.8)	70.8 (68.2 - 75.0)
	Hundred Kernel Weight (g)			
	51.3 (37.2 - 79.0)	43.0 (31.0 - 55.0)	37.8 (28.3 - 49.0)	35.1 (26.7 - 44.0)

Note: Figures in parenthesis show range

ACKNOWLEDGEMENTS

We are thankful to Head, Nuclear Agriculture and Biotechnology Division, BARC, Mumbai for providing the seed of TG-37A and TPG-41, and facility for Gamma irradiation.

REFERENCES

Ahmed E H and Young C T 1982. Composition, nutrition and flavour of peanut. In: Pattee H E and Young C T (Eds.), *Peanut Science and Technology,* American Peanut Research and Education Society, Inc., Yoakum, 655-687.

Chao Q F, Chuan T W, Pi W W, Yue Y T, Xiu Z W, Feng G C and Shan Y 2012. Identification of a novel mutation in FAD 2 B from a peanut EMS mutant with elevated oleate content. *Journal of Oleo Science*, **61**(3): 143-148.

Kale D M and Patel N P 2012. Induction of promising mutants in groundnut (*Arachis hypogaea* L.) cultivar TPG-41. *Journal of Oilseeds Research*, **29**(1): 27-30.

Kale D M, Baddigannvar A M and Murty G S S 2000. Forty years of mutation research in groundnut at Trombay: Accomplishment and Potentials. In: *Proceedings of DAE-BRNS Symposium on use of Nuclear and Molecular Techniques in Crop Improvement*, 6-8 December 2000, pp. 184-193.

Kale D M, Murty G S S and Baddigannvar A M 2004a. TG-37A - a new Trombay groundnut variety with wider adaptation, *International Arachis Newsletter,* **24**: 19-20.

Kale D M, Murty G S S and Baddigannvar A M 2004b. TPG- 41, a new large seeded groundnut variety released in India. *International Arachis Newsletter*, **24**: 21-22.

Kavera N H L and Hanchinal R R 2013. Genetic improvement for oil quality through induced mutagenesis in groundnut (*Arachis hypogaea* L.). *Indian Journal of Genetics and Plant Breeding*, **73**(4): 378-385.

Ming L W, Brandom T, Yong Q, Charles A, Dave P, Viktor T, Gary A and Pederson 2015. Newly identified natural high-oleate mutant from *Arachis hypogaea* L. subsp. hypogaea. *Molecular Breeding*, **35**: 186.

Nordan A J, Borget D W, Knuaft D A and Young C T 1987. Variability in oil quality among peanut genotypes in the Florida breeding program. *Peanut Science*, **4**: 7-11.

Patil S H, Kale D M, Deshamukh S N, Fulzele G R and Weginwar D G 1995. Semi dwarf early maturing and high yielding new groundnut variety, TAG-24. *Journal of Oilseeds Research*, **12** (2): 254-257.

Studies on morpho-metric traits in some triploids of *Arachis*

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(Received: November 28, 2017; Revised: December 14, 2017; Accepted: December 22, 2017)

ABSTRACT

Four triploids *viz., Arachis hypogaea* L. Cv. VRI 3 x *A. diogoi*, *A. hypogaea* L. Cv. VRI 3 x *A. benensis, A. hypogaea* L. Cv. JL 24 x *A. diogoi* and *A. hypogaea* L. Cv. JL 24 x *A. benensis* were studied along with their respective parents for various vegetative and reproductive traits. Most of the triploids are erect in growth habit with reduced petiole length, stipule length and leaflet size. The triploids produced few flowers with orange standard petals. Pollen fertility percentage ranged from 5.0 to 6.5 in the triploids.

Keywords: Groundnut, Morpho-metric traits, Triploids, Wild diploid species

The genus *Arachis* consists of 80 well described species distributed over nine sections, which includes both cultivated and wild forms. The section *Arachis* comprises of both tetraploid (2n=4x=40) and diploid (2n=2x=20) species. Diploid wild species harbour resistance genes for economically important diseases and offers ample scope for broadening the genetic diversity. The cultivated species *Arachis hypogaea* L. is a segmental allopolyploid, highly susceptible to most of the foliar and fungal diseases, which causes devastating damage to the groundnut crop and reduces the quality of the produce significantly (Bhargavi *et al.,* 2017). Although crossability barriers are the major bottleneck, interspecific hybridization is of paramount importance in bringing the desirable resistant genes from the related wild species in to a common genetic background. Most of the diploid wild species of section *Arachis* are having either AA or BB genome and easily cross compatible with cultivated groundnut and more frequently utilized in evolving an agronomically desirable resistance varieties or extensively employed for the pre-breeding activities. The present study was undertaken to cross the cultivated *A. hypogaea* L. and diploid wild species to study various morpho-metric traits of the triploids.

MATERIALS AND METHODS

Materials of the study consists of two late leaf spot and rust disease susceptible cultivars *viz., A. hypogaea* Cv. VRI 3 and JL 24 and two resistant diploid wild species *viz., A. diogoi* Hoehne and *A. benensis* Krapov., W.C. Gregory & C.E. Simpson (Pande and Narayana Rao, 2001). Genes conferring resistance to the peanut root-knot nematode is also found in the *A. diogoi* Hoehne (Anderson *et al.,* 2004). The susceptible cultivars belongs to Spanish bunch type with erect in growth habit, orange standard and broad leaflets. The two diploid wild species are spreading in habit with orange standard and narrow leaflets. Flowers of *A. hypogaea* Cv. VRI 3 and JL 24 were hand-emasculated during the previous day evening and pollinated the emasculated flower next day morning with pollen from the selected diploid wild species during *rabi*/summer 2015-16. The crossed flowers were tied with coloured thread for easy identification. After maturity the crossed pods were harvested and dried properly. During *kharif* 2016 the crossed pods were hand shelled and the kernels were utilized for sowing along with their respective parents. Morphological characters were measured from the triploids and parents which included height of main stem (cm), number of primary branches, number of secondary branches, number of tertiary branches, length of primary branches (cm), length of secondary branches (cm), length of tertiary branches (cm), length of petioles (cm), leaflet length (cm), leaflet width (cm), stipule length (cm), sepal joined (cm), sepal single (cm), hypanthium length (cm), standard petal length (cm), standard petal width (cm), wing petal length (cm), wing petal width (cm), keel petal length (cm) and keel petal width (cm). Pollen collected from flowers were placed in microscopic slides with a drop of 2% acetocarmine and glycerin after which a cover slip was placed on the pollen sample and slight pressure was applied. The stained and unstained pollen grains were counted and recorded using an optical microscope.

RESULTS AND DISCUSSION

Introgression of genes for resistance to foliar and fungal diseases from related diploid wild species of the section *Arachis* has been the basis for genetic improvement of *A. hypogaea* (Singh, 1986; Stalker and Moss, 1987). The hexaploid pathway of incorporation of resistance genes involves several steps such as development of sterile triploids followed by doubling the chromosome number to alter the ploidy level to hexaploid and gradual elimination of chromosomes either spontaneously or through repeated backcrosses with *A. hypogaea* L. to isolate stable tetraploids through selection (Simpson, 2001).

As a preliminary step of genetic improvement *A. hypogaea,* crosses were performed between cultivated tetraploid and diploid wild species. Number of pollinations made and true triploids identified were analysed in each of the four crosses. The cross *A. hypogaea* L. Cv. VRI 3 x *A. diogoi* registered maximum number of 10 triploids. The success rate was 2.7 per cent. Although enough pollinations were made in the cross *A. hypogaea* L. Cv. VRI 3 x *A. benensis,* the success rate was only 0.7 per cent. Other two crosses observed very low success rate of 0.3 and 0.4 per cent respectively (Table 1). The lower success rate might be due to the prevalence of higher temperature (>33°C) at the time of flowering and pollination, which reduced the pollen viability and germination in groundnut (Oakes, 1958; Kakani *et al*., 2002).

Table 1 Number of pollinations, number of true triploids obtained and success rate (%) in each cross

Crosses	No. of pollina-tions	No. of triploids identified	Success rate (%)
A. hypogaea L. Cv. VRI 3 x *A. diogoi*	369	10	2.7
A. hypogaea L. Cv. VRI 3 x *A. benensis*	414	3	0.7
A. hypogaea L. Cv. JL 24 x *A. diogoi*	291	1	0.3
A. hypogaea L. Cv. JL 24 x *A. benensis*	247	1	0.4

Morphological features of triploids: In general, all the triploids resembled neither female nor male parent. They were weak, slow in growth and semi-erect in habit. Failure of the triploids to produce sufficient quantities of flower buds restricts the cytological confirmation of the chromosome number. However, morphological characters help to easily distinguish the triploids from its parents.

(a) Triploid of *A. hypogaea* Cv. VRI 3 x *A. diogoi* Hoehne: Altogether ten true triploids were obtained from the cross. The triploids were intermediate in plant height, number of primary and secondary branches and length of primary branches (Table 2). Moreover, they produced smaller petioles, leaflets, stipules and hypanthium than their respective parents. They produced few flowers with orange coloured standard petal. Flower structure and length, size of the standard, wing and keel petal were variable and mostly intermediate. Pollen fertility was 6.5 per cent. Such lower pollen fertility in triploids might be due to the failure to produce functional games as a result of abnormal or irregular meiosis, which prevents the formation of normal pollen grains (Vindhiyavarman *et al.,* 2000). However the parents showed pollen fertility of 93.0 and 87.5 per cent respectively.

(b) Triploid of *A. hypogaea* Cv. VRI 3 x *A. benensis* Krapov.,W.C. Gregory & C.E. Simpson: Three true triploids were recognized in this cross. The triploid also showed intermediate in height with reduced leaflet size, petiole and stipule length (Table 3). The triploids hardly produced one or two flowers with orange coloured standard petal. The triploid registered very low pollen fertility of 5.0 per cent. The pollen fertility of ovule parent and pollen parents were 93.0 and 89.0 per cent respectively. Several researchers reported sterile triploids (Raman, 1976 and Smart and Gregory, 1967).

Table 2 Various vegetative and reproductive traits of the triploid of *A. hypogaea* L. Cv. VRI 3 x *A. diogoi*

Characters	Triploid (3x)		*A. hypogae*a L. Cv. VRI 3 (4x) (Female)		*A. diogoi* (2x) (Male)	
	Mean± S.E	Range	Mean± S.E	Range	Mean± S.E	Range
Height of main stem (cm)	35.85±2.00	24.5-49.5	54.5±2.75	48.0-60.0	15.95±0.45	15.5-16.4
Number of primary branches	5.6±0.70	4.0-11.0	4.0±0.00	4.0-4.0	6.5±0.50	6.0-7.0
Number of secondary branches	10.3±2.10	3.0-26.0	3.5±0.86	2.0-6.0	15.0±1.00	14.0-16.0
Number of tertiary branches	1.6±0.73	0.00-6.0	-	-	19.5±1.50	18.0-21.0
Length of primary branches (cm)	22.04±1.81	2.0-49.0	21.53±1.19	13.5-28.0	39.1±1.58	29.7-46.8
Length of secondary branches (cm)	8.71±0.84	1.0-44.0	9.8±0.57	8.4-11.1	22.5±1.11	15.627.2
Length of tertiary branches (cm)	5.90±1.06	1.5-14.0	-	-	13.24±0.76	10.2-18.1
Length of petioles (cm)	1.98±0.02	1.9-2.0	5.28±0.16	4.0-6.6	3.58±0.22	2.4-5.2
Leaflet length (cm)	1.85-0.06	1.6-2.1	5.89±0.16	4.6-7.6	3.01±0.07	2.5-3.6
Leaflet width (cm)	1.12±0.11	0.8-1.6	2.86±0.08	2.5-3.6	1.18±0.03	0.9-1.4
Stipule length (cm)	1.52±0.03	1.4-1.6	3.92±0.08	3.3-4.4	2.22±0.09	1.7-2.9
Sepal joined (cm)	0.53±0.03	0.5-0.6	0.7±0.05	0.6-0.8	0.66±0.03	0.6-0.7
Sepal single (cm)	0.50±0.00	0.5-0.5	0.7±0.04	0.6-0.8	0.8±0.00	0.8-0.8
Hypanthium length (cm)	2.43±0.03	2.4-2.5	2.92±0.23	2.5-3.5	4.93±0.14	4.7-5.2
Standard petal length (cm)	1.33±0.03	1.3-1.4	1.0±0.05	0.9-1.1	1.46±0.03	1.4-1.5
Standard petal width (cm)	1.63±0.03	1.6-1.7	1.37±0.07	1.2-1.5	1.73±0.03	1.7-1.8
Wing petal length (cm)	0.83±0.03	0.8-0.9	0.8±0.00	0.8-0.8	0.96±0.02	0.9-1.0
Wing petal width (cm)	0.43±0.03	0.4-0.5	0.45±0.01	0.4-0.5	0.7±0.03	0.6-0.8
Keel petal length (cm)	0.40±0.00	0.4-0.4	0.7±0.04	0.6-0.8	0.66±0.03	0.6-0.7
Keel petal width (cm)	0.20±0.00	0.2-0.2	0.2±0.00	0.2-0.2	0.2±0.00	0.2-0.2
Pollen fertility (%)	6.5	-	93.0	-	87.5	-

Table 3 Various vegetative and reproductive traits of the triploid of *A. hypogaea* L. Cv. VRI 3 x *A. benensis*

Characters	Triploid (3x)		A. *hypogaea* L. Cv. VRI 3 (4x) (Female)		*A. benensis* (2x) (Male)	
	Mean± S.E	Range	Mean± S.E	Range	Mean± S.E	Range
Height of main stem (cm)	30.6±2.16	28.5-35.0	54.5±2.75	48.0-60.0	25.2±0.75	24.5-26.0
Number of primary branches	6.66±0.88	5.0-8.0	4.0±0.00	4.0-4.0	9.00±1.00	8.0-10.0
Number of secondary branches	22.0±7.0	9.0-33.0	3.5±0.86	2.0-6.0	17.5±1.50	16.0-19.0
Number of tertiary branches	7.66±3.17	4.0-14.0	-	-	24.00±2.00	22.0-26.0
Length of primary branches (cm)	21.35±2.13	7.5-39.0	21.53±1.19	13.5-28.0	48.91±0.42	46.5-51.0
Length of secondary branches (cm)	7.81±0.70	1.0-29.0	9.8±0.57	8.4-11.1	34.55±0.92	30.4-39.7
Length of tertiary branches (cm)	5.20±1.20	0.8-22.0	-	-	21.95±0.60	20.1-26.1
Length of petioles (cm)	1.48±0.02	1.4-1.5	5.28±0.16	4.0-6.6	2.74±0.06	2.3-3.0
Leaflet length (cm)	1.01±0.02	0.9-1.1	5.89±0.16	4.6-7.6	2.85±0.07	2.3-3.5
Leaflet width (cm)	0.43±0.01	0.4-0.5	2.86±0.08	2.5-3.6	1.16±0.02	1.0-1.4
Stipule length (cm)	1.03±0.01	1.0-1.1	3.92±0.08	3.3-4.4	2.02±0.04	1.5-2.3
Sepal joined (cm)	0.60±0.00	0.6-0.6	0.7±0.05	0.6-0.8	0.76±0.03	0.7-0.8
Sepal single (cm)	0.57±0.03	0.5-0.6	0.7±0.04	0.6-0.8	0.9±0.11	0.7-1.1
Hypanthium length (cm)	2.53±0.03	2.5-2.6	2.92±0.23	2.5-3.5	6.66±0.50	5.7-7.4
Standard petal length (cm)	0.93±0.03	0.9-1.0	1.0±0.05	0.9-1.1	1.23±0.14	1.0-1.5
Standard petal width (cm)	1.23±0.03	1.2-1.3	1.37±0.07	1.2-1.5	1.6±0.15	1.4-1.9
Wing petal length (cm)	0.80±0.00	0.8-0.8	0.8±0.00	0.8-0.8	0.93±0.05	0.8-1.1
Wing petal width (cm)	0.40±0.00	0.4-0.4	0.45±0.01	0.4-0.5	0.73±0.05	0.6-0.9
Keel petal length (cm)	0.57±0.03	0.5-0.6	0.7±0.04	0.6-0.8	0.6±0.00	0.6-0.6
Keel petal width (cm)	0.20±0.00	0.2-0.2	0.2±0.00	0.2-0.2	0.10±0.00	0.1-0.1
Pollen fertility (%)	5.0	-	93.0	-	89.0	-

Table 4 Various vegetative and reproductive traits of the triploid of *A. hypogaea* L. Cv. JL 24 x *A. diogoi*

Characters	Triploid (3x)		*A. hypogaea* L. Cv. JL 24 (4x) (Female)		*A. diogo*i (2x) (Male)	
	Mean± S.E	Range	Mean± S.E	Range	Mean± S.E	Range
Height of main stem (cm)	44.7	-	38.6±2.75	32.0-46.0	15.95±0.45	15.5-16.4
Number of primary branches	10.0	-	3.8±0.20	3.0-4.0	6.5±0.50	6.0-7.0
Number of secondary branches	27.0	-	1.4±0.40	0.0-2.0	15.0±1.00	14.0-16.0
Number of tertiary branches	-	-	-	-	19.5±1.50	18.0-21.0
Length of primary branches (cm)	26.72±4.64	9.00-51.5	25.57±0.83	18.0-29.0	39.1±1.58	29.7-46.8
Length of secondary branches (cm)	23.88±1.65	10.5-37.7	11.18±0.65	9.5-12.9	22.5±1.11	15.627.2
Length of tertiary branches (cm)	-	-	-	-	13.24±0.76	10.2-18.1
Length of petioles (cm)	1.45±0.01	1.2-1.8	4.25±0.15	3.5-6.0	3.58±0.22	2.4-5.2
Leaflet length (cm)	1.52±0.03	1.4-1.7	6.25±0.10	4.8-7.0	3.01±0.07	2.5-3.6
Leaflet width (cm)	0.83±0.04	0.6-1.0	2.95±0.07	1.9-3.6	1.18±0.03	0.9-1.4
Stipule length (cm)	1.04±0.02	1.0-1.1	4.35±0.06	3.9-4.9	2.22±0.09	1.7-2.9
Sepal joined (cm)	0.43±0.03	0.4-0.5	0.50±0.05	0.4-0.6	0.66±0.03	0.6-0.7
Sepal single (cm)	0.43±0.03	0.4-0.5	0.57±0.03	0.5-0.6	0.8±0.00	0.8-0.8
Hypanthium length (cm)	1.90±0.05	1.8-2.0	2.53±0.03	2.5-2.6	4.93±0.14	4.7-5.2
Standard petal length (cm)	1.13±0.03	1.1-1.2	1.23±0.03	1.2-1.3	1.46±0.03	1.4-1.5
Standard petal width (cm)	1.47±0.03	1.4-1.5	1.47±0.06	1.4-1.6	1.73±0.03	1.7-1.8
Wing petal length (cm)	0.77±0.03	0.7-0.8	0.87±0.03	0.8-0.9	0.96±0.02	0.9-1.0
Wing petal width (cm)	0.37±0.03	0.3-0.4	0.43±0.03	0.4-0.5	0.7±0.03	0.6-0.8
Keel petal length (cm)	0.40±0.00	0.4-0.4	0.53±0.03	0.5-0.6	0.66±0.03	0.6-0.7
Keel petal width (cm)	0.20±0.00	0.2-0.2	0.27±0.03	0.2-0.3	0.2±0.00	0.2-0.2
Pollen fertility (%)	6.0	-	94.5	-	87.5	-

A. hypogaea L. CV. JL 24 (4X) X *A. diogoi* (2X)

A. hypogaea L. CV. JL 24 (4X) X *A. benensis* (2X)

Fig. 1. Morphological features of triploids

(c) Triploid of *A. hypogaea* Cv. JL 24 x *A. diogoi* Hoehne: Only one triploid was identified in the cross. The triploid of *A. hypogaea* Cv. JL 24 x *A. diogoi* has orange standard petal and a shorter hypanthium than their parents (Table 4). Plant height, number of primary branches, number of secondary branches was higher than either of its parents. Reduced petiole length, leaflet size and stipule length were the characteristic features of triploids studied (Fig.1 and Fig. 2). Only few flowers were produced on the plant during the *kharif* 2016 season. The pollen fertility observed was 6.0 per cent. However the parents registered higher pollen fertility percentage of 94.5 and 87.5 respectively.

(d) Triploid of *A. hypogaea* Cv. JL 24 x *A. benensis* Krapov., W.C. Gregory & C.E. Simpson: The lone triploid *A. hypogaea* Cv. JL 24 x *A. benensis* was found to be intermediate in height and number of primary branches (Table 5). The triploid plants tend to have smaller petiole length, leaflet length and width and stipule length than tetraploid and diploid. The triploid produced flower with orange coloured standard petal. Pollen fertility of the triploids was 6.0 per cent, while the parents involved, showed normal pollen fertility of 94.5 and 89.0 per cent respectively.

In the present study it was clearly observed that the triploids were intermediate in height with smaller petiole length, stipule length and reduced leaflet size. Most of the triploids produced only one or two flowers with orange colour standard petal. Irrespective of the crosses studied, the pollen fertility was invariably very low and ranged from 5.0 to 6.5 per cent. The poor pollen fertility might be due to the failure of triploids to produce the functional pollen grains.

Table 5 Various vegetative and reproductive traits of the triploid of *A. hypogaea* L. Cv. JL 24 x *A. benensis*

Characters	Triploid (3x)		*A. hypogaea* L. Cv. JL 24 (4x) (Female)		*A. benensis* (2x) (Male)	
	Mean± S.E	Range	Mean± S.E	Range	Mean± S.E	Range
Height of main stem (cm)	21	-	38.6±2.75	32.0-46.0	25.2±0.75	24.5-26.0
Number of primary branches	3	-	3.8±0.20	3.0-4.0	9.00±1.00	8.0-10.0
Number of secondary branches	11	-	1.4±0.40	0.0-2.0	17.5±1.50	16.0-19.0
Number of tertiary branches	-	-	-	-	24.00±2.00	22.0-26.0
Length of primary branches (cm)	35.33±1.64	33.0-38.5	25.57±0.83	18.0 – 29.0	48.91±0.42	46.5-51.0
Length of secondary branches (cm)	5.90±0.61	2.0-8.0	11.18±0.65	9.5-12.9	34.55±0.92	30.4-39.7
Length of tertiary branches (cm)	-	-	-	-	21.95±0.60	20.1-26.1
Length of petioles (cm)	1.4±0.04	1.3-1.5	4.25±0.15	3.5 – 6.0	2.74±0.06	2.3-3.0
Leaflet length (cm)	1.42±0.05	1.2-1.5	6.25±0.10	4.8 – 7.0	2.85±0.07	2.3-3.5
Leaflet width (cm)	0.78±0.04	0.6-0.9	2.95±0.07	1.9 – 3.6	1.16±0.02	1.0-1.4
Stipule length (cm)	1.52±0.03	1.4-1.6	4.35±0.06	3.9 – 4.9	2.02±0.04	1.5-2.3
Sepal joined (cm)	0.47±0.03	0.4-0.5	0.50±0.05	0.4-0.6	0.76±0.03	0.7-0.8
Sepal single (cm)	0.40±0.00	0.4-0.4	0.57±0.03	0.5-0.6	0.9±0.11	0.7-1.1
Hypanthium length (cm)	2.13±0.03	2.1-2.2	2.53±0.03	2.5-2.6	6.66±0.50	5.7-7.4
Standard petal length (cm)	1.23±0.03	1.2-1.3	1.23±0.03	1.2-1.3	1.23±0.14	1.0-1.5
Standard petal width (cm)	1.53±0.03	1.5-1.6	1.47±0.06	1.4-1.6	1.6±0.15	1.4-1.9
Wing petal length (cm)	0.80±0.00	0.8-0.8	0.87±0.03	0.8-0.9	0.93±0.05	0.8-1.1
Wing petal width (cm)	0.40±0.00	0.4-0.4	0.43±0.03	0.4-0.5	0.73±0.05	0.6-0.9
Keel petal length (cm)	0.37±0.03	0.3-0.4	0.53±0.03	0.5-0.6	0.6±0.00	0.6-0.6
Keel petal width (cm)	0.2±0.00	0.2-0.2	0.27±0.03	0.2-0.3	0.10±0.00	0.1-0.1
Pollen fertility (%)	6.0	-	94.5	-	89.0	-

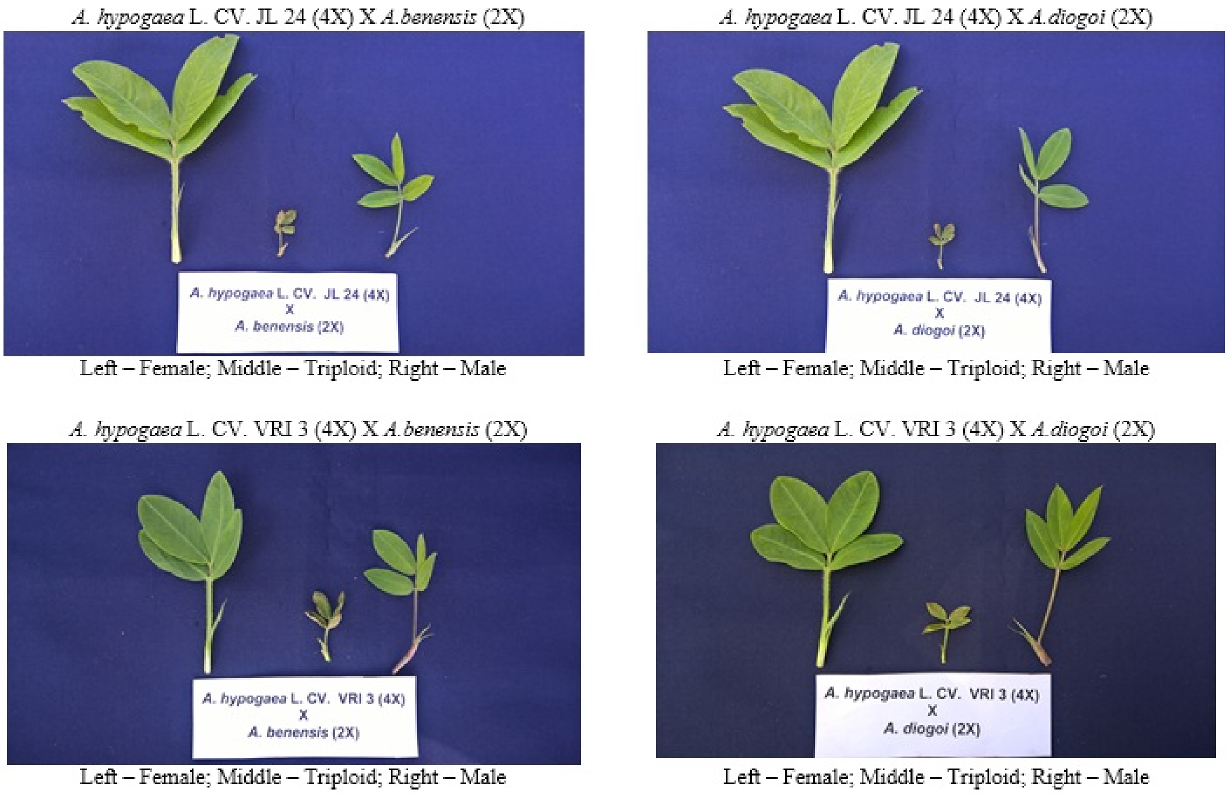

Fig. 2. Leaf morphological differences between parents and triploids

REFERENCES

Anderson W F, Kochert G, Holbrook C C and Stalker H T 2004. Phenotypic and molecular evaluation of interspecific peanut (*Arachis*) lines. *Peanut Science,* **31**: 65-70.

Bhargavi H, Srinivasa Reddy M, Tirumala Reddy S, Kavitha P, Reddy U V B and Babu P V R 2017. Productivity of groundnut (*Arachis hypogaea* L.) as influenced by varieties and plant densities. *Journal of Oilseeds Research*, **33**(1): 83-86.

Kakani V G, Prasad P V V, Craufurd P Q and Wheeler T T 2002. Response of *in vitro* pollen germination and pollen tube growth of groundnut (*Arachis hypogaea* L.) genotypes to temperature. *Plant, Cell and Environment*, **25**: 1651-1661.

Oakes A J 1958. Pollen behavior in peanut (*Arachis hypogaea* L.). *Agronomy Journal*, **50**: 387-389.

Panda S and Narayaa Rao J 2001. Resistance of wild *Arachis* species to late leaf sot and rust in green house trials. *Plant Disease*, **85**: 851-855.

Raman V S 1976. *Cytogenetics and Breeding in Arachis.* Today and Tomorrow Printers and Publishers, New Delhi, India.

Simpson C E 2001. Use of wild *Arachis* species/introgression of genes into *A. hypogaea* L. *Peanut Science*, **28**: 114-116.

Singh A K 1986. Utilization of wild relatives in the genetic improvement of *Arachis hypogaea* L. *Theoretical and Applied Genetics*, **72**: 433-439.

Smart J and Gregory W C 1967. Interspecific cross compatibility between the cultivated peanut *Arachis hypogaea* L. and other members of the genus *Arachis. Oleagineux,* **22**: 455-459.

Stalker H T and Moss J P 1987. Speciation, cytogenetics and utilization of *Arachis* species. *Advances in Agronomy*, **41**: 1-40.

Vindhiyavarman P, Mothilal A, Ganesan K N and Naina Mohammed S E 2000. An appraisal of triploids of Amphidiploids in the Genus *Arachis*. *International Arachis Newsletter*, **20**: 8-9.

Impact of irrigation schedules and mulch on productivity and moisture extraction pattern of linseed (*Linum usitatissimum*)

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(Received: August 11, 2017; Revised: November 9, 2017; Accepted: December 7, 2017)

ABSTRACT

A field experiment was conducted during *rabi* 2010-11 and 2011-12 to evaluate the effect of irrigation and mulch on seed yield, oil yield and water use of linseed. Linseed irrigated at IW/CPE of 0.6 showed 6.72 and 17.63 per cent higher seed yield compared to IW/CPE of 0.4 (669 kg/ha) and rainfed (607 kg/ha), respectively and was significantly superior. Maximum seed yield of about 707 kg/ha under the treatment receiving black polythene mulch, which was about 4.33, 8.72 and 14.76 per cent higher over the treatments receiving straw @ 5 t/ha, water hyacinth @ 5 t/ha and no mulch, respectively. Maximum oil yield was registered by the crop irrigated at IW/CPE of 0.6 and treatment receiving black polythene mulch. Water use efficiency was highest with rainfed treatment and that receiving black polythene. The significant increase in seed yield has led to increase in water productivity of the crop. Linseed extracted maximum soil moisture at its grand growth stage. The treatment combination receiving irrigation at IW/CPE of 0.6 along with black polythene mulch maintained its superiority with highest net return and B:C ratio and proved as best treatment combination.

Keywords: Linseed, Irrigation, Mulch, Yield, Water use, Economics

The demand for edible oils is continuously increasing due to ever increasing population and improvement in the standard of living. In India, linseed is a major winter (*rabi*) season oilseed crop next to rapeseed-mustard. It is a good source of complete protein, high order linolenic acid, carbohydrates, vitamins, minerals and grown for dual purpose-seed and fibre (Sharma *et al.,* 2017). Linseed oils are used as vegetable oil and especially important for industrial uses. So, great emphasis has to be placed on increasing its production to meet the requirements. On the other hand, excessive use and continuous increase in cost of irrigation inspired us to explore the possibilities to restrict the water loss. It is true that farmers are far behind the expectations of irrigation adoption in a scientific manner. They need comprehensive technological support which is simple to use and easy to integrate into farm management. In future, due to climate change and shrinking water availability, demand for irrigation might not meet fully. Adequate and timely water application is a basic pre-requisite for proper plant growth for augmenting crop yield. Limited quantity of water available for irrigation calls for scheduling of irrigation which can avoid excess water applied to the crop and thereby water productivity of linseed could also be improved. Therefore, irrigation is being scheduled based on climatological approach which is considered as most scientific, since it integrate all weather parameters giving them natural weightage in a given climate-plant continuum (Parihar *et al.,* 1976). To reduce evaporation loss of water and enhance moisture availability to crop the most appropriate agronomical moisture conservation practice is mulching. Organic mulches are poor conductor of heat that effectively reduce soil temperature and retain soil moisture for longer period (Vaidya *et al.,* 1995). Biodegradable mulching materials are not able to compete with polythene mulch due to uncontrolled degradation behavior, poor mechanical properties and high cost. Non degradable polythene mulch enhances crop water use efficiency, water productivity but cause pollution if not disposed of from the field after harvesting of the crop. The present experiment was therefore, undertaken with aimed to find out efficient irrigation schedules with optimum requirement and suitable moisture conservation practices for enhancing production and productivity of linseed.

MATERIALS AND METHODS

A field experiment with linseed was conducted during the winter (*rabi*) season of 2010-12 at Research Farm, Bidhan Chandra KrishiViswavidyalaya, Kalyani (22°58' N latitude and 88°3' E longitude with an altitude of 9.75 m above the mean sea level) in West Bengal. The soil of the experimental site was alluvial and sandy loam in texture with pH 7.86, organic carbon 0.61%, available N 250.12 kg/ha, available P and K of 15.81 and 153.22 kg/ha, respectively. The moisture content at field capacity was 21.2% and at permanent wilting point 9.5%.The experiment was laid out in split plot design with three replications. Main plot treatments consisted of three levels of irrigation, *viz.,* I_1 : Rainfed, I_2: Irrigation at IW/CPE of 0.4, I_3 :Irrigation at IW/CPE of 0.6 and sub-plots with four levels of mulch, *viz.,* M_1: No mulch, M_2: Water hyacinth @ 5 t/ha, M_3: Straw mulch @ 5 t/ha, M_4: Black polythene with 25 micron thickness. Recommended doses of N, P_2O_5 and K_2O @ 60: 30:30 kg/ha were applied through urea, single super-phosphate and muriate of potash, respectively during both the years of experiment. The full dose of phosphorus, potassium and ½ dose of nitrogen were applied as basal and remaining ½ dose of nitrogen was applied at 45 DAS. Linseed cv. 'Neela (B-67)' was sown in rows, 30 cm apart using 20 kg seeds/ha in the 2nd week of November. Plot size was 5m x 3m. A pre-sowing irrigation was given for proper germination and establishment. Remaining irrigations were applied as and when required as per treatment schedule. One irrigation in plots under I_2 treatment and two irrigations in plots under I_3 treatment were applied. Irrigation water depth (IW) of 50 mm was maintained for each irrigation with the help of parshall flume. Irrigation was withdrawn 15 days before harvesting of the crop. For irrigation scheduling, 'Climatological approach' was followed, which involved estimation of atmospheric evaporative demand by taking ratio between 'amount of irrigation water applied (mm) to the cumulative pan evaporation (CPE) (mm). Upon the arrival of pre-determined CPE, irrigation was applied in respective plots. In polythene mulch treated plots irrigation was applied in crop row zone only. The crop was harvested at maturity i.e., in 3rd week of March and yield data was recorded. Total rainfall during the crop growth period was 10.4 and 11.1 mm in successive years of experiment, respectively. The mean minimum and maximum temperature of about 15.4 and 33.2°C, respectively were recorded during the crop growth period. The mean relative humidity ranged from 33.6 to 95.9 per cent. The mean pan evaporation per day ranged for 1.3 to 3.2 mm. Soil moisture studies were done during the entire crop period starting from sowing to final harvesting of the crop. Soil samples for soil moisture determination were collected from middle of each plot and space between crop rows corresponding to all treatments from 0-15, 15-30, 30-45 and 45-60 cm soil depths with the help of an auger at sowing, immediately before and 48 hours after giving irrigation of each irrigation and at the same time from I_1 (rainfed) plots nearly about 15 days interval and finally at harvest to determine the total soil moisture used by the crop. The soil samples were dried in the oven at 105°C for 72 hours to calculate the moisture content on gravimetric basis. Volumetric moisture content was then calculated by multiplying the respective bulk density with the gravimetric moisture content. Water-use efficiency (WUE) was calculated based on the yield of the crop per unit of water used in CU. Irrigation water productivity (IWP) was calculated as: IWP= Output/Q (where, IWP, Productivity of irrigation water in kg/m^3; Output, Productivity of linseed in kg/ha; Q, irrigation water applied to the crop in m^3/ha. The oil content of the seed was determined by Soxhelt ether extraction method. Production efficiency (PE) (kg/ha/day) was computed by dividing the economic yield of linseed (kg/ha) with number of days between sowing to harvesting, while monetary efficiency (ME) (₹/ha/day) was calculated by dividing the net returns (₹/ha) with the number of days between sowing to harvesting (Narkhede *et al*., 2015). The economic analysis of the experiment was carried out by taking into consideration the prevailing market prices (₹/kg) of inputs used and economic produce. The data recorded for different parameters were analysed with the help of analysis of variance technique for a split-plot design (Panse and Sukhatme, 1967; Gomez and Gomez, 1984). The results are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Yield attributes and oil content: Irrigation levels significantly influenced the number of capsules/plant, seeds/capsule and 1000-seed weight of linseed during both the years of investigation (Table 2). Irrigation applied at IW/CPE of 0.6 (I_3) proved as superior to other irrigation treatments by producing maximum capsules/plant and seeds/capsule. About 12.74 and 11.12 per cent more number of capsules/plant and seeds/capsule were obtained with the application of irrigation at IW/CPE of 0.4 (I_2) over no irrigation (I_1). Similar finding was reported by Ram *et al.* (2001). Black polythene mulching (M_4) recorded significantly highest number of capsule/plant and seeds/capsule over other mulch treatments. Treatment receiving straw as mulching material @ 5 t/ha (M_3) ranked in second position with 6.79 and 3.50 per cent higher numbers, respectively over that mulched with water hyacinth @ 5 t/ha (M_2). Irrigation applied at IW/CPE of 0.6 (I_3) showed best performance with 3.81 and 10.07 per cent higher 1000 seed weight over irrigation applied at IW/CPE of 0.4 (I_2) and rainfed (I_1), respectively. Omidbaigi *et al.* (2001) opined alike. Treatment receiving black polythene mulch (M_4) increased 1000 seed weight to the tune of 5.09, 8.79 and 11.87 per cent over straw mulch @ 5 t/ha (M_3), water hyacinth @ 5 t/ha (M_2) and no mulch (M_1), respectively. Oil content was highest when linseed was irrigated at IW/CPE of 0.6 (I_3) and was followed by the treatment receiving irrigation at IW/CPE of 0.4 (I_2) producing about 1.32 per cent more oil percentage over no irrigation (I_1). Increased oil content of linseed with the application of irrigation was also stated by Gabiana *et al.* (2005). Data clearly attested that the effect of mulches were positive to the oil percentage of seeds over no mulch. Black polythene mulch (M_4) recorded the maximum seed oil content. The next higher oil content was observed with straw mulch @ 5 t/ha (M_3) to the tune of 0.94 per cent over water hyacinth mulch @ 5 t/ha (M_2).

