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Niger improvement : Current status and future strategies

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ABSTRACT

The present research efforts of breeding are reviewed in relation to the potential, considering the niger cultivation by resource poor farmers. The history of domestication and the diversity in the plant genetic resources is critically analysed for the formulation of crop improvement strategies with the emphasis on enhancing the average low yield levels in India and in the African subcontinent. The utilization of primary gene pool and the potential uses of wild species are included. Niger improvement is analysed considering population improvement, development of superior inbreds and future strategies for hybrid development. Further biotechnology, mutation and resistance breeding for biotic and abiotic stresses are considered for the production of agronomic types with wider adaptation. Niger being a cross pollinated crop, where seed quality is a serious concern, maintenance breeding and nucleus seed production is covered in detail, since 30-50 per cent productivity improvement can be realised, easily through the intervention of quality seed supply. The production and protection technologies are reviewed for improvement in niger productivity. The potential areas for future line of research are indicated for productivity improvement in niger.

Keywords: *Guizotia abyssinica*, Improvement, Niger, Production, Protection, Status

Niger [*Guizotia abyssinica* (L. f.) Cass.] is an important minor oilseed crop grown in Tropical and Subtropical countries like India, Ethiopia, East Africa, West Indies and Zimbabwe. India ranks first in area, production and export of niger in the world. India and Ethiopia are two major producers in the world. Niger though a native of Tropical Africa, is wide spread and cultivated extensively in India since long. Niger is commonly known as *ramtil, jagni* or *jatangi* (Hindi), *ramtal* (Gujrati), *karale* or *khurasani* (Marathi), *uhechellu* (Kannada), *payellu* (Tamil), *verrinuvvulu* (Telugu), *alashi* (Oriya), *sarguza* (Bengali), *ramtil* (Punjabi) and *sorguja* (Assamese) in different parts of the country (Rao and Ranganatha, 1989). It is the lifeline of tribal agriculture and economy in India. It is grown by tribals on marginal and submarginal lands with negligible inputs under rainfed conditions (Ranganatha, 2009). Niger although considered a minor oilseed crop, is important in terms of its 32 to 40 per cent of quality oil with 18 to 24 per cent protein in the seed.

Niger is an important oilseed crop in Ethiopia where it provides about 50-60 per cent of the oil for domestic consumption (Riley and Belayneh, 1989). It is also used as an oilseed crop in India where it provides about 3 per cent of the edible oil requirement of the country (Getinet and Sharma, 1996). Niger oil is slow drying, used in food, paint, soap and as an illuminant. The oil is used in cooking as a ghee substitute. It is also used as a substitute for olive oil. The oil is used in cooking and also used to treat burns and in the treatment of scabies. The seed is eaten fried, used as a condiment or dried, powdered and mixed with flour to make sweet cakes. The press cake from oil extraction is used for livestock feed. The oil is considered good for health. Whole plants are used as green manure in the pre-flowering stage. Plants are used as a bee plant. Niger meal can also be used as a relatively cheaper growth medium for *Bacillus* species responsible for the production of alkaline protease. The oil contains minor quantities of substances such as tocopherols, phospholipids and sterols that provide protection against cardiovascular disorders and cancer.

The crop is capable of giving good seed yield even under low soil fertility, moisture stress and poor crop management. It has good degree of tolerance to insect pests, diseases and attack of wild animals (Ranganatha *et al*., 2014). It has good potential for soil conservation, land rehabilitation and as a biofertilizer, consequently the crop following niger is always good. These attributes favour its cultivation on hilly areas, marginal and submarginal lands in and around the forest (Ranganatha *et al*., 2009). It has the yield potential of 800-1000 kg/ha under optimum growing conditions. The low seed rate, capability to grow on a wide range of soils and sowing period starting from the onset of monsoon to September-October, makes this crop ideal for contingent crop under rainfed situations.

ORIGIN AND DOMESTICATION

Cultivated niger might have originated from the wild species *Guizotia scabra* sub sp. *schimperi* due to selection by Ethiopian farmers thousands of years ago. *Guizotia* is a small Afromontane endemic genus that belongs to the tribe Heliantheae in the family Asteraceae, subtribe Coreopsideae. The genus *Guizotia* has 6 species, all species except *G.*

abyssinica are wild and are endemic to East Africa especially Ethiopia. From Ethiopia, the cultivated niger is believed to have spread to India during third millennium BC along with other crops, such as finger millet.

Niger belongs to the VI Centre of origin of cultivated plants, the Abyssinian Centre, along with other oilseeds, such as safflower, sesame and castor. Although archeobotanical evidence regarding the origin and domestication of niger is lacking, based on morphological, phytogeographical and cytological evidences, it was reported that *G. abyssinica* might have originated from *G. scabra* subsp. *schimperi* through selection and further cultivation. Further based on these evidences, Ethiopia, where the crop has been under cultivation for much longer time than in any other place, has been considered as the center of origin, domestication and diversity of *G. abyssinica* (Baagoe, 1974; Hiremath and Murthy, 1988; Murthy *et al.*, 1993; Dagne, 1994, 1995, 2001; Weiss, 2000).

Being a crop, niger has the widest geographic distribution among the guizotias. It has also been collected as a weed and as a wild plant in Ethiopia (Baagoe, 1974 and Weiss, 2000). The genus *Guizotia*, named in 1829 by Cassini after the French historian Guizot. It is modified taxonomically and reported by the different authors.

De Wet and Harlan (1975) considered niger to be among the earliest domesticated crops in Ethiopia, along with teff, ensete or false banana (*Ensete ventricosum*), finger millet and coffee. From Ethiopia it is believed to have migrated to East African highlands and during the second millennium BC might have moved to India with other crops. Thus, Harlan describes as the Seventh Complex. It is believed to have been taken to India by Ethiopian immigrants, probably in the third millennium BC along with other crops such as finger millet (Doggett, 1987). It is important to note that its wild relatives were not taken with it. As reported by Seegeler (1983) botanist studying the Indian flora used several names. On the Indian side, the name *Verbesina sativa* was given to this species and published in 1807 (Baagoe, 1974). In 1834, the famous botanist De Candolle (1836) described a new genus *Ramtilla*, where he placed the Indian *V. sativa* under the new name of *Ramtilla olifera*. De Candolle then recognized that his *Ramtilla* and Cassini's *Guizotia* are the same and consequently changed the name *Ramtilla olifera* to *Guizotia olifera* (Baagoe, 1974). However, in 1877, the epithet *abyssinica* was maintained instead of *olifera* by Oliver and Hiern (Baagoe, 1974). De Candolle, first unaware of the Ethiopian and Indian plants, described the new genus *Ramtilla* in 1834. Further named the species *Ramtilla oleifera* and described two varieties. Two years later De Candolle recognized that *Ramtilla* was the same as Cassini's *Guizotia* and by the principle of priority, made the new combination *Guizotia oleifera*. De Candolle knew of the older epithet abyssinica but, he thought that the plant was native to India and not to Ethiopia, kept the own *oleifera*. Oliver and Hiren correctly deduced De Candolle's *Guizotia oleifera* to *Guizotia abyssinica* in 1877. Upon the introduction of the concept of type species at the Cambridge Congress in 1930 and the enumeration of type species for already conserved names, *Guizotia abyssinica* (L.f.) Cass., was proposed as the type species of *Guizotia* Cass.