Yield: Irrigation increased seed and oil yield mainly due to the improvement in yield attributing characters of the crop (Table 2). crop irrigated at IW/CPE of 0.6 (I_3) maintained its superiority by producing 6.72, 17.63 per cent higher seed yield and 7.66, 20.26 per cent higher oil yield over the treatment receiving irrigation at IW/CPE of 0.4 (I_2) and rainfed (I_3), respectively. Lodhi *et al.* (2007) also reported increased seed yield with the increase in irrigation number. Black polythene mulch (M_4) maintained its superiority with highest seed production which was about 4.33, 8.72 and 14.76 per cent higher over the treatments receiving straw mulch @ 5 t/ha (M_3), water hyacinth mulch @ 5 t/ha (M_2) and no mulch (M_1), respectively. Straw mulch @ 5 t/ha (M_3) treatment recorded 4.21 and 10 per cent more seed yield over water hyacinth @ 5 t/ha (M_2) and no mulch (M_1) treatments, respectively and proved as next best treatment. These results are supported by Kalita *et al.* (2005). Mulched plots showed better responses towards oil yield than the unmulched plots. Black polythene mulch (M_4) showed the maximum oil yield and was significantly superior to other three mulch treatments. The next best performance was noticed with the application of straw mulch @ 5 t/ha (M_3) and was followed by the application of water hyacinth @ 5 t/ha (M_2). The beneficial effect of mulch on oil yield was also reported by Yenpreddiwar *et al.* (2007).

Table1 Water use planning for irrigating the linseed

Treatment	Number of irrigation applied	Irrigation depth (cm)	Amount of total water applied (m^3) in 15 m^2 area	Amount of total water applied (m^3/ha)
I_1 = Rainfed	0	0	0	0
I_2: Irrigation at IW/CPE of 0.4	1	5	0.75	500
I_3: Irrigation at IW/CPE of 0.6	2	5+5	1.5	1000

Table 2 Effect of levels of irrigation and mulches on yield components, yield and oil yield of linseed

Treatments	Capsules/plant		Seeds/ capsule		1000-seed weight (g)		Oil content (%)		Seed yield (kg/ha)		Oil yield (kg/ha)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Irrigation levels												
I_1 = Rainfed	54.45	56.85	8.28	8.44	5.40	5.47	34.68	34.76	601.87	612.13	208.80	212.89
I_2: Irrigation at IW/CPE of 0.4	60.24	62.57	8.65	8.83	5.71	5.82	35.13	35.23	664.18	673.85	233.49	237.56
I_3: Irrigation at IW/CPE of 0.6	61.00	64.48	9.20	9.38	5.93	6.04	35.60	35.73	709.51	718.47	250.26	256.86
SEm (±)	0.249	0.46	0.07	0.07	0.04	0.04	0.072	0.084	1.836	1.166	0.291	0.946
CD at 5%	0.74	1.39	0.23	0.22	0.12	0.14	0.216	0.256	5.510	3.502	0.876	2.837
Mulch treatments												
M_1: No mulch	53.00	55.16	8.13	8.36	5.39	5.49	34.53	34.62	611.92	621.28	211.39	215.18
M_2: Water hyacinth @ 5 t/ha	56.30	59.89	8.61	8.72	5.55	5.64	35.01	35.11	645.85	655.84	222.98	230.48
M_3: Straw mulch @ 5 t/ha	60.98	63.09	8.88	9.06	5.73	5.85	35.33	35.44	673.96	682.56	238.31	242.09
M_4: Black polythene	63.98	67.05	9.22	9.40	6.04	6.13	35.67	35.79	702.32	712.91	250.71	255.32
SEm (±)	0.513	0.59	0.06	0.07	0.05	0.04	0.077	0.099	1.642	1.594	0.849	0.828
CD at 5%	1.53	1.77	0.20	0.21	0.15	0.12	0.230	0.295	4.927	4.786	2.544	2.480

Economics: Cost of cultivation increased with the increase in number of irrigation and among various mulch treatments, black polythene (M_4) showed highest cost (Table 3). Linseed irrigated at IW/CPE of 0.6 (I_3) gave 11.14 and 28.25 per cent higher net return over irrigation at IW/CPE of 0.4 (I_2) and rainfed (I_3), respectively. The returns were more by 6.88, 14.22 and 25.23 per cent in black polythene mulch (M_4) than straw mulch @ 5 t/ha (M_3), water hyacinth mulch @ 5 t/ha (M_2) and no mulch (M_1), respectively. Among irrigation levels, maximum benefit cost ratio was obtained with the application of irrigation at IW/CPE of 0.6 (I_3) followed by irrigation at IW/CPE of 0.4 (I_2). Black polythene (M_4) showed highest benefit cost ratio over other mulch treatments. Therefore, irrigation scheduling at IW/CPE of 0.6 (I_3) along with black polythene (M_4) was best in terms of economic benefit and proved as best treatment combination.

Production and economic efficiency: Application of irrigation at IW/CPE of 0.6 (I_3) recorded the highest production and economic efficiency over other irrigation levels and it increased to 6.67 and 11.23%, respectively over irrigation applied at IW/CPE of 0.4 (I_2) (Table 3). Among various mulch treatments, black polythene mulch (M_4) recorded maximum production efficiency of about 4.39 and 8.76 per cent increment over straw mulch @ 5 t/ha (M_3) and water hyacinth mulch @ 5 t/ha (M_2), respectively. Maximum economic efficiency was also observed with black polythene mulch (M_4), increased to the magnitude of 25.27 per cent over no mulch (M_1). This might be due to higher seed yield owing to increased production and economic efficiencies. The results confirm the findings of Tetarwal *et al.* (2013) in Indian mustard.

Water use and irrigation water productivity: The consumptive use of water (CU) was higher with irrigation at IW/CPE of 0.6 (I_3) but water use efficiency (WUE) was higher with rainfed (I_1) (Table 3). This might be on account of ease with which moisture was available for crop growth due to more number of irrigations at IW/CPE of 0.6 (I_3) which enhanced the CU of water by luxuriant plant growth. The higher CU at IW/CPE of 0.6 (I_3) reduced WUE. But at rainfed (I_3) treatment, WUE was highest due to greater increase in seed yield as compared to the increase in quantity of water used. These findings are in conformity with Patel *et al.* (2007) in fennel. The highest CU was observed under no mulch (M_1) treatment. Water hyacinth @ 5 t/ha (M_2) has higher CU over straw mulch @ 5 t/ha (M_3) and black polythene mulch (M_4). The highest WUE was recorded with the application of black polythene mulch (M_4) probably due to more check in evaporation loss of water resulting lower CUW and higher seed yield. Irrigation water productivity (IWP) was higher at IW/CPE of 0.4 (I_2) than that at IW/CPE of 0.6 (I_3) (Table 4). IWP also depicted improvement due to use of different mulches and was maximum with the application of black polythene mulch (M_4).

Moisture extraction pattern and moisture extraction at different growth stages: Soil moisture extraction pattern was markedly influenced by different irrigation and mulch practices (Table 4). Linseed irrigated at IW/CPE of 0.6 (I_3) extracted maximum moisture from top layers due to more availability of irrigation water and minimum was extracted under rainfed (I_1) treatment. Maximum soil moisture extraction was recorded from top soil layer (0-15 cm) in no mulch (M_1), while the least with black polythene mulch (M_4). This might be due to higher evaporation from top layer which was exposed to solar radiation under no mulch treatment (M_1) while the evaporative loss of water was minimum with black polythene (M_4). In 16-30 cm soil layer also the same trend was noticed. However, the reverse trend was registered in deeper soil layer from 31-45 and 46-60 cm and the maximum depletion was recorded with black polythene mulch (M_4) followed by straw mulch @ 5 t/ha (M_3) and least with no mulch (M_1). This is mainly due to higher moisture availability in deeper layers under different mulch treatments compared to no mulch. Usually, under dry situation crop showed a tendency to extract more moisture from deeper soil layers as compared to wet condition, where the crop extracted more water from upper layers as reported by Sher-Singh *et al.* (2006). Soil moisture extraction by the crop increased with the advancement of growth and development and then again gradually decreased at maturity mainly due to ageing, senescence etc. Water use of linseed increased from its lower value at seedling stage to higher at grand growth period. Crop extracted less moisture from soil at maturity than that recorded at grand growth period. At grand growth stage, linseed irrigated at IW/CPE of 0.6 (I_3) extracted about 6.94 and 26.26 per cent more moisture from soil over that irrigated at IW/CPE of 0.4 (I_2) and rainfed (I_1), respectively. The crop receiving no mulch (M_1) was more active to extract maximum moisture (12.14 cm) from the surrounding rhizosphere over other mulch treatments and was followed by water hyacinth @ 5 t/ha (M_2) and then straw @ 5 t/ha (M_3) as mulch. Thus, application of irrigation at IW/CPE of 0.6 along with black polythene mulch helps in achieving highest productivity and profitability and proved as best treatment combination.

Table 3 Effect of levels of irrigation and mulches on economics, efficiencies and consumptive use of water of linseed

Treatments	Cost of cultivation ($x10^3$₹/ha)	Net Returns ($x10^3$₹/ha)		Benefit: Cost ratio		Production efficiency (kg/ha/day)		Economic efficiency (₹/ha/day)		Consumptive use (cm)		WUE (kg/ha/mm)	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Irrigation levels													
I_1 = Rainfed	14.44	7.27	7.66	0.50	0.53	4.85	4.94	58.60	61.75	18.68	17.73	3.22	3.45
I_2: Irrigation at IW/CPE of 0.4	15.50	8.42	8.81	0.54	0.57	5.36	5.43	67.92	71.01	21.08	21.96	3.15	3.07
I_3: Irrigation at IW/CPE of 0.6	16.15	9.42	9.74	0.58	0.61	5.72	5.79	75.97	78.57	23.59	23.78	3.01	3.02
Mulch treatments													
M_1: No mulch	14.65	7.40	7.74	0.50	0.53	4.93	5.01	59.66	62.40	21.56	21.75	2.84	2.88
M_2: Water hyacinth @ 5 t/ha	15.17	8.12	8.48	0.53	0.56	5.20	5.29	65.38	68.40	21.24	21.17	3.04	3.11
M_3: Straw mulch @ 5 t/ ha	15.59	8.70	9.03	0.56	0.58	5.44	5.50	70.19	72.84	20.88	20.90	3.23	3.29
M_4: Black polythene	16.03	9.27	9.69	0.58	0.60	5.66	5.75	74.75	78.14	20.77	20.80	3.38	3.45

Market Price of produce: Seed - Rs 35/ kg, Stalk- Rs 0.25/kg, Mean crop duration -124 days

Table 4 Effect of levels of irrigation and mulches on irrigation water productivity and moisture extraction pattern and moisture extraction at different growth stages of linseed

Treatments	Irrigation water productivity (kg/m^3)		Moisture extraction pattern (%)				Soil moisture extraction at different growth stages (cm)		
	2010-11	2011-12	0-15 cm	16-30 cm	31-45 cm	46-60 cm	Seedling stage	Grand growth stage	Maturity stage
Irrigation levels									
I_1 = Rainfed	-	-	30.71	30.31	21.69	17.29	4.03	10.13	4.05
I_2: Irrigation at IW/CPE of 0.4	1.32	1.34	34.02	27.44	21.39	17.15	4.23	11.96	5.33
I_3: Irrigation at IW/CPE of 0.6	0.71	0.71	36.55	28.65	19.34	15.46	4.38	12.79	6.52
Mulch treatments									
M_1: No mulch	0.95	0.96	36.24	30.12	18.76	14.88	4.11	12.14	5.41
M_2: Water hyacinth @ 5 t/ha	1.00	1.01	34.33	29.19	20.24	16.24	4.00	12.00	5.21
M_3: Straw mulch @ 5 t/ha	1.03	1.05	34.19	28.71	20.77	16.33	4.06	11.79	5.04
M_4: Black polythene	1.08	1.10	32.77	28.19	21.73	17.31	3.98	11.46	5.35

REFERENCES

Gabiana C, McKenzie B A and Hill G D 2005. The influence of plant population, nitrogen and irrigation on yield and yield components of linseed. *Agronomy New Zealand*, **35**: 44-56.

Gomez K A and Gomez A A 1984. *Statistical Procedures for Agricultural Research*, edn 2, An International Rice Research Institute Book, Wiley-Inter-Science Publication, John Wiley & Sons, New York.

Kalita H, Bora P C and Debnath M C 2005. Effect of sowing date and tillage on soil properties, nutrient uptake and yield of linseed (*Linum usitatissimum*) grown in winter rice (*Oryza sativa*)-fallows. *Indian Journal of Agronomy*, **50**(1): 70-72.

Lodhi M D, Singh U P, Chauhan D V S and Verma N K 2007. Studies on the effect of different dates of sowing varieties and number of irrigations on growth, yield and quality of linseed (*Linum usitatissimum* L.). *Bhartiya Krishi Anusandhan Patrika*, **22**(4): 295-298.

Narkhede W N, Deshmukh M S and Gangwar B 2015. Alternate cropping system for central plateau zone of Maharashtra. *Indian Journal of Agronomy*, **60**(2):192-196.

Omidbaigi R,Tabatabaei S M F and Akbari T 2001. Effects of N-fertilizers and irrigation on the productivity (growth, seed yield, and active substances) of linseed. *Iranian Journal of Agricultural Sciences*, **32**(1): 53-64.

Panse V G and Sukhatme P V 1984. *Statistical Methods for Agricultural Workers*, ICAR, New Delhi.

Parihar S S, Khera K L, Sandhu K S and Sandhu B S 1976. Comparison of irrigation schedule based on pan evaporation and growth stages in wheat. *Agronomy Journal*, **68**: 650-653.

Patel B S, Joshi M K, Patel J C and Patel N B 2007. Influence of irrigation based on IW/CPE ratio and nitrogen levels on yield and water use efficiency of fennel (*Foeniculam vulgare* Mill.). In: *Production Development, Quality and Export of Seed Spices*, Malhotra S K and Vashistha B B (Eds.) National Research Centre on Seed Spices, Ajmer, pp.262-266.

Ram S D, Rahman A, Singh R S and Das P K 2001. Management for higher linseed (*Linum usitatissimum* L.) production in Jharkhand. *Journal of Research Birsa Agricultural University*, **13**(2): 163-165.

Sharma D, Satish P and Ranjana P 2017. Study on genetic divergence analysis of indigenous and exotic lines of linseed (*Linum usitatissimum* L.) based on morphological and quality traits. *Journal of Oilseeds Research*, **34**(1): 38-43.

Sher-Singh, Malik R K and Punia S S 2005. Performance of late-sown chickpea (*Cicer arietinum* L.) and its economic feasibility as affected by irrigation, sulphur and seed inoculation. *Haryana Agricultural University Journal of Research*, **35**(2): 131-134.

Tetarwal J P, Ram B and Raiger P R 2013. Yield, nutrient balance and water use efficiency as influenced by moisture conservation practices and sulphur sources of Indian mustard under rainfed conditions. *Indian Journal of Fertilizers*, **9**(7): 58-64.

Vaidya V B, Varshneya M C, Bote N L and Naidu T R V 1995. Estimation of thermal efficiency and apparent reflectivity of mulches using soil temperature. *Journal of Maharashtra Agricultural Universities*, **20**(3): 341-344.

Yenpreddiwar M D, Nikam R R, Dange R B and Gaidhane S N 2007. Water use studies in linseed as influenced by different irrigation levels and moisture conservation practices. *Journal of Soils and Crops*, **17**(1): 176-177.

Accurate estimation of biomass production and partitioning efficiency in castor (*Ricinus communis* L.)

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(Received: December 7, 2017; Revised: December 22, 2017; Accepted: December 28, 2017)

ABSTRACT

There is continuous leaf fall due to senescence from 35-60 days after sowing (DAS) till harvest depending on crop duration in castor which is not quantified in general for computation of total dry matter (TDM) and harvest index (HI). By calculating HI with the TDM at harvest of the plant which excludes senesced fallen leaf weight gives high HI values than actually are. In castor, major emphasis is on selecting genotypes with high partitioning efficiency which is shown by high HI. Hence, an experiment was conducted during 2013-15 for two years to devise suitable methodology for quantification of senesced fallen leaf while working out plant dry matter. Senesced fallen leaf was collected, quantified, factor for estimation of senesced leaf weight was developed using linear regression equation and model was validated. The equations derived for estimation of TDM and HI from senesced leaf include: TDM with senesced leaf weight = 1.217 * TDM without senesced leaf weight and HI with senesced leaf weight = 0.805* HI without senesced leaf weight. This factor can be used for accurate estimation of TDM at harvest and HI to enhance the quality of data for selection of genotypes with high partitioning efficiency.

Keywords: Castor, Harvest index, Linear regression, Senesced leaf, Total dry matter

Castor is an indeterminate crop. There is continuous production of branches and leaves. The first leaves in each order are smaller than later ones. Petiole length is also shorter in early leaves and longer in late leaves and takes 40 days for completion. The incident angle between petiole and apical stem shows continuous and linear increase throughout the life time of the leaf. Leaf blade takes 20 days for full expansion and average life span is 60 days (Udo Jongebloed *et al*., 2004). An important leaf function is storing reserves (assimilated carbon and nutrients) to be remobilized during seed filling. Leaves in the same plant can have widely variable leaf lifespan (LLS) which is defined as the period between the leaf's full expansion or when it becomes a source and its senescence. LLS can be influenced by many environmental factors i.e., it can be reduced by diseases, severe drought stress, high temperature, salt stress, high plant population and it can be increased by sink reduction and low temperature (Lim *et al*., 2007). The beginning of leaf senescence is primarily controlled by leaf age, but it is also under the influence of environmental conditions, biotic stresses, and physiological factors. Leaf senescence is the final phase of leaf development and during senescence, instead of carbon assimilation, the main metabolic process is the breaking down of chlorophyll and macromolecules such as proteins, membrane lipids, and RNA (Severino and Dick, 2013). In castor plants, the leaf area reduction starting just after the onset of the reproductive phase confirms this source-sink relationship (Severino *et al*., 2010). Leaf yellowing and abscission were observed to spread from the bottom to the top of the plants indicating that the senescence process was related to leaf age. Membrane deterioration in plant senescence is commonly associated with progressive decreases in membrane phospholipid content (Fobel *et al*., 1987). Phospholipid dehydrogenase activity has been suggested to play a role in the progressive decline in membrane phospholipid content in senescing tissues (Paliyath *et al*., 1987). Thus, there is continuous leaf fall due to senescence from 35-60 DAS till harvest in castor depending on crop duration.

For physiological studies, total dry matter (TDM) is the most important parameter and senesced fallen leaf weight is not quantified in general for computation of TDM and harvest index (HI) in castor. By calculating HI with the TDM at harvest of the plant which excludes senesced leaf weight gives high HI values than actually are. In castor, major emphasis is on selecting genotypes with high partitioning efficiency which is shown by high HI. The objective of this study was to develop factor for estimation of fallen leaf due to senescence during crop growth.

MATERIALS AND METHODS

Experimental details: An experiment was conducted during 2013-15 for two years to devise suitable methodology for senesced leaf quantification while working out plant dry matter. During *kharif* 2013-14, 31 genotypes which include 29 breeding lines along with varieties 48-1, Haritha were sown in single rows for selecting genotypes with high TDM and HI. Senesced fallen leaf data was recorded in this experiment for developing a factor. During *kharif* 2014-15,

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three genotypes with differences in LAI [(RG 2149 (>5 LAI), RG2058 (>5), RG 387(<1)] along with variety 48-1 (3), hybrid DCH-519 (3) were sown in three replications with five rows each to study the senesced leaf quantification and to validate the factor developed. Each leaf on 10 plants per replication was tagged by using different colour ribbons for different genotypes. Senesced fallen leaf was collected at 10 days interval from 35 DAS. Data on senesced fallen leaf number, senesced leaf dry weight (SLW), seed yield of different order branches and TDM at harvest were recorded. TDM and HI with and without senesced leaf weight was calculated using the data of 2013-14 to build a model by linear method for estimation of TDM and HI including senesced leaves. Validation of the model was done using the data of 2014-15.

Estimation of factor: TDM and HI data of 31 genotypes grown in 2013-14 were used for estimation of factor for calculation of TDM and HI with senesced leaf as it is very difficult to record the senesced/fallen leaf weight during crop growth every time. The following Linear regression model that is one of the types of probabilistic models was used for estimation of the factor. It contains deterministic component and random error.

$$Y = a + b*x + e$$

"a" and 'b" are parameters of the model where "a" is the intercept, "b" is the slope of the model, "Y" is the dependent variable i.e. TDM with senescence/HI with senescence, "X" is independent variable i.e. TDM without senescence/HI without senescence and "e" is the error term.

The intercept is the expected mean value of Y when all X=0. If X sometimes = 0, the intercept is simply the expected mean value of Y at that value. If X never = 0, then the intercept has no intrinsic meaning. In this factor estimation, the purpose of a regression model is to understand the relationship between predictors and the response. If so, and if X never = 0, there is no interest in the intercept. It doesn't give anything about the relationship between X and Y. Steps followed in linear regression include: estimation of the parameter, specifying the probability distribution of error term and finally validation of the fitted model using regression diagnostics. Validation was done by checking the pattern of residuals by means of residual plots (Draper and Smith, 1998). Regression diagnostics used here was Leverage values and Cooks distance. The leverage value is a measure of how far a particular case is from the average of all cases, with distance being measured in such a way that the correlations between the X-variables is taken into account. A leverage point is characterized by fitted value close to the observed target value, its residual is likely to be closer to zero. Cook's distance, measures the change in the fitted regression coefficients if a case was dropped from the regression. SPSS was used for developing model. Developed factor was cross validated with 2014-15 year data. Cross-validation is the process of assessing how the results of a statistical analysis will generalize to an independent data set. If the model has been estimated over some, but not all, of the available data, then the model using the estimated parameters can be used to predict the held-back data.

RESULTS AND DISCUSSION

Data on senesced leaf number, leaf dry weight, seed yield of different order branches, TDM at harvest were recorded and HI was calculated with and without senesced leaf weight. During 2013-14, the senesced leaf weight (SLW) accounted for 10-32 per cent of TDM at harvest with an average of 17 per cent (Table 1). In 2014-15, it ranged from 15-27 per cent with an average of 20 per cent (Table 2). Major portion of leaf dry weight includes petiole weight. Petiole weight was calculated by separating petioles from senesced leaves, taking dry weight separately and adding to total senesced fallen leaf weight to see the percent petiole weight in total leaf weight. It ranged from 24.4 - 34.9 per cent in total leaf weight with an average of 30.3 per cent.

Total dry matter and harvest index estimation is an important measurement for prediction of yield component. Field data on senesced fallen leaf weight was collected to build a model using linear method for estimation of TDM and HI including fallen leaves. Estimation of regression line for TDM and HI with and without senesced leaf weight (Fig. 1) shows that the linear regression line passing through the origin fitted the data well (R^2 = 0.997, 0.995). Regression equations were developed for both the characters and presented in Table 3. Observed and predicted values showed high correlation (0.993) indicating the goodness of fit of the models. Validation of the models using regression diagnostics was done by checking the pattern of the residuals by means of residual plots and for individual data points. The residual plot (Fig. 2) indicating the normality assumption of the model and fit the data well. The low leverage points (0.002 to 0.056 and 0.01to 0.055) and small cook's D value (0.017 and 0.033) signifies the estimated factor accurate (Cook and Dennis, 1977). The following equation has been derived for estimation of TDM and HI (Fig.2) from senesced leaf.

TDM with senesced leaf weight = 1.217 * TDM without senesced leaf weight

HI with senesced leaf weight = 0.805* HI without senesced leaf weight

Table 1 Senesced leaf weight, TDM and HI with and without senesced leaf weight and seed yield (2013-14)

Genotype	Senesced leaf weight (SLW) (g/pl.)	SLW % in TDM at harvest	Total dry matter (TDM) at harvest excluding SLW (g/pl.)	TDM at harvest including SLW (g/pl.) observed	TDM at harvest including SLW (g/pl.) predicted	Seed yield (g/pl.)	HI excluding SLW (%)	HI including SLW (%) observed	HI including SLW (%) predicted
48-1	84.7	13.2	558	643	655	181.6	32.6	28.3	27.2
Haritha	75.1	11.7	565	640	691	149.8	26.5	23.4	37.9
k12-86-2	67.4	10.3	588	655	583	267.0	45.4	40.8	43.9
k12-91-2	67.3	11.9	496	564	597	260.8	52.5	46.3	39.2
k12-98-3	64.7	11.3	508	573	594	238.4	46.9	41.6	31.4
k12-1555-1	94.3	15.7	506	600	435	190.1	37.6	31.7	25.7
k12-1841-1	79.4	17.7	370	449	460	113.5	30.7	25.3	40.6
DCS-89	69.7	15.1	392	461	664	190.2	48.6	41.2	22.1
DPC-15	53.9	29.0	132	186	155	45.1	34.2	24.3	28.6
DPC-16	74.9	16.4	383	458	450	94.2	24.6	20.6	20.6
DPC-17	61.9	17.2	298	360	350	101.9	34.2	28.3	28.6
DPC-19	74.9	13.8	466	541	547	151.9	32.6	28.1	27.2
DPC-20	78.0	14.4	466	544	547	154.8	33.3	28.5	27.8
DPC-21	98.7	17.8	456	555	536	170.0	37.3	30.7	31.2
DPC-23	78.6	15.9	416	494	489	145.9	35.1	29.5	29.3
DPC-24	71.9	15.4	396	468	465	102.4	25.8	21.9	21.6
DPC-25	67.9	14.9	388	456	456	118.1	30.5	25.9	25.5
M-571	67.1	17.1	325	392	382	125.9	38.7	32.1	32.3
M-574	83.8	26.1	238	321	278	54.7	23.0	17.0	19.2
M-DPC-9-1	65.1	11.1	521	586	612	116.0	22.3	19.8	18.6
DCS-108	45.5	12.9	307	352	361	81.0	26.4	23.0	22.1
DCS-109	58.1	20.8	222	280	261	101.9	45.9	36.4	38.4
DCS-110	66.3	13.7	417	484	490	136.6	32.7	28.2	27.3
DCS-112	86.7	15.6	468	555	550	139.5	29.8	25.1	24.9
DCS-113	80.3	14.1	490	571	576	151.6	30.9	26.6	25.8
DCS-117	75.3	15.7	405	481	476	88.0	21.7	18.3	18.1
DCS-118	70.6	19.5	293	363	343	76.1	26.0	20.9	21.7
DCS-119	84.4	31.8	181	266	213	69.9	38.6	26.3	32.3
DCS-120	89.1	21.9	318	407	374	55.7	17.5	13.7	14.6
DCH-1551	66.3	16.3	340	406	399	96.3	28.3	23.7	23.6
DCH-1566	69.9	21.2	260.0	330	305	97.5	37.5	29.5	31.3
Mean	73.3	16.8	393	466	461	131.2	33.1	27.6	27.7

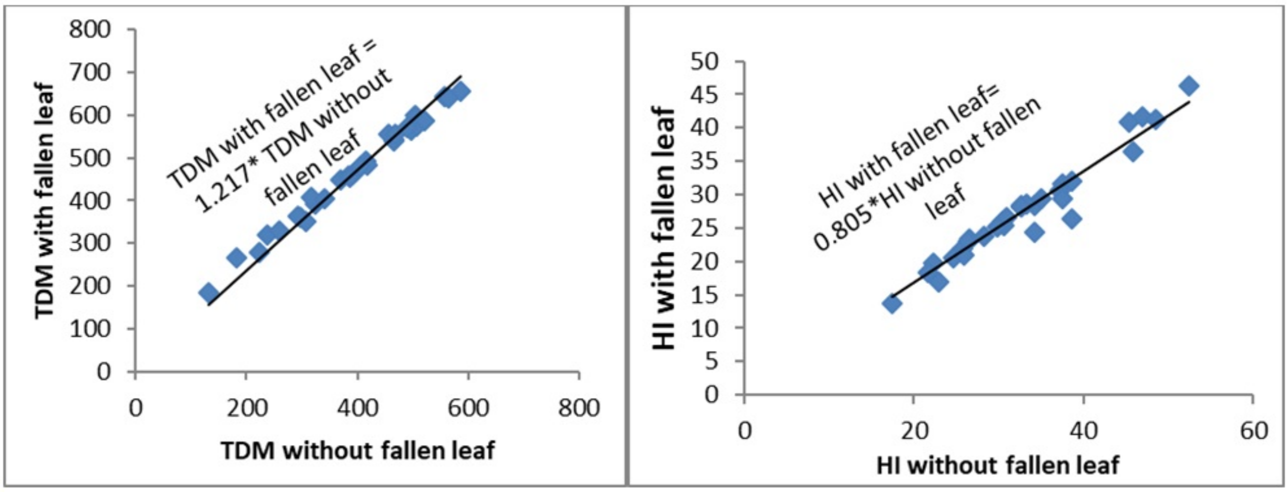

Fig. 1. Estimation of regression line for TDM and HI with and without senesced leaf weight

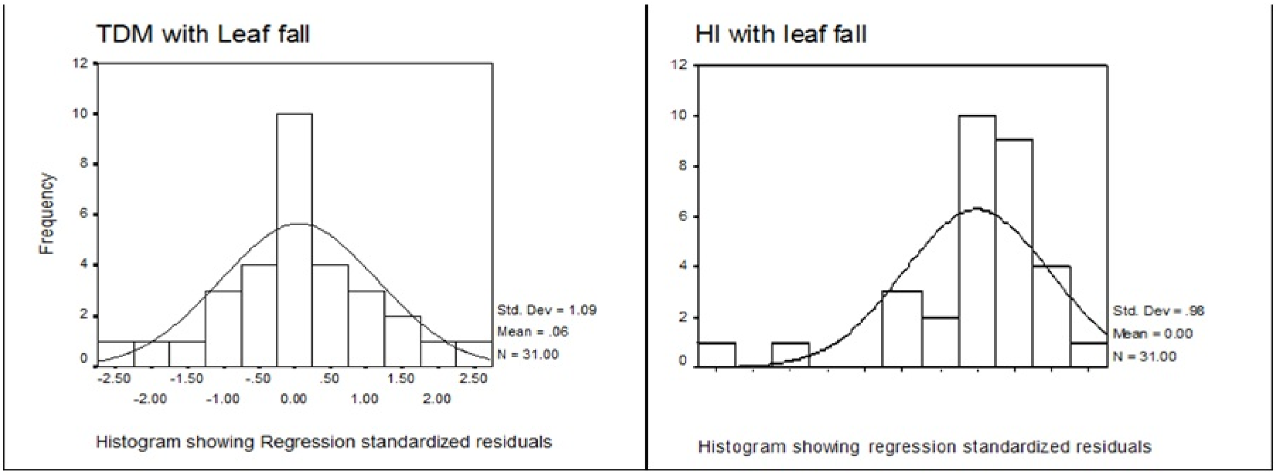

Fig. 2. Regression standard residuals for TDM and HI with leaf fall

Validation of the factor using 2014-15 year data of 5 genotypes for TDM and HI with chi-square test (P=0.14, 0.97 respectively) indicates the strong association between the observed and calculated values with leaf fall using the developed factor. Similarly, a factor for leaf area estimation was developed by Pandey and Hema Singh (2011) using 33 species data.

The withdrawal of nutrients (particularly nitrogen) from leaves during reproductive development plays an important role in the process of leaf senescence. Leaf area is an important variable for most eco physiological studies in terrestrial ecosystems concerning light interception, evapo-transpiration, photosynthetic efficiency, fertilizers, irrigation response and plant growth (Blanco and Folegatti, 2005). Hence, pre mature leaf fall due to any stress may result in yield reduction. But under estimation of total leaf dry matter produced will result in showing less TDM and HI in a genotype. In this trial, there was 17-20 per cent reduction in actual TDM due to senesced leaf fall. The harvest index difference was 5.5 per cent during both years with and without senesced leaf weight. Selection of genotypes with more partitioning efficiency based on HI without SLW may also give same genotypes with high HI but the average increase of 5.5 per cent in general is very difficult to attain in any breeding program and may give wrong indication of high HI in castor than it actually has. Thus, the factor derived for senesced leaf fall quantification to get accurate TDM at harvest and HI can be used in castor research studies to enhance the quality of the data recorded.

Total dry matter and harvest index are of crucial importance for selection of genotypes to be used in breeding programs. These traits are usually determined without considering senesced leaf weight. This leads to under estimation of TDM and over estimation of HI. Hence, the developed factor for estimation of TDM and HI helps the researchers to estimate the TDM and HI without adding the fallen leaf weight.

Table 2 Senesced leaf weight, TDM and HI with and without senesced leaf weight and seed yield (2014-15)

Genotype	Senesced leaf weight (SLW) (g/pl.)	SLW % in TDM at harvest	Total dry matter (TDM) at harvest excluding SLW (g/pl.)	TDM at harvest including SLW (g/pl.)	Seed yield (g/pl.)	HI excluding SLW (%)	HI including SLW (%)
48-1	103.1	19.1	447	550	133.3	30.7	24.7
RG2149	151.5	23.1	521	673	48.9	9.7	7.4
RG2058	131.3	26.5	400	532	102.2	28.9	20.5
RG387	61.1	15.2	349	410	115.8	33.5	28.4
DCH-519	96.6	18.2	437	533	129.1	30.3	24.7
Mean	109	20.4	431	540	105.9	26.6	21.1

Table 3 Linear relationship of TDM, HI with and without senesced leaf

Character	Factor	R^2	Confidence intervals	
			LB	UB
TDM	1.217	0.997	1.195	1.24
HI	0.805	0.995	0.784	0.826

REFERENCES

Blanco F F and Folegatti M V 2005. Estimation of leaf area for greenhouse cucumber by linear measurements under salinity and grafting. *Agricultural Science*, **62**(4): 305-309.

Cook and Dennis R 1997. Detection of influential observations in linear regression. Technometrics, *American Statistical Association*, **19**(1): 15-18.

Draper N R and Smith H 1998. *Applied Regression Analysis*, 3rd edn, N R Draper and H Smith, Wiley, New York.

Fobel M, Lynch D V and Thompson J E 1987. Membrane deterioration in senescing carnation flowers. *Plant Physiology*, **85**: 204-211.

Landsberg J J 1977. Some useful equations for biological studies. *Experimental Agriculture,* **13**: 273-286.

Lim P O, Kim H J and Nam H G 2007. Leaf senescence. *Annual Review of Plant Biology*, **58**: 115-136.

Paliyath G, Lynch D V and Thompson J E 1987. Regulation of membrane phospholipid catabolism in senescing carnation flowers. *Physiologia Plantarum*, **71**: 503-511.

Pandey S K and Hema Singh 2011. A simple, cost-effective method for leaf area estimation. *Journal of Botany*, **2011**: 1-6.

Phillips D A, Pierce, R O, Edie S A, Foster K W and Knowles P F 1984. Delayed leaf senescence in soybean. *Crop Science,* **24**: 518-522.

Severino L S, Freire M A O, Lucena A M A and Vale L S 2010. Sequential defoliations influencing the development and yield components of castor plants (*Ricinus communis* L.). *Industrial Crops and Products*, **32**: 400-404.

Severino L S and Dick L A 2013. A framework for the study of the growth and development of castor plant. *Industrial Crops and Products*, **46**: 25-38.

Udo Jongebloed, Judit Szederkenyi, Katja Hartig, Christian Schobert and Ewald komor 2004. Sequence of morphological and physiological events during natural ageing and senescence of a castor bean leaf: sieve tube occlusion and carbohydrate back-up precede chlorophyll degradation. *Physiologia Plantarum*, **120**: 338-346.

Peptide polymorphism under recommended dose of nitrogen fertilization in *Brassica juncea*

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(Received: November 23, 2017; Revised: December 14, 2017; Accepted: December 21, 2017)

ABSTRACT

Electrophoretically detectable seed storage proteins such as cruciferin, procruciferin and napin in mustard seeds possess the potential for taxonomic and evolutionary characterization of germplasm. This study was intended to see the genetic diversity among 24 genotypes of Indian mustard and the effect of N80 application on the protein profile. SDS-PAGE based profiles of seed proteins showed major differences in banding patterns among these genotypes. A total of eight peptide bands were assayed for their specificity in detecting genetic variability among Brassica genotypes under N_0 and N_{80} conditions. Under N_0 condition, a total of 166 bands (86.5%) were scored ranging from 10 kDa to 71 kDa in all genotypes, of which 118 showed polymorphic loci with 71.08 per cent polymorphism and similarity coefficient ranging from 0.375 to 1.0. Genotypes were clustered using UPGMA based clustering method into two major clusters. Cluster-I comprises of two cultivars, while cluster-II included the remaining twenty two cultivars. Under N_{80} condition, a range of 170 bands (88.5%) were found among 24 genotypes, of which 74 bands showed 38.5 per cent polymorphism with similarity coefficient ranging from 0.5 to 1.0. HB-9916 showed maximum variation (62.5%) in banding pattern of peptides with 3 per cent rise in polymorphism over N_0 condition.

Keywords: *Brassica juncea,* Genetic diversity, Nitrogen fertilizer, Protein profile

Oilseed *Brassica juncea* commonly known as Indian Mustard is cultivated mainly in the northern part of India spreading from the western Rajasthan to north eastern region of India. It is believed to have originated in central Asia. It has amphidiploid genome consisting of 18 chromosomes. Mustard contains 40-42 per cent oil, 20-30 per cent proteins, and contains a cocktail of nutritionally important compounds having health benefits. It is utilized worldwide as oilseed, condiment, vegetable, green manure, forage and fodder (Singh *et al*., 2016; Kumar *et al*., 2017). Despite the continuous efforts of plant breeders the yield and oil content of this crop has not increased substantially in the past decades. The narrow genetic base and lack of sufficient genetic diversity for desirable traits in the germplasm are major bottlenecks for crop improvement programmes. It is imperative to further explore the genetic diversity available in this crop for better utilization of genetic resources in yield and quality improvement programmes.

Genetic diversity analysis using morphological traits requires extensive observation of mature plants but cannot serve as unambiguous markers because of environmental influences. Molecular markers and biochemical markers have been used extensively to assess the genetic diversity and phylogenetic relationships in plant genetic resources. Seed storage proteins are stable products encoded by number of gene families and subgene families that cannot be denatured during seed formation (Jin *et al*., 2006). Seed storage protein markers are polymorphic and environmental influence on their electrophoretic pattern is limited (Sadia *et al*., 2009). Polypeptide or protein profiling serves as useful genetic marker system with expressed gene diversity and has been applied in gene mapping, gene regulation, developmental genetics, evolution, screening for mutants and cultivar identification (Tanksley, 1993; Kumar *et al*., 2017). SDS-PAGE is one of the simple and reliable techniques for genetic diversity analysis and cultivar identification which can be useful to determine the correct starting material for plant breeding. Peptide profiling using SDS-PAGE have been done for diversity evaluation in *Brassica juncea* (Sadia *et al*., 2009; Rabbani *et al*., 2001, Khurshid and Rabbani, 2012), *Brassica napus* (Sadia *et al*., 2009; Khurshid and Rabbani, 2012; Mahasi and Kamundia, 2007], *Brassica oleracea* (Sadia *et al*., 2009), *Brassica rapa* (Sadia *et al*., 2009; Khurshid and Rabbani, 2012) and *Brassica carinata* (Khurshid and Rabbani, 2012; Zada *et al*., 2013). Planting locations have shown to contribute to genetic diversity in morphological characters (Alemayehu and Becker, 2002) which in turn can affect the genes responsible for a particular trait. Many of the diversity studies were done for different species from different geographical regions. In the present study the diversity in the effect of recommended dose of nitrogen fertilizer (N_{80} kg/ha) on the crops was analysed. Changes owing to the major storage protein cruciferin and napin were observed. In many of the mustard growing regions in India, use of 80 kg N/ha has been recommended to enhance the productivity of mustard (Shekhawat *et al*., 2012).

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There have been numerous studies that relate fertilizer use and its effect on yield, productivity and oil content of oilseed *Brassica* (Joshi, 1998; Parmar and Parmar, 2012; Mawlong, 2017). However, little is known about the effect of N fertilizer application on chemical composition of oil and seed meal. Keeping this in view, in this study we have tried to see the effect of nitrogen fertilizer on the nutritional quality of oil and seed meal. No data to our knowledge are available on effect of nitrogen fertilizer on polymorphism of peptide bands as well.

MATERIALS AND METHODS

Experimental site: The experiment was conducted at ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan, India (115° 42 E, 36° 61 N). Details of the experimental site and design are explained in a previous report (Mawlong *et al.,* 2017).

Total nitrogen estimation: The total nitrogen was estimated by micro-kjeldahl method as suggested by AOAC (1955).

Seed storage protein: Soluble protein content in the defatted seed meal was estimated by the method of Lowry (1951) after precipitation with trichloro acetic acid. Bovine serum albumin was used as standard. Soluble protein was resuspended in laemmili lysis buffer and denatured at 95°C for 4min.

Gel electrophoresis: SDS-PAGE of total seed storage protein was carried out in a 12 per cent polyacrylamide gel in a discontinuous buffer system. 15 µl (20 µg/µl) was loaded in each well of the stacking gel. Wide range prestained protein ladder (GCC Biotech # GCR-P4) was run on the side as reference. The gel was stained with solution containing 2% Coomassie Brilliant Blue, followed by destaining after 1 h with a mixture of methanol, acetic acid and water (5:1:4).

UPGMA Cluster analysis based on SDS-PAGE database: With regard to the protein banding pattern, eight peptide bands specific to procruciferin, cruciferin (6 subunits) and napin were considered for Cluster analysis. Jaccard's similarity coefficient estimated by the UPGMA was used to generate the dendrogram depicting genetic relationship among the *Brassica* genotypes. All bands visible to the eye were scored and only unambiguously scored bands were used in the analyses. Each band was given score of 1 for presence and 0 for absence. Data analyses was done using NTSys-pc, version 2.2 (Exeter software, Setauket,N.Y.). Consequently, the band intensities, band number and presence or absence of polypeptide bands at different Nitrogen treatments N_0 and N_{80} were also assigned approximate values to indicate genetic relationships among genotypes in the dendrogram.

RESULTS AND DISCUSSION

Peptide polymorphism: Assessing genetic diversity is an important prerequisite in any population genetics because it affects the evolutionary potential of a population. To improve the quality of protein it is very essential to understand the structure and diversity of storage proteins. The electrophoretic banding patterns of total seed storage protein as revealed by SDS-PAGE at N_0 and N_{80} conditions were used for analyzing the genetic diversity among twenty four *Brassica juncea* genotypes (Fig. 1). Under N_0 altogether, a total of 166 bands (86.5%) ranging from 10 kDa to 71 kDa were found in all the genotypes, of which 118 showed polymorphic loci with 71.08 per cent polymorphism (Table 1a). Lowest number of bands (3) were found in HB-9916 with 1.8 per cent polymorphism and maximum numbers of peptide bands (8) with 4.81 per cent polymorphism were found in DRMR-IJ-31, MAYA, EC-399294, EC-399300, ROHINI, IC212031, NRCHB-101, NRCHB-506, Pusa jai kisan, RL-1359 and BEC-16 (Table 1b).

Under N_{80} treatment, out of the 24 genotypes analyzed, maximum number of bands (8) were observed in genotypes 78-1-1-1, EC-399307, GM-2, ROHINI, HB-9916, QM-16, RGN-55, NRCHB-101, NRCHB-506, Pusa jai kisan, RL-1359 and BEC-16 (Table 1b). Further, it was seen that the total peptide bands among Indian mustard genotypes increased from 86.5 per cent at N_0 to 88.5 per cent at N_{80} (Table 1c). Greater polymorphism reflects higher genetic diversity among the genotypes. Our observations were also in tune with previous reports in wheat (Dupont *et al.,* 2006). The results indicate that diversity analysis by SDS-PAGE can generate valuable information. Studies on wheat protein have also shown the application of nitrogen and its relation to polymeric fractions (Jia *et al.,* 1996; Scheromm *et al.,* 1992; Johansson *et al.,* 2001). However, on changing the nitrogen condition from N_0 to N_{80}, a decrease in polymorphic loci was also noticed among genotypes from 71.08 to 38.54 per cent (Table 1a) indicating the genotype dependent reoccurrence and disappearance of certain peptides at higher nitrogen conditions. Further, out of the 24 genotypes studied, six genotypes (ROHINI, NRCHB-101, NRCDR-2, NDRE-7, RL-1359, BEC-16 and DHR-991) showed no change in the number of bands under N_0 and under N_{80} application (Table 1b) indicating effect of external factors like nitrogen fertilizers on protein profile is genotype dependent. Similar reports by others (Leesawatwong *et al*., 2005) on wheat have shown increase in individual storage protein to be genotype dependent. On the basis of per cent change in total polymorphism of proteins, maximum change of 3 per cent was observed in HB9916, followed by QM16 (2.4%), RGN-55 (1.79%) and 78-1-1-1 (1.79%) (Table 1b). Appearance of new bands usually results from different DNA structural changes (e.g. breaks, transpositions, deletions), which leads to changes in amino acids, and consequently the protein product (Mondini *et al.,* 2009). The 62.5 per cent increase in peptide polymorphism in HB9916 under N_{80} condition may also indicates role of nitrogen application at protein translational level, although 11 genotypes including DRMR-IJ-31, HB-207, HB-9902, HB-9912, IC212031, NATP-124, NRCHB-506, Pusa jai kisan, MAYA, EC399294, EC399300 showed decrease in total protein polymorphism from 0.6-1.2 per cent and peptide polymorphism from 12.5-25 per cent. It implies that the influence of nitrogen is not same for all genotypes taken in our studies. Similar reports (Prieto *et al.,* 1992; Pechanek *et al.,* 1997) pertaining to our findings were observed in wheat proteins results. To understand further we looked into the total nitrogen content in seed where about 63 per cent of the genotypes showed variation in total seed nitrogen by 3.0 (DRMR-IJ-31) to 34.0 per cent (NRCDR-2) over N_0. The polymorphism within genotypes can be observed as variation in the individual peptides based on the presence and absence of bands for pro-cruciferin, cruciferin and napin.

The mobility of peptides molecular weights were compared with previous reports on brassicaceae oilseeds. The peptides ranged from 10 kDa to 71 kDa. Molecular weight of cruciferin ranged from 18.1 kDa and 31.2 kDa in *B. juncea.* According to some researchers (Wanasundara, 2011; Wanasundara *et al.,* 2012) cruceferin has α chains with four subunits and β chain with two subunits. At N_0 condition, 8 peptide bands were analyzed for peptide polymorphism, of which 6 (75%) were polymorphic and two bands were found to be monomorphic (Table 1c). It was observed that α_1 and α_3 peptides were present consistently among all the genotypes contributing 14.4 per cent of total peptide followed by β_1 and napin (13.2%), β_2 (12.60%), procruciferin (11.44%), α_4 (10.84 %) and α_2 (9.60 %) (Table 1a). Under N_{80}, 8 peptide bands were analysed, of which 4 bands (50%) were found to be polymorphic and 4 monomorphic (Table 1b). Individual peptides such as pro cruciferin, α_1, α_3 and β_2 were uniformly present in all the genotypes contributing 14.1 per cent each to total peptide, followed by β_1 (13.0 %), α_2 (12.4%), α_4 (10.0 %) and napin (8.2%) (Table 1d). A range of 170 bands (88.5%) were found among the 24 genotypes, of which 74 bands showed 38.5 per cent polymorphism (Table 1a).

In the present study, comparative analysis among the 24 genotypes showed banding pattern of the pro cruciferin under N_0 application was almost same in all genotypes except in NDRE-7 and QM-16. However, under N_{80} application, no change was observed in the banding pattern of pro cruciferin (Fig. 1 and Table 1e). Subunit α_1 and α_3 failed to contribute to any variation among mustard genotypes at N_0 and N_{80}, whereas all the other subunits contributed significantly (Table 1d and Table 1e). But the α_2 subunit was absent in DHR-991, EC-399307, GM-2, HB-207, HB-9902, HB-9916, QM-16 and NRCDR-2 under N_0 application. Under N_{80} application, α_2 subunit was observed to be absent in EC-399294, EC-399300 and HB-207 (Table 1e). Under N_0 change was seen in case of subunit α_3 under both treatments in all genotypes. At N_0, α_4 subunit bands was absent in DHR-991 EC399307, GM-2, HB-207, HB-9902, HB9916, QM-16 and NRCDR-2. While under N_{80} the α_4 subunit polymorphisms showed absence of bands in Maya, EC-399294, EC-399300, HB9-902, HB-9913, NATP-124 and NRCDR-2 (Table 1e). β_1 subunit was absent in two genotypes HB-9916 and RGN-55 under N_0 while at N_{80}, bands corresponding to this subunit reappeared in both genotypes and was absent in genotypes HB-207 and NRCDR-2. Genotypes 78-1-1-1, HB-9916 and QM-16 showed absence of β_2 subunit at N_0. But under N_{80}, all the lines confirmed presence of this subunit (Table 1e).

According to Wanasundara *et al.* (2012), molecular weight of napin ranged between 6.5 and 12 kDa in *B. juncea* under reducing conditions. But in our study, we found the corresponding band between 15 and 16 kDa for napin which could be due to the slight modification in protocol. Under N_0, polymorphism was observed only in two genotypes namely 78-1-1-1 and RGN-55 while under N_{80} we observed polymorphism in nine genotypes namely DRMR-IJ31, DHR-991, HB-9902, HB-9912, IC212031, NATP-124, NRCHB-506, Pusa jai kisan and NDRE-7 (Table 1e). In our experiment polymorphism was observed to be maximum for β subunits and napins (Table 1c) at N_0 application, whereas monomorphic bands were observed for the α subunits particularly α_1 and α_3 subunits. Surprisingly, under N_{80} application the maximum polymorphism among the protein subunits was observed only for $\beta_1$subunit and minimum polymorphism for napin (Table 1d). Pro-cruciferin, α_1 and α_3 showed monomorphic bands (Table 1d) which may be attributed to the conservative nature of the seed protein (Bonfitto *et al.,* 1999) and also indicates that peptide profile of some genotypes may remain unaffected under N_{80}. The effect of nitrogen application is also reflected in protein polymorphism. The polymorphism under N_0 could be due to the change in the amino acid sequence which varies with N content as reported by others (Mosse *et al.,* 1985; Triboi *et al.,* 1990; Bulman *et al.,* 1996; Boila *et al.,* 1996).

Clustering: To get a closer view of the change in the banding pattern of these proteins we clustered them using UPGMA. Clustering based on the profiles of seed storage proteins under N_0 and N_{80} treatments was performed to generate the phylogenetic relationships among 24 Indian mustard genotypes.

Under N_0 treatment, The UPGMA clustering dendrogram was consistent with their genetic similarity based on SDS-PAGE data, and the distance matrix exhibited two major clusters (I) and (II) at 0.51 coefficient (Fig. 2). The first cluster (I) consisted of two genotypes, HB-9916 and QM-16 while the second cluster consisted of twenty two genotypes that is MAYA, 78-1-1-1, DHR-991, EC399294, EC-399300, EC-399307, GM-2, ROHINI, HB-207, HB-9902, HB-9912, IC212031, NATP-124, RGN-55, NRCHB-101, NRCDR-2, NRCHB-506, Pusa jai kisan, NDRE-7, RL-1359, BEC-16 and DRMR-IJ-31. The Cluster II was further bifurcated into two subclusters (i) and (ii) at coefficient 0.57. Subcluster (i) included two genotypes of 78-1-1-1 and RGN-55 whereas subcluster (ii) was further bifurcated at similarity coefficient 0.75 into two subclades i. and ii. Subclade i consisted of NRCDR-2, GM-2 and subclade ii consisted of Pusa jai kisan, NDRE-7, RL-1359, BEC-16, DRMR-IJ-31, MAYA, DHR-991, EC-399294, EC-399300, EC-399307, ROHINI, HB-207, HB-9902, HB-9912, IC-212031, NATP-124, NRCHB-101, and NRCHB-506. At the similarity coefficient of 0.88, almost all the genotypes of Cluster II were found to be identical to each other and could not be bifurcated anymore (Fig. 2 and Table 3).

Table 1a Comparing the peptide profiling under both N_0 and N_{80} conditions

Among genotypes							
N_0		Total %	N_{80}		Total %	% change	
Total no. of bands	192		Total no. of bands	192			
Total no. of bands observed	166	86.5	Total no. of bands observed	170	88.54	2%	Increase
No. of bands absent	26	13.5	No. of bands absent	22	11.45	2%	Decrease
Total no of polymorphic band	118	71.08	Total no of polymorphic band	74	38.54	32%	Decrease
Total no of monomorphic bands	48	25	Total no of monomorphic bands	96	50	25%	Increase
Among proteins							
N_0		%	N_{80}		%	%	% change
Total bands	8		Total bands	8			
Monomorphic	2	25	Monomorphic	4	50	25	Increase
Polymorphic	6	75	Polymorphic	4	50	25	Decrease

Table 1b Comparative overview of the diversity of polymorphism under N_0 and N_{80} application among 24 genotypes of *Brassica juncea*

Genotypes	No. of bands at N_0 application	% Peptide polymorphism at N_o	% Total polymorphism at N_o	No. of bands at N_{80} application	% Peptide polymorphism at N_{8o}	% Total polymorphism at N_{8o}	% Change in peptide polymorphism over N_0 to N_{8o}	% Change in total polymorphism over N_0 to N_{8o}	Change at N_{8o}
DRMRIJ31	8	100	4.8	7	87.5	4.2	12.5	0.6	Decrease
MAYA	8	100	4.8	6	75	3.6	25	1.2	Decrease
78-1-1-1	5	62.5	3.01	8	100	4.8	37.5	1.79	Increase
DHR-991	7	87.5	4.2	7	87.5	4.2	0	0	No change
EC399294	8	100	4.8	6	75	3.6	25	1.2	Decrease
EC399300	8	100	4.8	6	75	3.6	25	1.2	Decrease
EC399307	7	87.5	4.2	8	100	4.8	12.5	0.6	Increase
GM-2	6	75.0	3.6	8	100	4.8	25	1.2	Increase
ROHINI	8	100	4.8	8	100	4.8	0	0	No change
HB-207	7	87.5	4.2	6	75	3.6	12.5	0.6	Decrease
HB-9902	7	87.5	4.2	6	75	3.6	12.5	0.6	Decrease
HB-9912	7	87.5	4.2	6	75	3.6	12.5	0.6	Decrease
HB-9916	3	37.5	1.8	8	100	4.8	62.5	3.0	Increase
IC212031	8	100	4.8	7	87.5	4.2	12.5	0.6	Decrease
NATP-124	7	87.5	4.2	6	75	3.6	12.5	0.6	Decrease
QM-16	4	50.0	2.4	8	100	4.8	50	2.4	Increase
RGN-55	5	62.5	3.01	8	100	4.8	37.5	1.79	Increase
NRCHB-101	8	100	4.8	8	100	4.8	0	0	No change
NRCDR-2	6	75.0	3.6	6	75	3.6	0	0	No change
NRCHB-506	8	100	4.8	7	87.5	4.2	12.5	0.6	Decrease
Pusa Jai Kisan	8	100	4.8	7	87.5	4.2	12.5	0.6	Decrease
NDRE-7	7	87.5	4.2	7	87.5	4.2	0	0	No change
RL-1359	8	100	4.8	8	100	4.8	0	0	No change
BEC-16	8	100	4.8	8	100	4.8	0	0	No change

Table 1c Showing level of peptide polymorphism among genotypes under N_0 condition

Name of peptide band	No. of bands observed	No. of bands absent	Total no. of bands	Type of band	% presence of peptide bands in all genotypes	% contribution of each peptide for total peptide
pro cruceferin	19	5	24	Polymorphic	79.10	11.44
α1	24	0	24	Monomorphic	100.0	14.40
α2	16	8	24	Polymorphic	66.60	9.60
α3	24	0	24	Monomorphic	100.0	14.40
α4	18	6	24	Polymorphic	75.0	10.84
β1	22	2	24	Polymorphic	91.6.0	13.20
β2	21	3	24	Polymorphic	87.5	12.60
napin	22	2	24	Polymorphic	91.6	13.20

Table 1d Showing level of peptide polymorphism under N_{80} condition

Name of peptide band	No. of bands observed	No. of bands absent	Total no. of bands	Type of band	% presence of peptide bands in all genotype	% contribution of each peptide for total peptide
Pro cruceferin	24	0	24	Monomorphic	100	14.1
α1	24	0	24	Monomorphic	100	14.1
α2	21	3	24	Polymorphic	87.5	12.4
α3	24	0	24	Monomorphic	100	14.1
α4	17	7	24	Polymorphic	70.8	10.0
β1	22	2	24	Polymorphic	91.6	13.0
β2	24	0	24	Monomorphic	100	14.1
napin	14	10	24	Polymorphic	58.3	8.2

Table 1e Showing peptide polymorphism among genotypes under N_0 and N_{80} conditions

Nitrogen Treatment	N_0							
Storage Protein	Procruciferin	Cruciferin						Napin
		α_1	α_2	α_3	α_4	β_1	β_2	
Genotypes	Absent in NDRE-7 QM-16	No change	Absent in DHR-991 EC399307 GM-2 HB-207 HB-9902 HB9916 QM-16 NRCDR-2	No change	Absent in EC399294 EC399300 HB-207	Absent in HB-9916 RGN-55	Absent in 78-1-1-1 HB-9916 QM-16	Absent in 78-1-1-1 RGN-55
	N_{80}							
Genotypes	No change	No change	Absent in EC399294, EC399300 HB-207	No change	Absent in Maya EC399294 EC399300 HB9902 HB9913 NATP124 NRCDR-2	Absent in HB-207 NRCDR-2	No change	Absent in DRMR-IJ31 DHR-991 HB-9902 HB-9912 IC212031 NATP-124 NRCHB-506 Pusa Jai Kisan NDRE-7

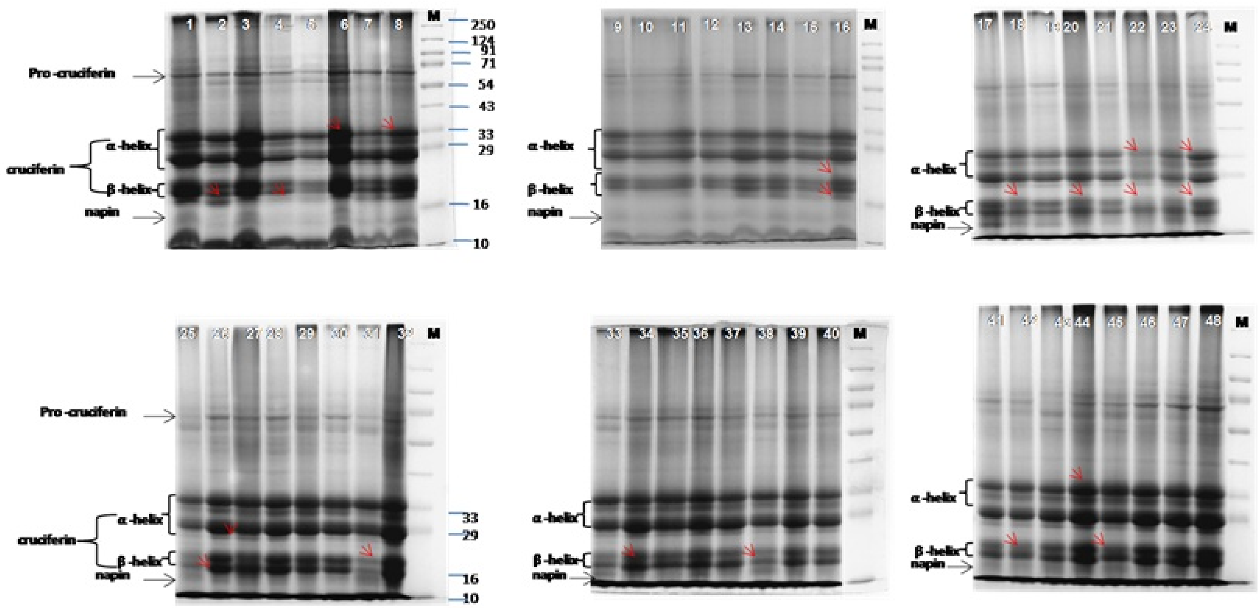

Fig. 1. Lane 1 and 2 : DRMR IJ-31 under control and 80 kg N/ha; Lane 3 and 4: Maya under control and 80 kg N/ha; Lane 5 and 6: 78-1-1-1 under control and 80 kg N/ha; Lane 7 and 8: DHR-991 under control and 80 kg N/ha; Lane 9 and 10:GM-2 under control and 80 kg N/ha; Lane 11 and 12 : EC-399307 under control and 80 kg N/ha; Lane 13 and 14: EC-399300 under control and 80 kg N/ha; Lane 15 and 16: EC-399294 under control and 80 kg N/ha Lane 17 and 18: Rohini under control and 80 kg N/ha. Lane 19 and 20 : HB-207 under control and 80 kg N/ha; Lane 21 and 22 : HB-9902 under control and 80 kg N/ha; Lane 23 and 24: HB-9912 under control and 80 kg N/ha; Lane 25 and 26: HB-9916 under control and 80 kg N/ha; Lane 27 and 28: IC212031 under control and 80 kg N/ha; Lane 29 and 30: NATP-124 under control and 80 kg N/ha; Lane 31 and 32: QM-16 under control and 80 kg N/ha; Lane 33 and 34: RGN-55 under control and 80 kg N/ha; Lane 35 and 36: NRCHB-101 under control and 80 kg N/ha; Lane 37 and 38: NRCDR-2 under control and 80 kg N/ha; Lane 39 and 40: NRCHB-506 under control and 80 kg N/ha; Lane 41 and 42:Pusajai kisan under control and 80 kg N/ha; Lane 43 and 44: NDRE-7 under control and 80 kg N/ha; Lane 45 and 46: RL-1359 under control and 80 kg N/ha; Lane 47 and 48 BC-16: under control and 80 kg N/ha; Lane M: wide ranged protein ladder (kDa). (–>) indicates the change in α and β banding pattern (Source Mawlong *et al*., 2017).

The similarity indices between different genotypes ranged from 0.375 to 1.0 across the genotypes. The lowest genetic similarity coefficient of 0.375 was found between the genotypes RGN-55 and QM-16 and among HB9916 and nine genotypes of subclade i (DRMR-IJ-31, MAYA, EC-399294, EC-399300, ROHINI, NRCHB-506, NRCHB-101, RL-1359, BEC-16) of Cluster II. Highest genetic similarity coefficient of 1.0 was observed among genotypes of group A of Subclade i (DRMR-IJ-31, MAYA, EC-399294, EC-399300, ROHINI, NRCDR-2, NRCHB-101, RL-1359, BEC-16) and among group B of subclade i (DHR-991, EC-399307, HB-207, HB-9902) and among group C of subclade i (HB-9912, NDRE-7, NATP-124) of Cluster II. GM-2 and NRCRDR-2 also showed genetic similarity coefficient of 1.0 bifurcated at similarity coefficient of 0.75 (Fig.2 and Table 3).

Under N_{80} treatment, the distance matrix exhibited two major clusters, I and II at 0.70 similarity coefficient (Fig. 3). The first cluster (I) bifurcated into four genotypes EC-399294, EC-399300, HB-207 and NRCDR-2 at 0.74 coefficient. EC-399294 and EC-399300 were found to be almost identical at this coefficient. The Cluster II was further bifurcated into two subcluster I and II at coefficient 0.83. Subcluster i included ten genotypes 78-1-1-1, EC-399307, BEC-16, RGN-55, QM-16, HB-9916, NRCHB101, RL-1359, GM-2 and ROHINI exhibiting 100% similarity at similarity coefficient 0.83 whereas subcluster ii consisted of DRMR-IJ-31, DHR-991, IC212031, NRCHB-506, Pusa jai kisan and NDRE7 in one identical group and MAYA, HB9902, HB9912 and NATP124 in another group at 0.87 coefficient (Fig. 3 and Table 3).

The similarity indices between different genotypes ranged from 0.5 to 1.0 across all the genotypes. The genotypes HB-207 and HB-9902, HB-207 and HB-9912, HB-207 and IC212031 had lowest genetic similarity coefficient of 0.5. Maximum genetic similarity coefficient of 1.0 was found among genotypes of Cluster II at the similarity coefficient of 0.88. Under N_0 we observed two major clusters (Fig. 2, Table 3). The genotypes ROHINI, NRCHB-101, NRCDR-2, NDRE-7, RL-1359, BEC-16, DHR-991 which showed no variation in protein subunits were clustered in subclade ii of cluster II indicating identical genetic base among them (Fig. 2, Table 3), Similarly under N_{80} they were clustered under same subgroups of cluster II (Fig. 3, Table 3) with the exception of NRCDR2 falling in cluster I (Fig. 3 and Table 3). Clustering in Fig. 3, showed genotypes with high and low nitrogen content to be clustered together, which further confirms the effect of nitrogen to be genotype dependent and hence the changes in their banding pattern. Few genotypes such as HB-9916, QM16, RGN-55 and 78-1-1-1 which showed maximum variation in their peptide profile were also clustered separately from other genotypes indicating their distinctness. However, more ties were found among the accessions which may be because they were from same locations or they may be sharing the similar pedigree. Similarity coefficient of 0.5 and 0.7 under both conditions reveals the narrow genetic base of genotypes used for the study. A shift in similarity coefficient of genotypes under control to high dose of nitrogen indicates its influence at translation level of genotypes. Genotypes showing lowest similarity coefficient and higher divergence can be utilised in breeding programmes for developing protein rich mustard.

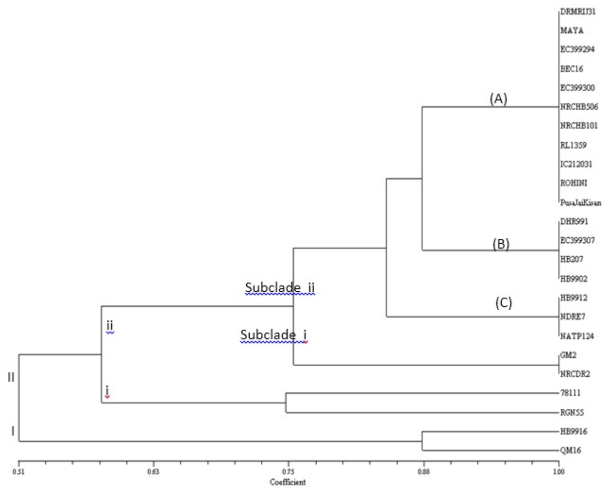

Fig. 2. Dendrogram showing genetic diversity among *Brassica* genotypes under N_0 conditions

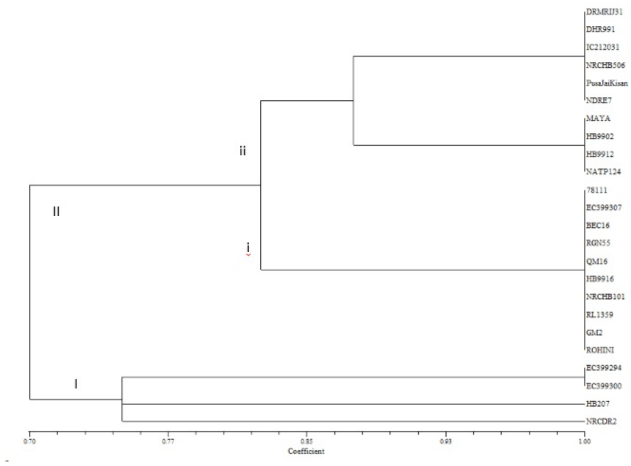

Fig. 3 Dendrogram showing genetic diversity among *Brassica* genotypes under N_{80} conditions

Expression of protein: After comparing the band intensities under N_0 and N_{80} we observed that the genotypes 78-1-1-1, DHR-991, HB-9916, RGN-55, NRCHB-101 and NDRE-7 with bands corresponding to various proteins had higher intensities compared to control (Fig. 1). This indicates that they might be over expressed under nitrogen application. In subunit α_1 the genotypes showing high intensities in the banding pattern in comparison to control were identified as 78-1-1-1, DHR-991, GM-2, HB-207, HB-9912, HB-991, RGN-55, NRCHB-101 and NDRE-7.

Visual validation also showed α_2 subunit expression under N_{80} application in genotypes 78-1-1-1, DHR-991, GM-2, HB-207, HB-9912, HB-9916, RGN-55, NRCHB-101 and NDRE-7 (Fig. 1 and Table 2). Band intensities of α_3 subunits were also observed in 78-1-1-1, DHR-991, GM-2, HB-207, HB-9912, HB-9916, RGN-55, NRCHB-101 and NDRE-7. Subunit α_4 showed high intensities in 78-1-1-1, DHR-991, GM-2, HB-207, HB-9912, HB-9916, RGN-55, NRCHB-101, NDRE-7 and RL-1359 (Fig. 1 and Table 2). β_1 subunit with higher band intensities were observed in 78-1-1-1, DHR-991, GM-2, HB-207, HB-9902, HB-9912, HB-9916, QM-16, RGN-55, NRCHB-101, NDRE-7 and RL-1359. Looking into the expression pattern of β_2 subunit we observed highly intense band in genotypes 78-1-1-1, DHR-991, GM-2, HB-207, HB-9912, HB-9916, QM-16, RGN-55, NRCHB-101, NDRE-7 and RL-1359 (Fig. 1 and Table 2). Under N_{80}, we observed the intensity of the napin band to be maximum in genotypes 78-1-1-1, DHR-991, HB-9912, QM-16, RGN-55, NRCHB-101, NRCDR-2 and NDRE-7 (Fig. 1 and Table 2). Further, in our experiments an increase in band intensities under N_{80} application was observed which could be due to differences in allelic composition of storage proteins and over expression of genes controlling biosynthetic pathways of storage proteins. In our study it was observed that the cruciferin peptides appears in N_0 but disappears under N_{80} and *vice versa.* Cruceferin has a hexameric quantinary structure with six protomers. Each subunit/protomer is governed by multiple genes and thus different from each other (Withana-Gamage *et al.,* 2013). This could be the reason behind the up regulation and down regulation of the gene(s) encoding cruciferin. Similarly, for napin each subunit is governed by multigenes (Scofield and Crouch, 1987; Raynal *et al.,* 1991) and its regulation can be due to external factors like nitrogen application. Study in tobacco shows that overexpression of gene coding napin like protein was found effective against fungus (Yang *et al.,* 2007). Similarly in mustard, the presence of napin protein and its overexpression under nitrogen fertilization could be a way to improve insect pest resistance by optimizing nitrogen application. Their positive role has also found a future in pharmaceutical industries for use as antibiotics (Nai and Ng, 2004; Barciszewski *et al.,* 2000). It is worthy to mention that there are not many studies in mustard on individual storage proteins. Polymorphisms may serve as genetic markers because their variability is generally highly heritable (Mondini *et al.,* 2009).

There is considerable variation among the varieties on the basis of peptide profile under recommended dose of nitrogen fertilization. SDS-PAGE based profiles of seed storage proteins showed major differences in banding patterns among these genotypes with respect to nitrogen application besides differences in seed nitrogen content. Peptide bands which were absent under N_0 condition in some genotypes, appeared under N_{80} condition. This finding can help us in altering the peptide profile of chosen genotypes and the developed breeding material can be starting point for many crop improvement programmes such as protein rich mustard. Therefore, peptide profiling seems to be a powerful tool to analyze the genetic structure of different varieties of mustard. However, molecular marker based profiling may better depict the phylogenetic relationships among the genotypes. Knowing the changes in protein profile can give insight into the mechanism of plant-environment interaction. This can further lead to manipulation of individual proteins for quality improvement programmes and mining of individual proteins for food fortification.

ACKNOWLEDGEMENT

Authors are grateful to plant breeders for sharing their breeding materials and Director of ICAR-DRMR is highly acknowledged. Indian Council of Agricultural Research (Project DRMR B-7) for funding the work.

REFERENCES

Alemayehu N and Becker H 2002. Genotypic diversity and patterns of variation in a germplasm material of Ethiopian mustard (*Brassica carinata* A. Braun). *Genetic Resources and Crop Evolution*, **49**: 573-582.

AOAC 1955. *Official Methods of Analysis,* 16th edn, Association of official analytical chemists, Washington DC.

Barciszewski J, Maciej S and Haertlé T 2000. Minireview: analysis of rape seed napin structure and potential roles of the storage protein. *Journal of Protein Chemistry*, **19**: 249-254.

Boila R J, Stothers S C and Campbell L D 1996. The relationships between the concentrations of individual amino acids and protein in wheat and barley grain grown at selected locations throughout Manitoba. *Canadian Journal of Animal Science*, **76**: 163-169.

Bonfitto R, Galleschi L, Macchia M, Saviozzi F and Navari-Izzo F 1999. Identification of melon cultivars by gel and capillary electrophoresis. *Seed Science and Technology*, **27**: 779-783.