PLANT GENETIC RESOURCES

Cultivated niger, its wild and weedy relatives have a pattern of distribution in areas where this occurs. Intercrossing takes place as the cultivated and other species retain genomic homology and some interfertility. The wild and weedy relatives of niger are potential sources of genes responsible for resistance to pests, diseases and abiotic stresses. All the related species of the cultivated niger are distributed in Africa. All the niger grown in India shows little variation and has a narrow genetic base. However, some variability has been observed in the habit of the plant type, stem colour, seed colour and time of maturation. The Ethiopian germplasm collection contains the three known maturity groups. As there is a host of contrasting features particularly between the early maturing Bunigne and the late maturing about niger, there appears to be ample variability present for the improvement for desirable qualities. The early and late maturing types differ with respect to number of important characters such as heads/plant, seeds/head, seed weight, plant height, days to maturity and number of primary branches. The niger populations of Ethiopia, present rich genetic variability for the development of varieties with ideal characters. The niger accessions at the Biodiversity Institute were collected from relatively secure areas of the country accessible from major roads. Niger germplasm apparently has only been collected from Ethiopia and India and there is no information regarding germplasm collection from other countries. The niger landraces in Ethiopia, India and possibly other countries have been geographically isolated for a very long time and therefore may carry valuable genes. Germplasm collection in other countries such as Uganda and Zimbabwe should be carried out. Collection of germplasm should include wild relatives within the genus *Guizotia*. Characterization and evaluation should be standardized for better descriptors development. The valuable germplasm, particularly the Ethiopian genepool, was not characterized and needs thorough characterization and evaluation. Such germplasm evaluation would result in identification of valuable germplasm with high oil content, high seed yield, male sterile and dwarf lines.

Germplasm exchange between Ethiopia and India should be explored. However, the Indian materials are early to make use in the long Ethiopian growing seasons. Therefore elite lines, e.g., male sterile and dwarf lines, rather than accessions would be preferred for Ethiopia. Striking genetic differences exist between the Ethiopian and Indian niger. These differences could be investigated using isozyme and molecular markers. It would be interesting to investigate which niger ecotype migrated to India. The variation among abat, bungne and mesno ecotypes could be differentiated using isozyme and molecular markers. All species within the genus *Guizotia* are diploids with chromosome number of 2*n*=30 (Hiremath and Murthy, 1992 and Hiremath *et al*., 1992). Speciation within the genus was not as a result of changes in chromosome number. The four species *viz*., *G. abyssinica, G. scabra subsp. scabra, G. villosa* and *G. scabra* subsp. *schimperi* are not reproductively isolated so hybrids among these species could be obtained with ease. The karyotype of *G. abyssinica, G. scabra* subsp. *schimperi* and *G. villosa* was symmetrical (Hiremath and Murthy, 1992) and that of *G. scabra* subsp. *scabra, G. zavattarii* and *G. reptans* asymmetrical. It would be important to study the progenitor of niger using random amplified polymorphic DNAs. The solution to the problem of the phylogeny of the species could come from molecular techniques.

Genetic diversity: Genetic diversity is key to unlock the productivity by adding desirable traits in appropriate cultivar. The highest morpho-physiological variability was noticed in central and eastern peninsular areas. For example, some genotypes from Orissa possess bold seed, compared with the medium seed types of Karnataka, which have higher oil content 40-43 per cent. Cold-adaptable germplasm also occurs in the eastern hills, especially in Sikkim, while drought tolerant germplasm occurs in central peninsular regions of India (Getinet and Sharma, 1996). Niger is originated in Africa and introduced in India and hence there is little possibility for exploration activities within the country. Thus, attention must be given for introduction of cultivated and wild germplasm. The available records indicate that large number of accessions has been introduced through NBPGR. Presently, 1600 accessions of cultivated germplasm are available for utilization. The introduced germplasm have been characterized and evaluated for important agromorphic traits.

The African germplasm, particularly from Ethiopia is considered good source for high yield, bold seed, resistance to water logging, drought, low land situations and late maturity. Genetic differences caused by the long history of geographical isolation are reported to exist between Indian and African gene pools. For broadening the genetic base, introduction need to be made from African countries like Ethiopia, Sudan, Uganda, Tanzania, Malawi, Zimbabwe and Zaire and Asian countries like Nepal and Bangladesh.

In niger, meager efforts have been made for the collection and conservation through crop specific and a few multi crop/region specific explorations. So far, a total of 1482 indigenous collections have been made in major niger growing areas and the diversity is mainly represented from the roadside fields. The collections exhibited variability for days to maturity, plant height (46 to 196 cm), number of primary branches/plant (3 to 17), number of capitula (30 to 112), number of seeds/capitulum (13 to 47), 1000-seed weight (1.6 to 6.0 g), seed yield/plant (0.7 to 4.1 g), oil content (30 to 47%), seed colour (light black, black, dark black, gray and golden), seed shape (cylindrical, straight, curved and sickle shaped), flower colour (pale, yellow and orange), stem colour (green, purplish green, purple, deep purple with and without blotches), leaf colour (pale green, light green, green and dark green) and leaf margin (entire, serrate and dentate).

Local types still constitute a reservoir of underutilized diversity (Tripathi *et al*., 2010). The collections maintained in the depositories in India do not represent the wide genetic diversity. Many of these collections are either sporadic or confined to roadsides and more so, the germplasm from some pockets of the country are not represented. Therefore, the interior areas where maximum variability is expected need to be explored to broaden the base. In addition, the interior areas in tribal belts of Gujarat and Rajasthan, Dharmapuri in Tamil Nadu, north eastern hill region of Assam, Arunachal Pradesh, Manipur, Mizoram, Nagaland and Meghalaya, particularly, Garo and Khasi hills should be explored. The collections also need to be made from other countries of the Indian subcontinent where variability is expected *viz.*, Surlahi and Palchauk areas of Nepal and hilly region of Comilla, Jamalpur, Faridpur (winter niger), Tangail, Anikgonj, Dhaka, Chandpur, Lakshmipur, Barisa and Sarapur regions of Bangladesh.

The genetic resources such as released varieties, obsolete varieties, breeding lines with specific traits, prebreeding materials, advanced cultivars, mutants, cytogenetic stocks are need to be conserved. It is essential to (i) identify the gaps in the existing collection on the basis of crop geography, biosystematics and crop ecology, (ii) set up priorities with regard to types to be collected and areas to be covered, (iii) formulate sampling strategy and constitute teams for collection. Jibat and Mecha collected 15506 lines of niger from Shoa, Ethiopia at 2490 m altitude, 15518 lines of niger was collected by Tabor at 2590 m altitude from Gonder region of Ethiopia and also collected 15519 working collections of niger from Gonder region of Ethiopia at the altitude of 2590 m. Ticho collected 15535 working collections of niger from Assi region of Ethiopia at the altitude of 2480 m, similarly Markose collected 15536 lines of niger from the altitude of 2510 m at Gojam, Ethiopia. In India, the facilities for long term conservation of germplasm had been developed at NBPGR. For safe conservation, the base collection has been preserved for long term storage at -20°C. Apart from long term storage, medium term storage at 4°C is also used. There is need to find out what fraction of diversity is conserved and what is not, and to find out what can be exploited and how this can be achieved. Simultaneously the threatened resources including wild species should be accorded priority. Presently, a total of

1600 working collections are being regenerated. The National Active Germplasm Site (NAGS) at NBPGR, Regional Station, Akola maintains 618 collections.

In India, the genetic variability has been used through straight selections in the locally adapted materials. Twenty improved varieties have been developed for different niger growing states. Improved breeding methods so far have been least employed in niger. The genetic base of cultivars is narrow. Therefore, the efforts on germplasm utilization need to be intensified for improvement.

Interspecific hybridization: The genus *Guizotia* belongs to the family Compositae representing six species *Guizotia abyssinica* (L.f.) Cass.; *Guizotia scabra* (Vis.) Chiov. subsp. *schimperi* (Sch. Bip.); *Guizotia arborescens* I. Friss; *Guizotia reptans* Hutch; *Guizotia villosa* Sch. Bip.; *Guizotia zavattarii* Lanza. *Guizotia scabra* contains two subspecies, namely *scabra* and *schimperi* (Table 1). *Guizotia scabra* subsp. *schimperi,* known as 'mech' is a common annual weed in Ethiopia. As reported by Murthy *et al*. (1993), *Guizotia abyssinica, Guizotia schimperi* and *Guizotia scabra* are diploid species (2*n*=2x=30) characterized by 15 bivalents during prophase-I of meiosis. The former species is cultivated whereas the latter two are wild. Interspecific hybrids between these three species were generated and the F_1 hybrids were analyzed to assess cytogenetic relationships and crop evolution within the genus *Guizotia.* Meiotic chromosome configurations at diakenesis in pollen mother cells of hybrids averaged 0.25 I + 14.60 II + 0.15 IV for *Guizotia abyssinica* x *Guizotia schimperi*; 0.05 I + 13.6 II + 0.14 III + 0.58 IV for *Guizotia abyssinica* x *Guizotia scabra* and 0.8 I + 12.7 II + 0.08 III + 0.88 IV for *Guizotia schimperi* x *Guizotia scabra* [I = Univalent, II = Bivalent, III = Trivalent and IV = Quadrivalent]. Based on the results, concluded that the genomes of *Guizotia abyssinica* and *Guizotia schimperi* are similar and homologous, whereas the *Guizotia scabra* genome is only partially homologous to that of *Guizotia abyssinica* and *Guizotia schimperi.* Further the species of *Guizotia abyssinica* might have originated from *Guizotia schimperi* through selection and cultivation. The chromosome translocations appear to have played a significant role in the divergence and differentiation of the three species.

Table 1 Different species of *Guizotia abyssinica* and their characteristics

Species	Distribution	Characteristics
Annual *Guizotia abyssinica* (L.f.) Cass.	Cultivated in East African and Indian subcontinent	Annual cultivated type
G. scabra (Vius.) Chiov. ssp. *schimperi* (Sch. Bip. In Walp.) Bogg	Native to Ethiopian highlands	Moderately branched weed especially in niger cultivation with outer involural leaves ovate, shorter than disc center
G. villosa Sch. Bip.	Distributed in Northern and South-Western Ethiopian highlands	Highly branched and weed of open places
Perennials *G. scabra* (Vis.) Chiov. ssp. *scabra*	Distributed widely from Ethiopia to Zimbabwe in the South to the Nigerian highlands in the West	Moderately branched, scabrous, sufrutescent herb and differentiated from annual species *Schimperi* in having outer involucral leaves lanceolate
G. reptans Hutch	A rare species with distribution restricted in Mount Kenya, the Aacberdares and Mount Elgon region in East Africa. It is only species not reported in Ethiopia	Sparsely branched, creeping and mat forming herb
G. zavattarii Lanza	Endemic in distribution around Mount Mega in Southern Ethiopia and Hari Hills of Northern Kenya	An erect, glandulous and predominantly shrub habit
G. arborescens L. Frcis.	Endemic to South West of Ethiopia and Imontong mountain on the border between Sudan and Uganda	A rare arboreal species

CROP IMPROVEMENT

Productivity of niger in India and Ethiopia are heterogeneous, indicating that the potential for yield increases through breeding and the programmes exist in both the countries. Large variation and high heritability were found for plant height and days to flowering. Both variability and heritability were lower for number of branches, number of flower heads, 1000-seed weight and seed yield. Breeding objectives for niger include increase in seed yield and oil content with reduced shattering.

Development of ideal plant types: Niger is a minor oilseed crop endowed with certain desirable characters.

Nevertheless, systematic work has not been done. This is because niger is a crop of developing countries where funds are scarce and continuous breeding efforts are not pursued. Further, niger is not mandated to any of the international institutes. For niger to be competitive with other crops, its seed yield must be significantly improved. To achieve this, dwarf types must be developed which have better seed set, uniform maturity resulting in reduced shattering losses. The Ethiopian collection contains short stature plants which could be used for the development of dwarf types. There is genetic variation for number of capitula that could be utilized to select single capitulam types. The presently used tall niger material has many leaves, high biomass and a low harvest index. Reducing plant height would decrease the number of leaves, inter-nodal distance and will result in better harvest index. The other objective for niger improvement is increasing the seed oil content. There exists a great genetic variability for oil content in Ethiopian and Indian collections which could be used to significantly increase oil content. An increase in oil content of 4-5 per cent appears to be feasible. The genetic improvement must be based on its pollination behaviour. Because of its self-incompatibility nature, breeding procedures used in the improvement of cross pollinating crops are the methods of choice for niger. The standard breeding procedure for cross pollinated crops is recurrent selection. The resulting varieties are open pollinated varieties. The pollination behaviour of niger is similar to that of sunflower. Thus, niger is also a candidate for hybrid development. The identification of genetic male sterility in India and recently in Ethiopia has opened the way for the exploitation of heterosis.

As modern high yielding, genetically uniform cultivars are grown, threats from diseases will increase which will require increased emphasis on resistance breeding. Wild species of the genus *Guizotia* could serve as sources for disease resistance genes which could be introgressed into the cultivated species. During the last few years modern techniques of doubled haploid and transformation are increasingly used. Protocols to regenerate plants from niger hypocotyls, cotyledon tissues and seedlings were developed. Plant regeneration was dependent on genotype and media composition. If niger is susceptible to *Agrobacterium tumefaciens* infection, then it will be a good candidate for gene transfer. Self-compatible lines, dwarf and single headed doubled haploid plants were indicated from anther culture. Anther and microspore derived dihaploids can be used to develop homozygous inbred lines. Recessive, simply inherited and easily identifiable marker traits which are important for niger to ensure genetic purity of varieties could be developed through microspore culture technology. Quality and marketing aspects influence breeding objectives. The confectionery market or the oil mills have different requirements. Seed size, shape, coat texture, colour and sweet taste are not so important to the oil industry; however these characters are essential for the confectionery which is increasing globally with the growing health concerns.