Bulman P, Zarkadas C G and Smith D L 1994. Nitrogen fertilizer affects amino acid composition and quality of spring barley grain. *Crop Science*, **34**: 1341-1346.

Dupont F M, Hurkman W J, Vensel W H, Tanaka C, Kothari K M, Chung O K and Altenbach S B 2006. Protein accumulation and composition in wheat grains: effects of mineral nutrients and high temperature. *European Journal of Agronomy*, **25**: 96-107.

Kumar A V, Bharti V, Kumar V, Meena P D and Suresh G 2017. Hyperspectral imaging applications in rapeseed and mustard farming. *Journal of Oilseeds Research*, **34**(1): 1-8.

Jia Y Q, Masbou V, Aussenac T, Fabre J L and Debaeke P 1996. Effects of nitrogen fertilization and maturation conditions on protein aggregates and on the bread making quality of Soissons, a common wheat cultivar. *Cereal Chemistry*, **73**: 123-130.

Jin W D, Li N and Hong D L 2006. Genetic diversity of seed storage proteins in different ecotype varieties of Japonica rice and its application. *Rice Science*, **13**: 85-92.

Johansson E, Prieto-Linde M L and Jönsson J Ö 2001. Effects of wheat cultivar and nitrogen application on storage protein composition and bread making quality. *Cereal Chemistry,* **78**:19-25.

Joshi N L, Mali P C and Saxena A 1998. Effect of nitrogen and sulphur application on yield and fatty acid composition of mustard (*Brassica juncea* L.) oil. *Journal of Agronomy and Crop Science*, **180**: 59-63.

Khurshid H and Rabbani M A 2012. Comparison of electrophoretic protein profiles from seed of different oilseed *Brassica* cultivars. *Journal of Public Health and Biological Sciences*, **1**: 36-42.

Kumar P, Dolkar R, Manjunatha G and Pallavi H M 2017. Molecular fingerprinting and assessment of genetic variations among advanced breeding lines of *Moringa oleifera* L. by using seed protein, RAPD and Cytochrome P 450 based markers. *South African Journal of Botany*, **111**: 60-67.

Leesawatwong M, Jamjod S, Kuo J, Dell B and Rerkasem B 2005. Nitrogen fertilizer increases seed protein and milling quality of rice. *Cereal Chemistry*, **82**: 588-593.

Lowry O H, Rosebrough N J, Farr A L and Randall R J 1951. Protein measurement with the Folin phenol reagent. *Journal of Biological Chemistry*, **193**: 265-275.

Mahasi M J and Kamundia J W 2007. Cluster analysis in rapeseed (*Brassica napus* L.). *African Journal of Agricultural Research*, **2**: 409-411.

Mawlong I, Sujith Kumar M S, Kandpal B K, Premi O P, Gurung B and Singh D 2017. Meal and oil quality among genotypes of Indian mustard (*Brassica juncea*) varies under recommended dose of nitrogen fertilizer. *Applied Ecology and Environmental Research*, **15**(4): 1427-1445.

Mondini L, Noorani A and Pagnotta M A 2009. Assessing plant genetic diversity by molecular tools. *Diversity*, **1**: 19-35.

Mossé J, Huet J C and Baudet J 1985. The amino acid composition of wheat grain as a function of nitrogen content. *Journal of Cereal Science*, **3**: 115-130.

Ngai P H K and Ng T B 2004. A napin-like polypeptide from dwarf Chinese white cabbage seeds with translation-inhibitory, trypsin-inhibitory, and antibacterial activities. *Peptides*, **25**: 171-176.

Parmar J K and Parmar R M 2012. Effect of nitrogen and sulphur on quality characteristics and accumulation of some fatty acids in mustard seeds grown under loamy sand soil of North Gujarat. *Asian Journal of Soil Science*, **7**: 167-171.

Pechanek U, Karger A, Gröger S, Charvat B, Schöggl G and Lelley T 1997. Effect of nitrogen fertilization on quantity of flour protein components, dough properties, and bread making quality of wheat. *Cereal Chemistry*, **74**: 800-805.

Prieto J A, Kelfkens M, Weegels P L and Hamer R 1992. Variations in the gliadin pattern of flour and isolated gluten on nitrogen application. *Zeitschrift für Lebensmittel-Untersuchung und -Forschung*, **194**: 337-343.

Rabbani M A, Qureshi A A, Afzal M, Anwar R and Komatsu S 2001. Characterization of mustard [*Brassica juncea* (L.) Cezern & Cross] germplasm by SDS-PAGE of total seed protein. *Pakistan Journal of Botany*, **33**: 173-179.

Raynal M, Depigny D, Grellet F and Delseny M 1991. Characterization and evolution of napin-encoding genes in radish and related crucifers. *Gene*, **99**: 77-86.

Sadia M, Malik S A, Rabbani M A and Pearce S R 2009. Electrophoretic characterization and the relationship between some *Brassica* species. *Electronic Journal of Biology*, **5**: 1-4.

Scheromm P, Martin G, Bergoin A and Autran J C 1992. Influence of nitrogen fertilization on the potential bread-baking quality of two wheat cultivars differing in their responses to increasing nitrogen supplies. *Cereal Chemistry*, **69**: 664-664.

Scofield S R and Crouch M L 1987. Nucleotide sequence of a member of the napin storage protein family from *Brassica napus. Journal of Biological Chemistry*, **262**: 12202-12208.

Shekhawat K, Rathore S S, Premi O P, Kandpal B K and Chauhan J S 2012. Advances in agronomic management of Indian mustard [*Brassica juncea* (L.) Czernj. Cosson]: An overview. *International Journal of Agronomy*, **2012**: 1-14.

Singh D, Arya R K, Chandra N, Niwas R and Salisbury P 2016. Genetic diversity studies in relation to seed yield and its component traits in Indian mustard (*Brassica juncea* L. Czern & Coss.). *Journal of Oilseed Brassica*, **1**: 19-22.

Tanksley S D 1993. Mapping polygenes. *Annual Review of Genetics*, **27**: 205-233.

Triboi E, Branlard G and Landry J 1990. Environmental and husbandry effects on the content and composition of proteins in wheat. *Aspects of Applied Biology*, **25**: 149-158.

Wanasundara J P 2011. Proteins of Brassicaceae oilseeds and their potential as a plant protein source. *Critical Reviews in Food Science and Nutrition*, **51**: 635-677.

Wanasundara J P, Abeysekara S J, McIntosh T C and Falk K C 2012. Solubility differences of major storage proteins of Brassicaceae oilseeds. *Journal of the American Oil Chemists' Society*, **89**: 869-881.

Withana-Gamage T S, Hegedus D D, Qiu X, McIntosh T and Wanasundara J P 2013. Structural and physicochemical property relationships of cruciferin homohexamers. *Journal of Agricultural and Food Chemistry*, **61**: 5848-5859.

Yang, X., Xiao, Y., Wang, X. and Pei, Y 2007. Expression of a novel small antimicrobial protein from the seeds of motherwort (*Leonurus japonicus*) confers disease resistance in tobacco. *Applied and Environmental Microbiology* **73**: 939-946.

Zada M, Shinwari Z K, Zakir N and Rabbani M A 2013. Study of total seed storage proteins in Ethiopian mustard (*Brassica carinataa.* Braun) germplasm. *Pakistan Journal of Botany*, **45**: 443-448.

Influence of integrated use of microbial inoculants and inorganic fertilizers on growth and nutrient dynamics of oil palm seedlings

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(Received: October 27, 2017; Revised: November 17, 2017; Accepted: December 8, 2017)

ABSTRACT

Nursery experiment was conducted to observe influence of microbial fertilizers on growth and nutrient dynamics of oil palm (*Elaeis guineencies* Jacq.) seedlings for two years. *Azotobacter chroococcum, Azospirillum brasilense, Bacillus megaterium, Frateuria aurantia* and *Glomus aggregatum* were used individually, combinedly and integrated with chemical fertilizers. Promising results for seedling height, leaves, root volume and dry matter were recorded under microbial fertilizers+25% recommended dose of chemical fertilizers. Maximum availability of organic carbon, phosphorus, iron, manganese, copper, zinc and boron with microbial fertilizers+25% recommended dose of chemical fertilizers, potassium in *Frateuria aurantia* and calcium and magnesium in *Azospirillum brasilense* were observed in potting mixture. Similarly, significant enhancement in total uptake of nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, copper and zinc by seedlings with microbial fertilizers+25% recommended dose of chemical fertilizers. Integrated use of microbial fertilizers with lower dose of chemical fertilizers played a significant role in enhancing growth, soil fertility and nutrient uptake.

Keywords: Microbial fertilizers, Integration, Oil palm seedling, Growth, Nutrient uptake

Oil palm (*Elaeis guineencies* Jacq.) is the most productive oil seed crop with economic life span of 25-30 years in farmers' gardens. Quality seedlings are must for establishing commercial oil palm gardens in the long run and so production of superior quality seedlings is mainly decided by nutrition. To meet the nutrient requirement and for quick growth of seedlings, commercial oil palm nursery growers are applying huge amount of chemical fertilizers which are expensive and potentially more detrimental to environment. Microbial fertilizers/bio-inoculants are promising components for integrated solutions to agro-environmental problems because they possess the capacity to promote plant growth, enhance nutrient availability in soil, promote nutrient uptake and support the plant health by improving the microflora (Han and Lee, 2005). Enhanced seedling growth and nutrient assimilation was reported in oil palm seedlings (Amir *et al.,* 2005). Significant increase in plant growth and nutrient uptake under integrated use of microbial fertilizers and chemical fertilizers was observed in teak seedlings (Seema Paroha *et al.,* 2009) and sheesham clones (Jaisankar *et al.,* 2013) as compared with individual and combined use of biofertilizers. Decreasing non-renewable reserves all over the world, high nutrient requirement and increasing cost of chemical fertilizers have necessitated the demand for less expensive and alternative renewable sources to meet the need of plant nutrition. Literature available in oil palm is scant as research studies are mostly focussed on growth of oil palm seedlings. Therefore, an effort was made to study an influence of microbial fertilizers on nutrient dynamics in potting mixture and oil palm seedlings during the nursery stage.

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MATERIALS AND METHODS

The present investigation was carried out at ICAR-Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh for two consecutive years (2009-10 and 2010-11). The experimental site is located at 160 43'N and 81° 09'E with a mean sea level of 13.41 m. Average annual temperature ranged from 21.8°C to 34.8°C in first year and from 19.6°C to 36.7°C during second year. Average relative humidity was 69.3 per cent during first year and 67.7 per cent in second year. Total amount of rainfall received was 1813.7 mm and 1026 mm during the first and second years, respectively.

Experimental details: The nursery trial was laid out in completely randomized design with eleven treatments replicated five times and there were 30 seedlings in each treatment. Treatments used were T_1-*Azotobacter chroococcum*, T_2-*Azospirillum brasilense*, T_3-*Bacillus megaterium*, T_4-*Frateuria aurantia*, T_5-*Glomus aggregatum*, T_6-Consortium of all microbial fertilizers, T_7-Consortium of all microbial fertilizers+25% recommended dose of chemical fertilizers (RDF), T_8-Consortium of all microbial fertilizers+50% RDF, T_9-Consortium of all microbial fertilizers +75% RDF, T_{10}-100% RDF and T_{11}-Control without microbial and chemical fertilizers. Tank silt and cattle manure mixed in 2:1 ratio (v/v) was used as a potting mixture (Table 1) for raising oil palm nursery for 12 months in double stage nursery system i.e. primary stage for 4 months under UV stabilized HDPE agro shade net house with 50 per cent shade and secondary stage for 8 months in open condition.

Oil palm seedlings were raised in poly bags of 23cm x 15cm during the primary stage and 45cm x 38cm in secondary stage. Uniform, healthy and 65 days old oil palm seed sprouts of Tenera hybrid combination (1140 Dura x 1988 Pisifera) were used as a planting material during both the years. Microbial fertilizers were applied thrice at 4 month interval whereas chemical fertilizers *viz.,* Di-ammonium phosphate (DAP) and complex (17:17:17) were applied manually to the nursery at monthly interval. Nursery operations like watering and weeding were carried out uniformly for all the treatments.

Table 1 Physico-chemical characteristics of potting soil used for raising oil palm nursery

Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC (dS/m)	OC (%)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
54.67	8.35	36.98	Clayey	7.12	0.46	1.25	24.62	145.65	3.34	2.16

Lignite based *Azotobacter chroococcum* ($1x10^8$cfu/g), *Azospirillum brasilense* ($1x10^8$cfu/g), *Bacillus megaterium* ($1x10^8$cfu/g), *Frateuria aurantia* ($1x10^8$cfu/g) and soil based *Glomus aggregatum* (800 infectious propagules/g) were applied to potting mixture at the time of planting of seed sprouts, shifting of primary seedlings to secondary stage, finally 8 months after planting of sprouts and the quantity of microbial fertilizers used was 10g, 25g and 5g per bag, respectively. In the combined and integrated treatments, *Bacillus megaterium, Frateuria aurantia* and *Glomus aggregatum* with above mentioned doses while *Azotobacter chroococcum* (5g, 12.5g and 2.5g) and *Azospirillum brasilense* (5g, 12.5g and 2.5g) with 50 of above mentioned doses per bag were mixed together and applied to the potting mixture.

Growth observations and nutrient analysis: Growth characters of oil palm seedlings namely seedling height, number of leaves, root volume and dry matter of seedlings were recorded at the end of the nursery (12 month old). Nutrient analysis in potting mixture was taken up 6 and 12 months after planting of seed sprouts. The pH and EC of potting mixture were measured by following the standard methods. Organic carbon, available phosphorous and exchangeable potassium in potting mixture were determined by wet digestion method (Walkley and Black's, 1934), Olsen's method (1954) and ammonium acetate extract method (Merwin and Peach, 1951), respectively. Calcium and magnesium in potting mixture were estimated by ammonium acetate extract method (Merwin and Peach, 1951) by using ICP-OES (Inductively Coupled Plasma-Optical Emission Spectroscopy). Available micro nutrients-Fe, Cu, Mn, Zn and B in potting mixture were extracted with DTPA (Lindsay and Norvell, 1978) and estimated by using ICP-OES. Nutrient analysis in plant samples was carried out in 6 and 12 month old seedlings. The total nitrogen, phosphorous, potassium content in plant samples were estimated by Micro Kjeldahl's method, Vanado-Molybdate colour reaction method and Flame Photometer, respectively. Calcium, magnesium, iron, manganese, copper, zinc and boron in plant samples were quantified by ICP-OES directly from the di-acid digestion. Nutrient uptake by 12 month old oil palm seedlings was calculated individually during both the years by using the standard formula.

Statistical analysis: Treatment effects were assessed for individual years using one way ANOVA and pooled effects were assessed using repeated measures ANOVA. Significance levels were tested at $p< 0.5$. Post-hoc analysis was done using Least Significant Difference (LSD) test. All the statistical analysis was carried out using SAS ver. 9.3.

RESULTS AND DISCUSSION

Growth parameters of oil palm seedlings: The results for growth parameters clearly indicated that growth of oil palm seedlings under integrated use of microbial fertilizers+chemical fertilizers expressed maximum values for seedling height, number of leaves, root volume and dry matter production when compared to other treatments (Table 2). Enhancement in growth of oil palm seedlings under integrated application of microbial fertilizers+chemical fertilizers can be attributed directly to better nitrogen fixation by *Azotobacter* and *Azospirillum,* phosphorus (P) solubilisation with *Bacillus* and *Glomus*, potassium (K) mobilization with *Frateuria*, secretion of plant growth regulating substances, root proliferation, photosynthetic rate and metabolic activity. Further, significant enhancement in seedling dry matter under T_7-microbial fertilizers+25% recommended dose of chemical fertilizers (RDF) might be due to vigorous growth of seedlings with more number of leaves and root density which is certainly due to greater absorption of nutrients, higher photosynthetic rate and metabolic activities (Mathur and Vyas, 1995) and accumulation of nutrients in plant tissues. Findings of the present study are confirmed with the results reported in ber

(Aseri and Rao, 2005) and in oil palm seedlings (Noor Aishah *et al*., 2009).

Although, nutrients present in soil, the mobility of these nutrients into vegetative tissues is a big concern. Hence, the mobility of nutrients might be achieved by microbial fertilizers especially arbuscular mycorrhizal fungi (AMF) instead of chemical fertilizers. Results of the present study clearly revealed that there was a decreasing trend in effect on seedling height, leaf, root and dry matter production under integration of microbial fertilizers and chemical fertilizers as the chemical fertilizer dose was increased from 25 to 75 per cent RDF.

Seedlings treated with microbial fertilizers expressed better growth and biomass as compared with the control. High chlorophyll content and more accumulation of various metabolites like reducing sugar, total phenols and amino nitrogen can be attributed to enhanced plant growth and biomass production upon microbial inoculation (Kohler *et al*., 2007). Results of the current study reflected that T_5-*Glomus aggregatum* was found at par with T_{10}-100% RDF and T_6-Combined use of microbial fertilizers for growth parameters. Similarly, remarkable improvement in growth of AMF inoculated oil palm seedlings as compared with inorganic fertilizers was reported (Umme Aminun Naher *et al*., 2013). Better seedling height, leaf area, stem girth, dry matter, photosynthetic rate and nutrient accumulation in plant tissues might be responsible for better growth of seedlings under present study.

It is vivid from the present results that application of chemical fertilizers proved superiority over some of individual microbial fertilizers and the control. This may be ascribed to better availability of nutrients in potting mixture and uptake of nutrients by seedlings. It was observed in the current study that growth of seedlings was significantly lesser in control than inoculated seedlings. Though tank silt was mixed with cattle manure, relatively the growth and quality of the seedlings was poor. This may be due to lesser availability of nutrients and microbial population which were not enough to promote the growth of seedlings. So, this situation indicated the need for exogenous application of beneficial bio-inoculants for mobilization of nutrients in potting mixture.

Nutrient status in potting mixture: There were relatively higher pH values in potting mixture under individual microbial fertilizers (T_1-T_5) and T_6-combined use of microbial fertilizers and however differences were found non-significant among themselves (Table 3). Enhanced pH in inoculated treatments might be due to release of NH_3/NH_4 ions (Xavier Moses Martin *et al*., 2011) by microbes. Lower pH under integrated application of microbial fertilizers+chemical fertilizers and 100% RDF indicated an acidic effect of chemical fertilizers. Generally, pH of soil determines the mineral content as well as microbial composition. It was observed that fungi are predominant in the rhizosphere under low pH while nitrogen fixing bacteria are favoured at neutral pH (Bhuvaneshwari and Sadhana, 2014).

Table 2 Effect of microbial fertilizers and chemical fertilizers on growth characters of oil palm seedlings during the nursery stage

Treatment	Seedling height (cm)			Leaves/seedling			Root volume (cc)			Drymatter (g)		
	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean
T1	128.17	117.77	122.97	17.33	18.33	17.83	460.00	259.40	359.70	441.08	328.63	384.86
T2	128.87	116.43	122.65	16.33	18.00	17.17	390.00	240.00	315.00	409.06	351.54	380.30
T3	131.63	116.47	124.05	16.67	18.67	17.67	470.00	276.67	373.34	424.12	346.43	385.28
T4	131.73	118.27	125.00	17.33	17.33	17.33	393.33	230.00	311.67	411.64	313.38	362.51
T5	136.03	120.87	128.45	17.67	18.67	18.17	400.00	320.00	360.00	449.62	393.81	421.72
T6	137.67	124.10	130.89	17.67	18.67	18.17	473.33	375.80	424.57	456.82	460.87	458.85
T7	151.87	133.80	142.84	18.00	19.67	18.84	593.33	456.67	525.00	676.40	491.13	583.77
T8	144.50	135.10	139.80	17.33	19.00	18.17	496.67	420.33	458.50	580.24	440.63	510.44
T9	143.27	125.20	134.24	17.00	17.33	17.17	496.67	400.00	448.34	598.32	419.05	508.69
T10	144.13	118.77	131.45	18.00	16.67	17.34	546.67	293.33	420.00	555.24	409.90	482.57
T11	121.37	109.37	115.37	15.67	15.00	15.34	370.33	236.67	303.50	393.90	197.58	295.74
LSD-5%	5.25	4.32	4.79	1.33	1.69	1.51	48.53	47.68	48.11	46.32	96.91	71.62
SEM	3.08	2.53	2.81	0.75	0.99	0.87	28.50	27.99	28.25	27.20	56.90	42.05

T_1-*Azotobacter chroococcum*, T_2-*Azospirillum brasilense*, T_3-*Bacillus megaterium*, T_4-*Frateuria aurantia*, T_5-*Glomus aggregatum*, T_6-Mixture of biofertilizers, T_7-Biofertilizers+25% RDF, T_8-Biofertilizers+50% RDF, T_9-Biofertilizers+75% RDF, T_{10}-100% RDF and T_{11}-Control.

Table 3 Influence of microbial fertilizers and chemical fertilizers on pH, EC, OC and P levels in potting mixture used for raising oil palm nursery

Treatment	pH			EC (dS/m)			OC (%)			P (ppm)		
	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean
T1	8.06	8.10	8.08	0.75	0.69	0.72	1.30	1.39	1.34	21.08	17.72	19.43
T2	8.00	7.90	7.94	0.70	0.63	0.67	1.26	1.40	1.33	20.38	19.48	19.93
T3	8.06	7.96	8.01	0.71	0.63	0.67	1.25	1.50	1.37	20.87	20.86	20.86
T4	7.87	8.03	7.95	0.68	0.66	0.67	1.17	1.61	1.45	20.06	18.81	19.43
T5	8.02	7.99	8.00	0.75	0.70	0.72	1.37	1.85	1.61	24.20	19.97	22.08
T6	7.96	8.06	8.01	0.69	0.66	0.67	1.52	1.62	1.57	22.83	23.57	23.20
T7	7.80	7.84	7.82	0.82	0.77	0.79	1.76	1.82	1.78	24.07	35.02	29.54
T8	7.55	7.76	7.65	0.80	0.75	0.77	1.58	1.72	1.65	22.49	33.34	27.91
T9	7.56	7.55	7.55	0.86	0.74	0.80	1.5	1.57	1.53	22.91	29.51	26.21
T10	7.32	7.41	7.36	0.88	0.83	0.85	1.5	1.67	1.58	22.66	22.92	22.78
T11	7.75	7.84	7.79	0.70	0.65	0.67	1.11	1.21	1.16	18.52	16.07	17.29
LSD-5%			0.20			0.05			0.14			3.14
SEM			0.25			0.07			0.17			3.89

The treatment T_{10}-100% RDF (0.85dS/m) recorded the highest electrical conductivity (EC) in potting mixture (Table 3) which was markedly higher than other treatments except T_9-microbial fertilizers+75% RDF (0.80dS/m). A significant improvement in potting mixture EC was noticed under integrated treatments and the values were more or less the same among themselves. Chemical fertilizers might be responsible for higher values of EC in potting mixture. Electrical conductivity indicates the level of dissolved salts by measuring the ability of soil solution to carry out an electric current. Similar study (Jaisankar *et al.*, 2013) reported nonsignificant results for EC in soil used for growing *Dalbergia sissoo* clonal plants between integrated application of chemical fertilizers+biofertilizers and the control. But present results are in contrast with the above findings.

Macro-nutrients: The treatment T_7-microbial fertilizers+ 25% RDF (1.78%) was found as the most effective in increasing availability of organic carbon (OC) in potting mixture (Table 3). With respect to OC in potting mixture, all the treatments were distinctly better than the control. Among individual microbial fertilizers, T_5-*G. aggregatum* (1.61%) was significantly better than other microbial fertilizers. Mycorrhizal fungi contribute to carbon storage in soil by altering the quality and quantity of soil organic matter (Ryglewicz and Anderson, 1994). Results reflected that T_5-*G. aggregatum* (1.61%) expressed relatively better performance as compared with T_6-combined use of microbial fertilizers (1.57%) and T_{10}-100% RDF (1.58%). Mycorrhizal fungi might have added nitrogen in rhizosphere by decomposing organic matter. Growth promoting substances might have stimulated the production of root exudates which are known to transfer photosynthetically fixed carbon to the rhizosphere, resulting in substantial increase of soil carbon (Walker *et al.*, 2003).This might be the reason for enhanced OC in inoculated treatments in the present study.

Except T_1-*A. chroococcum*, T_4-*F. aurantia* and T_2-*A. bresilense*, rest of the treatments were significantly superior to the control for phosphorous (P) availability in potting mixture (Table 3). Relatively, higher values of P were noticed under integration of microbial fertilizers+chemical fertilizers (T_7-T_9) among the treatments. Out of individual microbial fertilizers, T_5-*G. aggregatum* (22.08ppm) and T_3-*B. megaterium* (20.86ppm) expressed better results and both were found on par with T_6- combined use of microbial fertilizers (23.20ppm) and T_{10}-100% RDF (22.78ppm). It is proven scientifically that arbuscular mycorrhizal fungi (AMF) establish symbiotic relation with oil palm rhizosphere. Roots absorb and translocate phosphorous (P) from distant areas by increasing root surface area which otherwise inaccessible to roots (Sanders and Tinker, 1973). Further, AM fungal colonization is known to alter inherent phosphorous in the rhizosphere by increasing phosphatase enzyme. Phosphatases secreted by fungal hyphae catalyse the hydrolysis of both organic P esters and anhydrate of phosphoric acid to inorganic phosphorous (Allen *et al.*, 1985). Phosphate solublizing bacteria (PSB) secret organic acids and enzymes that act on insoluble phosphates convert to soluble form and provide P to plants and acids produced reduce pH of soil (Ponmurugan and Gopi, 2006). Availability of lesser P in control might be due to precipitation of adsorbed P in soil. Enhanced phosphatase activity improves phosphorous mobilization and thereby increases the biomass production (Tarafdar and Gharu, 2006) in inoculated treatments.

All the treatments except T_1-*A. chroococcum* were found significantly superior to the control with respect to potassium (K) content in potting mixture. Maximum K in potting mixture was observed in T_4-*F. aurantia* which was highly significant than the control (Table 4). Here the trend was different when compared with OC and P in potting mixture. Results were not impressive under integrated application of microbial fertilizers+chemical fertilizers when compared with individual and combined use of microbial fertilizers. Similarly, results were found nonsignificant among all the treatments under integrated use of microbial fertilizers+chemical fertilizers.

Better results for both calcium (Ca) and magnesium (Mg) in potting mixture were found under individual application of microbial fertilizers rather than combined and integrated use of microbial fertilizers+chemical fertilizers (Table 4). Under integrated application of microbial fertilizers+ chemical fertilizers, better availability of Ca (6.63meq/kg) and Mg (2.92meq/kg) in potting mixture was noticed with T_8-biofertilizers+50% RDF which differed distinctly from the control. Similarly, higher Ca and Mg levels in potting mixture were obtained under individual treatments of biofertilizers when compared with the control. The results of the current study are in line with the results obtained in other studies (Seema Paroha *et al*., 2009; Ramakrishnaiah and Vijaya, 2013).

Combined application of microbial inoculants significantly increased availability of organic carbon, P, K, Ca and Mg in potting mixture when compared with the control. Current results are similar to the findings reported by Ramakrishnaiah and Vijaya (2013). Among individual treatments of microbial fertilizers, T_5-*G. aggregatum* was found significantly superior to the control with respect to organic carbon, P, K, Ca and Mg availability in potting mixture.

It is evident from the results that integrated use of microbial fertilizers+chemical fertilizers was quite impressive in enhancing the organic carbon and phosphorous content in potting mixture as compared with other treatments. Similar observations are made (Han and Lee 2005; Noor Ai'shah, 2009; Seema Paroha *et al*., 2009) in potting mixture used for raising various nurseries. Improvement of OC, P and K in potting mixture can be attributed to higher microbial population under inoculated treatments when compared with the control. Increased availability of N, P and K in potting mixture under integrated use of biofertilizers+25%RDF (T_7) may be attributed to better nitrogen fixing capacity of *Azotobacter* and *Azospirillum*, phosphorus solubilization and mobilization by *Bacillus* and *Glomus* and mobilization of potassium by *Frateuria* with milder dose of inorganic fertilizers.

Micro-nutrients: It is reflected from the results that integrated application of microbial fertilizers+chemical fertilizers (T_7-T_9) particularly T_7 was the most impressive in increasing availability of iron (Fe), manganese (Mn), copper (Cu) and boron (B) in potting mixture when compared with rest of the treatments (Table 5). The results obtained under present study are in agreement with other studies (Seema Paroha *et al*., 2009; Ramakrishnaiah and Vijaya, 2013) which recorded better Fe, Mn, Cu and Zn contents in potting mixture. Combined application of microbial inoculants also significantly increased availability of Fe (23.93ppm), Mn (54.58ppm), Cu (5.39ppm), Zn (5.20ppm) and B (1.41ppm) in potting mixture when compared with the control. Present results are similar to the findings reported by Sumathi *et al.* (2011).

Among individual microbial fertilizers, T_5-*G. aggregatum* in case of Mn (48.18ppm), Cu (4.95ppm), Zn (5.16ppm) and B (1.35ppm), T_4-*F. aurantia* for Mn (42.08ppm) and Cu (3.90ppm) and T_3-*B. megaterium* for Cu (3.84ppm) and B (1.39ppm) in potting mixture were found markedly superior to the control. Effect of *Glomus aggregatum* was at par with T_6-combined use of microbial fertilizers for all the micronutrients. There was a considerable improvement in availability of Fe, Mn, Cu, Zn and B in potting mixture under the influence of T_{10}-100% RDF which was notably higher than the control and individual microbial fertilizers except T_5-*G. aggregatum.* Further, T_{10}-100% RDF was found at par with T_5-*G. aggregatum* and T_6-combined application of microbial fertilizers. It reflected neither use of individual microbial fertilizers nor combined microbial fertilizers could influence the micro nutrient status in potting mixture as compared with T_{10}-100% RDF.

Table 4 Influence of microbial fertilizers and chemical fertilizers on K, Ca, Mg and Fe in potting mixture used for raising oil palm nursery

Treatment	K (ppm)			Ca (meq/kg)			Mg (meq/kg)			Fe (ppm)		
	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean
T1	246.73	341.04	293.88	6.86	5.76	6.31	3.22	2.15	2.68	19.84	18.94	19.39
T2	265.45	334.72	300.08	7.41	5.99	6.70	3.42	2.6	3.01	19.44	18.54	18.99
T3	230.25	355.87	307.66	6.64	5.84	6.24	2.9	2.3	2.60	22.83	15.02	18.92
T4	292.22	456.73	374.47	7.44	5.46	6.45	3.1	2.72	2.91	20.64	17.51	19.07
T5	267.5	432.76	350.13	7.43	5.71	6.57	3.14	2.87	3.00	25.25	16.88	21.06
T6	307.22	413.28	360.24	7.06	5.37	6.22	2.8	3.04	2.92	29.72	18.14	23.93
T7	255.25	427.91	341.58	6.14	5.27	5.63	2.94	2.75	2.84	38.10	24.41	31.25
T8	254.44	380.81	317.62	7.25	6.01	6.63	3.17	2.68	2.92	38.27	22.56	30.41
T9	291.94	354.56	323.25	6.02	5.08	5.55	2.95	2.68	2.81	30.15	23.6	26.87
T10	298.30	334.78	316.54	5.99	5.09	5.53	2.87	2.6	2.73	25.11	23.91	24.51
T11	215.08	311.97	263.52	5.83	4.9	5.36	2.74	2.37	2.55	17.28	14.69	15.98
LSD 5%			36.91			0.38			0.38			7.48
SEm±			45.64			0.47			0.48			9.25

Nutrient uptake by oil palm seedlings: Highly positive and most significant improvement in accumulation of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in plant tissues (Table 6) was noticed with integrated application of microbial fertilizers+25% RDF (T_7) when compared to the control which recorded the lowest values for the same. The present outcome of the study is in consonance with others findings in teak seedlings (Seema Paroha *et al*., 2009) and in *Dalbergia sissoo* clones (Jaisankar *et al*., 2013). Treatment T_6-combined application of microbial fertilizers expressed better results for N, P, K, Ca and Mg accumulation in plant tissues than individual microbial fertilizers and the control. Current results are similar to the studies in oil palm seedlings (Amir *et al.,* 2005).

All individual microbial fertilizers expressed significant results over the control for all the macro nutrients. Among individual microbial fertilizers, T_5-*G. aggregatum* exhibited impressive performance for N (7.31g) and P (1.02g) and T_4-*F. aurantia* (12.04g) for K and the performance of both the treatments can be compared with T_6-combined use of microbial fertilizers. Similar results were obtained in papaya nursery (Sharada and Bernard, 2009). There was an increased uptake of less mobile elements like N, P, K, Ca and Mg (Sadhana, 2014) by plants treated with VAM fungi. Oil palm has poorly developed root system with no root hairs, so it cannot take up nutrients particularly P without mycorrhizal assistance. This is supported by Blal *et al.* (1990) who reported that coefficient of fertilizer utilization was increased by 4-5 folds in micro propagated oil palms after mycorrhization.

There is a symbiotic relation between AMF and oil palm root system (Corley and Tinker, 2003). Roots absorb and translocate phosphorous from distant areas by increasing root surface area which otherwise inaccessible to roots. Moreover, higher uptake of P can be attributed to greater physical contact between phosphate ions and hyphal network in rhizosphere (Sanders and Tinker, 1973). Further, uptake of higher phosphorus from soil must be linked to rapid root growth, extensive root hair production and modification of rhizospheric conditions which help in increasing P availability (Smith *et al.,* 2001). Increased nitrogen content in microbe inoculated seedlings was due to enhanced nitrate reductase activity which was attributed to improved P nutrition provided by AMF symbiosis (Oliver *et al.,* 1983). Increased root growth of host plants could be due to higher N uptake and direct transport of inorganic ammonium ions through hyphae of AM fungi (Tholkappian *et al*., 2001). The above findings might be the reasons for enhanced nutrient uptake by oil palm seedlings treated with *G. aggregatum.* Similarly, T_3-*B. megaterium* was quite effective in improving the status of P (1.04g) in plant tissues.

The treatment T_{10}-100% RDF was significantly superior to the control for all the macro nutrients. Similarly, it fared significantly better than all individual microbial fertilizers for N and some individual microbial fertilizers for P, K, Ca and Mg. Moreover, the treatments T_{10}-100% RDF and T_6-combined application of microbial fertilizers were found equally effective for uptake of N, P, K, Ca and Mg by oil palm seedlings. There was a sudden drop in N, P, K, Ca and Mg levels under integration as the recommended dose of chemical fertilizers increased from 25 to 50% (T_7-T_8) but consistency in uptake of N, P, K, Ca and Mg as the chemical fertilizer dose was increased from 50 to 75% under integration (T_8-T_9). It denotes that most significant effect was manifested under mild dose of chemical fertilizers.

Micro-nutrients: Among the treatments, the highest concentration (Table 7) of iron (9.93mg), manganese (8.08mg), copper (1.58mg) and zinc (0.85mg) in plant tissues was observed under T_7-microbial fertilizers+25% RDF whereas boron was observed as the maximum under T_8-microbial fertilizers+50% RDF (1.02mg). Integrated application of T_7-microbial fertilizers+25% RDF was emerged as the most significant treatment in effecting Fe, Mn, Cu, Zn and B levels in plant tissues. Similar conclusions are drawn (Seema Paroha *et al*., 2009) in teak seedlings. However, B uptake was increased as the chemical fertilizer dose enhanced from 25 to 50% and then dropped down when the fertilizer dose was increased from 50 to 75%. This reflected improved uptake of above micro nutrients by seedlings at lower to medium dose of chemical fertilizers.

The treatment T_6-combined use of microbial fertilizers was significantly greater than some of the individual microbial fertilizers in promoting the uptake of Mn, Cu, Zn and B by seedlings. Similarly, higher uptake of micronutrients was recorded in pomegranate cuttings (Muzaffar Mir *et al*., 2012). Enhanced uptake of micronutrients can be correlated with multiple use of microbial fertilizers especially AMF.

Performance of all individual microbial fertilizers was significantly better than the control for Fe, Mn, Zn and B. The treatment T_5-*G. aggregatum* was equally effective for Mn, Cu, Zn and B when compared with T_6-combined use of microbial fertilizers and T_{10}-100% RDF. The role of AMF in Fe nutrition is well documented and increased Fe uptake by AMF may be due to production of siderophores which specifically chelate Fe (Bar-Ness *et al.,* 1991). Similarly, higher concentration of Zn, Cu and Mn was reported in inoculated plants with AMF (Sadhana, 2014). Good colonization in roots must be responsible for improved absorption of nutrients by seedlings under inoculated treatments particularly under T_5-*G. aggregatum*, T_7-microbial fertilizers+25% RDF and T_6-combined use of microbial fertilizers.

Table 5 Influence of microbial fertilizers and chemical fertilizers on Mn, Cu, Zn and B in potting mixture used for raising oil palm nursery

Treatment	Mn (ppm)			Cu (ppm)			Zn (ppm)			B (ppm)		
	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean
T1	39.64	31.42	35.52	2.81	2.33	2.57	5.78	3.57	4.67	1.39	1.07	1.23
T2	40.72	30.47	35.59	3.93	2.66	3.29	5.95	3.61	4.78	1.50	0.94	1.21
T3	39.74	31.54	35.63	5.27	2.42	3.84	5.92	3.90	4.91	1.51	1.27	1.39
T4	54.90	29.20	42.05	5.35	2.45	3.90	5.67	3.83	4.75	1.57	1.04	1.30
T5	65.47	30.90	48.18	7.44	2.46	4.95	6.13	4.20	5.16	1.44	1.29	1.35
T6	77.38	31.78	54.58	8.41	2.38	5.39	6.29	4.12	5.20	1.60	1.23	1.41
T7	86.11	36.77	61.44	9.03	2.76	5.89	6.60	4.63	5.61	2.00	1.70	1.85
T8	74.01	38.81	56.41	8.85	2.64	5.75	6.53	4.15	5.34	2.00	1.50	1.75
T9	45.62	39.39	52.50	7.91	2.70	5.30	6.24	4.42	5.33	1.81	1.23	1.52
T10	58.27	40.37	49.31	6.51	2.73	4.62	5.78	4.63	5.20	1.75	1.12	1.44
T11	32.56	26.56	29.56	2.42	1.89	2.16	5.22	3.70	4.46	1.28	0.90	1.10
LSD 5%			11.17			1.46			0.65			0.22
SEm±			13.82			1.80			0.81			0.27

Table 6 Influence of microbial fertilizers and chemical fertilizers on uptake of N, P, K, Ca and Mg by 12 month old oil palm seedlings

Treatment	N (g)			P (g)			K (g)			Ca (g)			Mg (g)		
	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean
T1	8.35	5.72	7.04	1.12	0.66	0.89	11.46	8.65	10.06	4.20	2.36	3.77	2.26	2.16	2.21
T2	7.64	5.39	6.51	1.08	0.66	0.87	9.46	7.48	8.47	3.74	1.90	3.50	2.09	1.89	1.99
T3	7.30	5.58	6.44	1.15	0.92	1.04	10.03	7.64	8.84	4.22	3.67	3.94	2.00	1.99	2.00
T4	7.02	5.27	6.14	1.03	0.56	0.79	13.21	10.87	12.04	4.37	3.11	3.74	2.45	2.02	2.23
T5	8.78	5.84	7.31	1.13	0.90	1.02	11.80	9.22	10.52	3.48	2.63	3.06	2.10	1.86	1.98
T6	9.57	6.25	7.91	1.26	0.95	1.11	13.05	9.94	11.49	4.54	3.70	4.12	2.65	2.33	2.49
T7	14.70	6.97	10.84	2.04	0.97	1.51	18.25	12.21	15.23	7.07	3.26	5.16	3.99	2.46	3.23
T8	12.12	6.36	9.24	1.71	0.80	1.26	14.89	10.25	12.57	6.11	3.87	4.99	3.47	1.78	2.62
T9	12.32	6.13	9.23	1.65	0.87	1.26	14.68	9.70	12.19	5.90	3.34	4.62	3.40	1.52	2.46
T10	10.23	6.17	8.20	1.48	0.66	1.07	16.09	5.91	11.00	5.21	3.03	4.12	3.66	1.37	2.52
T11	6.98	2.75	4.87	1.00	0.36	0.68	8.98	3.80	6.39	3.45	1.27	2.36	1.59	1.84	1.72
LSD 5%			0.81			0.28			1.43			0.75			0.50
SEm±			0.69			0.24			1.24			0.65			0.42

Table 7 Influence of microbial fertilizers and chemical fertilizers on uptake of Fe, Mn, Zn, Cu and B by 12 month old oil palm seedlings

Treatment	Fe (mg)			Mn (mg)			Cu (mg)			Zn (mg)			B (mg)		
	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean	1st yr	2nd yr	Pooled mean
T1	8.31	4.63	6.47	6.69	4.83	5.76	1.24	0.48	0.86	0.70	0.54	0.62	0.86	0.50	0.68
T2	6.78	6.41	6.60	5.93	4.92	5.43	1.02	0.45	0.73	0.67	0.50	0.59	0.87	0.42	0.65
T3	7.76	5.07	6.42	7.50	4.55	6.02	0.86	0.44	0.65	0.73	0.58	0.66	0.63	0.55	0.59
T4	7.07	5.14	6.10	7.03	2.91	4.97	1.40	0.42	0.91	0.70	0.58	0.64	0.79	0.54	0.67
T5	7.35	5.80	6.58	7.27	5.39	6.33	1.34	0.49	0.92	0.76	0.66	0.71	0.86	0.51	0.69
T6	7.26	6.24	6.75	7.62	6.13	6.87	1.68	0.53	1.11	0.79	0.67	0.73	1.01	0.55	0.78
T7	11.90	7.96	9.93	11.12	5.03	8.08	2.56	0.59	1.58	1.07	0.63	0.85	1.27	0.67	0.97
T8	10.30	5.85	8.08	10.17	5.04	7.60	2.03	0.55	1.29	0.95	0.56	0.75	1.30	0.74	1.02
T9	9.94	4.77	8.08	9.89	4.15	7.02	1.46	0.49	0.98	0.90	0.55	0.73	1.12	0.55	0.83
T10	9.55	4.34	8.12	9.41	4.27	6.84	1.55	0.47	1.01	0.92	0.38	0.65	0.97	0.50	0.74
T11	5.59	2.20	3.90	5.43	1.59	3.51	1.08	0.18	0.63	0.57	0.22	0.40	0.64	0.21	0.43
LSD-5%			1.18			1.12			0.24			0.10			0.12
SEM			1.02			0.97			0.20			0.08			0.10

Moreover, soil nutrient status and plant nutrient demand may also cause variations in uptake of nutrients by plants. It is also observed that specific microbes simultaneously influenced uptake of other nutrients. Nitrogen fixing bacteria (NFB) inoculated seedlings absorbed higher P and K along with higher N. Similarly, PSB treated seedlings exhibited higher uptake of P with N and K and AMF inoculated seedlings had higher N and K with P. Uptake of micro nutrients in microbial inoculated plants was also noticed higher due to direct or indirect effect of inoculants (Seema Paroha *et al*., 2009). Based on the unusual morphology of root system in oil palm which produces thick cylindrical adventitious roots without root hairs, it appears that oil palm is functionally dependant on AMF to obtain nutrition (Corley and Tinker, 2003) and this may be the main reason for enhanced uptake of nutrients by oil palm seedlings treated with AMF. Similarly, it was stated by somebody (Clark, 1997) that VAM fungi are responsible for more than two fold increased acquisition of less mobile elements like P, Ca, Zn, Mg and Cu from the rhizosphere.

Results of the present study have shown that integrated application of microbial fertilizers+chemical fertilizers and combined use of microbial fertilizers played significant role in improving the nutrient uptake by oil palm seedlings. This impact can be ascribed to synergistic effect among various types of microbial fertilizers and between microbial fertilizers and chemical fertilizers. Rhizosphere is an active metabolic zone of soil-plant-microbe interaction responsible for transformation of various nutrients for plant uptake resulting in higher growth and development. Indirectly, it is assumed that plant nutrient uptake is equally proportional to microbial activity (Aseri and Rao, 2005).

Inoculated seedlings were found to contain significantly higher amount of N, P, K, Ca, Mg, Fe, Mn, Cu, Zn and B when compared with the control. This enhancement might be due to production of nutrient solubilizing enzymes by microorganisms and ability of AM fungal hyphae towards uptake of immobile ions, besides increasing the surface area of roots by tapping large soil volume (Kothari *et al*., 1991). Further, higher root density in inoculated seedlings might have facilitated higher nutrient and water uptake. Higher macro and micro nutrients uptake by seedlings is directly associated with the rate of mycorrhizal root colonization (Dolcet Sanjuan *et al*., 1996).

Therefore, it can be inferred from the foregoing results and discussion that outstanding results for growth characters, nutrient status in potting mixture and nutrient uptake by seedlings were obtained under integrated application of microbial fertilizers with 25% recommended dose of chemical fertilizers rather than combined use of different types of microbial fertilizers, 100% recommended dose of chemical fertilizers and the control. Hence, microbial fertilizers along with mild dose of chemical fertilizers can be exploited commercially for sustainable raising of oil palm nursery without affecting seedling growth and vigour.

REFERENCES

Allen E B, Allen M F, Helm D J, Trappe J M, Moliva R and Rincon E 1985. Patterns of and regulation of mycorrhizal and fungal diversity. *Plant Soil*, **170**: 47-62.

Amir H G, Shamsuddin Z H, Halimi M S, Ramlan M F and Marziah M 2005. Enhancement in nutrient accumulation and growth of oil palm seedlings caused by PGPR under field nursery conditions. *Communications in Soil Science and Plant Analysis*, **36**: 2059-2066.

Aseri G K and Rao A V 2005. Interaction of bio-inoculants and chemical fertilizers on biomass production, rhizosphere activity and nutrient uptake of ber. *Indian Journal of Forestry*, **28**: 58-64.

Bar-Ness E, Chen Y, Hadar Y, Marschner H and Pomheld V 1991. Siderophores of *Pseudomonas putida* as an iron source for dicot and monocot plants. *Plant and Soil*, **130**: 231-241.

Bhuvaneshwari N and Sadhana B 2014. Arbuscular mycorrhizal status of non-leguminous plants. *Indian Journal of Advances in Plant Research*, **1**: 31-38.

Blal B and Gianinazzi Pearson 1990. Interest of endomycorrhizae for production of micropropagated oil palm (*Elaeis guiniensis* Jacq.). *Agriculture Ecosystems and Environment*, **29**: 39-43.

Clark R B 1997. *Arbuscular mycorrhizal* adaptation, spore germination, root colonization and host plant growth and mineral acquisition at low pH. *Plant Soil*, **192**: 15-22.

Corley R H V and Tinker P B 2003. *The Oil Palm*. 4th ed. Blackwell Science Ltd, Oxford, UK.

Dolcet-Sanjuan R, Claveria E, Camprouby A, Estaun V and Calvet C 1996. Micropropagation of walnut trees (*Juglans regia* L.) and response to arbuscular mycorrhizal inoculation. *Agronomie*, **16**: 639-645.

Han H and Lee K D 2005. Phosphate and potassium solubilizing bacteria effect on mineral uptake, soil availability and growth of egg plant. *Research Journal of Agriculture and Biological Sciences*, **1**:176-180.

Jaisankar I, Revathi R, Parthiban K T, Backiyavathy M R, Jude Sudhagar R and Sivakumar K 2013. Response of *Dalbergia sissoo* clones to integrated nutrient management practices. *Indian Journal of Hill Farming*, **26**: 42-48.

Kohler J, Caravaca F, Carraco L and Rolden A 2007. Interactions between a plant growth promoting rhizobacterium, an AM fungus and phosphate solubilizing fungus in the rhizosphere of *Lactuca sativa. Applied Soil Ecology*, **35**: 480-487.

Kothari S K, Marschner H and Romheld V 1991. Contribution of VA mycorrhizal hyphae in acquisition of phosphorous and zinc by maize grown in a calcareous soil. *Plant and Soil*, **133**: 177-185.

Lindsay W L and Norvell W A 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal*, **42**: 421-428.

Mathur N and Vyas V 1995. Changes in isozyme patterns of peroxidase and polyphenol oxidase by VAM fungi in roots of Ziziphus sp. *Journal of Plant Physiology*, **145**: 498-500.

Merwin H D and Peach M 1951. Exchangeability of soil potassium in sand, silt and clay fraction as influenced by the nature of complementary exchangeable cations. *Soil Science Society of America*, **15**: 125-128.

Muzaffar Mir, Hassan G I, Sheikh K and Sanjeev Kumar Sharma 2012. Impact of biofertilizers on growth, nutrient uptake, yield, metabolism and rhizosphere enzyme activities of pomegranate (*Punica granatum* L.) 'Kandhari Kabuli'. *Applied Biological Research*, **14**: 168-175.

Noor Ai'shah O, Amir H G, Chan Lai Keng and Othman A R 2009. Influence of various combinations of diazotrophs and chemical N fertilizer on plant growth and N_2 fixation capacity of oil palm seedlings (*Elaesis guineensis* Jacq.). *Thai Journal of Agricultural Science*, **42**: 139-149.

Oliver A J, Smith S, Nicolas D J D, Wallace W and Smith A 1983. Effect of mycorrhizal infection and phosphorous nutrition in *Trifolium subterrneum* F A L. *New Phytology*, **94**: 63-79.

Olsen S R, Cole C V, Watanabe F S and Dean L A 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate USDA Cir.939 USDA, Washington DC.

Ponmurugan P and Gopi C 2006. Distribution pattern and screening of phosphate solubilizing bacteria isolated from different food and forage crops. *Journal of Agronomy*, **5**: 600-604.

Ramakrishnaiah G and Vijaya T 2013. Influence of VAM fungi, *Azotobacter* sp. and PSB on soil phosphatase activity and nutrients status in the rhizosphere of *Stevia rebaudiana* (Bert.) plants. *American Journal of Plant Sciences*, **4**: 1443-1447.

Ryglewicz P T and Anderson C P 1994. Mycorrhizae alter quality and quantity of carbon below ground. *Nature*, **369**: 58-60.

Sadhana B 2014. *Arbuscular mycorrhizal* fungi as a biofertilizer-A review. *International Journal of Current Microbiology and Applied Sciences*, **3**: 384-400.

Sanders F E and Tinker P B 1973. Phosphate inflow into mycorrhizal roots. *Pesticidal Science*, **4**: 385-395.

Seema Paroha K, Chandra K and Rakhi Yadav 2009. Integrated effect of biofertilizers fertilizers (AM, *Azotobacter* and PSB) on growth and nutrient acquisition by *Tectona grandis. Journal of Tropical Forestry*, **25**: 54-61.

Sharada W K and Bernard F R 2009. Studies on effects of *arbuscualar mycorrhizal* (Am.) fungi on mineral nutrition of *Carica papaya* L. *Notulae Botanicae Horti Agrobotanici Cluj,* **37**: 183-186.

Smith S E, Dickson S and Smith F A 2001. Nutrient transport in arbuscular mycorrhizae: How are fungal and plant processes integrated. *Australian Journal of Plant Physiology*, **28**: 683-694.

Sumathi C S, Ramesh N, Balasubramanian V and Rajesh Kannan V 2011. Microbial bioinoculant potential on turmeric growth improvement under tropical nursery conditions. *Asian Journal of Experimental Biological Sciences*, **2**: 612-623.

Tarafdar J C and Classen N 1988. Organic phosphorous compounds as a phosphorous source for higher plants through the activity of phosphatase by plant roots and microorganisms. *Biology and Fertility of Soils*, **5**: 308-312.

Tholakappian P, Prakash M and Sundaram M D 2001. Effect of AM fungi on proline, nitrogen and pod number of soybean under moisture stress. *Indian Journal of Plant Physiology*, **6**: 98-99.

Umme Aminun Naher, Radziah Othman and Qurban Ali Panhwar 2013. Beneficial effects of mycorrhizal association for crop production in the Tropics-A Review. *International Journal of Agriculture and Biology*, **15**: 1021-1028.

Walkley A and Black I A 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, **37**: 29-37.

Walker T S, Bais H P, Grotewold E and Vinanco M 2003. Root exudation and rhizoshpere biology. *Plant Physiology*, **132**: 44-51.

Xavier Moses Martin, Chettipalayam Samiappan Sumathi and Velu Rajesh Kannan 2011. Influence of agrochemicals and *Azotabacter* sp application on soil fertility in relation to maize growth under nursery conditions. *Eurasian Journal of Bio Sciences*, **5**: 19-28.

Forecasting oilseeds prices in India: Case of groundnut

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(Received: September 27, 2017; Revised: December 8, 2017; Accepted: December 14, 2017)

ABSTRACT

Oilseed crops contribute 13 per cent of the country's gross cropped area and 10 per cent of the value of all agricultural produce. Groundnut is the major oilseed crop accounting about 30 per cent of the total oilseeds cropped area in the country with a production share of about 36 per cent. Prices of groundnuts are highly volatile, hence farmers need a reasonable forecasting of harvest period price to decide on the acreage under groundnut. Hence, the present study aimed to build a model to forecast the groundnut prices and applied to forecast *kharif* harvesting season prices in major producing states *viz.,* Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra. The prices were forecasted by using the time series data of monthly average prices for the period of 11 years (January 2006 to December 2016). ARIMA model introduced by Box and Jenkins (1970) which is the most widely used amongst time series models was used for predictions. R^2, RMSE, MAPE, MAE and normalized BIC these parameters were used to test the reliability of model. Model parameters were estimated by using the Statistical Packages for Social Sciences software. In India *kharif* season groundnut is harvested during the period of September to December. Forecast shows that market prices of groundnut, would be ruling in the range of ₹ 3,760 to 5,520 per quintal in *kharif* harvesting season (2017-18). Hence, using ARIMA model to forecast groundnut prices is very useful not only to farmers but in policy formulation and also in promoting efficiency of groundnut marketing. The farmers are advised to take marketing decision accordingly.

Keywords: ACF, ARIMA, Box and Jenkins, Forecasting, Groundnut, PACF

Groundnut is the third largest oilseed produced in the world and stands second largest oilseed in India. Asian and African countries have major shares in groundnut production. Asia accounts for about 50 per cent of area and 60 per cent of world production of groundnut. China ranks first in production of groundnut, with a share of about 42 per cent to overall world production. India (16-18%) is the second largest producer of groundnut after China and then the United States of America (6-8%). Being populated countries, maximum part of China and India's groundnut production is consumed domestically so, they account for a small part of international trade. Major exporters of groundnut are the US, Argentina, Sudan, Senegal and Brazil, while the major importers are EU, Canada and Japan. India has been net exporter of groundnut seed (http://www.commoditiescontrol.com). Major export destinations are Asian countries *viz.,* Indonesia, Vietnam, Malaysia, Philippines, Thailand, Ukraine and Pakistan.

India is the second largest producer of groundnut in the world and first in terms of area. Groundnut production, within the country, is mainly concentrated in five states including Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Rajasthan and Maharashtra accounting for nearly 90 per cent of the total production of groundnut in the country (Reddy and Reddy, 2011). The remaining groundnut cultivated area is scattered in the states of Madhya Pradesh, Uttar Pradesh, Punjab, and Odisha. Gujarat is the single largest as well as the best quality producer of groundnuts accounting for over 40 per cent of total groundnut produced in the country. Rajkot, Ahmedabad, Mumbai and Delhi are the major trading centers of groundnut in India. The *kharif* groundnut crop of 2016-17 is estimated at 54.80 lakh tonnes against 32.30 lakh tonnes in 2015-16 up by 70 per cent, according to the estimate of industry body Solvent Extractors Association (SEA). Groundnut is largely cultivated in India during *kharif* season (June to October). So that the present study aimed to forecast the groundnut prices during *kharif* harvesting season in major producing states *viz.,* Gujrat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra during *kharif* harvesting season (September to December).

Price forecasts will help farmers in allocating their limited land for different crops, help in taking decisions like where to sell and when to sell and to whom to sell and will assist farmers in making informed marketing decisions (Kwasi and Kobina, 2014). Price prediction is highly useful for forecasting the market price for the oilseeds. It is also useful for farmers to plan their crop cultivation activities so that they could fetch more price in the market (Bannor and Kobina, 2014). But forecasting of agricultural commodity prices is of formidable challenge and needs application of sophisticated econometric tools. Auto Regressive Integrated Moving Average (ARIMA) model was introduced by Box and Jenkins (1976) for forecasting prices. Sahu and Mishra (2013) studied forecasting the production, import-export and trade balance of total spices in India and China along with world using ARIMA model for time series data and forecasted for year 2020. Hence, using ARIMA model to forecast groundnut prices is very useful not only to farmers but in policy formulation and also in promoting efficiency of groundnut marketing in the State. An efficient farm marketing system due to market price information is an important means for raising the income levels of farmers and for promoting the economic development of a country.

MATERIALS AND METHODS

Data collection: The study has utilized secondary source of data. The time series data on monthly price of groundnut required for the study was collected from the AGMARKNET website. The 11 years data of major producing states *viz.,* Gujrat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra was collected from January 2006 to December 2016. The data on prices refer to model prices in a month. It is aggregation of all markets in the state. Modal price was considered superior to the monthly average price as it represented the major proportion of the commodity marketed during the month.

Auto regressive integrated moving average (ARIMA) model (Box-Jenkins model): Basically ARIMA models was introduced by Box and Jenkins (1976). However, the optimal forecast of future values of a time-series are determined by the stochastic model for that series. A stochastic process is either stationary or non-stationary. Most of the time series are non-stationary and the ARIMA model refers only to a stationary time series. Therefore, it is necessary to have a distinction between the original non-stationarity time series and its stationarity counterpart. The main objective in fitting ARIMA model is to identify the stochastic process of the time series and predict the future values accurately. Ansari and Ahmad (2001) worked with application of ARIMA modelling and co-integration analysis on time series of tea price. Different stages in forecasting model are given below.

Identification: A good starting point for time series analysis is a graphical plot of the data. It helps to identify the presence of trends. Before estimating the parameter p and q of the model, the data are not examined to decide about the model which best explains the data. This is done by examining the sample ACF (Autocorrelation function) and PACF (Partial autocorrelation function) of differenced series Yt. Both ACF and PACF are used as the aid in the identification of appropriate models. There are several ways of determining the order type of process, but still there was no exact procedure for identifying the model.

1) Estimating the parameters: After tentatively identifying the suitable model, next step is to obtain least square estimates of the parameters, such as R^2, Root mean square error (RMSE), Mean absolute percentage error (MAPE), Mean absolute error (MAE) and normalized Bayesian Information Criterion (BIC) to check the accuracy of the model.

2) Diagnostic checking: After having estimated the parameters of a tentatively identified ARIMA model, it is necessary to do diagnostic checking to verify that the model is adequate. Examining ACF and PACF of residuals may show an adequacy or inadequacy of the model. If it shows random residuals, then it indicates that the tentatively identified model is adequate. When an inadequacy is detected, the checks should give an indication of how the model need to be modified, after which further fitting and checking take place. The residuals of ACF and PACF considered random when all their ACF were within the limits (Burark and Sharma, 2012).

3) Forecasting: After satisfying about the adequacy of the fitted model, it can be used for forecasting future prices. This was done with the help of SPSS package.

Similar model was used by Darekar *et al.* (2015) to forecast onion prices in Lasalgaon and Pimpalgaon market using ARIMA model and drawn conclusions. Mishra and Singh (2013) and Singh and Mishra (2015) used ARIMA methodology given by Box and Jenkins for forecasting prices of groundnut oil in New Delhi from January 1994 to July 2010. It has been concluded that ARIMA model performed better than the ANN.

RESULTS AND DISCUSSION

Model identification and estimation: The groundnut prices were forecasted for the *kharif* season during October to November by ARIMA model using Box-Jenkins methodology (Kumar *et al.,* 2011, Mishra *et al.,* 2013). ARIMA model was estimated only after transforming the variable under forecasting into a stationary series. The stationary series is the one whose values vary over time only around a constant mean and constant variance. In this case difference of order 1 was sufficient to achieve stationarity in mean. As the results (Fig. 1) indicate, none of these autocorrelations was significantly different from zero at any reasonable level. The ACF and PACF of the residual indicated the 'good fit' of the model. This proved that the selected ARIMA model was an appropriate model for forecasting groundnut price in India.

Model verification: The model parameters were estimated using SPSS package. Results of estimation are reported in Table 1. The R^2, RMSE, MAPE, MAE and normalized BIC criterion were used to measure of the forecast accuracy and to judge the forecasting ability of the fitted ARIMA model. So it was observed that the most suitable model for forecasting groundnut prices was ARIMA (0,1,0) (0,0,0), (0,1,0) (1,0,0), (0,1,0) (0,0,0), (0,1,2) (0,0,0), (0,1,0) (0,0,0) and (0,1,0) (0,0,0) as it had the lowest R^2, RMSE, MAPE, MAE and normalized BIC values for Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and India respectively. It is revealed that the R2, RMSE, MAPE, MAE and normalized BIC for groundnut price in India were 0.95, 217.84, 4.20, 150.40 and 10.80 respectively. It indicated that the forecasting inaccuracy was low and the model shown best fit to the data.

Figure 2 shows observed and forecasted prices of groundnut in selected states and India. The figure indicates that the forecasted prices predicts prices with 95% confidence interval.

Table 1 Model statistics for forecasting the monthly prices of groundnut in selected states

State	ARIMA Model	R^2	RMSE	MAPE	MAE	Normalized BIC
Gujarat	(0,1,0) (0,0,0)	0.82	391.98	7.40	232.30	11.98
Andhra Pradesh	(0,1,0) (1,0,0)	0.94	221.03	5.02	163.07	10.83
Tamil Nadu	(0,1,0) (0,0,0)	0.86	500.30	8.32	338.63	12.46
Karnataka	(0,1,2) (0,0,0)	0.88	381.94	7.36	253.19	11.92
Maharashtra	(0,1,0) (0,0,0)	0.86	693.53	8.30	411.38	13.12
India	(0,1,0) (0,0,0)	0.95	217.84	4.20	150.40	10.80

Table 2 Projected prices for groundnut in selected states during *kharif* harvesting season 2017-18 (₹./q)

State	Lower Confidence Level	Forecast	Upper Confidence Level
Gujarat	1,630	4,260	6,050
Andhra Pradesh	2,750	4,310	5,820
Tamil Nadu	2,180	4,550	4,990
Karnataka	2,490	4,430	5,380
Maharashtra	3,120	4,670	5,460
India	3,760	4,730	5,520

Forecasting with ARIMA model: Expert modeler considers seasonal models. Figure 3 depicts the forecasts for monthly groundnut price during *kharif* harvesting season (September to December). It shows that market prices of groundnut in India would be ruling in the range of ₹ 3,760 to 5,520 per quintal in *kharif* harvesting season, 2017-18. The prices would be high in the state of Maharashtra (₹ 4,670), Tamil Nadu (₹ 4,550) and Karnataka (₹ 4,260). While in case of Andhra Pradesh and Karnataka the prices would be low i.e. ₹ 4,310 and ₹ 4,260 respectively (Table 2).

Edible oil sector in India is highly exposed to international price fluctuations (Reddy and Bantilan, 2012; Reddy, 2009). Given the high fluctuations, farmers are unable to make informed decisions on acreage under oilseed crops like groundnut. Hence, accurate price forecasting tools are important to disseminate among farmers before sowing dates to decide on acreage under the crop. The paper built price forecasting model and applied it to groundnut crop to forecast prices for the *kharif* harvest season 2017-18. ARIMA model is an extrapolation method that requires only the historical time series data on the variable under study. Nevertheless the model is handy have been successfully used for forecasting in the future. Similar model was used by Zhang (2003) and Darekar *et al.* (2015) to forecast the prices of agricultural commodities and drawn conclusions. There are different factors influencing groundnut prices such as crop condition and output expectations, demand expectation, stocks available in the market, external demand and supply, change in government policy relating to change in tariffs etc. Wide fluctuation in marketing price can be avoided by adopting procurement policy as in sugarcane. It will protect the farmers to get assured price for their produce. In the regulated markets, certain amenities should be provided to sellers and exorbitant market charges and deductions in settled price should not made. The growers should secure maximum value for their produce in the regulated markets. Credit has to be made available in the village by the banks directly to the farmers to free them from the clutches of the greedy local merchants so that they secure fair price for their produce. Awareness amongst the groundnut farmers should be raised with the help of appropriate extension programs. It is clearly noted from the discussion that, such forecasting of groundnut prices will definitely be helpful not only to producers and consumers but also to wholesalers, retailers, government agencies and other stakeholders in groundnut trading especially in major growing area of the country.

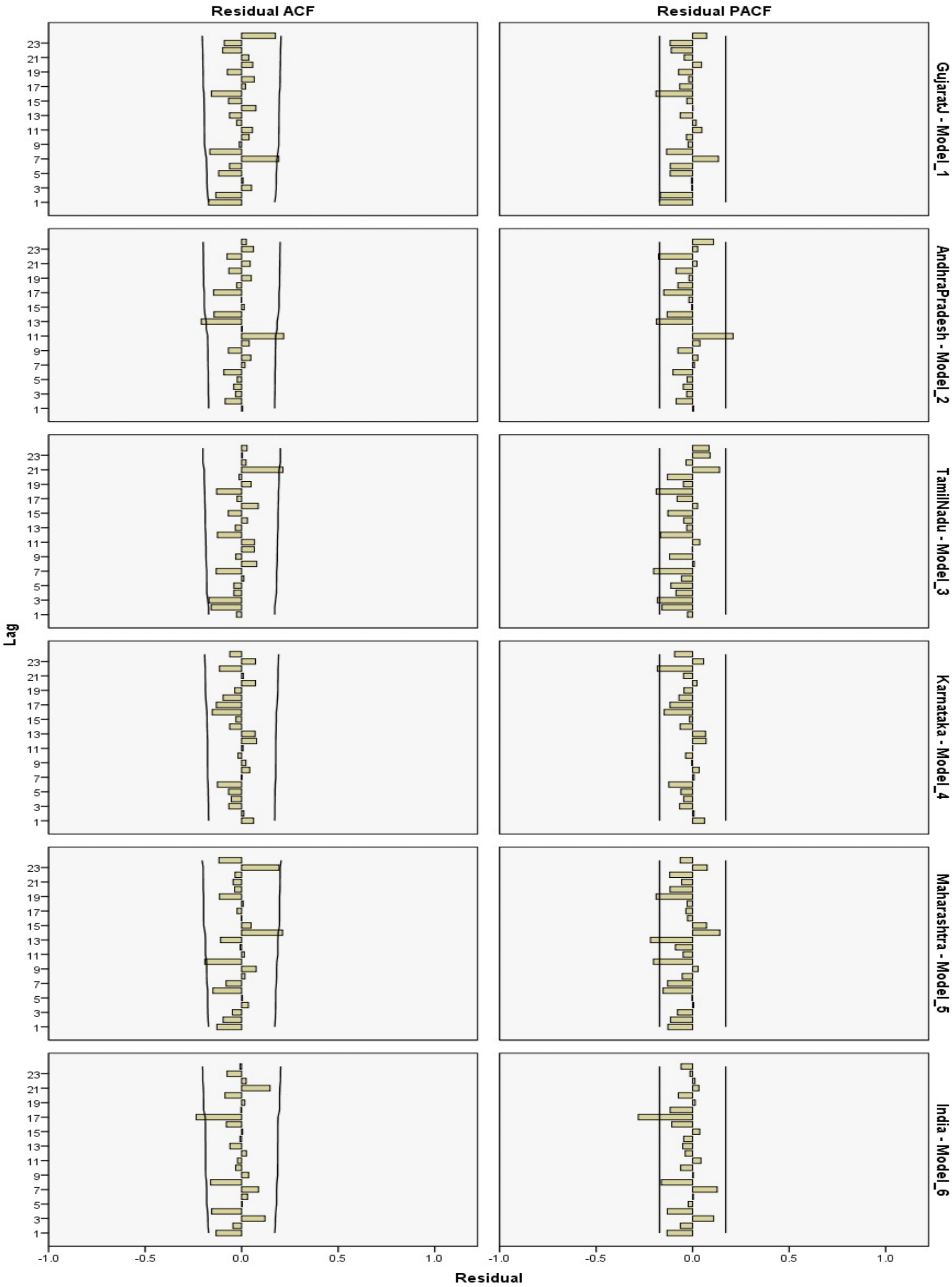

Fig. 1. ACF and PACF of residuals of fitted model for groundnut prices in selected states and India

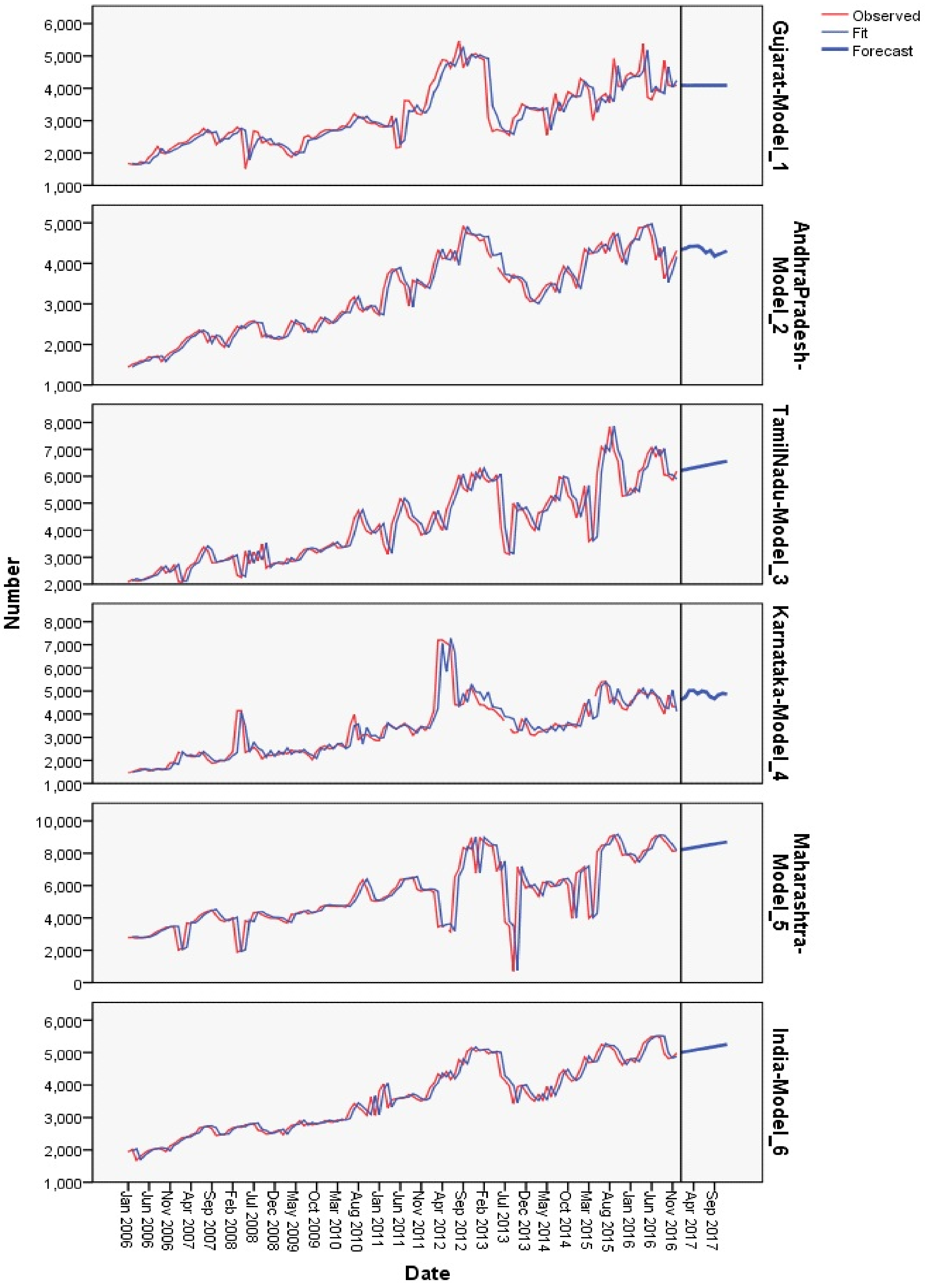

Fig. 2. Observed and forecasted prices of groundnut in selected states and India

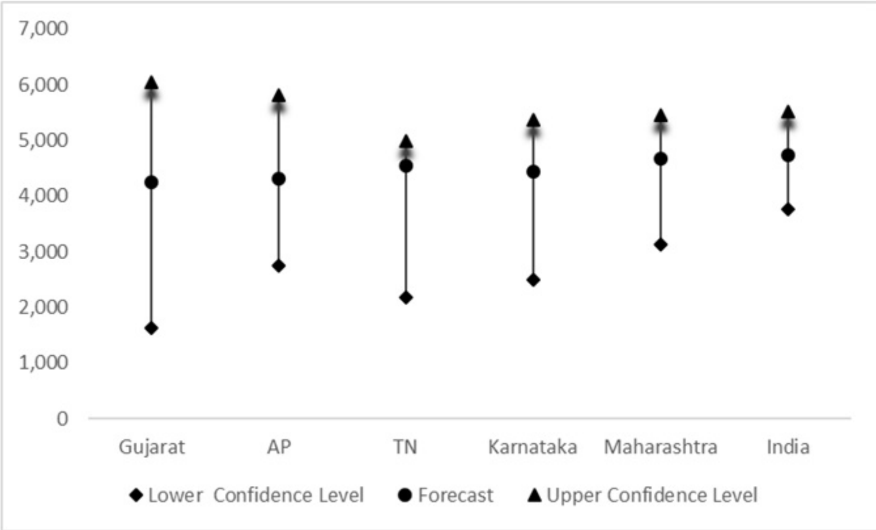

Fig. 3. Projected prices for groundnut in selected states during *kharif* harvesting season 2017-18 (₹/q)

REFERENCES

Ansari M I and Ahmed S M 2001. Time series analysis of tea prices: An application of ARIMA modeling and co integration analysis. *Indian Journal of Economics*, **48**: 49-54.

Bannor K R and Kobina B J 2014. Cassava markets integration analysis in the central region of Ghana. *Indian Journal of Economics and Development*, **10**(4): 319-329.

Box G E P and Jenkins G M 1976. *Time Series Analysis: Forecasting and Control*. Holden-Day, San Francisco.

Burark S S and Sharma H 2012. Price forecasting of coriander: methodological issues. *Agricultural Economics Research Review*, **25**: 530.