Development of inbred lines: Development of inbred lines and hybrid is a necessity along with the development of varieties, synthetics with high yield and consistency of performance across the different environmental conditions. Pollination in niger occurs primarily by insects and only to a limited extent by wind. Development of hybrids is one of the objectives of breeding, although improved open pollinated and synthetic varieties also have importance, especially tribal areas where hybrid is not feasible for economic reasons. Development of inbred lines is a difficult task and concrete efforts in this direction are required. The major point for hybrid development is inbred development. For development of inbreds, selection of best individual plant selections (IPS) from the population for the following characters are required 1) Higher number of branches/plant, 2) Higher number of flowers/capitula, 3) Higher number of capitula/plant, 4) Higher number of seeds/capitula, 5) Bold seed or high 1000-seed weight and 6) Higher seed yield. The seed of individual plants should be kept separately after threshing. The plant to progeny should be raised in isolation of location, space, time and pollinator barrier. The above procedure is to be repeated till fixation of the inbreds. Nema and Singh (1965) reported heritability ranging from 95.52 to 30.49 per cent for earliness and seed yield, respectively. Branching, number of capitula and number of seeds/capitula had moderate heritability. Phenotypic selection for capitula diameter, 1000-seed weight and oil content was found to be useful because of their higher heritability values. Nayakar (1976) observed high heritability for number of primary branches/plant, number of capitula/plant, 1000-seed weight and low heritability for yield/plant. Goyal and Kumar (1985) observed moderate to high estimates of heritability, genotypic and phenotypic coefficient of variation for various characters. Channarayappa (1987) reported high phenotypic variation for seed yield/plot, number of capitula/plant, plant height and moderate variation for number of seeds/capitulum, seed yield/plant, however, low variation for 1000-seed weight. Plant height had higher heritability and genetic advance. Mishra (1995) observed greater variability among days to 50 per cent flowering, plant height, number of branches/plant and number of seeds/capitulum. Borole and Patil (1997) reported low heritability for primary branches, moderate for seed yield/plant and high heritability for other characters. Patil (2000) studied 30 genotypes and observed substantial genetic variability for all characters. Positive correlation of seed yield with days to maturity and seeds/ capitulum was also observed. High heritability along with high genetic advance was observed for capitula/plant and plant height.

Self-incompatibility: Self-incompatible nature and exclusively entomophilous mode of pollination renders selfing a difficult process. High inbreeding depression upto 91 per cent is associated with poor seed setting with the generation advancement from S_3 onwards (Ramachandran and Menon, 1979). The outcrossing nature of *Guizotia* species can be inferred from the cross compatibility between various taxa that produces viable and fertile hybrids (Murthy *et al*., 1993; Dagne, 1994; 2001). However, direct evidence regarding self-incompatibility is available for *G. abyssinica* (Ramachandran and Menon, 1979; Riley and Belayneh, 1989; Nemomissa *et al*., 1999). Self- incompatibility in niger is of the sporophytic type that causes inhibition of pollen germination or twisting of pollen tube over the surface of the papillae (Prasad, 1990; Nemomissa *et al*., 1999). Self-compatible genotypes were also reported in low frequencies (up to 5%) in the Ethiopian gene pool (Getinet and Sharma, 1996; Nemomissa *et al*., 1999).

Several aspects of self-incompatibility have been compared in self and cross pollination experiments in which seed set was considered to be a measure of compatibility. Results indicated the presence of around ten self-incompatibility alleles and one self-compatibility allele at the S locus in niger. Most of these alleles behave differently in the pollen and pistil. About two thirds of the allelic interactions in both the pollen and pistil were dominant/recessive and one third was codominant. The reciprocal cross pollinations (RCPs) resulted in progeny with similar levels of compatibility within and among populations because of a wide distribution of S alleles in the populations and consequently, low population differentiation at the S locus. An analysis of molecular variance revealed that only 2% of the total genetic variation at the S-locus differentiates the populations.

During the flowering initiation, the selfing or sib mating is followed by covering two or more representative adjacent plants by muslin cloth bag or nylon mosquito net bags to exclude the insects. The shaking of bags or bagged plants is attended on alternate days to ensure pollination, the seeds within the bag will be S_0 for raising the S_1 generation. Shrivastava and Shomawanshi (1974) have suggested a procedure for crossing and to produce crossed seed and indicated that flowers from two plants to be rubbed together. However, rubbing the florets may result in some selfing. Thus, it may be preferable to attempt specific crosses by removing all the disc florets, just as the bud begins to open, however leaving the ray female florets intact. By bagging the emasculated capitula and pollinating the ray florets the next morning, when the stigma arms have opened, several crossed seed/capitulam can be obtained. In niger a very high amount of cross pollination, almost reaching to 100 per cent was obtained. Selfing with parchment paper bags reduced seed setting drastically to only 0.2 seed/capitulum as compared to 40-60 seeds in open pollination.

Anthesis takes place during 8.00 am and disc florets open up to 10.30 am during sunny days and upto 11.30 am during cooler days in Indian conditions. The number of capitula opening ranged from 2 to 5 with a flowering period of about 6 to 7 days. Seed set ranged from 0.10 to 2.11 per cent when bagging a capitulum; zero to 5.35 per cent when bagging two capitula; 3.33 to 10.16 per cent when bagging three capitula; zero to 1.415 per cent when bagging a single branch and 2.43 to 4.68 per cent when bagging a whole plant. This could be attributed to self-incompatibility in niger. Under open pollinated condition, per cent seed set ranged from 26.32 to 56.57 per cent with a mean of 42.59 per cent.

Maintenance of line is a problem because of self-incompatibility of the crop. However, sibbing of the collections can be carried out by covering 10 to 50 plants within a muslin bag or mosquito net to exclude insects and rubbing of flowering capitula together two to three times a week. Seed increase of advanced lines can be done in isolated plots, preferably one km away from other niger crop.

Inheritance of characters: Genetical studies on seed yield and yield component characters have been carried out which is summarized in the Table 2.

Based on these reports the niger breeders should exploit the additive gene action by following selection of characters for development of high yielding variety. For long term improvement of polygenic characters of both additive and non-additive gene action, population improvement and synthetic procedure may be followed.

Population improvement: In mass selection individual plants are selected for specific trait with high heritability of phenotypic appearance. Further, S_1 selection, half-sib progeny selection and full-sib progeny selection may be followed. Recurrent selection is reselection with intermating of selected plants to produce the population for the next cycle of selection. The idea was to ensure the isolation of superior inbreds. The isolation of an outstanding inbred line depends on two factors. The proportion of superior genotypes present in the base population from which lines are isolated and the effectiveness of selection during the inbreeding of desirable genes. A large number of plants (10,000-20,000) are selected from the open pollinated population. Seeds of selected plants analysed for oil content, husk per cent, etc. Finally about 1000-2000 plants are selected. A portion of seed from each selected plant is sown in the progeny testing nursery, one row/plant in two replications, every third row being a control. Progeny testing of plants, whose families performed well during first season, will be repeated during next season using remnant seed of selected plants. Remnant seeds of elite plants giving best families are sown in spatially isolated multiplication field during next season for crossing *inter se.* Each entry in controlled pollination is harvested and identity of individual plants maintained. After lab analysis, seed from selected plants is utilized in two ways (i) seeds from best plants retained for next breeding cycle, (ii) remaining seeds bulked family-wise to test in preliminary trials. Second cycle of selection is initiated using crossed seeds. Recurrent selection for SCA is performed using homozygous tester. A number of plants are selfed and at the same time crossed. The resultant hybrid is crossed and the test cross progenies are evaluated in replicated plots. The best progenies are recombined using remnant selfed seed of "I" composite. The best progenies are recombined using remnant selfed seed of "II" composite. The reconstitution of synthetic variety is exactly when parental lines are inbreds. But exact reconstitution is not possible in case of short term inbreds or open population variety. The above procedure is to be repeated till fixation of inbred. When the initiation of flowering takes place, the selfing or sib mating is done by covering two or more representative adjacent plants in a line by muslin cloth bag or nylon mosquito net bags to exclude the insects. The shaking of bags or bagged plants is practiced on alternate days to ensure pollination. At maturity, the seeds within the bag will be So for raising S_1 generation.