Darekar A S, Pokharkar V G, Gavali A V and Yadav D B 2015. Forecasting the prices of onion in Lasalgaon and Pimpalgaon market of Western Maharashtra. *International Journal of Tropical Agriculture*, **33**(4): 3563-3568.

Kwasi B R and Kobina B J 2014. Forecasting of cassava prices in the Central Region of Ghana Using Arima Model. *Intercontinental Journal of Marketing Research Review*, **2**(8): 30-40.

Mishra G C and Singh A 2013. A study on forecasting prices of groundnut oil in Delhi by ARIMA methodology and artificial neural networks. *Economics and Informatics*, **5**(3): 25-34.

Reddy A A 2009. Policy options for India's edible oil complex. *Economic and Political Weekly,* 22-24.

Reddy A A and Bantilan M C S 2012. Competitiveness and technical efficiency: Determinants in the groundnut oil sector of India. *Food Policy*, **37**(3): 255-263.

Reddy A A and Reddy G P 2011 Integration of wholesale prices of groundnut complex. *Indian Journal of Agricultural Marketing,* **25**(2): 89-108.

Singh A and Mishra G C 2015. Application of Box-Jenkins Method and Artificial Neural Network Procedure for time series forecasting of prices. *Statistics in Transition New Series, Spring,* **16**(1): 83-96.

Zhang P G 2003. Time series forecasting using a hybrid ARIMA and neural network model. *Neurocomputing*, **50**: 159-175.

GreenPHABLET™ video for effective information dissemination on hermetic groundnut storage technology

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(Received: September 13, 2017; Revised: November 21, 2017; Accepted: November 29, 2017)

ABSTRACT

Information and communication technologies (ICT) tools can facilitate dissemination of need based and farmer centric information at an affordable cost to India's rural population. One of the major constraints of groundnut production is aflatoxin accumulation and insect infestation during storage. In our studies conducted at ICRISAT, the Purdue Improved Crop Storage (PICS) hermetic storage technology proved effective against insect infestation and aflatoxin accumulation during storage. To facilitate visual learning of the use of hermetic storage, a five minute GreenPHABLET™ video (GPV) in the local language was developed at ICRISAT. A 3-month long experiment was conducted in collaboration with an NGO Samatha of Penugonda in Anantapur district of Andhra Pradesh, India to assess the dissemination potential of GPV. A survey conducted among 30 farmers who received the video, revealed that about 80% of farmers received the video from a fellow farmer and only 20 per cent farmers received from the extension agents. Majority of the farmers received the video on their mobile phones through "Share It" (73.3%) and 13.3 per cent received via "Bluetooth", further 10 per cent reported through "WhatsApp" and while only 3.3% received it through the computer by USB Copy. After three months, 300 farmers from 40 villages received the GPV, while our 30 respondents shared the GPV with 150 farmers and screened the GPV to 200 farmers. The experiment shows that GPV can be an effective tool for spreading information about the groundnut hermetic storage technology and other agricultural innovations.

Keywords: Aflatoxin, Bruchids, GreenPHABLET™ video, Groundnut, PICS bags, ICT

Information and communications technology (ICT) has immense potential in empowering farming communities in many parts of the world. The major challenge is the widespread illiteracy in rural areas. One approach that shows potential is video based information dissemination through mobile phones. It was found to be effective and illiterate farmers in rural areas could easily understand the information conveyed. Digital Green in India produces videos and provides public screenings in villages to transfer information and enable dissemination of best agricultural practices that can boost farm productivity and improve nutrition (Gandhi *et al.,* 2009). However, this approach remains largely unused by the extension services. Hence farmers have little or no access to informative videos which can support agricultural operations. In India the number of mobile network subscribers had reached 969.89 million in March 2015. Of this around 43 per cent (414.18 million) were rural subscribers (TRAI, 2015). A rural population of 833 million (Census of India, 2011) implies that every second person in rural India owns a mobile phone. Hence mobile phones are fast becoming a tool of choice for disseminating need based and farmer centric information services at an affordable cost in a timely manner. Mobile phones have become an important tool for communication in rural India, with availability of cheaper and imported mobiles from developed and developing countries. Video access, Share it, WhatsApp and Bluetooth technology have become increasingly accessible to the rural population. An added advantage of mobile based video dissemination is that they are mainly viewed by individual farmers or by entire family members at their convenient time.

In India, smallholder farmers face numerous challenges in storing their produce after harvest. Damage during storage significantly reduces the quality and quantity of the produce resulting in loss of income. Many smallholder farmers lack access to effective and economic storage technologies, such as hermetic (airtight) storage bags. This technology has proved effective against groundnut storage pests and aflatoxin accumulation during storage. Groundnut (*Arachis hypogaea* L.) is an important food legume and oilseed crop with huge revenue potential. In India, the crop is grown on 5.25 million ha with a production of 9.47 mt and productivity of 1.80 tonnes/ha (FAOSTAT, 2013). All over the world, groundnut production is hampered by several biotic and abiotic stresses which results in severe yield losses. After harvest, insect pests (especially bruchids) and mold fungi are majorly responsible in reducing the quantity and quality of produce during storage. For this reason, farmers usually do

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not store groundnut and prefer to sell-off even the price is not remunerative immediately after harvest. Another important biotic stress in groundnut cultivation is aflatoxin contamination which occurs at both pre-and post-harvest stages of the crop (Waliyar *et al.*, 2008). It is a qualitative problem affecting grain quality and trade. The Purdue Improved Crop Storage (PICS) bags works on the principle of hermetic storage. Typically the bag consists of two inner liners each 80 microns in thickness made of high density polyethylene (HDPE) and an outer layer made up of polypropylene woven sack. All the three layers are disconnected. The efficacy of these bags for groundnut storage has been proved recently (Sudini *et al.,* 2015). However, the method for sealing the bags is tricky and difficult to describe accurately in words, but most farmers understand this if it is shown in video format.

Initially the project team depended on village-level demonstrations to train all farmers about sealing of PICS bags for storage of groundnuts. The demonstrations include various modules on how to distinguish an acceptable bag for storing groundnut and how to test these bags for air tightness, etc. However covering all farmers through live demonstrations is very time consuming. Organizing these demonstrations in every village is practically impossible and it is also not possible for everyone to attend these demonstrations due to lack of time as some of the activities such as sensitization and demonstration coincide with the period when farmers are busy harvesting and threshing their groundnut or engaged in other agricultural activities. To overcome these issues ICRISAT has developed a five minute GreenPHABLET* video (GPV) (https://www.youtube.com/watch?v=IeE3OySdSaI) to disseminate information on the effective use of PICS bags. However, effective implementation use of the PICS bag requires that farmers be able to access the video. Hence the objective of this study is to assess the dissemination potential of the GPV on PICS storage in groundnut.

MATERIALS AND METHODS

Description of the study area: The three month study was conducted in Anantapur district of Andhra Pradesh, India between October to December, 2016. The area was selected as groundnut is the principal rainy season crop grown over an area of about 800,000 ha and 90 per cent of the area is under rainfed conditions. The selected mandals in this survey area show a high incidence of insect induced storage losses, the damaged pods are also of lighter weight and poorer quality, and would therefore fetch lower price in the market. In addition, low quality groundnuts mainly due to aflatoxin contamination and bruchid damage are hampering the farmers from selling their produce in niche markets.

Methodology: The five minute GreenPHABLET^{TM} video (GPV) was developed in the local language (Telugu). The video showed viewers how to hermetically seal the PICS bags. The GPV was provided to two extension agents and two pilot farmers initially. ICRISAT staff followed up as to whom the video was shown and to whom and how it was transferred. A questionnaire was designed to capture socio-economic characteristics of the farmers, irrigation sources, land and livestock owned; ICT infrastructure and usage; mobile phone particulars and how the videos were received by the farmers. In this study, 30 farmers were interviewed using survey questionnaire. The participants were those who had received or seen the video and were engaged in groundnut production and storage activities. A field assistant was appointed for data collection and he was trained by the researcher. During the interview questions were asked in the local language using survey questionnaire and the responses recorded in English by the field assistant for ease of analysis.

Data analysis: Data collected from the survey questionnaire including socio-demographic characteristics of respondents, irrigation sources, land and livestock owned; ICT infrastructure and mobile phone particulars including their network providers, way of approach to receive the video were summarized and analyzed using Statistical Package for Social Sciences (SPSS). Descriptive statistics in the form of frequencies and means were used to analyze the data obtained.

RESULTS AND DISCUSSION

Socio-demographic background of respondents: The socio-demographic characteristics of the interviewed respondents in this study area are depicted in Table.1. Of the 30 respondents 86.6 per cent were males while 13.3 per cent were females. Majority (63.3%) of the respondents were below 39 years of age. Most of the interviewed respondents were married (80%). Half the respondents had studied up to graduate level and above, around 43 per cent had some level of education between primary level and below graduation while 6.6 per cent had no education. With regards to household income, the highest number of respondents (53.3%) earned between ₹ 50,000 to 100,000 per annum, while 40 per cent earned less than ₹ 50,000 per annum.

Table 2 gives the details of the land particulars, source of irrigation and livestock owned. Around 90 per cent of the respondents had unirrigated land and 73.3 per cent had irrigated land (since some of the respondents had both categories). Responses on size of land showed that 83.3 per cent were small farmers, 13.3 per cent were marginal farmers

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GreenPHABLETTM: An electronic device integrated with phone and tablet (Phablet) technology, coupled with other required components for use of agriculture data, information, knowledge, aggregation, dissemination, and various other activities. The device comes with unique features like water resistance, dustproof, shockproof, break proof, sunlight readability, etc.

and 3.3 per cent were large farmers. With regards to livestock details owned by the interviewed respondents, majority were having cows (56.6%) and buffaloes (26.6%). In addition, very few respondents had ox (10%) while 26.6% had no livestock. Responses regarding the using of these livestock in the survey area indicated that cows and buffaloes are used for milk and production of farmyard manure (63.3%) and 6.6% of the respondents reported that ox were used for ploughing, while 3.3% mentioned livestock were used for production of Gobar gas (3.3%) for cooking.

Table 3 gives the details of the ICT infrastructure possessed by respondents. Responses regarding ICT infrastructure owned showed that no more than 3.3% had radio to access information. All the respondents noted that they had TVs and the majority had a cable network connection (93.3%), while 3.3% did not have cable network connection. Very few respondents (6.6%) in the study had computer and laptop, and without internet connection. Almost, all the interviewed respondents had mobile phones. However, smart mobile phones penetration is very high in comparison with feature phones in the study area. In our study, all the respondents had smart mobile phones (100%) for personal use and about 26.6% had feature phones for family access.

Table 1 Socio-demographic characteristics of the interviewed respondents

Variables	Responses	Total	Percentage (%)
Gender	Male	26	86.6
	Female	4	13.3
Age	<39 Years and below	19	63.3
	>40 Years and above	11	36.6
Marital Status	Unmarried	6	20
	Married	24	80
Education Level	None of Education	2	6.6
	Primary Standard (1-7th Class)	2	6.6
	Upper Primary Standard (8-10th Class)	6	20
	Intermediate Education (>10th Class)	5	16.6
	Higher education (Graduation and above)	15	50
Household income per year	Up to ₹ 50,000 (Low income category)	12	40
	₹ 51,000 - < 1,00, 000 (Middle class)	16	53.3
	Above ₹ 1,00,000 (Upper middle class)	2	6.6

N=30; Values with the same subscript under the "Percentage" add up to 100; Indian National Rupee (INR)

Table 2 Irrigation sources, land and livestock owned by interviewed farmers

Variables	Response	Total	Percentage (%)
Land particulars owned	Rainfed	27	90
	Irrigated	22	73.3
Distribution of farmers	Small (1-5 Acres)	25	83.3
	Marginal (6-10 Acres)	4	13.3
	Large (Above 10 Acres)	1	3.3
Available Irrigation sources	Bore well	27	90
	Farm ponds	2	6.6
	Rivers	0	0
	Others	1	3.3
Livestock owned	None	8	26.6
	Cow	17	56.6
	Ox	3	10
	Buffaloes	8	26.6
Livestock usage	Milk and farmyard manure	19	63.3
	Agri. Ploughing activities	2	6.6
	Bio-gas production	1	3.3

*Some of the interviewed respondents have both irrigated and rain-fed lands

Table 3 Responses regarding ICT infrastructure owned by the interviewed respondents

Variable	Response	Total	Percentage (%)
Radio	FM	1	3.3
	AM	0	0
TV	With cable network	28	93.3
	Without cable network	1	3.3
Computer/Laptop/Tablet	With Internet	0	0
	Without internet	2	6.6
Mobile Phones	Feature Phone	8	26.6
	Smart Phone	30	100

*Some of the interviewed respondents having both normal phone and smart phone
*Very few interviewed respondents having computer and laptop without internet

In the study area, about 70 per cent of the respondents reported that they subscribed to Airtel while 13.3 per cent subscribed to Idea followed by Vodafone 10 per cent, and BSNL 6.6 per cent (Table 4.) The majority of the respondents reported that they had procured their mobile phones over two years (36.6%), 33.3 per cent had procured a year ago while 30 per cent had purchased more than 3 years ago. Further, 93.3 per cent of the respondents were not receiving agricultural information on their mobile phones while 6.6 per cent were received through iKisan & IKSL. All the respondents would like to receive the agricultural information on their mobile phones.

Figure 1 gives details of the source of the video received by the interviewed respondents. Most of the farmers reported that they come to know about the source of the video from the fellow farmer. Females share the GPV only to females and male share only with males. About 80 per cent of the respondents had indicated that they received the video from fellow farmers and only 20 per cent were received from ICRISAT representative. After three months, 300 farmers from 40 villages received the GPV, while our 30 respondents shared the GPV with 150 farmers and screened the GPV to 200 farmers.

Figure 2 details the channel through which GPV was received by the interviewed respondents. As per the survey conducted among 30 farmers these who have received the video, revealed that 73.3 per cent were received the video via Share It and 13.3 per cent indicated via Bluetooth, further 10 per cent reported WhatsApp while only 3.3 per cent received it through the computer.

GreenPHABLET™ Video is a new tool for visual and oral communication about PICS-based triple layer plastic bags technology for effective storage of groundnut produce at farmers' level. The videos are easy and inexpensive to produce and successful videos like GPV go viral with little or no effort. Once proved useful these videos are passed from farmer to farmer via different ICT tools. Previously farmers in rural communities had limited or no access to computers and the internet, but GPV could serve as communication intermediaries for disseminating skills that are difficult to describe in text/writings or by audio (on the radio) and print. The method for sealing the bags is tricky and difficult to describe accurately in words, but most farmers understand this if it is shown in video format. This on-farm experience shows how GPVs have potential for assisting agricultural producers with information and advice that could help them improve crop productivity, reduce losses and improve profitability. GPVs have the potential to help many development and government agencies interested in improving the lives of rural communities by disseminating skills that are difficult to describe in writing/print.

Table 4 Respondents using information on their mobile phone

Item	Total	Percentage (%)
Details of the interviewed respondents network provider		
Airtel	21	70
BSNL	2	6.6
Vodafone	3	10
Idea	4	13.3
No. of years using mobile phone		
One Year	10	33.3
Two Years	11	36.6
Three Years	9	30
Receiving any agricultural information on their mobile phones		
Yes	2	6.6
No	28	93.3
If no, would you like to receive agricultural information		
Yes	30	100
No	0	0

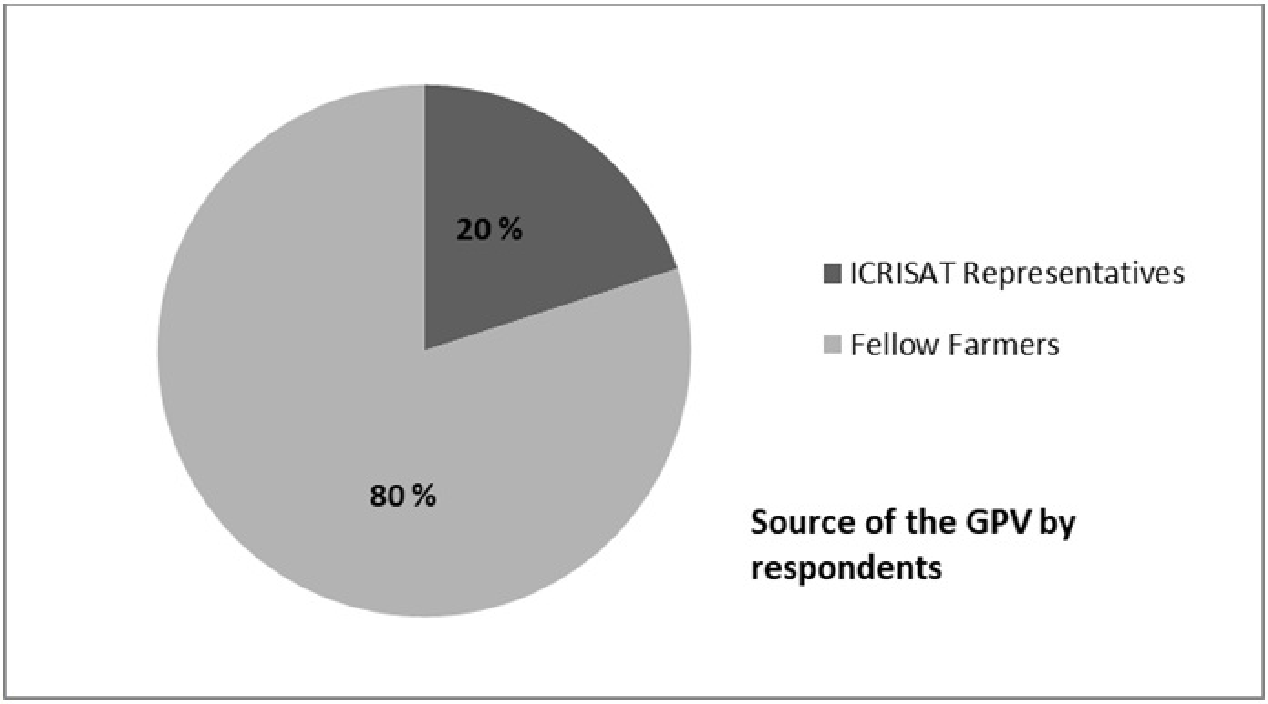

Fig. 1. Response regarding Source of GPV by Respondents

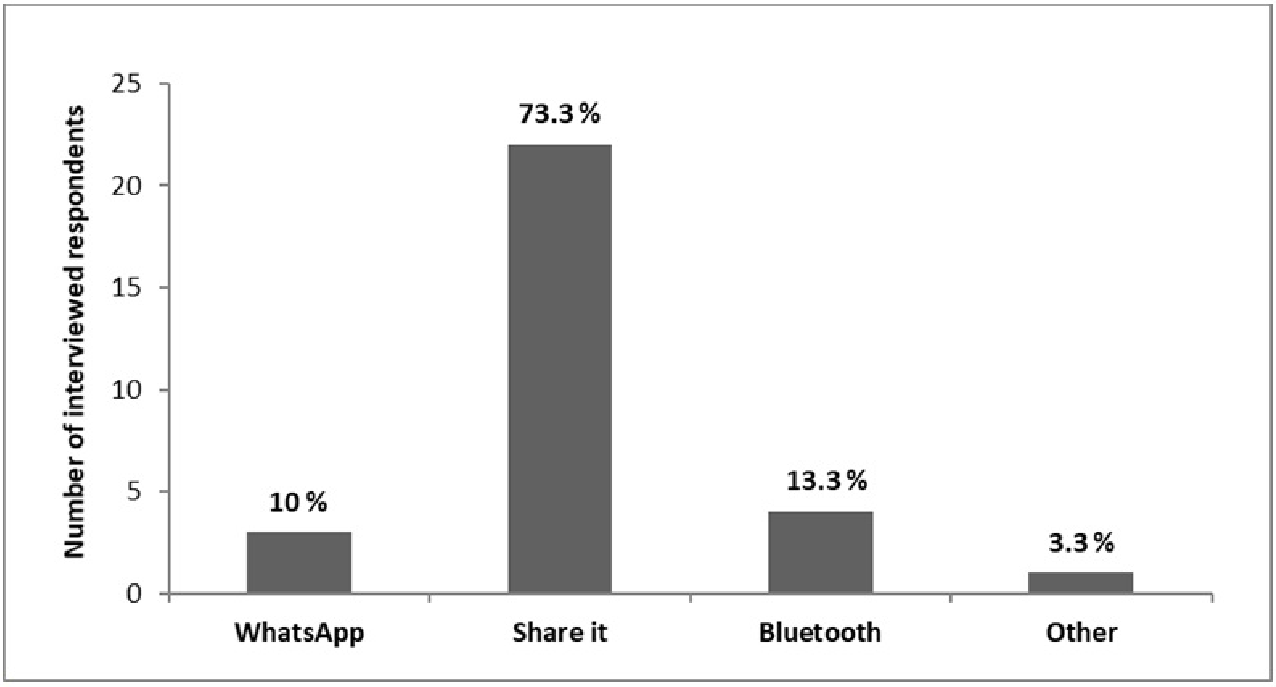

Fig. 2. Channel of GPV dissemination among interviewed farmers

The GPV can strengthen the public extension system to deliver up-to-date information on post-harvest management in groundnut in a more effective and timely manner. Such information can be disseminated by using the contemporary information and communication technologies (ICTs) like GreenPHABLET^{TM}, through the existing system of government extension workers and farmer's groups as the main channels in the study areas. However strong partnerships are required between research institutions, the state department of agriculture of various states, marketing agencies, NGOs, farmers and consumer groups and other stakeholders to make effective use of contemporary ICTs like GreenPHABLETTM Video.

ACKNOWLEDGEMENTS

The support provided to carry out this study, by the Research Program Director of Asia, ICRISAT is greatly acknowledged. We are thankful to the support received from the partner organizations and farmers engaged in this study.

REFERENCES

Balaji V, Meera S N and Dixit S 2007. ICT-enabled knowledge sharing in support of extension: Addressing the agrarian challenges of the developing world threatened by climate change, with a case study from India. *SAT eJournal*, **4**(1): 1-18.

Banerjee S 2013. Mobile Telephony in Agriculture: Unlocking Knowledge Capital of the Farmers. In: *Information and Communication Technologies for Sustainable Agriculture. Indicators from the Asia and the Pacific, Part II - Technologies for Agricultural Information Sharing*, G Sylvester (ed.), Bangkok: FAO Regional Office for the Asia and the Pacific.

Cole S and Fernando A 2012. *The Value of Advice: Evidence from Mobile Phone-Based Agricultural Extension.* Working Paper 13-047, Harvard Business School, Harvard University.

Dhaka B L and Chayal K 2010. Farmers' experience with ICTs on transfer of technology in changing agri-rural environment. *Indian Research Journal of Extension Education*, **10**(3): 114-118.

FAOSTAT 2013. *Food and agricultural organization statistics database* (FAOSTAT). http://faostat3.fao.org/home/E.

Gandhi R, Veeraraghavan R, Toyama K and Ramprasad V 2009. Digital green: Participatory video for agricultural extension. In: *Proceedings of International Conference on Information and Communication Technologies and Development,* 17-19 April, 2009, Doha, Qatar.

https://www.microsoft.com/en-us/research/wp-content/uploads/2009/03/322-797-2-PB.pdf.

Kameswari V L V, Kishore D and Gupta V 2011. ICTs for agricultural extension: A study in the Indian Himalayan region. Electronic *Journal of Information Systems in Developing Countries*, **48**(3): 1-12.

Mittal S 2016. Role of mobile phone-enabled climate information services in gender-inclusive agriculture. *Gender, Technology and Development*, **20**(2): 1-18.

Mukherjee A and Maity A 2015. Public-private partnership for convergence of extension services in Indian agriculture. *Current Science*, **109**(9): 1557-1563.

Saravanan R and Bhattacharjee S 2015. Mobile Phone Applications for Agricultural Extension in India. http://www.e-agriculture.org/content/mobile-phone-applications-agricultural-extension-india accessed 21 Sept 2016.

Sudini H, Ranga Rao G V, Gowda C L L, Chandrika R, Margam V, Rathore A and Murdock L L 2015. Purdue Improved Crop Storage (PICS) bags for safe storage of groundnuts. *Journal of Stored Products Research*, **64**: 133-138.

Vodafone. Towards a more equal world: the mobile internet revolution, Policy Paper Series Number 16. http://www.vodafone.com/content/dam/vodafone-images/public-policy/inequality/Vodafone -equal-world-small%20farmers.pdf accessed 10 August 2016.

Waliyar F, Kumar P L, Traore A, Ntare B R, Diarra B and Kodio O 2008. Pre and post-harvest management of aflatoxin contamination in peanuts, In: *Mycotoxins Detection Methods, Management, Public Health and Agricultural Trade*, J Leslie, R Bandyopadhyay and A Visconti (Eds), CABI, pp. 209-218.

Inheritance of morphological characters and sex expression in castor (*Ricinus communis* L.)

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(Received: June 29, 2017; Revised: September 14, 2017; Accepted: November 3, 2017)

ABSTRACT

The segregation of morphological characters and sex expression of the traits was studied to understand the pattern of inheritance involving pistillate lines from different backgrounds like S type, NES and new sources like using F_1 and F_2 populations. Inheritance of stem colour in four crosses of pistillate x monoecious lines indicated that stem colour was controlled by single gene while red stem colour was dominant over green stem colour in F_1. However, in other cross it showed digenic epistatic ratio. Study on bloom colour indicates that it is controlled by monogene and presence of bloom was dominant over absence of bloom respectively. While the present study indicated that two genes control the leaf shape in three crosses where as in presence of either of a dominant gene masks the phenotype as flat or semi-cup while both recessive genes result in cup shaped leaf. Sex expression character indicating the dominance of monoecious over pistillate character in some crosses while in other crosses the dominance of pistillate character over the monoecious character. Based on sex expression study it concluded that the proportion of monoecious and pistillate flowers is greatly influenced by both genetic and non-genetic factors.

Keywords: Castor, Inheritance, Morphological characters, Sex expression

Castor is a highly cross pollinated crop and has highly polymorphic sex expression. Natural out crossing as estimated in a dwarf-internode genotype ranged between 70 and 90 per cent for Texas high plains (Bringham, 1967). Morphological characters like colour of stem, bloom, plant type, leaf shape and capsule nature are important markers used for distinctness, uniformity and stability (DUS) tests in castor under different environments. Stem colour in castor is classified as red, green and mahogany based on the pigmentation of sap colour in epidermal palisade cells and parenchymatous areas of the stem. However, information on inheritance of morphological markers *viz.,* stem colour, plant type, leaf shape etc., has not been worked out and the available information is either scanty or very old. The first inheritance studies by Peat (1928) and Harland (1922) were on leaf and stem colour, bloom and its distribution, spines on the capsules, colour and pattern of the seed coat, leaf shape and albinism. Information on morphological characters in pistillate lines is less worked out.

Castor is a sexually polymorphic species with different sex forms *viz.,* monoecious, having pistillate or female flowers at the top and staminate or male flowers at the bottom of the inflorescence. Pistillate spike with all female flowers without any males and interspersed staminate flowers (ISF) with intermittent male flowers and revertants. There are three types of pistillate lines that could be used for hybrid production: N, S, and NES. In the N type, the occurrence of only female flowers is controlled by a monogenic recessive gene (George, 1966). In the S type the production of only female flowers is controlled by a polygenic complex with dominant and epistatic effects. In the S type the plant starts as female, but a reversion to the production of dioecious flowers can occur at any time. In the NES type, the plant has the recessive gene (ff) that allows it to start as female, but when air temperatures exceed 31°C there is a sexual reversion (Zhang and Liang, 1993). Sex expression in castor is highly influenced by genotypes and environmental factors *viz.*, temperature, photoperiod, soil fertility, age of the plant and nutrition, etc. (Seshadri and Muhammd, 1951). For seed production of hybrids in commercial scale, a stable pistillate line is a prerequisite. The new sources like Geeta and DPC-17 with a different inheritance pattern in contrast to S type (VP-1 and M-568) pistillate sources need to be further explored and utilized in breeding programmes. In the absence of a cytoplasmic male sterility-fertility restoration system in castor, understanding the mechanism of sex expression is a paramount importance as the hybrid seed production is solely depends on the pistillate system. In the present study an attempt made to study the inheritance of morphological characters and sex expression in castor.

The experimental material for the study on inheritance of morphological characters and sex expression involved 5 pistillate lines *viz.,* M-568, VP-1, Geeta, DPC-16 and DPC-17 and six male lines *viz.,* DCS-28, RG-297, DCS-9, 48-1, DCS-97 and DCS-64 obtained from Directorate of Oilseeds Research, Rajendranagar, Hyderabad differing in morphological characters is presented in Table 1. Seven crosses *viz.,* M-568 × DCS-28, VP-1 × RG-297, VP-1 × DCS-9, VP-1 × 48-1, Geeta × DCS-97, DPC-16 × DCS-97,

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DPC-17 × DCS-64 were made in *rabi* 2009-10. Each of the seven F_1s was raised in *kharif* 2010 and selfed to generate F_2 material. All the three generations *viz.,* P_1, P_2, F_1, F_2 were planted in *rabi* 2010-11 and observations on both morphological characters and sex expression were recorded on individual plants in each generation. The inheritance of stem colour, plant type and leaf shape was studied in populations of four crosses *viz.,* M-568 × DCS-28, VP-1 × RG-297, VP-1 × DCS-9 and VP-1 × 48-1 with contrasting stem colour, plant type, leaf shape and capsule nature. While the inheritance of bloom was studied in populations of four crosses *viz.,* M-568 x DCS-28, VP-1 x 48-1, DPC-17 x DCS-64 and DPC-16 x DCS-97 with contrasting bloom (zero, single, double and triple). The inheritance of sex expression was studied in five crosses *viz.,* VP-1 × RG-297, M-568 × DCS-28, Geeta × DCS-97, DPC-16 × DCS-97 and DPC-17 × DCS-64. Observation on sex expression in castor is recorded at the time of primary spike flowering based on the presence and absence of male flowers as monoecious and pistillate. The present study is restricted to only primary spike and thus observations on sex reversion to monoecious (sex revertants) or interspersed staminate flowers (ISF) were not taken. The number of plants bearing monoecious or pistillate spikes was counted in all the populations. Observations on >20 plants were recorded on parents, F_1s, while sample size in F_2 varied in different crosses. The data from F_2 generation for different characters for different expected genetic ratios were subjected to Chi-square test for goodness of fit.

The present study conducted on segregation of morphological characters and sex expression of the traits to understand the pattern of inheritance involving pistillate lines from different backgrounds like S type (VP-1, M-568), NES (DPC-16) and new sources like Geeta and DPC-17. Seven crosses were made using 5 pistillate lines. The F_1's of the seven crosses were raised to self and generate F_2. The F_2s along with F_1's, parents were studied for traits related to morphological characters and sex expression.

Stem colour is classified as red, green and mahogany based on pigmentation of sap colour in epidermal cells and parenchymatous areas of stem. The inheritance of stem colour was studied in all four crosses (Table 2) involving either green x red (M-568 x DCS-28; VP-1 x 48-1) or red x green (DPC-17 x DCS-64) or green x green (VP-1 x RG-297), red stem colour was dominant over green in F_1. The F_2 segregation ratios in three crosses (VP-1 x RG-297, VP-1 x DCS-9 and VP-1 x 48-1) indicated that stem colour is monogenic and segregated in 3:1. A single gene Rst/rst is responsible for stem colour in three crosses of castor. It was in conformity with the results reported by Chandra Mohan (2002), Lavanya and Gopinath (2008) and Solanki and Joshi (2000). However, in the cross, M-568 x DCS-28, red stem colour is dominant over green stem colour in F_1 and F_2 population indicated a good fit to the digenic epistatic ratio of 12 red: 3 green: 1 mahogany where red stem colour is epistatic green stem colour. Similar report on digenic epistatic was also reported by Kulkarni and Ramanamurthy (1977). Mahogany colour has both green and red colours with overlapping of red colour over green colour. The presence of two recessive genes rst gst produces mahogany stem colour in cross M-568 x DCS-28.

In the present study, the four crosses involving (M-568 x DCS-28; VP-1 x RG-297; VP-1 x DCS-9 and VP-1 x 48-1) dwarf (Dw) and normal (N) plant types, normal plant type is dominant over dwarf in F_1 and F_2 segregated in to 3 normal: 1 dwarf (Table 2) indicating the role of single gene PtN as reported earlier by Moshkin (1986) and Peat (1928).

There are very few reports on the inheritance pattern of leaf shape in castor. The present study indicated the dominance of flat leaf over cup shaped leaf in all the F_1's four crosses (Table 2). The segregating ratios in the cross M-568 x DCS-28 indicated the role of monogenic, dominant genes for flat leaf. However, in the other three crosses, another distinct morphological between flat and cup leaf a "semi cup" leaf with partial folding of leaf lobes was observed. The segregation in the other three crosses VP-1 x RG-297; VP-1 x DCS-9 and VP-1 x 48-1 fit well into 12:3:1 for flat: semi cup: cup phenotypes. It indicated that two genes control the leaf shape in these three crosses wherein presence of either of dominant genes masks the phenotype as flat or semi-cup while both recessive genes result in cup shaped leaf. The role of the cup shaped leaf as a distinct morphological character for female lines in generation of hybrids and hybrid seed production plots is well documented (Solanki and Joshi, 2001).

Castor plants are mainly classified based on the presence of bloom on combination of plant parts, genotypes in castor were usually classified as single bloom (stem + petiole + capsule stalks), double bloom (stem + petiole + capsule stalks + lower side of the leaf) and triple bloom (stem + petiole + capsule stalks + lower side of the leaf + upper side of the leaf) (Kulkarni and Ramanamurthy, 1977). Bloom is an important morphological marker and serves as a natural protection against drought, cold, jassids etc. In the present study, inheritance of bloom character indicated that presence of bloom is dominant over no bloom in F_1. In cross, VP-1 x DCS-9 and VP-1 x 48-1, as both the parents VP-1 (triple bloom) and DCS-9 and 48-1 (double bloom) are bloom types, F_2 population is classified as triple vs either single or double and fit to the 3 : 1 ratio indicating the role of single gene (PtBl) for bloom character. Monogenic inheritance for bloom character was reported by Harland (1922). While, Zimmerman (1957) later established that expression of bloom is due to two complementary genes.

The inheritance of sex expression is particularly important in the development of hybrids. There are three types of pistillate lines that could be used for hybrid production: N, S, and NES. Sex expression in castor is polymorphic in nature and varies as monoecious, pistillate, interspersed staminate flowers (ISF). Monoecious (M) is the most natural occurrence of annual and perennial castor. The sex variants based classified on the proportion of female and male flowers on the spike by Podukuichenko (1987).

In the present study, five crosses involving two S type pistillate lines, VP-1 and M-568; one NES type pistillate line (DPC-16) and diverse sources like Geeta (from 48-1) and DPC-17 were crossed with male/monoecious lines RG-297, DCS-28, DCS-97 and DCS-64. The F_1s in two crosses *viz.,* M-568 x DCS-28; DPC-16 x DCS-97 were monoecious indicating the dominance of monoecious over pistillate character. However, in the cross VP-1 x RG-297, the F_1 population expressed high tendency towards female character in the primary spike and segregation was 13 female: 3 monoecious in F_2 (Table 2). The two crosses Geeta x DCS-97 and DPC-17 x DCS-64 involving diverse pistillate sources segregated for 3 female: 1 monoecious ratio indicating the role of monogenic, dominant genes for pistillate character in F_2. As per Lavanya and Gopinath (2008), one to four genes controlled pistillate expression in four different crosses. In contrast, additive and epistatic gene effects were also reported in 8 x 8 diallel crosses (Solanki and Joshi, 2001). Pistillate behavior of castor is controlled by a combination of a large number of different genes. The inheritance of sex in gynodioecious strains suggested that gene (a) determines the female condition and gene (A) the normal monoecious reported by Katayama (1957). Environment has a strong influence on sex expression. Female expression is enhanced by moderate temperature and optimum soil fertility and moisture; male expression is enhanced by high temperature and low soil fertility and moisture. Under perennial culture, male tendency may also be increased by fairly low temperatures (Shiffriss, 1956). Expression of sex is influenced by the seasons. Female expression is greatest in spring and early summer, male expression in late summer and early fall.

The success of castor hybrids relied on the development of VP-1 from TSP 10-R, an exotic source of pistillate line from USA. Limited studies on mechanism of pistillate lines indicated the role of recessive genes in 'N' type, dominant and epistatic genes in 'S' type and a combination of recessive genes and environmentally sensitive genes for ISF in NES type (Zimmerman and Smith, 1966). Diversification of pistillate sources resulted in several new sources of pistillate character like Geeta, DPC-17, DPC-18 (Lavanya and Solanki, 2010) either by mutation, selection from germplasm accessions or hybridization between diverse sources. The new sources like Geeta and DPC-17 with a different inheritance pattern in contrast to S type (VP-1 and M-568) pistillate sources need to be further explored and utilized in breeding programmes. The present study indicated the diverse nature of pistillate lines and need to be further confirmed in multilocations or seasons.