Table 2 Gene action for different traits based on heritability and genetic advance

Character	Gene action	Reference
Seed yield and yield attributes	Non-additive	Bilaiya (1987)
Plant height	Additive	Channarayappa (1987)
Capitula/plant, 1000-seed weight and days to flower	Additive	Bilaiya *et al.* (1992)
Seed yield and yield traits	Non-additive	Upadhyaya and Reddy (1997) Patil (2000) Patil and Duhoon (2007)
Capitula/plant and plant height	Additive	Nema and Singh (1965)
Seed yield and capitula/plant	Additive	Payasi *et al.* (1987)
Days to maturity	Non-additive	
Capitula/plant	Additive	Misra (1992)
Days to flower, maturity and plant height	Non-additive	
Seed yield and harvest index	Additive	Mathur and Gupta (1993)
Days to flower, maturity, protein and oil content	Non-additive	
Branches/plant and1000-seed weight	Additive	Patel *et al.* (1993)
Days to flower, branches/plant and seeds/capitula	Additive	Mishra (1995)
Days to flower, plant height and seeds/capitulum	Additive	Pradhan *et al*. (1995)
Secondary branches, seeds/ capitulum	Additive	Borole and Patil (1997)
Days to flower and maturity	Non-additive	
Plant height and capitula/plant	Additive	Patil (2000)
Seed yield, capsules/plant and seeds/ capitula	Additive	Sreedhar *et al.* (2005)
Days to maturity and 1000-seed weight	Non-additive	
Seed yield, branches/plant, capitula/plant, seeds/capitula and 1000-seed weight	Additive	Patil and Duhoon (2007)
Days to flower and maturity	Non-additive	
Plant height	Environment has major role	

Evaluation of inbreds for GCA: Inbred lines are evaluated for general combining ability. There are three methods *viz*., top cross, poly cross and single cross. In top cross, crosses are made between inbreds and tester or an open pollinated variety. This is also known as inbred - variety cross. In poly cross, selected inbreds are allowed to intermate by open pollination with a random sample of pollen from a number of selected lines. These lines are grown in same nursery. The lines are grown at random in a poly cross nursery with a minimum of ten replications. Free out crossing takes place and seed set on a line in replicates is pooled and the performance is tested. In third method, all possible crosses are made among selected inbreds each in isolation. The crosses are evaluated for general combining ability for yield or other desirable traits in replicated trials in comparison with check. The lines performing superior on the basis of GCA are selected as constituents of synthetic variety.

Production of synthetics: Synthetic variety may be produced in two ways: In method 1 equal amount of seeds from inbreds (Syn_0) are mixed and planted in isolation. Open pollination is allowed and it is assumed that it follow the random mating or crosses in all possible combinations. The seeds from this population are harvested in bulk. The population raised from this seed is known as Syn_1 generation. Evaluate lines for GCA and seed multiplied by open pollination in isolation. For seed multiplication, equal seed from all crosses composited. In second way all possible crosses among the selected lines are made in isolation. The parental lines constitute the Syn_0 generation. Equal amount of seed from all the crosses are mixed to produce the synthetic variety. Equal seed from all the crosses mixed to produce the synthetic variety (Syn_1) and seed multiplied by open pollination under isolation. The population derived from this mixed seed is known as the Syn_1 generation.

Multiplication of synthetics: After a synthetic variety is synthesized it is generally multiplied in isolation for one or more generations before it is distributed for cultivation. This is done to produce commercial quantities of seed as it is common practice. The open pollinated progeny received from Syn_1 is termed as Syn_2 that from Syn_2 as Syn_3, etc. The performance of Syn_2 is expected to be lower than Syn_1 due to the production new genotypes and decrease in the level of heterozygosity as a consequence of random mating. However, there will be no noticeable decline in the subsequent generations Syn_3, Syn_4, Syn_5, etc. because in one generation of random mating zygotic equilibrium for any gene is reached after one generation of random mating. The synthetic variety may be maintained by open pollination and further may be improved by population improvement schemes, particularly through recurrent selection.

The narrow genetic base is the main bottle neck for genetic improvement and extent of heterosis. However, using diverse parents in large number of crosses, variability can be generated and extent of heterosis can be exploited. For the future improvement of niger, hybrid and synthetic varieties are better options. From the agro-eco analysis of growing seasons it is evident that drought stress is an important factor limiting productivity in the major niger growing states. In addition one or the other biotic stresses especially diseases are causing significant recurring yield losses. Niger production in India continues to face challenges as the crop is often grown on marginal land which is inherently deficient in moisture and nutrients. The limited genetic variability in the working collections maintained and used in breeding has restricted the genetic advance.

Niger productions in Ethiopia are mainly based on local land race populations. Four improved varieties such as Sendafa, Fogera-1, Esete-1 and Kuyu were released by the Institute of Agricultural Research, Holetta Research Centre, Addis Abeba. In India, the niger breeding programme and seed production are stronger than in Ethiopia but the yield of niger are higher in Ethiopia than in India. On the basis of diversified climatic conditions in the regions of India, a total of 20 varieties with desirable characteristics have been released for cultivation in different states (Table 3 and 4).

Mutation breeding: Niger is highly cross pollinated due to the presence of twin mechanisms of protandry and self-incompatibility. However, these mechanisms were found to breakdown with the alteration in temperature. It has very small flowers (disk florets) arranged in a capitulum that opens on 3-4 consecutive days which poses problems for emasculation and pollination. Male sterile lines which are handy in heterosis breeding do seem to exist or at least reported. Induction of male sterile mutants artificially acquires significance. Mutations have been used to produce cultivars with improved economic value and to advance genetics and plant developmental phenomena (Fahad and Salim, 2009; Poornananda and Hosakatte, 2009). Mutations are employing fast neutron irradiation to develop new varieties (Sodkiewicz and Sodkiewicz, 1999) and is widely used for the induction of mutations resulting in increase in the yield of crops, including niger (Zhang *et al.*, 2002).

Quality breeding: The oil content of niger is variously reported as 29-39 per cent (Dutta *et al*., 1994), 30-35 per cent (Kandel and Porter, 2002) and 40-44 per cent (Dagne and Johnsson, 1997). Niger oil is good quality edible oil with pleasant nutty sweet taste. It is pale yellow in colour and may have bluish tinge. The raw oil has low acidity and can be used directly for cooking. Still, in some pockets of tribal hilly areas the niger oil is used for lighting purpose. The oil normally has poor shelf life and becomes rancid on storage. The oil contains 0.5 to 1.0 per cent unsaponifiables and 0.4 to 3.0 per cent free fatty acids. Vles and Gottenbos (1989) found niger oil rich in linoleic acid content which is nutritionally valuable and safe for human consumption. Dutta *et al*. (1994) reported that the Ethiopian niger seed oil contains more than 70 per cent linoleic acid, whereas, Dagne and Johnsson (1997) reported 66-69 per cent linoleic acid. In all the works so far done on the fatty acid composition of niger, linoleic acid is unequivocally the dominant fatty acid present in seed oil followed by palmitic, oleic and stearic acids (Dutta *et al*., 1994; Dagne and Johnsson, 1997; Ramadan and Morsel, 2003). The percentage of oleic acid in the Ethiopian niger seed oil was reported to be in the range of 6-11 per cent (Dutta *et al*., 1994) and 5.4-7.5 per cent (Dagne and Jonsson, 1997). It is indicated that the oil content and the fatty acid profile may vary depending on the origin of the material and the maturity level of the seed (Riley and Belayneh, 1989). The quality of oil and its suitability for a particular purpose, be it for human consumption and industrial use depends on the proportion of the different fatty acids. Oils where linoleic acid is the predominant fatty acid are reported to have poor shelf life, whereas those with high oleic acid content are more stable. Fujimato *et al*. (1990) also reported the medicinal properties of niger oil, beneficial to human being. The niger cake is dark in colour and contains 24 to 34 per cent protein, 4 to 14 per cent oil, 8 to 24 per cent crude fiber, 20 to 28 per cent sugars and 8 to 12 per cent ash.

Table 3 Characteristics of niger varieties of India

Variety	Recommended regions/areas (Area of adoption)	Days to maturity	Oil content (%)	Average yield (kg/ha)	Salient features
Madhya Pradesh					
Ootacamund	Whole Madhya Pradesh	95-105	36-38	500-550	Black seed
JNC-6	Madhya Pradesh, Bihar, Maharastra, Karnataka and Rajasthan	95-100	37-38	650-700	Shiny dark black seed
JNC-1	Madhya Pradesh, Maharastra, Bihar, Rajasthan and Karnataka	90-100	38-40	650-700	Black seed
JNS-9 (JNC-9)	All Niger growing states	95-100	38-40	650-700	Black seed. Tolerant to moisture stress
Maharastra					
IGP-76	Niger growing areas of Maharastra, Odisha, Gujarat, Tripura and Daman	95-105	36-39	600-650	Black seed
N-5	Maharashtra and Bihar	95-100	36-39	600-650	Small black and sickle shaped seed
IGPN-2004-1 (Phule Karala-1)	*Kharif* season in Maharastra and Karnataka (High rainfall areas of Maharashtra)	95-105	39-41	650-700	Shiny black seed. Tolerant to *Alternaria*, powdery mildew and root rot
Karnataka					
RCR-317	Karnataka	90-95	35-38	600-650	Black seed
No.71	Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu, Odisha and North East Hill region	95-105	36-38	500-600	Black bold seed
KBN-1	Karnataka	85-95	36-38	600-650	Black seed
RCR-18	Zone 1,2,3 and Karnataka	95-110	33-35	500-600	Shiny black seed
Odisha					
GA-10	Odisha (Tribal areas)	110-115	39-41	600-650	Dark black seed
Utkal Niger-150	Odisha	105-110	38-40	650-700	Black seed. Tolerant to *Alternaria* and *Cercospora*
Jharkhand					
Birsa Niger-1	Uplands of Bihar and Madhya Pradesh	95-100	36 -38	550-600	Light black seed
Birsa Niger-2 (BNS-8)	All niger growing states	95-100	35-38	600-650	Black seed
BNS-10 (Pooja-1)	All niger growing states	95-100	36-38	650-700	Shiny black seed
Tamil Nadu					
Paiyur-1	Tamil Nadu (Hilly region)	90-95	35-38	600-650	Black seed
Gujarat					
Gujarat Niger - 1	Gujarat	95-100	35-38	600-650	Black seed
NRS-96-1	All niger growing states	90-95	35-38	650-700	Black seed

Table 4 Characteristics of niger varieties of Ethiopia

Variety	Maturity (days)	Plant height (cm)	Average yield (kg/ha)	Oil content (%)
Sendafa	145	133	780	40
Fogera-1	146	138	820	41
Esete-1	146	139	830	39
Kuyu	138	131	1060	41

Resistance to insect pests and diseases: Development of varieties resistant to insect pests and diseases is also an important aspect. So far there is not much work is carried out on this aspect. However, the efforts in this direction are needed for development of resistant varieties. During the evolutionary process, niger has evolved more for survival, fitness and tolerance to stresses rather than for high seed yield. The crop is mainly grown under marginal and submarginal conditions with poor management and also subjected to vagaries of nature, which adversely affect the crop yield. However, niger survives over a wide range of conditions and adjusts with change that may occur in its surroundings due to various kinds of stresses. Different promising lines have been identified, which may be utilized in resistance breeding programme for the development of tolerant lines against major pest and diseases of niger (Table 5).

Table 5 Tolerant lines identified for different diseases and insect pests

Disease/ Insect pests	Tolerant lines
Cercospora	JN-13, JN-106, JN-107, JN-112, JN-118, JN-128, JN-130, JNS-9, PCU-45, PCU-46, N-24, N-128, AJSR-48, ONS-157
Alternaria	RCR-328, JN-121, N-17, N-18, N-24, N-87, N-128, N-141, N-142, N-165, N-187, AJSR-47, AJSR-48
Powdery mildew	KEC-6, RCR-238, RCR-290, JN-17, JN-19, JN-20, JN-21, JN-37, JN-60, JN-68, JN-72, JN-77, JN-78, JN-85, JN-86, JN-87
Aphids and flea beetle	JNS-14
Capsule fly	N-10, N-116, N-126, N-133, N-142, N-144

Biotechnological approaches for niger improvement: Biotechnology is being used to address problems of agricultural production and processing. This includes breeding to raise and stabilize yield, to improve resistance to insect pests, diseases and abiotic stresses and to enhance the nutritional content. Simmonds and Keller (1986) developed plant regeneration protocol of niger from leaf tissue. Efforts to develop dihaploids from ovule culture were unsuccessful. During the last few years modern techniques of plant tissue culture, doubled haploid technology and transformation are used. Protocols to regenerate plants from niger hypocotyl, cotyledon tissues and seedlings were developed (Sarvesh *et al*., 1993b; 1994a). Plant regeneration was dependent on genotypic and media composition. Dihaploid plant of niger have been reported by anther culture (Sarvesh *et al*., 1993a; 1994b). Murthy *et al*. (2003) developed a protocol for *Agrobacterium* mediated genetic transformation of niger using hypocotyl and cotyledon explants. Dempewolf *et al*. (2010) developed a library of expressed sequence tags, microsatellite loci and the sequencing of its chloroplast genome for establishing genomic tools and resources for *Guizotia abyssinica* from Ethiopia.

In vitro technology application depends on the plant regeneration system. Niger has been subjected to numerous cell tissue culture studies. Regeneration has been reported for cotyledons and hypocotyl (Ganapathi and Nataraja, 1993; Nikam and Shitole, 1993; 1997), leaves (Sujatha, 1997; Jadimath *et al*., 1998; Kumar *et al*., 2000) and seedling explants (Nikam and Shitole, 1997). Establishment of embryogenic suspension cultures has potential for *in vitro* selection of variants especially selection of salt tolerance, disease resistance, cold tolerance lines. Homozygous lines obtained through anther and microspore culture would be used for crop improvement (Tiwari *et al*., 2011). Induction of embryogenesis from cultured anthers and plant regeneration from unpollinated ovule cultures has been reported in niger (Bhat and Murthy, 2007; 2008). Nikam and Shitole (1993) obtained multiple shoot formation from root tips cultured. Sarvesh *et al*. (1994a) regenerated 150 plants from enbryogenic callus of the genotype. Simmonds and Keller (1986) indicated that the homozygous diploids can be obtained in a single generation by anther culture. These fertile homozygous plants can be used for selection of desirable recombinants. In highly heterozygous cross pollinating crops, haploidy creates a rapid method of producing pure lines which can serve as parents in hybrid development. Because homozygous lines can be generated rapidly; a saving of time up to 50 per cent can be achieved in developing new cultivars. Simmonds and Keller (1986) identified a number of factors, which influence embryo/ callus formation from gameotophytic cell and they are donor plant physiology, developmental stage of gametophytic cells, pretreatment of gametophytic cells, culture medium composition, physical factors, culture environment and donor genotype. The micropropagation method also has potential application for niger breeding, cell selection for desirable mutants and genetic transformation.