Table 1 Morphological characters and sex expression in parents and F_1s

Parents/Crosses	Stem colour	Bloom	Plant type	Leaf shape	Spines	Sex
Cross-I						
M-568	Green	Double	Dwarf	Cup	Spiny	Pistillate
DCS-28	Red	Double	Normal	Flat	Spiny	Male
M-568 × DCS-28(F_1)	Red	Triple	Normal	Flat	Spiny	Male
Cross-II						
VP-1	Green	Triple	Dwarf	Cup	Spiny	Pistillate
RG-297	Green	Triple	Normal	Flat	Spiny	Male
VP-1 × RG-297 (F_1)	Green	Triple	Normal	Flat	Spiny	Mostly female
Cross-III						
VP-1	Green	Triple	Dwarf	Cup	Spiny	Pistillate
DCS-9	Red	Double	Normal	Flat	Spiny	Male
VP-1 × DCS-9 (F_1)	Red	Triple	Normal	Flat	Spiny	Male
Cross-IV						
VP-1	Green	Triple	Dwarf	Cup	Spiny	Pistillate
48-1	Red	Double	Normal	Flat	Non-spiny	Male
VP-1 × 48-1 (F_1)	Red	Triple	Normal	Flat	Semi-spiny	Male
Cross-V						
Geeta	Red	Double	Normal	Flat	Non-spiny	Female
DCS-97	Red	Double	Normal	Flat	Spiny	Monoecious
Geeta × DCS-97 (F_1)	Red	Triple	Normal	Flat	Spiny	Female
Cross-VI						
DPC-16	Red	Zero	Normal	Flat	Spiny	Female
DCS-97	Red	Double	Normal	Flat	Spiny	Male
DPC-16 × DCS-97 (F_1)	Red	Single	Normal	Flat	Spiny	Male
Cross-VII						
DPC-17	Red	Single	Normal	Flat	Spiny	Female
DCS-64	Green	Single	Normal	Flat	Spiny	Male
DPC-17 × DCS-64(F_1)	Red	Double	Normal	Flat	Spiny	Female

Table 2 Inheritance of morphological characters and sex expression in F_1 and F_2 of different crosses of castor

Cross	F_1 phenotype	Generation	No. of plants observed (Segregation)				Expected ratio	χ^2 value
			Total	Red	Green	Mahogany		
Crosses for stem colour								
M-568 × DCS-28	Red	F_2	137	110	20	7	12:3:1	0.087301
VP-1 × RG-297	Red	F_2	241	170	71	0	3:1	0.035372
VP-1 × DCS-9	Red	F_2	162	131	31	0	3:1	0.061136
VP-1 × 48-1	Red	F_2	147	121	26	0	3:1	0.095074
Crosses for plant type	F_1 phenotype	Generation	Total	Normal	Dwarf	-	-	-
M-568 × DCS-28	Normal	F_2	137	122	15	-	3:1	0.350992
VP-1 × RG-297	Normal	F_2	241	210	31	-	3:1	0.261876
VP-1 × DCS-9	Normal	F_2	162	141	21	-	3:1	0.257583
VP-1 × 48-1	Normal	F_2	147	121	26	-	3:1	0.095074
Crosses for leaf shape	F_1 phenotype	Generation	Total	Flat	Semi-cup	Cup		
M-568 × DCS-28	Flat	F_2	137	126	0	11	3:1	0.512014
VP-1 × RG-297	Flat	F_2	241	200	25	16	12:3:1	0.214802
VP-1 × DCS-9	Flat	F_2	162	125	31	6	12:3:1	0.167234
VP-1 × 48-1	Flat	F_2	147	118	17	11	12:3:1	0.190718
Crosses for bloom	F_1 phenotype	Generation	Total	With bloom	No bloom	-	-	-
M-568 X DCS-28	Triple	F_2	194	145	52	-	3:1	0.2416
VP-1 X 48-1	Triple	F_2	190	142	48	-	3:1	0.0712
DPC-16 X DCS-97	Single	F_2	162	131	31	-	3:1	0.0611
DPC-17 X DCS-64	Double	F_2	137	126	11	-	3:1	0.5120
Crosses for sex expression	F_1 phenotype	Generation	Total	Pistillate	Monoecious	-	-	-
VP-1 × RG-297	Female	F_2	241	211	30	-	13:3	0.280088
M-568 × DCS-28	Male	F_2	137	14	123	-	1:3	0.388406
Geeta × DCS-97	Female	F_2	114	92	22	-	3:1	0.057796
DPC-16 × DCS-97	Male	F_2	128	23	105	-	1:3	0.087891
DPC-17 × DCS-64	Female	F_2	133	106	27	-	3:1	0.039259

5 pistillate lines *viz.,* M-568, VP-1, Geeta, DPC-16 and DPC-17 and six male lines viz., DCS-28, RG-297, DCS-9, 48-1, DCS-97 and DCS-64

F_1s: M-568 × DCS-28, VP-1 × RG-297, VP-1 × DCS-9, VP-1 × 48-1, Geeta × DCS-97, DPC-16 × DCS-97, DPC-17 × DCS-64;

The inheritance of stem colou, plant type and leaf shape was studied in populations of four crosses *viz.,* M-568 × DCS-28, VP-1 × RG-297, VP-1 × DCS-9 and VP-1 × 48-1;

While the inheritance of bloom was studied in populations of four crosses *viz.,* M-568 x DCS-28, VP-1 x 48-1, DPC-17 x DCS-64 and DPC-16 x DCS-97;

The inheritance of sex expression was studied in five crosses *viz.,* VP-1 × RG-297, M-568 × DCS-28, Geeta × DCS-97, DPC-16 × DCS-97 and DPC-17 × DCS-64.

REFERENCES

Bringham R D 1967. Natural out crossing in dwarf-internode castor, *Ricinus communis* L. *Crop Science*, **7**: 353-355.

Chandra Mohan Y 2002. Genetic analysis of some qualitative and quantitative traits in castor (*Ricinus communis* L.). Ph.D. Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad, India.

George W L 1966. Genetics of interspersed staminate flowers in *Ricinus communis* L. *Dissertation Abstracts*, **38**: 66.

Harland S C 1922. Inheritance of *Ricinus communis* L. Part II. *Journal of Genetics*, **10**: 207-218.

Kulkarni L G and Ramanamurthy G V 1977. *Castor*. Indian Council of Agricultural Research, New Delhi, p.105.

Lavanya C and Gopinath V 2008. Inheritance studies for morphological characters and sex expression in pistillate lines of castor (*Ricinus communis* L.). *Indian Journal of Genetics and Plant Breeding*, **68**(3): 275-282.

Lavanya C and Solanki S S 2010. Crop improvement of castor: The challenges ahead. In: Hegde, D.M. (Ed.). *Research and Development in Castor: Present Status and Future Strategies*. Indian Society of Oilseeds Research, Hyderabad, pp.36-55.

Moshkin V A 1986. *Castor*. Amerind Publ. Co. Pvt. Ltd. New Delhi, India.

Peat J E 1928. Genetic studies in *Ricinus communis* L. *Journal of Genetics*, **19**:373-389.

Shiffriss O 1956. Sex instability in *Ricinus*. *Genetics*, **41**: 265-280.

Solanki S S and Joshi P 2001. Inheritance study of some morphological traits in castor (*Ricinus communis* L.). *Indian Journal of Genetics and Plant Breeding*, **61**(2): 136-139.

Solanki S S and Joshi P 2000. Inheritance of sex expression in castor (*Ricinus communis* L.). *Indian Journal of Genetics and Plant Breeding*, **60**(1): 97-104.

Zhang W and Liang Y 1993. *The Genetic Study on the Pistillate Characters in Castor.* Hereditas (Beijing).

Zimmerman L H 1957. *Complementary genes for bloom in Ricinus communis* L. *Journal of Heredity*, **48**(5) : 242-243.

Zimmerman L M and Smith J D 1966. Production of F_1 seed in castor beans by use of sex genes sensitive to environment. *Crop Science*, **6**: 406-409.

Effect of boron and potassium levels on seed yield and oil quality of sunflower (*Helianthus annuus* L.)

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(Received: November 7, 2017; Revised: December 8, 2017; Accepted: December 22, 2017)

ABSTRACT

A field experiment was conducted at College farm, College of Agriculture, Rajendranagar during *rabi* 2016-17 with sunflower hybrid GK 2002 in a factorial randomized block design with 16 treatment combinations comprising of four levels of boron and four levels of potassium *viz*., B_0K_0, B_0K_{15}, B_0K_{30}, B_0K_{60}, $B_{0.5}K_0$, $B_{0.5}K_{15}$, $B_{0.5}K_{30}$, $B_{0.5}K_{60}$, B_1K_0, B_1K_{15}, B_1K_{30}, B_1K_{60}, $B_{1.5}K_0$, $B_{1.5}K_{15}$, $B_{1.5}K_{30}$, $B_{1.5}K_{60}$ to investigate and find out the optimum dosage of boron and potassium to increase the sunflower seed yield and oil quality. Significantly higher seed yield was obtained with $B_{1.5}K_{60}$ treatment (1430 kg/ha) followed by $B_{1.5}K_{30}$ (1419 kg/ha), B_1K_{30} (1410 kg/ha) and B_1K_{60} (1416 kg/ha). However, B_1K_{30} treatment showed economically beneficial. Significantly higher oil and protein yields were recorded with B_1K_{30}, B_1K_{60}, $B_{1.5}K_{30}$ and $B_{1.5}K_{60}$. The highest linoleic acid content (75.3 %) was recorded with B_1K_{30} and lowest (71.29 %) with control.

Keywords: Boron, Oil quality, Potassium, Seed yield, Sunflower

Sunflower (*Helianthus annuus* L.) is one of the important edible oilseed crops cultivated in India on various soil types. Soil fertility in terms of nutrient sufficiency and deficiency for all types of Indian soils is well documented (Sahrawat *et al*., 2007; Pathak 2010; Shukla *et al.,* 2014). Sunflower growing soils of Telangana state are found to be deficient in important nutrients *viz.,* nitrogen, potassium, sulphur, zinc and boron (Rego *et al.,* 2007; Murthy *et al.,* 2009; Bhupal Raj *et al.,* 2009) which are highly essential to attain higher seed yield and oil quality. Sunflower is one of the most sensitive crops to B deficiency and symptoms are generally observed on leaves, stems, reproductive parts which finally affects dry matter, yield components and seed yield. Asad *et al.* (2002 and 2003) reported that B requirement of sunflower during reproductive growth is higher than during vegetative growth. At flowering, B deficiency can affect pollen viability and abortion of stamens and pistils which contribute to poor seed set due to malformed capitulums and consequently low seed yield (Chatterjee and Nautiyal, 2000). Potassium plays a key role in increasing crop yield and improving the quality of product (Soleimanzadeh *et al.,* 2010). The effect of potassium application on sunflower plant growth, yield and quality was reported by some investigators, who found that increasing potassium level led to a significant increase in plant height (Sirbu and Ailincai, 1992), number of leaves, leaf area and head diameter (Lewis *et al.,* 1991).

Boron and potassium have overlapping roles to play in plant physiology and hence, are synergistic. Like potassium, boron is also involved in some aspects of flowering and fruiting processes, pollen germination, cell division, nitrogen metabolism, carbohydrate metabolism, active salt absorption, hormone movement and action, water metabolism and the water relations in plants. They both serve in acting as a buffer and are necessary in the maintenance of conducting tissues and to exert a regulatory effect on other elements. It has been shown that an optimal level of boron increases potassium permeability in the cell membrane (Ujwala, 2011). Considering the importance and role of these two nutrients, a field experiment was conducted to study and find out optimum dosage of boron and potassium to increase the sunflower seed yield and oil quality.

A field experiment was conducted on sandy loam soil at Agricultural College farm, Rajendranagar, Hyderabad during *rabi*, 2016-17. The experimental field was moderately alkaline in soil reaction (pH 8.24), non-saline (EC 0.35 d/Sm) and low in organic carbon (0.42%) content. The chemical properties of soil showed that it was medium in available nitrogen (294 kg/ha), available phosphorus (30 kg/ha) and available potassium (204.2 kg/ha) and deficit in available soil boron i.e. 0.4 mg/kg.

The experiment was laid out in factorial randomized block design with 16 treatment combinations comprising of four levels of boron and four levels of potassium *viz*., T_1(B_0 K_0), T_2 (B_0 K_{15}), T_3 (B_0 K_{30}), T_4 (B_0 K_{60}), T_5 ($B_{0.5}$ K_0), T_6 ($B_{0.5}K_{15}$), T_7 ($B_{0.5}$ K_{30}), T_8 ($B_{0.5}K_{60}$), T_9 (B_1 K_0), T_{10} (B_1 K_{15}), T_{11} (B_1K_{30}), T_{12} (B_1K_{60}), T_{13} ($B_{1.5}K_0$), T_{14} ($B_{1.5}$ K_{15}), T_{15} ($B_{1.5}$ K_{30}), T_{16} ($B_{1.5}$ K_{60}) with recommended dose of N and P fertilizers on sunflower. GK-2002 was used as a test hybrid in the experiment. Nitrogen was applied in the form of urea in two splits while phosphorus was applied in the form of DAP as basal dose. All the need based crop management practices as recommended by PJTSAU were followed. At

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harvest, sunflower seed yield and test weight (1000-seed weight) were recorded. By following the standard procedures, oil (Tiwari *et al*., 1974) and protein content (Walinga *et al*., 1989) as well as fatty acid composition (Ghadge and Raheman, 2005) were determined.

Protein content (%) = N Content (%) x 6.25

$$\text{Protein yield (kg/ha)} = \frac{\text{Seed yield x protein content (\%)}}{100}$$

Oil yield (kg/ha) = Seed yield x oil content (%)

Seed yield of sunflower was significantly influenced by soil application of boron and potassium. Maximum seed yield (1430 kg/ha) of sunflower was recorded with the application of 1.5 kg B/ha as compared to control. However, it was statistically at par with that of 1 kg B/ha (Table 1). Potassium application also had significant effect on yield and there was progressive increase in mean seed yield with increasing levels of potassium reaching highest value at K_{60} (1285 kg/ha). Seed yield was also significantly influenced by B x K interaction. The highest and significantly higher seed yield (1430 kg/ha) was recorded with treatment $B_{1.5}K_{60}$, however, it was statistically on par with B_1K_{30} (1410.7 kg/ha), B_1K_{60} (1416 kg/ha) and $B_{1.5}$ K_{30} (1419.3 kg/ha) treatments (Table 1). Based on B:C ratio, it was found that B_1K_{30} treatment was economically beneficial (Table 2).

Adequate supply of recommended dose of fertilizers along with boron and potassium application could help in achieving higher seed yield. Boron known to play major role in improving the head diameter and viability, germination and growth of pollen tubes which in turn might have resulted in more filled seeds. Seed yield increased through potassium application may be due to its key role in transport of nutrients essential for metabolism in active areas. Similar results were obtained by Ahmed *et al.* (2001) who found that head diameter, weight of thousand seed and seed yield increased with increasing potassium application rates from 0 to 150 kg/ha. Renukadevi *et al.* (2002) studied the effect of different levels of boron (0.5, 1.0, 1.5 and 2.0 kg/ha) as soil application and two levels of foliar spray (0.2 % and 0.3 %). The highest seed yield was recorded for the soil application of B @2.0 kg/ha. The yield increase in sunflower was 3.6 to 15.8 per cent and 7.2 to 18.9 per cent over the control for both seed and stalk, respectively.

The highest 1000-seed weight was recorded in treatment $B_{1.5}$ K_{60} (51.04 g). On an average, the percentage increase in test weight was 38 per cent in the treatment $B_{1.5}$ K_{60} over the control. B x K interaction effect was found non-significant. The increase in 1000-seed weight due to application of B and K might be due to better translocation of photosynthates from vegetative sources towards the reproductive organs (Reddy *et al*., 2002).

The oil content of sunflower seeds was not significantly influenced by application of boron and potassium levels (Table 1). These results corroborate the observations of Rao and Sagar (1981). Ahmed Khan *et al.* (1990) reported that boron had no influence on increasing oil content of sunflower. On the contrary, Zahoor *et al.* (2011) reported that maximum sunflower seed oil (43.5%) due to application of boron @ 8 kg/ha. Malihe *et al.* (2013) reported highest oil content (43.08%) due to application of 150 kg/ha potassium. Soleimanzadeh *et al.* (2010) have reported increase in oil content of sunflower seed due to application of potassium fertilizer.

Sunflower oil yield among the various B and K treatments ranged from 368.3 to 561.2 kg/ha (Table 1). Soil application of boron had significant effect on oil yield and maximum oil yield was recorded with 1.5 kg B/ha as compared to control. However, it was statistically at par with 1 kg B/ha (Table 1). Potassium application also had significant effect on oil yield and there was a gradual increase in oil yield with increasing levels of potassium. The highest oil yield was recorded in treatment $B_{1.5}K_{60}$ however; it is statistically on par with B_1K_{30}, B_1K_{60} and $B_{1.5}K_{30}$ treatments (Table 1). The per cent increase in oil yield was 52.3 per cent in the treatment $B_{1.5}K_{60}$ over the control. Oil yield was also significantly influenced by B x K interaction.

From the results of this study, it is observed that oil yield significantly increased with application of boron and potassium levels may be due to increase in seed yield and oil content, which resulted in higher oil yield. Boron and potassium have overlapping roles to play in plant physiology. Potassium, boron is also involved in some aspects of flowering and fruiting processes, pollen germination and cell division. Balanced application of boron with potassium increased the seed yield and increased the oil content *vis-a-vis* oil yield. Similar results were reported by Tiwari *et al*. (2012). Oil content in mustard seed increased significantly with the application of K up to 60 kg K_2O/ha. The highest oil content (40.98 per cent) was obtained at 60 kg K_2O/ha which was about 16 per cent higher than the control, i.e. without any K application.

Application of different levels of boron and potassium and their interaction effects to sunflower (cv GK-2002) had not shown any significant effect on protein content (Table 1). Sunflower protein yield among the various B and K treatments varied from 180.0 kg/ha to 274.0 kg/ha (Table 1). Soil application of boron had significant effect on protein yield (kg/ha) and maximum protein yield was recorded with 1.5 kg B/ha as compared to 0 kg B/ha (Table 1). However, it was statistically at par with 1 kg B/ha. Potassium application also had significant effect on protein yield and there was progressive increase in mean protein yield from 183.2 to 255.7 kg/ha with increasing levels of potassium.

The highest protein yield was recorded in treatment $B_{1.5}K_{60}$ however it is statistically on par with B_1K_{30}, B_1K_{60} and $B_{1.5}K_{30}$ treatments. Protein yield was also significantly influenced by B x K interaction (Table 1).

Table 1 Effect of boron and potassium levels on seed yield, test weight, oil content, oil yield, protein content and protein yield of sunflower

Potassium (kg/ha)	Boron (kg/ha)				Mean
	0	0.5	1	1.5	
Seed yield (kg/ha)					
0	953	961	975	988	969
15	1025	1115	1272	1291	1176
30	1156	1226	1411	1419	1303
60	1187	1306	1416	1430	1335
Mean	1080	1152	1269	1285	
	SEm±	CD (P=0.05)			
Boron levels	16.2	46.8			
Potassium levels	16.2	46.8			
Interaction (B x K)	32.4	93.7			
Test weight (g)					
0	33.63	37.75	41.12	39.73	38.06
15	37.19	43.49	44.25	45.71	42.66
30	40.06	49.33	50.07	50.09	47.39
60	40.45	42.62	50.08	51.04	46.05
Mean	37.83	43.30	46.38	46.64	
	SEm±	CD (P=0.05)			
Boron levels	0.73	2.12			
Potassium levels	0.73	2.12			
Interaction (B x K)	1.47	NS			
Oil content (%)					
0	38.6	38.7	38.8	38.9	38.8
15	38.7	39.3	38.9	39.0	39.0
30	38.5	39.2	39.4	39.3	39.1
60	39.2	38.4	39.3	39.2	39.0
Mean	38.8	38.9	39.1	39.1	
	SEm±	CD (P=0.05)			
Boron levels	0.16	NS			
Potassium levels	0.16	NS			
Interaction (B x K)	0.32	NS			
Oil yield (kg/ha)					
0	368	372	378	384	376
15	397	438	495	503	458
30	445	481	556	558	510
60	466	502	556	561	521
Mean	419	448	496	502	
	SEm±	CD (P=0.05)			
Boron levels	7.14	20.62			
Potassium levels	7.14	20.62			
Protein content (%)					
0	18.9	18.9	18.9	18.9	18.9
15	19.1	19.1	19.1	19.1	19.1
30	19.1	19.1	19.1	19.2	19.1
60	19.1	19.2	19.2	19.2	19.2
Mean	19.0	19.1	19.1	19.1	
	SEm±	CD (P=0.05)			
Boron levels	0.08	NS			
Potassium levels	0.08	NS			
Interaction (B x K)	0.15	NS			
Protein yield (kg/ha)					
0	180	182	184	187	183
15	196	213	243	247	225
30	221	234	270	272	249
60	227	250	271	274	256
Mean	206	220	242	245	228
	SEm±	CD (P=0.05)			
Boron levels	3.29	9.5			
Potassium levels	3.29	9.51			
Interaction (B x K)	6.59	19.03			

Table 2 Treatment wise cost of cultivation (₹/ha), gross returns (₹/ha), net returns (₹/ha) and B:C ratio of sunflower hybrid (cv. GK-2002) as influenced by different levels of boron and potassium

Treatment	Cost of cultivation (₹/ha)	Gross returns (₹ /ha)	Net returns (₹/ha)	B:C ratio
B_0K_0	22193	36205.6	14013	1.63
B_0 K_{15}	22612	38962.1	16350	1.72
B_0 K_{30}	23031	43915.3	20884	1.91
B_0 K_{60}	23869	45118.7	21250	1.89
$B_{0.5}$ K_0	22513	36530.7	14018	1.62
$B_{0.5}K_{15}$	22932	42357.3	19425	1.85
$B_{0.5}K_{30}$	23351	46588.0	23237	2.00
$B_{0.5}$ K_{60}	24189	49615.3	25426	2.05
B_1 K_0	22833	37062.7	14230	1.62
B_1 K_{15}	23252	48336.0	25084	2.08
B_1 K_{30}	23671	53605.3	29934	2.26
B_1 K_{60}	24509	53808.0	29299	2.20
$B_{1.5}$ K_0	23153	37544.0	14391	1.62
$B_{1.5}$ K_{15}	23572	49045.3	25473	2.08
$B_{1.5}$ K_{30}	23991	53934.7	29944	2.25
$B_{1.5}$ K_{60}	24829	54340.0	29511	2.19

Table 3 Effect of boron and potassium levels on fatty acid composition of sunflower oil

Treatment	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)
B_0K_0	6.7	6.1	15.9	71.3
B_0 K_{15}	6.7	5.8	14.1	73.4
B_0 K_{30}	6.9	5.4	14.4	73.3
B_0 K_{60}	6.9	5.7	15.6	71.8
$B_{0.5}$ K_0	6.8	6.1	14.8	72.3
$B_{0.5}K_{15}$	6.9	5.8	14.0	73.3
$B_{0.5}K_{30}$	7.0	5.9	14.8	72.6
$B_{0.5}$ K_{60}	6.8	5.4	16.1	71.7
B_1 K_0	7.0	6.0	13.3	73.7
B_1 K_{15}	7.1	6.0	12.0	74.9
B_1 K_{30}	7.1	5.0	12.7	75.3
B_1 K_{60}	7.0	5.9	15.3	74.9
$B_{1.5}$ K_0	6.8	6.4	14.3	72.5
$B_{1.5}$ K_{15}	6.8	6.5	13.3	73.3
$B_{1.5}$ K_{30}	7.0	5.5	14.3	73.3
$B_{1.5}$ K_{60}	6.8	5.9	14.1	73.3

The protein yield is a result of protein content and seed yield. Protein content of seed being essentially a manifestation of its nitrogen content seems the result of higher N content of seed. Jaiswal *et al.* (2015) reported that, in mustard crop appropriate dose of boron with sulphur increased the seed protein yield.

Perusal of fatty acid composition of oil as influenced by different levels of boron and potassium application (Table 2) revealed that highest palmitic acid (7.07%) was recorded with B_1+K_{30}, B_1K_{15} and lowest at control (6.73%). Stearic acid content varied from 4.99 per cent to 6.54 per cent among the treatments. Highest stearic acid (6.37%) with $B_{1.5}K_0$ treatment and lowest was 4.99 per cent with B_1K_{30} treatment. The highest oleic acid (16.13%) content was recorded with $B_{0.5}K_{60}$ and lowest (14.02%) in $B_{0.5}K_{15}$ treatment. The highest linoleic acid content (75.3%) was recorded in $B_{1.5}$ K_{30} and lowest (71.29%) in control. Among the treatments of boron and potassium $B_{1.5}$ K_{30} showed higher palmitic and linoleic acid contents than that of control. Shehzad *et al.* (2015) reported that 4.0 kg B/ha proved to be best for increasing palmitic acid concentration which was followed by 2.0 kg/ha of boron. Increment in boron rate up to 4.0 kg/ha enhanced the palmitic acid concentration, but, further boron addition reduced its percentage. The boron @ 2.0 and 4.0 kg/ha depicted highest concentration for linoleic acid. Murthy and Nagaraj (2005) reported that influence of increasing doses of potassium up to 20 kg/ha and 40 kg/ha for a castor variety and hybrid, respectively in improving and/or altering the fatty acid profile of oil extracted from seeds at different picking intervals.

Maximum seed yield was obtained with $B_{1.5}K_{60}$ treatment followed by $B_{1.5}K_{30}$, B_1K_{30} and B_1K_{60}. B and K levels and B x K interaction were found significant. B_1K_{30} treatment showed economically beneficial. Maximum oil content found with B_1K_{30} whereas higher oil yield, protein content, protein yield were observed with $B_{1.5}$ K_{60}. However they are at par with B_1K_{30}. It can be concluded that application of boron @ 1kg and potassium @ 30 kg/ha recorded higher net returns.

REFERENCES

Ahmed Khan T, Venugopal K, Devaih C and Seenapa K 1990. Effect of secondary nutrients and boron on growth characters and yield of sunflower. *Journal of Oilseeds Research*, **7**: 136-139.

Ahmed R, Saeed M, Mahmood T and Ullah E 2001. Yield potential and oil quality of two sunflower hybrids as affected by K application and growing seasons. *International Journal of Agricultural Biology*, **3**(1): 51-53.

Chatterjee C and Nautiyal N. 2000. Developmental aberrations in seeds of boron deficient sunflower and recovery. *Journal of Plant Nutrition*, **23**: 835-841.

Farhad I S M, Islam M N, Hoque S and Bhuiyan M S I 2010. Role of potassium and sulphur on the growth, yield and oil content of soybean (*Glycine max* L.). *Academic Journal of Plant Sciences*, **3**(2): 99-103.

Ghadge S V and Raheman H 2005. Biodiesel production from mahua (*Madhuca indica*) oil having high free fatty acids. *Biomass Bioenergy*, **28**(6): 601-605.

Jaiswal A D, Singh S K, Singh Y K, Surendra Singh and Yadav S N 2015. Effect of sulphur and boron on yield and quality of Mustard (*Brassica juncea* L.) grown on Vindhyan red soil. *Journal of the Indian Society of Soil Science*, **63**(3): 362-364.

Lewis D C, Potter T D and Weckert S E 1991. Effect of N, P and K fertilizers application on the seed yields of sunflower grown on sandy soil and the prediction of N, P and K response by soil test. *Fertilizer Research*, **28**:185-190.

Malihe M, Ganjali H and Fanaei H 2013. Effect of different levels of nitrogen and potassium on yield, yield components and oil content of sunflower. *International Journal of Farming and Allied Sciences*, **2**(1): 1237-1240.

Murthy I Y L N and Nagaraj G 2005. Effect of potassium levels and spike order on the fatty acid composition of castor (*Ricinus communis* L.). *Journal of Oilseeds Research*, **22**(2): 424-426.

Pathak H 2010. Trend of fertility status of Indian soils. *Current Advances in Agricultural Sciences*, **2**(1): 10-12.

Rao H G and Vidyasagar C 1981. Effect of nitrogen, phosphorus and potassium along with foliar and soil applied born on sunflower (*Helianthus annuus* L.). I. Growth, yield, seed oil content and varietal performance. *The Andhra Agriculture Journal*, **28**: 150-155.

Reddy S S, Yadahalli Y H, Kumar V K K, Kumara O and Naik A H K 2002. Effect of fertilizer, gypsum and boron application on yield and economics of sunflower hybrids. *Crop Research*, **23**(3): 450-453.

Renukadevi A, Savithri P and Andi K 2002. Evaluation of boron fertilizers for a sunflower (*Helianthus annuus* L.) - green gram (*Vigna radiata* L.) cropping sequence in Inceptisols. *Acta Agronomica Hungarica*, **50**(2): 163-168.

Sahrawat K L and Wani S P and Rego T J and Pardhasaradhi G and Murthy K V S 2007. Widespread deficiencies of sulphur, boron and zinc in dryland soils of the Indian semi-arid tropics. *Current Science*, **93**(10): 1428-1432.

Shehzad M A and Maqsood M 2015. Integrated nitrogen and boron fertilization improves the productivity and oil quality of sunflower grown in a calcareous soil. *Turkish Journal of Field Crops*, **20**(2): 213-222.

Shukla M P, Harishankar and Pathak R K 1983. S, Zn and B nutrition of rai (*Brassica juncea* L.). *Journal of the Indian Society of Soil Science*, **31**: 517-520.

Shukla A K, Tiwari P K and Chandra Prakash 2014. Micronutrients deficiencies *vis-a-vis* Food and Nutritional Security of India. *Indian Journal of Fertilisers*, **10**(12):94-112.

Sirbu M and Ailincai D 1992. Effect of long term fertilizer application including NPK on the grain yields and quality of sunflower. *Agronomy in Mold*, **25**: 181-187.

Soleimanzadeh H, Habibi D, Ardakani M R, Paknejad F and Rejali F 2010. Response of sunflower (*Helianthus annuus* L.) to drought stress under different potassium levels. *World Applied Sciences Journal*, **8**(4): 443-448.

Tiwari D D, Pandey S B and Dubey M K 2012. Effect of potassium application on yield and quality characteristics of pigeon pea (*Cajanuscajan*) and mustard (*Brassica juncea* L. Czern) crops in central plain zone of Uttar Pradesh. *e-ifc*, **31**: 16-20.

Tiwari P N, Gambanit P N and Rajan T S 1974. Rapid and non-destructive of seed oil by pulse nuclear magnetic resource technique. *Journal of American Oil Society*, **57**: 305-308.

Ujwala R M 2011. Interaction of micronutrients with major nutrients with special reference to potassium. *Karnataka Journal of Agricultural Sciences*, **24**(1): 106-109.

Walinga I, Vanwark W, Houba V J G and Vanderles J J 1989. Plant analysis procedure (part 7). In: *Soil And Plant Analysis-A Series of Syllabi*.

Zahoor R, Basra S M A, Munir H, Nadeem M A and Yousaf S 2011. Role of boron in improving assimilate partitioning and achene yield in sunflower. *Journal of Agriculture and Social Sciences*, **7**: 49-55.

Effect of different culture media, temperature and pH on growth and sporulation of *Alternaria carthami*

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(Received: July 11, 2017; Revised: October 17, 2017; Accepted: October 26, 2017)

ABSTRACT

Among the eight culture media tested for the growth of *Alternaria carthami,* the potato dextrose agar showed highest growth (90.00 mm) followed by potato malt agar (84.16 mm) and yeast mannitol agar (73.33 mm). The colony growth recorded in different temperature ranged from 5.66 mm at 5°C to 85.66 mm at 30°C. The highest mycelial growth (85.66 mm) was recorded at 30°C with excellent sporulation followed by 25°C (83.83 mm) and 20°C (66.33 mm). The colony growth recorded with all the pH levels was ranged from 30.50 mm at pH 4.0 to 85.83 mm at pH 6.5, the maximum mycelial growth (85.83 mm) was recorded at pH 6.5 with excellent sporulation, followed by pH 6 (82.00 mm) and pH 7 (70.33 mm) with excellent and good sporulation, respectively.

Keywords: *Alternaria carthami,* Culture media, Growth, pH, Temperature, Sporulation

Safflower is known to suffer from many fungal diseases at different stage of crop growth. Alternaria blight caused by *Alternaria carthami* is one of the most important diseases. In general, the season was suitable for the development of foliar diseases particularly for Alternaria leaf spot/blight development as there were rains after sowing in Maharashtra and a disease severity from 10 to 95 per cent was observed. In Marathwada region of Maharashtra, Alternaria leaf spot intensity of 30 to 40 per cent, while in Karnataka and Andhra Pradesh maximum intensity of Alternaria leaf spot upto 25 per cent and 20 per cent respectively were observed (Anonymous, 2012). With this view, the present investigation was undertaken to evaluate the efficacy of different culture media and physiological studies on Alternaria leaf spot of safflower.

To study the effect of different solid culture media on characteristics of *A. carthami,* eight culture media *viz.,* potato dextrose agar, corn meal agar, potato malt agar, Czapek's dox agar, yeast extract agar, yeast mannitol agar, malt extract agar and Ashby's mannitol agar were used. The media were sterilized in autoclave at 15 lbs/inch^2 pressure for 15 min. The experiment was conducted by using CRD design with eight treatments and three replications. Autoclaved and cooled media were poured (20 ml/plate) in sterilized glass Petri plates (90 mm diameter) and allowed to solidify at room temperature. On solidification of the media, Petri plates of each culture medium (five plates/medium/replication) were inoculated by placing in the centre 5 mm mycelial disc of actively growing 7 days old pure culture of *A. carthami.* Each culture medium was replicated thrice. Plates were incubated at room temperature (27 ±1°C).

For studying the temperature effects different levels of temperature were maintained either in refrigerator, incubator, or in hot air oven at 5, 10, 15, 20, 25, 30, 35 and 40°C as per the adjustability of the instruments. The experiment was conducted by using CRD design with eight treatments and three replications. Experiment was conducted in Petri plates on Potato dextrose agar (PDA). PDA was sterilized and poured in sterile Petri plates. For each treatment of 5 mm inoculums disc were used. Plates were incubated at respective treatment of temperature and observations on colony diameter and sporulation were recorded after seven days of inoculation.

Hydrogen ion concentration or pH plays a key role in the maintenance of metabolic rate of the pathogen *A. carthami.* The experiment was conducted by using CRD design with nine treatments and three replications. For this experiment PDA was used as basal medium. The pH levels of PDA were adjusted by using 0.1 N HCl or 0.1 N NaOH. After adjustment of pH, basal medium PDA was sterilized in autoclave. The cooled media was poured in Petri plates (20 ml/plate) and allowed to solidify at room temperature. On solidification of the media Petri plates were inoculated with 5 mm disc of actively growing culture organism and incubated at temperature 27±1°C for seven days. Three replication of each treatment was maintained. The observations on radial mycelial growth or colony diameter (mm) and sporulation were recorded at 24 hrs interval and continued till seven days after inoculation.

Cultural characteristics *viz.,* mycelium, colony growth, colony elevation, colony colour and sporulation of *A. carthami* were studied *in vitro* on eight culture media and results obtained are presented in Table 1 and Fig.1.

The results (Table 1) revealed that, all the media tested encouraged better growth and variable sporulation of *A. carthami.* The mean colony growth recorded with all the test media was ranged from 41.66 mm (Yeast extract agar) to 90.00 mm (Potato dextrose agar). However, significantly highest mean mycelial growth (90.00 mm) was recorded with Potato dextrose agar. The second and third best media was found were Potato malt agar (84.16 mm) and Yeast mannitol agar (73.33 mm) respectively. This was followed by Malt extract agar (69.16 mm), Asbhy's mannitol agar (65.33 mm) and Czapek's dox agar (51.33 mm). Corn meal agar (48.83 mm) and Yeast extract agar (41.66 mm) were found least suitable to the growth of the test pathogen.

All the culture media tested exhibited a wide range of colony morphology, growth and colour. The mycelial growth produced on all the culture media was mostly circular to irregular profuse, wooly and loose cottony colonies developed were circular to irregular. Colour of colonies produced was varied from greenish grey to black, olivaceous black with whitish grey periphery, circular periphery of the colonies were whitish grey coloured. All the eight culture media tested exhibited a wide range of sporulation from fair (++) to excellent (++++). However, Potato dextrose agar and Potato malt agar recorded excellent (++++) sporulation. Good (+++) sporulation was recorded on Yeast manitol agar, Malt extract agar and Ashby's manitol agar. Whereas, fair (++) sporulation was recorded on Corn meanl agar, Czpack dox agar and Yeast extract agar.

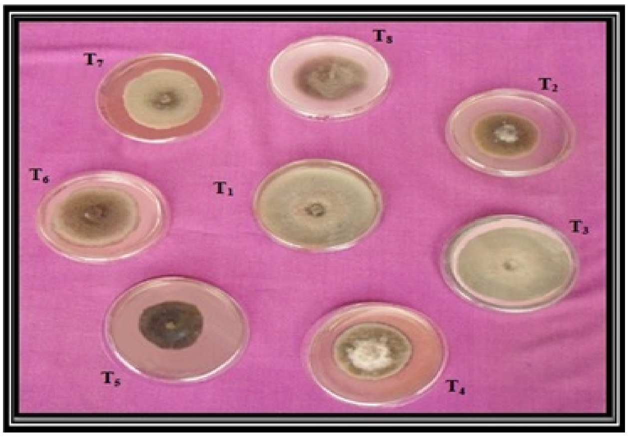
Media tested exhibited varied of radial mycelial growth and sporulation of the test pathogen. However, highest radial mycelial growth (90.00 mm) and excellent sporulation of (++++) was recorded on Potato dextrose agar, followed by Potato malt agar (growth: 84.16 mm and sporulation: excellent). Least radial mycelial growth was recorded on Yeast extract agar (41.66 mm) with fair (++) sporulation. Thus, results of the present study on the effect of various culture media on morphological and cultural characteristics and sporulation in *A. carthami* are in consonance with those reported earlier by several workers (Awadhiya, 1991; Jash *et al.*, 2003; Khan *et al.,* 2007; Yadav and Khan, 2008; Hubballi *et al.,* 2010).

Temperature is one of the most crucial factors, which affects the pathogen host or host pathogen interaction during pathogenesis. Therefore, present study includes mycelial growth and sporulation at eight different temperature levels ranging from 5°C to 40°C. The data obtained during the study are presented in Table 2 and Fig. 2. The results revealed that, all the temperature tested encouraged variable mycelial growth and sporulation of *A. carthami.* The mean colony growth recorded with all the different temperature was ranged from 5.66 mm at 5°C to 85.66 mm at 30°C. However, significantly highest mean mycelial growth (85.66 mm) was recorded at 30°C. The second and third best temperature regimes were found 25°C (83.83 mm) and 20°C (66.33 mm). This was followed by at 35°C (60.16 mm), 15°C (46.16 mm) and 40°C (25.66 mm) temperature. Temperature 5°C and 10°C was found least suitable and which recorded minimum mean mycelial growth 5.66 mm and 21.33 mm, of the test pathogen respectively. All the eight temperature regimes tested exhibited a wide range of sporulation from poor (+) to excellent (++++). However, at 25°C and 30°C recorded excellent (++++) sporulation. Good (+++) sporulation was recorded at 20°C. At 15°C and 35°C temperature fair (++) sporulation was recorded. Whereas, poor (+) sporulation was recorded at 10°C and 40°C temperature. At temperature 5°C sporulation was not observed.

Thus, at all the temperature regimes tested exhibited varied of radial mycelial growth and sporulation of the test pathogen. However, highest radial mycelial growth (85.66 mm) and excellent sporulation (++++) was recorded at 30°C, followed by 25°C (growth: 83.83 mm and excellent sporulation). Least radial mycelial growth (5.66 mm) was recorded at 5°C with poor sporulation (+). The temperatures between 25°C to 30°C were better for growth and sporulation of test pathogen and the temperature below 15°C and above 35°C were unfavorable for growth and sporulation of the test pathogen. Thus, the similar results of the present study on the effect of different temperature *viz.*, 20°C, 25°C, 30°C and 35°C to supported maximum growth and sporulation in *A. carthami* and different *Alternaria* spp. were reported earlier by several workers (Raranciuc, 2002; Singh *et al.*, 2005; Ramegowda and Naik, 2006; Hubballi *et al.*, 2010; Mishra and Mishira, 2012).

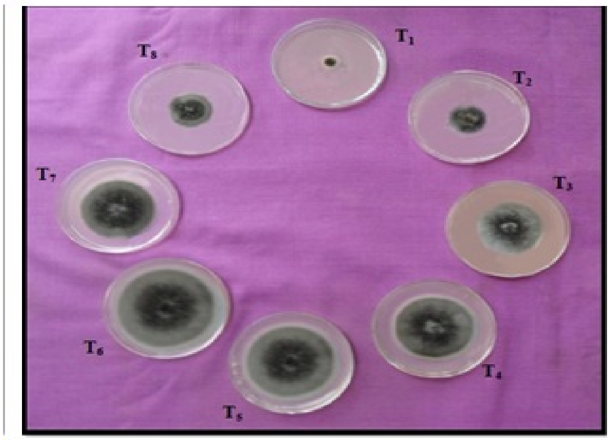
Hydrogen ion concentration (pH) has marked effect on the growth of fungus. The pH requirement may differ from fungus to fungus therefore; present study includes nine different pH levels ranging from 4.0 to 8.0. The results obtained during the study are presented in Table 3 and Fig.3. The results revealed that all the pH levels tested encouraged variable growth and sporulation of *A. carthami* (Table 3). The mean colony growth recorded with all the pH levels was ranged from 30.50 mm at pH 4.0 to 85.83 mm at pH 6.5. However, significantly maximum mean mycelial growth (85.83 mm) was recorded at pH 6.5. The second and third best pH levels found was pH 6 (82.00 mm) and pH 7 (70.33 mm). This was followed by pH 7.5 (63.16 mm), pH 8.0 (51.00 mm) and pH 5.5 (53.16 mm). The pH 4.0 and 4.5 was found least suitable and which recorded minimum mycelial growth 30.50 mm and 35.83 mm respectively of the test pathogen. All the nine pH levels tested exhibited a wide range of sporulation from poor (+) to excellent (++++). However, at pH 6.0 and 6.5 recorded excellent (++++) sporulation. Good (+++) sporulation was recorded at pH 5.5, 7.0 7.5 and 8.0. At pH 4.5 and 5.0 fair (++) sporulation was recorded. Whereas, poor (+) sporulation was recorded at pH 4.0.

At all the pH levels exhibited varied of radial mycelial growth and sporulation of the test pathogen. However, highest radial mycelial growth (85.83 mm) and excellent sporulation (++++) was recorded at pH 6.5. This was followed by pH 6.0 (growth 82.00 mm and excellent sporulation).



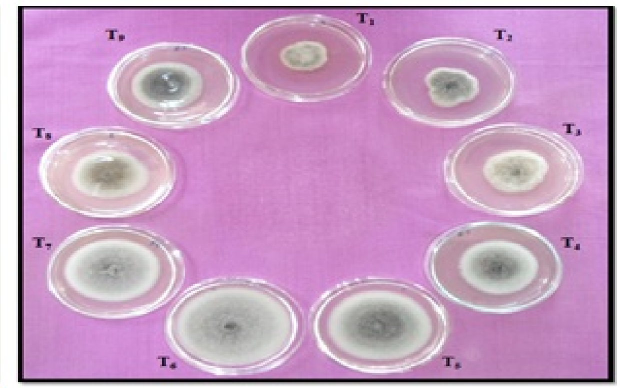
T_1- Potato Dextrose Agar; T_2-Corn meal Agar; T_3-Potato malt Agar; T_4-Czapek's dox agar; T_5-Yeast Extract Agar; T_6-Yeast Mannitol Agar; T_7- Malt Extract Agar; T_8 -Asbhy's Mannitol Agar

Fig. 1. Growth and sporulation of *A. carthami* on different culture media *in vitro*



T_1- 5°C; T_2-10°C; T_3-15°C; T_4-20°C; T_5-25°C; T_6-30°C; T_7- 35°C; T_8 -40°C

Fig. 2. *In vitro* effect of different temperature on growth and sporulation of *A. carthami*



T_1-4.0; T_2-4.5; T_3-5.0; T_4-5.5; T_5-6.0; T_6-6.5; T_7- 7.0; T_8 -7.5; T_9 - 8.0

Fig. 3. *In vitro* effect of different pH on mycelial growth and sporulation of *A. carthami*

Least radial mycelial growth (30.50 mm) was recorded at pH 4.0 with poor sporulation (+). The pH between 6 to 6.5 was better for growth and sporulation of test pathogen. The results are in agreement with the findings of Jash *et al.* (2003); Singh *et al.* (2005); Prathibha *et al.* (2008); Hubballi *et al.* (2010) and Ramjegathesh and Ebenezar (2012) who reported the effect of different pH on growth and sporulation of *A. carthami* and different *Alternaria* species.

REFERENCES

Anonymous 2012. *Annual Progress Report.* AICRP on Safflower, Directorate of Oilseeds Research, Rajendranagar, Hyderabad.

Awadhiya G K 1991. Effect of some cultural factors on growth and spore germination of *Alternaria carthami. Journal of Oilseeds Research*, **8**(1): 123-125.

Hubballi M, Nakkeran S, Raghuchander T and Samiyappan R 2010. Growth of *Alternaria alternata* causing leaf blight of noni on various culture media. *World Journal of Agricultural Sciences*, **6**(2): 171-177.

Jash S, Dudda S and Bandopadhyay S 2003. Effect of different culture media on growth and sporulation of *A. zinnia,* causing leaf blight of marigold. *Environment and Ecology*, **21**(2): 321-325.

Khan M M, Khan R U and Mohiddin F A 2007. *In vitro* effect of temperature and culture media on the growth of *A. brassicae* infecting rapeseed-mustard. *Annals of Plant Protection Sciences*, **15**(2): 526-527.

Mishra P T and Mishra V 2012. Effect of media, temperature and pH on growth of *Alternaria alternata* causing leaf spot of cotton. *Annals of Plant Protection Sciences*, **20**(1): 246-247.

Prathibha V S, Nanjegowda D and Nagaraju N 2008. Effect of temperature and pH on the growth of different isolates of *A. helianthi. Mysore Journal of Agricultural Sciences*, **42**(1): 139-142.

Ramegowda G and Naik M K 2006. Morphological, cultural and physiological in isolates of *Alternaria* spp. infecting Bt cotton. *Journal of Mycology and Plant Pathology*, **38**(2): 267-271.

Ramjegathesh R and Ebenezar E G 2012. Morphological and physiological characters of *Alternaria alternata* causing leaf blight disease of onion. *International Journal of Plant Pathology*, **3**: 34-44.

Raranciuc S 2002. Influence of temperature and light on the growth and *in vitro* sporulation of *Alternaria helianthi. Problem De-protectia-plante*, **30**(1): 23-29.

Singh R P, Singh A K and Singh H K 2005. Effect of temperature, carbon source and pH on the growth of isolates of *Alternaria triticina. Farm Science Journal*, **14**(2): 65-66.

Yadhav R and Khan R U 2008. Differential response of *Alternaria brasicicola* isolates at different temperatures and nutrient media. *Journal of Economic Agriculture*, **3**(1): 72-74.

Efficacy of newer insecticides against *Spodoptera litura* in sunflower (*Helianthus annuus* L.)

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(Received: June 21, 2017; Revised: August 11, 2017; Accepted: October 18, 2017)

ABSTRACT

Field experiment was conducted during *rabi*-summer season of 2014-15 and 2015-16 to evaluate the efficacy of certain newer chemical insecticides (flubendiamide 480SC, spinosad 48SC, thiodicarb 75WP, thiodicarb 80DF, novaluron 10EC) with conventional insecticides (dichlorvos 76EC and chlorpyriphos 20EC) against tobacco caterpillar, *Spodoptera litura* in sunflower. Results revealed that the maximum percentage of larval reduction and defoliation was in flubendiamide 480SC @ 150ml/ha followed by spinosad 48SC @ 150ml/ha. Highest seed yield were recorded in flubendiamide (1950 and 1825 kg/ha) followed by spinosad (1875 and 1740 kg/ha) and thiodicarb 75WP (1785 and 1700 kg/ha) as against 1500 and 1400 kg/ha in untreated control during 2014-15 and 2015-16, respectively. The maximum cost-benefit ratio of 1:2.1 and 1:2.05 was obtained with flubendiamide during 2014-15 and 2015-16, respectively.

Keywords: Field efficacy, Newer insecticides, *Spodoptera litura,* Sunflower

Sunflower is one of the important oilseed crops in West Bengal during *rabi* season and cultivated in an area of about 12,500 ha (2016-17). Due to short winter spell and delayed and heavy rainfall during rainy season, the sowing of mustard was delayed which ultimate reduced the production of rapeseed-mustard. The delayed sowing also invites the insect pests in most of the years. Sunflower being a photoperiod natural crop has wide scope to replace the rapeseed-mustard cultivation with high yield potentiality. The crop is attacked by a number of insect pest like tobacco caterpillar (*Spodoptera litura*), Bihar hairy caterpillar (*Spilarctia obliqua*) and gram pod borer (*Helicoverpa armigera*) which impose a great limitation in realizing the potential productivity. Conventional method of pest control includes extensive use of broad spectrum insecticides belonging to chlorinated hydrocarbons, organophosphates, carbamates and synthetic pyrethroids. Chitin synthesis inhibitors and newer insecticides of novel mode of action have recently been found to be highly effective in management of many lepidopteron insect pests (Khambete *et al.,* 1999; Vadodaria *et al.,* 2000; Tonishi *et al.,* 2005). Moreover, they are selective, safe, environmental friendly and can fit ideally in Integrated Pest Management (IPM) programme. In light of the above, an attempt has been made in the present study to evaluate the field efficacy of certain newer insecticides along with conventional insecticides against *S. litura* in sunflower.

The experiment was carried out during December to March in 2014-15 and 2015-16 at Research Farm, Nimpith Centre, West Bengal to assess the efficacy of newer insecticides along with conventional insecticides against tobacco caterpillar, *Spodoptera litura* in sunflower (Table 1). The experiment was carried out with sunflower hybrid, LSFH-171 in randomized complete block design with three replications. All the recommended agronomic practices were followed except for insect-pest management. The treatments were applied when the larval population crossed the economic threshold level using high volume knapsack sprayer with spray fluid @ 500 l/ha. The observation on larval population and per cent defoliation was recorded on 10 plant plants selected randomly. One day before spray (per count) and 7 and 15 days after the spray. The seed yield was recorded on net plot area basis which was converted to kg/ha for statistical interpretations. The data was subjected to appropriate transformation and data were analyzed statistically as suggested by Panse and Sukhatme (1988).

The result of the first year experiment conducted during *rabi* season 2014-15 revealed that spraying of flubendomide recorded the lowest mean number of larva and per cent defoliation (1.28 larvae and 10.6% defoliation per 10 plants). The next best treatment was spinosad (1.42 larvae and 14.6% defoliation per 10 plants) followed by thiodicarb 75WP (4.35 larvae and 18.2% defoliation per 10 plants) compared to untreated control (9.78 larvae and 40.8 defoliation per 10 plants). Higher seed yield was recorded in flubendiamide (1950 kg/ha) followed by spinosad (1875kg/ha), thiodicarb 75WP (1780kg/ha) as against the minimum seed yield of 1500 kg/ha in untreated control during 2014-15 (Table 1). The result of the second year experiment conducted during *rabi*-summer season of 2015-16 revealed that low mean larval population and mean per cent defoliation was recorded with flubendiamide (1.28 larvae and 11.4% defoliation)

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followed by spinosad (1.58 larvae and 14.6% defoliation), thiodicarb 75WP (5.12 larvae and 22.8% defoliation), novaluron (4.68 larvae and 19.4% defoliation) and dichlorvos (5.25 larvae and 24.6% defoliation) compared to untreated control (10.82 larvae and 41.8 defoliation per 10 plants). Higher seed yield was recorded in flubendiamide (1825 kg/ha) followed by spinosad (1740kg/ha), thiodicarb 75WP (1700kg/ha) as against the minimum seed yield of 1380 kg/ha in untreated control during 2015-16 (Table 1). In both year the higher cost: benefit ratio was recorded in flubendiamide (2.05 to 2.1) followed by spinosad (1.9 to 2.0). The results are in agreement with the findings of Venkataih *et al.* (2015), Tonishi *et al.* (2005) and Ameta and Kumar (2008) who reported that application of flubendiamide was significantly superior and highly effective in reducing the population of *S. litura* and *H. armigera.* Based on the efficacy and economics, the study suggests that flubendiamide 480SC @ 150 ml/ha or spinosad 48SC @ 150 ml/ha can be opted for inclusion in IPM programme against *S. litura* in sunflower.

Table 1 Effect of different insecticides on *S. litura* in sunflower

Treatment	Men incidence of larvae/10plants				Mean per cent of defoliation/10 plants				Seed yield (kg/ha)		C:B ratio	
	2014-15		2015-16		2014-15		2015-16		2014-15	2015-16	2014-15	2015-16
	BS	7 DAS	BS	7DAS	BS	15 DAS	BS	15DAS				
Thiodicarb 75WP @ 500g/ha	9.72	4.86 (2.16)	10.85	5.12 (2.46)	35.3	18.2	38.6	22.8	1785	1700	1: 1.7	1: 1.67
Flubendiamide 480SC @ 150ml/ha	9.36	1.28 (1.50)	10.28	1.42 (1.18)	36.2	10.6	38.2	11.4	1950	1825	1: 2.1	1: 2.05
Thiodicarb 80DF @ 500g/ha	9.62	4.35 (2.30)	10.42	4.58 (2.38)	36.8	18.5	39.6	20.7	1755	1680	1: 1.68	1: 1.64
Novaluron 10EC @ 500ml/ha	9.68	4.12 (2.06)	10.78	4.68 (2.42)	36.7	17.6	37.5	19.4	1680	1590	1: 1.65	1: 1.60
Dichlorvos 76EC @ 625ml/ha	9.76	4.38 (2.32)	10.48	5.25 (2.51)	37.2	22.8	37.8	24.6	1725	1610	1: 1.75	1: 1.71
Chlorpyriphos 20EC @ 1250ml/ha	9.78	4.82 (2.41)	10.62	5.12 (2.47)	37.5	27.4	38.6	28.3	1650	1560	1: 1.65	1: 1.60
Spinosad 48SC @ 150ml/ha	9.68	1.46 (1.47)	10.62	1.58 (1.52)	37.1	14.2	37.8	14.6	1875	1740	1: 2.0	1: 1.90
Untreated control	9.58	9.78 (3.16)	10.58	10.82 (3.36)	36.8	40.8	38.2	41.5	1500	1400	-	-
CD (P=0.05)	N.S	0.63	NS	0.85	NS	2.34	NS	1.98	211.6	164.2	-	-

BS - Before spray; DAY - Days after spray

REFERENCES

Ameta O P and Kumar A 2008. Efficacy of flubendiamide 480SC against *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fab.) in chilli. *Pestology*, **32**(5): 26-29.

Khambete M S, Kulkarni H, Chouhan H V S and Bishoni R C 1999. Bio-efficacy of rimon 10EC against diamond black moth, *Plutella xylostella* affecting cabbage. *Pestology*, **23**(12): 3-5.

Venkataih M, Anil Kumar B and Sreedhar C 2015. Efficacy of newer insecticides against *Spodoptera litura* in groundnut (*Arachis hypogaea* L.). *Journal of Oilseeds Research*, **32**(2): 152-154.

Panse V G and Sukhatme P V 1988. *Statistical Methods of Agricultural Workers*, ICAR , New Delhi, pp. 187-202.

Tonishi M, Nakao H, Furaya T, Sed A, Kodama H, Tsubata K, Fujika S, Hirooka T and Nishimastu T 2005. Flubendiamide, a novel insecticide highly active against lepidopteron insect pests. *Journal of Pesticide Science*, **30**(4): 354-360.

Vadodaria M E, Maisuria R B, Patel C J and Patel U G 2000. Insect growth regulator (IGR) - A new tool in the management of *Helicoverpa* in cotton in Gujarat. *Pestology*, **24**(10): 11-24.

Design and evaluation of scaring devices for the management of avian pests of oil palm (*Elaeis guineensis* Jacq.)

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(Received: November 11, 2017; Revised: December 14, 2017; Accepted: December 20, 2017)

ABSTRACT

Birds cause extensive damage to ripening oil palm fruits. Various methods and devices were evaluated for managing this menace in the past. The scaring devices designed in the present study using Compact Disks (CDs) proved effective in reducing the damage caused by avian pests on the ripening fruit bunches of oil palm. To increase the deterrent effect of CDs, the non-reflective sides were stuck with either red or yellow or black reflective radium sheets. Onto which two circular, concentric eye spots were designed and stuck horizontally. The CDs having circular eye spots stuck on red and yellow radium sheets protected the ripening fruit bunches from further damage by birds until harvest. The statistical analysis showed that the above treatments protected the ripening bunches from bird damage by 100 per cent. Protection was 97.2 per cent in the case of CDs having circular eye spots stuck on black radium sheets. CDs having no eye spots and radium sheet protected the bunches 84.6 per cent compared to control. This finding indicated that these devices could be effectively used judiciously to protect the ripening fruit bunches until harvest from avian pests in oil palm.

Keywords: Avian pests, Compact Disks, Oil palm, Management, Scaring devices

Oil palm, *Elaeis guineensis* Jacq. (Family: Arecaceae) is the richest source of vegetable oil with potential yield levels of more than 5 tonnes of oil per ha per annum. The productivity is not achieved due to infestation by a wide range of fauna which include insects, birds, mites and mammals (Dhileepan, 1991; Kalidas *et al.,* 2002; Shashank *et al.,* 2016), apart from diseases, nutrient deficiencies, water stress etc. Birds feeding on oil palm fruits have been reported from many countries (Wood, 1969; Turner and Gillbanks, 1974; Chau *et al.,* 1980). In India, many birds were reported to cause extensive damage to oil palm fruits and are occasionally emerging as major pests of oil palm. Among them, the common myna, *Acridotheres tristis*, the jungle crow, *Corvus macrorhynchos*, Wagner and house crow, *C. splendens* cause great damage. Other birds like crow pheasant, *Centropus sinensis* Stresmann, parakeet, *Psittacula eupatria* (Linn.), white headed babbler, *Turdoides* sp, pariah kite, *Milvus migrans* Skys, large pied wagtail, *Motacilla maderaspatensis* also occasionally feed on oil palm fruits (Dhileepan 1989 and 1990; Chakravarthy and Abraham, 1995; Kalidas, 2006). The feeding damage by birds is specific and feed exclusively on oil palm fruit mesocarp and fibres of the mesocarp are left attached to the seeds (Fig. 1a). The damage is observed throughout the year with no significant seasonal variation in the damage intensity. The average weight of fruit loss per hectare per year was estimated to be 2.8 tonnes which is equivalent to 420 kg of palm oil (Dhileepan, 1989). Many attempts to manage birds, despite alleviating frustration, often do not reduce damage. The techniques used are usually labour intensive and may have legal issues and social concerns. Alternatively, many visual and sound devices have been used to dissuade or scare birds from the orchards, agricultural fields, air ports, aquaculture ponds etc. in India and in abroad. Dhileepan and Jacob (1996) and Chakravarthy (1996) reviewed different conventional methods of protection against bird damage on oil palm which include shooting, scaring, baiting, covering the fruit bunches with wire mesh or leaves, use of reflective tapes etc. Kalidas (2006) reported that tying of nylon fishnets of 9 x 1 m between the palms proved effective in reducing the menace. With vast expansion of technology many people do not use their old CDs (Compact Disks) and DVDs (Digital Versatile/video Disks) any more for audio and video purposes as they use pen drive, external hard disks, memory card etc. and they are being thrown away. It is possible to use them again for agricultural purposes. Many gardeners are making use of CDs and DVDs around their garden to scare away birds in abroad (www.birdbusters.com, www.scarecrowvsbirds.com, www.hunder.com). In this present investigation, it was attempted to use CDs with increased deterring effect by incorporating images against avian pests of oil palm.

The experiment was carried out in oil palm gardens located at ICAR-Indian Institute of Oil Palm Research Farm, Pedavegi in West Godavari District and Katuru in Krishna District of Andhra Pradesh. In this experiment, old CDs were used with some modification to scare or deter the avian pests of oil palm. To increase the deterrent effect of CDs, the non-reflective sides (i.e. side used for labeling normally)

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were stuck with either red or yellow or black reflective radium sheets. Onto which two circular eye spots were designed and stuck horizontally. Each eye spot contained concentric rings of bright colour that resembles the general appearance of vertebrate or predator eyes (Fig. 1b). They were appeared to be alarming. On each CD, a small hole was made and a thread was tied. The thread was in turn tied to a piece of aluminum or iron string, bent at distal end. This set up was suspended over or near to the ripening oil palm bunches of 130-150 days old after flowering. While suspending the scaring devices it was ensured that they were visible to the birds, freely rotating in the air without any obstacle from the fronds or fruit bunches of oil palm (Fig. 1c). Suspending the scaring devices on shorter palms within arm reach is easy, but it is difficult on taller palms which are beyond arm reach. It is therefore, an extendable light weight aluminum pole was prepared for this operation (Fig. 1e). A threaded metal female anchor (nut) was set into one end of aluminum pole, while the other end was attached with a threaded bolt. The bolt is screwed into the threaded nut of the other pole and so the length of the aluminum pole could be extended to required height. The length of each pole was 8 feet. The tip of the pole was modified by addition of two small spikes to hold the iron string (modified to set on the spikes) of the scaring device while suspending over the fruit bunches (Fig. 1f). Border oil palms, having ripening fruit bunches, which were already targeted by birds were selected to evaluate the efficacy of devices. Four treatments *viz.,* circular concentric eye spots stuck on red, yellow and black radium sheets and CDs having no eye spots and radium sheets. A control was also included where no CDs were suspended over the fruit bunches. The treatments were replicated four times. Before imposing the treatments, the number of fruits eaten or damaged in the fruit bunches were counted. The treatments were regularly monitored. At ripening, the fruit bunches were harvested and the total number of fruits damaged by birds were determined. The per cent protection by each device was calculated by determining number of fruits eaten or damaged by birds before and after imposing the treatments. The data were subjected to one way analysis of variance by using IBM SPSS 21 Software published by IBM Corporation, Armonk, NY, USA.

Three criteria were considered before imposing treatments on oil palm fruit bunches. Firstly, imposing treatments on fruit bunches of oil palm in border area of the plantations. The reason being that border palms are susceptible to bird damage compared to inner palms in a plantation. Dhileepan (1989) quantified that fruit loss due to birds was higher in the palms in the border area of the plantations than the interior area; secondly, ripening bunches of 140-150 days old after fruit set. Seng (1983) reported that birds preferred ripening bunches due to increased oil content in the mesocarp; thirdly, fruit bunches on which some fruits were already damaged by birds. Turner and Gillbanks (1974) reported that once fruits in a bunch were damaged, it rendered the whole bunch was susceptible to birds infestation.

The scaring devices designed in the present study proved effective in protecting the ripening fruit bunches. They could be easily used and have merit compared to other traditional methods like shooting, scaring, baiting, covering the fruit bunches with wire meshes etc. The CDs having circular eye spots stuck on red and yellow radium sheets protected the ripening fruit bunches from further damage by birds until harvest. The statistical analysis on the difference between pre treatment damage and post treatment damage showed that the above devices protected the ripening bunches to the tune of 100 per cent. It means no fruit was damaged after suspending the above devices. Even the birds did not alight on those palms. In case of CDs having circular eye spots stuck on black radium sheets there was 97.2 per cent protection from the bird damage. However, this treatment was at par with above two treatments. CDs having no eye spots and radium sheet (i.e. commonly available CDs) protected the ripening bunches to the tune of 84.6 per cent. This implied that some fruits (15.4% fruits) were eaten by birds even after suspending CDs. The fruit bunches which were chosen to act as control where no treatments imposed, were found severely damaged by birds (Table 1). The success of these devices is that when they are suspended from oil palm petiole, they freely rotate even for the gentle breeze. Then the shiny sides of CDs that rotate in the breeze over or near the ripening oil palm bunches suddenly flash brilliantly in the sunlight and produce spectrum of light (Fig. 1d). This visual distraction would first confuse and then agitate the bird and driving them to move to different locations away from the area of irritation. Moreover, the rotating device over or near fruit bunches disturb the alighting birds physically and prevent from feeding on the fruits. The motion in this is an added advantage. In general, motionless devices either provide only short term protection or are ineffective as the threat from them is only perceived rather than real (Inglis, 1980). The effectiveness of devices was further increased by addition of eye spots, consisting of a circular concentric rings of bright colour. These eyes resemble or mimic vertebrate eyes or predatory birds. The radium sheets pasted on CDs provided a dimensional effect. Inglis (1980) reported that two circular eye spots arranged horizontally each containing concentric rings appeared to be most alarming. Many avian species have frontal threat displays in which the eyes are prominent and those that have a three dimensional appearance might enhance the effect.

It is found that the devices having concentric eye spots stuck onto yellow and red radium sheets performed better than the black radium sheets. This might be attributed to the brightness of the colour even at low sunlight. Birds like crows damage fruit bunches throughout the day hours whereas, *A. tristis* visit oil palm gardens as flock during

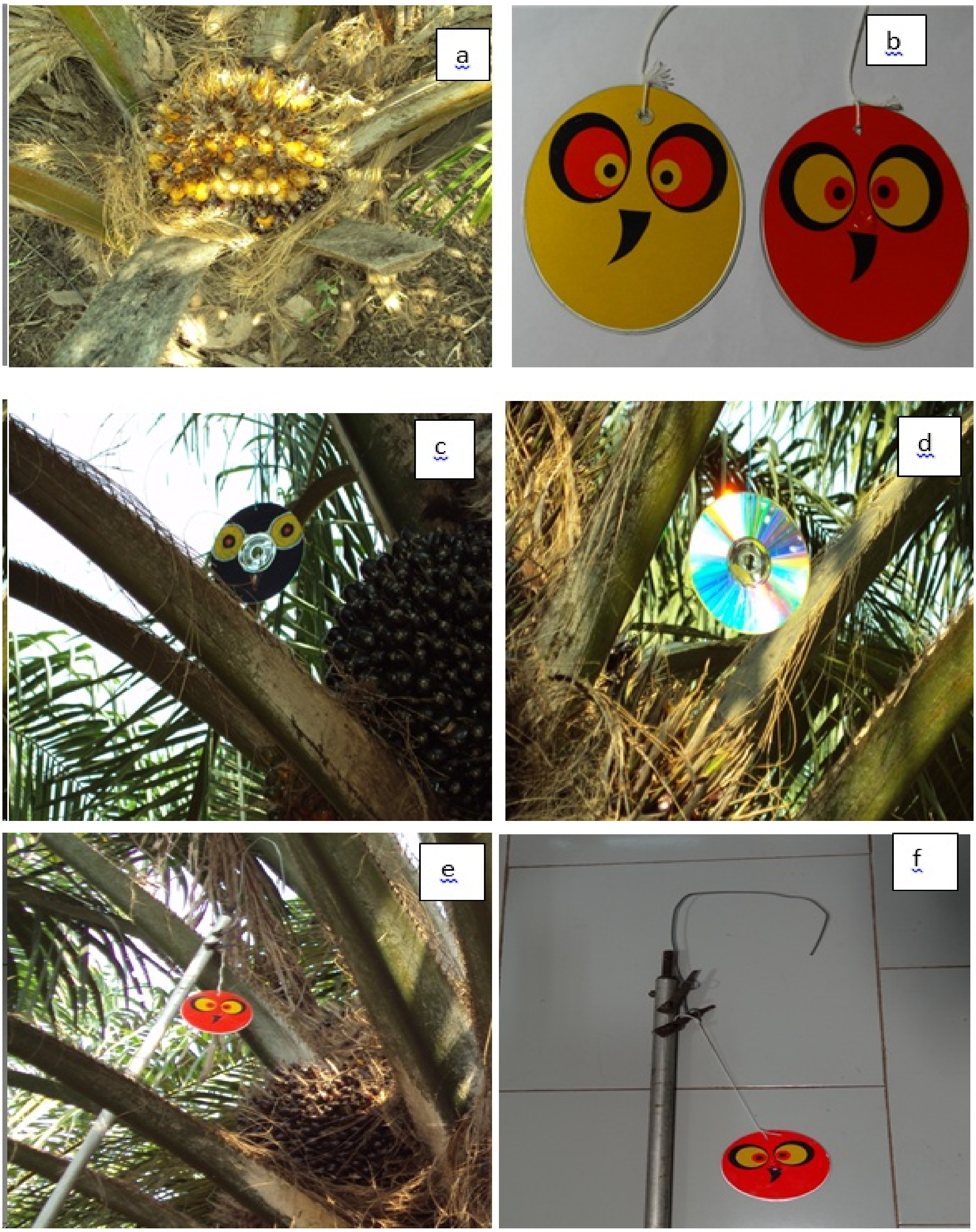

Fig. 1. Evaluation of scaring devices for the management of avian pests of oil palm: (a) Bird damaged oil palm fruit bunch; (b) CDs having concentric eye spots on yellow and red radium sheets; (c) CDs having concentric eye spot on black radium sheet; (d) Shiny side of the CD brilliantly flashing in the sunlight; (e) Hooking the visual device using aluminium pole; (f) Aluminium pole modified at the end for hanging the device

evening hours i.e. 4.00-5.30 P.M. At that time flashing of sunlight on the shiny side of the device is less due to poor sunlight. Under these circumstances, concentric, circular eye spots on bright yellow or red radium sheets would be brighter than black and perform better.

Suspending the visual devices on oil palms of 5-7 years old is comparatively easier. When the palms are the taller (more than 7 years), suspending the devices from leaf petiole are difficult. In India, oil palm fruit bunches are generally harvested by climbing the palms by harvesters. In this case, the harvesters could be trained to suspend the devices on or near fruit bunches which are ripening. Wherever, aluminium pole is used for harvesting, a light weight aluminium pole modified for hooking the devices developed in this investigation could be used.

The advantages of these devices are easy to suspend on or near oil palm fruit bunches wherever or wherever required, the devices are not damaged at the time of pruning leaves and harvesting fruit bunches, environmentally safe and compatible, economical as the unwanted CDs or DVDs could be used, cheaper and durable. However, there is always a chance that birds might become habituate to these devices. The long term effectiveness of this method could be increased by frequently changing the location (Vaudry, 1979). To extend the period of habituation, suspend the devices only on the ripening bunches whenever and wherever required and remove as soon as fruit bunches are harvested.

Table 1 Efficiency of scaring devices in protecting the ripening oil palm fruit bunches from avian pests

Treatment	*Per cent* protection
CD with concentric eye spots stuck on red radium sheet	100.00a
CD with concentric eye spots stuck on yellow radium sheet	100.00a
CD with concentric eye spots stuck on black radium sheet	92.73ab
CD without image (Normal CD)	84.62b
Control	0.0

Means followed by same letter in a column does not differ significantly by DMRT (p=0.05)

ACKNOWLEDGEMENT

The authors are grateful to Director, Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh for providing all the necessary facilities needed during the course of study.

REFERENCES

Chakravarthy A K 1996. Protection of oil palm fruits from bird pests. *Indian Oil Palm Journal*, **4**(31): 17-19.

Chakravarthy A K and Abraham V K 1995. Bird pests of oil palm in Karnataka. *Indian Oil Palm Journal*, **5**(28): 177-178.

Chakravarthy A K, Srihari K and Chandra Prakash J 1997. Management of bird pests in oil palm plantations in Karnataka. In: *Proceedings of National Symposium on Pest Management in Horticultural Crops: Environmental Implications and Thrusts*, 15-17 October 1997, Bangalore, pp.183-187.

Chau T H, Siew Y W, Tong F W and Lee T H 1980. Oil palm, a source of food for some large billed crows. *Planter, Kuala Lumpur*, **56**: 44-45.

Dhileepan K 1990. Trials on the protection of oil palm fruit bunches from bird damage in India. *Planter, Kuala Lumpur,* 66 (769): 171-177.

Dhileepan K 1991. Insects associated with oil palm (*Elaeis guineensis* Jacq.) in India. *FAO Plant Protection Bulletin*, **39**: 94-99.

Dhileepan K 1987. Pests of oil palm. In: *Training Manual on Production Technology for Oil Palm*, Central Plantation Crops Research Institute, Research Centre, Palode, India.

Dhileepan K 1989. Investigations on avian pests of oil palm, *Elaeis guineensis* Jacq. in India. *Tropical Pest Management*, **35**: 273-277.

Dhileepan K and Jacob S A 1996. Pests. *In: Oil Palm Production Technology*. Central Plantation Crops Research Institute, Research Centre, Palode, India, 49-58 pp.

http://www.birdbusters.com/scare_bird_pest.html.

http://www.birdbarrier.com/products/scare-devices

http://www.scarecrowvsbirds.com/bird-scarer-reviews/eds-tied-on-a-string.

http://www.stockergarden.com/stocker/products.php.

Inglis I R 1980. Visual bird scarers: An ethological approach, In: *Bird Problems in Agriculture,* E N Wright, I R Inglis and C J Feare, (eds), British Crop Protection Council, Croydon, United Kingdom. pp. 121-143.

Kalidas P, Ram Prasad K V and Rammohan K 2002. Pest status in irrigated oil palm orchards of coastal areas of India. *Journal of Indian Society for Coastal Agricultural Research*, **20**(1): 41-50.

Kalidas P 2006. Avian pest menace in oil palm and the impact of novel technologies on its management. *Journal of Plantation Crops*, **34**: 381-386.

Seng T K 1983. The Botany of Oil Palm. *Planter, Kuala Lumpur,* Malaysia: The Incorporated Society of Planters. 32 pp.

Shashank P R, Saravanan L, Kalidas P, Phanikumar T, Ramamurthy V V and N S Chandra Bose 2017. A new species of the genus *Acria* Stephens 1834 (Lepidoptera: Depressariidae: Acriinae) from India. *Zootaxa*, **3957**(2): 226-230.

Turner P D 1970. Vultures as pest of oil palm. *Planter, Kuala Lumper,* 46: 299.

Turner P D and Gillbanks R A 1974. Oil palm cultivation and management. Kuala Lumper, Malaysia: The Incorporated Society of Planters, 622 pp.

Vaudry A L 1979. *Bird control for agricultural lands in British Columbia.* British Columbia Publications, Ministry of Agriculture, pp. 21-78.

Wood B J 1969. The extent of vertebrate attack on the oil palm in Malaysia: In: *Progress in Oil Palm,* P D Turner (Ed.), Kuala Lumpur Incorporated Society of Planters, 204 pp.

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