CROP PRODUCTION

Niger is a short day plant and does not flower when the day length is more than 12 hours. After the induction of flowering, however, it would continue to produce flowers even if it is subjected to longer duration of daylight. The Ethiopian niger requires an optimum of 18°C day time temperature and 13°C night time temperature (Getinet and Sharma, 1996). In India niger is mainly grown in *kharif,* but it can be successfully grown in semi *rabi* and late *kharif* seasons with limited irrigation (Ranganatha *et al.,* 2011c). However, it is a winter loving crop and high yield are obtained in semi *rabi* season with protective irrigation. Being exclusively a rainfed crop, niger is grown with the onset of monsoon. The optimum sowing time is middle of July to early August for *kharif* crop and September for semi *rabi* crop (Ranganatha *et al.,* 2014). In Ethiopia there are three types of niger grown that are differentiated based on the duration to maturity. These are the early maturing type called Bunigne, a late maturing type called Abat and a frost resistant type called Mesno. In Ethiopia the sowing date differs depending on the maturity types. The Abat type is sown in mid May to early June, Bunigne in July and Mesno niger in September. All the three maturity groups flower when the day length is shortened and harvested in October (Bunigne), December (Abat) and February (Mesno). The optimum seed rate varies from 5-10 kg/ha and 5-8 kg/ha for the Indian and Ethiopian niger, respectively. Altitudinal variations of the growing areas of niger in Ethiopia range for the most part from 1600-2200 msl (Getinet and Sharma, 1996).

In India, niger is grown as a mixed crop with various pulses and other crops including millets in different states (Ranganatha and Pandey, 2012; Ranganatha *et al.,* 2013). However, the seed yield of sole crop is higher than that of intercropping. Intercropping systems have been found profitable and feasible in certain situations. However in Ethiopia, niger is cultivated in rotation with cereal crops like teff. It is reported that the cereals that follow niger in cultivation perform better with reduced infestation by weeds (Getinet and Sharma, 1996).

Niger is an important component of several sequential and intercropping system of India. The most common are as follow: Madhya Pradesh/Chhattisgarh- Early Black gram - Niger; Maharashtra- Little millet/Finger millet - Niger, Horse gram - Niger; Odisha- Common millet (*Panicum miliaceum*) - Niger, Little millet (*Panicum miliare*) - Niger, Early Finger millet-Niger, French bean - Niger. Inter cropping in Madhya Pradesh - Niger + Kodo/Kutki/Pearl millet/Greengram (2:2); Maharashtra - Niger + Finger millet/Horsegram/Rice bean (2:2 or 4:2), Niger + Finger millet/Little millet (2:4 or 3:6), Niger + Pearl millet/Groundnut (3:3); Odisha - Niger + Finger millet/Blackgram (2:2 or 4:2), Niger + Ricebean/Cowpea/ French bean (4:2); Bihar - Niger + Finger millet/Blackgram (2:2), Niger + Redgram (3:2), Niger + Rice bean (4:2); Andhra Pradesh - Niger + Cowpea (4:2); Karnataka - Niger + Finger millet (1:1).

It is also reported that an exudate from niger inhibits the growth of monocotyledonous weeds. Niger is tolerant to water logging and often grown in marginal areas with little or no fertilizer requirement (Almaw and Teklewold, 1995). The tolerance to water logging is due to the development of extensive aerenchyma when the plants are subjected to repeated water logging conditions (Getinet and Sharma, 1996; Petros, 1998). It is also reported that nitrogen fertilizers generally increase vegetative growth but do not increase the seed yield of niger (Almaw and Teklewold, 1995). Niger is adapted to a wide range of soil types from sandy, sandy loam, clay loam and gravely soil, however it thrives best on well drained, loamy soils of good depth and texture with pH range of 5.5 to 7. It can withstand slight alkalinity and salinity also. Heavy clay and black cotton soils are not suitable for high yield (Ranganatha *et al*., 2014). Farmers prefer particular varieties in different states for their popularity on the basis of the desirable traits *viz.*, seed colour, adaptability, resistance to biotic and abiotic stresses and higher market prices.

Among the four improved varieties of niger (Sendafa, Fogera, Esete and Kuyu) released in Ethiopia, Kuyu is a higher yielding variety both in terms of seed yield (1060 kg/ha) and oil content (41%). It also possesses desirable qualities like earliness and short stature. The future research of niger should make the selection for self-compatible lines with little inbreeding depression to minimize problem of low seed setting and development of hybrid varieties with desirable qualities is priority (Getinet and Sharma, 1996).

Weed management: Weeds are the major constraints in realizing the optimum yield of niger (Ranganatha *et al*., 2011a). The crop is generally sown as broadcast with the result weeding becomes difficult and interculture operations are not possible. The important weeds in niger crop are *Celosia argents, Corchorus* spp., *Commelina benghalensis, C. communis, Ageratum conyzoides, Hibiscus* sp., *Eclipta alba,* etc among broad leaved, *Echinochioa colonum, E. crusgalli, Cynodon dactylon, Setaria glauca, Digitaria sanguinalis,* etc., among grasses and *Cyperus rotundus*. Deshmukh *et al*. (2013) found that normal sowing of seed with one hand weeding at 15-30 days after sowing (DAS) followed by vegetative mulching proved significantly superior over normal sowing followed by two hand weedings at 15 and 30 DAS with regard to seed yield and net monetary returns (NMR). It produced seed yield of 650 kg/ha with NMR of ₹ 5214/ha and B:C ratio of 1.6 against normal sowing with seed yield of 541 kg/ha fetching NMR of ₹ 2942/ha and B:C ratio of 1.37. Other moisture conservation practices *viz.*, normal sowing with one hand weeding at 15 DAS followed by saw dust mulching or soil stirring also proved equally effective to farmers practice with regard to seed yield and monetary returns.

Seed production: Niger being a cross pollinated crop, it is difficult to maintain the genetic purity without adopting appropriate isolation distance. The identification of improved varieties of niger through diagnostic morphological characters is very difficult for seed production and certification personnel. In niger, the breeder seed is always surplus but always short of certified seed for farmers. The seed demands of niger are erratic due to tropical climatic condition. Delay in the onset of monsoon and low rainfall distribution are the two important factors which determine the seed demand in the niger growing areas. It is very difficult to meet such sudden seed demand unless governments have a buffer stock to meet the contingency. The seed multiplication is relatively easy due to high seed multiplication ratio to the extent of 200.

The commercial crop growing areas may not necessarily be suitable for seed production due to parallel build up of diseases and pests. The seed production shall be undertaken in the areas where the environment allows full expression of the diagnostic characters, facilities for protective irrigation, the productivity and seed quality is high. Cuscuta weed is the major menace for seed production. The areas for seed production have to be essentially free from cuscuta problem. The suitable areas for seed production are Vishakhapatnam and Ranga Reddy districts in Andhra Pradesh; Singhbhun, Dumka and Ranchi in Bihar; Chitradurga, Tumkur and Bangalore Rural in Karnataka; Sidhi, Narsingpur, Vidisha, Khandwa and Shivpuri in Madhya Pradesh; Bilaspur in Chhattisgarh; Solapur, Ratanagiri, Nasik and Latur in Maharashtra; Malakangiri, Koraput, Kalahandi and Navrangpur in Odisha.

Niger is mainly grown in *kharif* and the optimum sowing time is middle of July and continues to early August for *kharif* crop and ideal for September for semi *rabi* crop (Ranganatha *et al*., 2011b). Appropriate sowing period for different states; Madhya Pradesh and Chhattisgarh, third week of July to second week of August; Maharashtra, July and continue to early September; Odisha, second fortnight of August to first week of September; Bihar/Jharkhand, Second fortnight of August to first week of September; Andhra Pradesh, Second week of August; Gujarat and Karnataka, July to August. To protect the crop from seed and soil borne pathogens, seed should be treated with thiram or captan 3 g/kg seed before sowing. The line sowing has been recommended. Seeds are mixed with sand/powdered FYM/ash to increase the bulk, 20 times to ensure even distribution of seed. Seed should be sown 2-3 cm deep depending upon soil type and moisture. Seed bed temperature of 15-22°C is optimum. Temperature below 10°C and above 35°C impair germination. To obtain optimum yield, appropriate spacing is 30 to 45 cm between rows and 10 to 30 cm within a row. To maintain optimum plant population, thinning is recommended to remove extra plants after two weeks of sowing. Niger has shown good response to fertilizer application. Application of recommended N through urea + seed treatment with PSB 10 g/kg seed enhances yield significantly. Application of sulphur 20-30 kg/ha increases seed yield and oil content. Madhya Pradesh, 10 kg N + 20 kg P_2O_5/ha at sowing and 10 kg N/ha at 35 days after sowing; Maharashtra, four tonnes of FYM and 20 kg N/ha at sowing; Odisha, 20 kg N + 40 kg P_2O_5/ha at sowing and remaining 20 kg N/ha at 30 days after sowing; Bihar/Jharkhand, 20 kg N +20 kg P_2O_5 + 20 kg K_2O + 15 kg $ZnSO_4$ as basal; Andhra Pradesh, five tonnes of FYM and 10 kg N/ha at sowing; Karnataka, 20 kg N + 20-40 kg P_2O_5 + 10 kg K_2O/ha at sowing. Further organic, bio fertilizers and micronutrients are suggested for better seed set, higher yield with superior seed quality (Deshmukh *et al*., 2009). In Odisha, *Cuscuta* (*C. hyalina*/*C. chinensis*) infestation has become a major problem. Seed should be obtained from *Cuscuta* free areas and if the *Cuscuta* seed is found mixed with niger seed, sowing should be done after separation by sieving with a 1 mm sieve. Niger is generally produced in rainy season. Moisture stress adversely affects plant stand and growth of the plant. Protective irrigation helps in plant stand establishment and results in good yield. For semi-*rabi* seed production crop, two need based irrigations, one at flowering and other at seed filling stage give higher seed production yield. Field experiments were conducted on niger cv. JNC-1 in clay loam soils of Jabalpur during *rabi* seasons of 2007 and 2008 to determine the appropriate nutrient management for improving the productivity and monetary returns. Results revealed that application of 40 kg N + 20 kg P_2O_5 through SSP + 5 kg PSB/ha proved to be highly efficient with seed yield of 557 kg/ha with net monetary returns and benefit cost ratio of ₹ 9320/ha and 2.26, respectively (Deshmukh *et al*., 2012).

Isolation: Niger being cross a pollinated crop with self-incompatibility mechanism it is difficult to maintain the genetic purity without adopting appropriate isolation distance (Ranganatha *et al*., 2012a). An isolation distance of 1000 m is recommended for nucleus, breeder and the foundation stages of seed production, whereas 500 m for certified stage production and should be rigorously followed to produce genetically pure quality seed.

Rouging: Rouging should be done strictly to remove all the off-type plants, which exhibit variation from the parental variety. The plants infested by diseases and pests especially by *Cuscuta* weed, should be removed. The field should be inspected thoroughly at seedling, vegetative, flowering and maturity stages by monitoring team consisting of experts. Niger being cross pollinated crop, it is difficult to obtain the genetic purity without following appropriate isolation.

Seed village: Presently two seed production systems are operational in the country. The formal system is being operated through public sector agencies like NSC, SSC, SAU and Oil Federations, etc. The seed multiplication ratio in this system is extremely poor. The main advantage of this system is that the identity, genetic purity, quality and source of the seed are known to the farmers. The informal system includes multiplication of varieties by private growers or individual farmers and sharing the seed by the farmers. The seed of most of niger varieties under cultivation is being produced and supplied through this system. The main disadvantage of this system is that the identity, genetic purity, quality and source of the seed is not authenticated. However, the seed produced through this system is less expensive and easily available to the farmers.

The existing formal system of seed production had been hardly sufficient to cope up with the seed requirement. The possibility of improving the supply of quality seed in crops like niger through the formal system in near future appears not to be so bright. Therefore, in this crop, alternative system of seed supply may prove worthy for fulfillment of the requirement. In the direct supply limitations both of the formal and informal systems of seed supply are taken care. To overcome the limitations of the prevalent informal system and the existing formal seed supply system, the seed production can be undertaken by the research institutes and distributed through farmer fairs/field days/sale counters. The direct supply is also feasible and will be more effective in view of the advantages. This system has been successful to a certain extent to cover the maximum possible area under quality seed of improved varieties.

Another option to augment the seed supply in niger is seed village. The institutes can choose a single variety and produce seed sufficient to cover entire village with the single variety. The seed village should grow only one variety. The local or other varieties should not be grown in the seed village. Combining together the programme of demonstrations and seed village will prove synergistic for the improvement of seed replacement rate. A variety recommended for a state is available but not in use: Madhya

Pradesh - JNC-1, JNC-6, JNC-9; Maharastra- IGP-76, IGPN-2004-1, N-5, JNC-6, JNC-9; Jharkhand- Birsa Niger-1, Birsa Niger-2 (BNS-8), BNS-10; Gujarat- Gujarat Niger-1, NRS-96-1; Karnataka- KBN-1, RCR-18, DNS-4; Orissa- GA-10, Utkal Niger-150. There is need to integrate the breeding programmes with the potential seed growers so that the farmers can get the benefit of improved varieties in a shorter period. Hence, seed growers associations should be established on regional basis with the following objectives; to develop the effective local supply systems for quality seed, to increase the availability of quality seed of improved varieties and rapid multiplication of recently developed varieties through conscious seed production.

Maintenance breeding and nucleus seed production: Nucleus seed is genetically pure and directly used for multiplication as breeder seed. It is essential to have true to type pure seed. The measures to maintain the purity during seed production are preceding crop, proper isolation distance, rigorous rouging, monitoring by a team and control of mechanical mixtures (Ranganatha and Rao, 1998). The specific steps for the production of niger seed are as follows: Grow in isolation of 1000 m, at least 20,000 original population of a variety with full package of practices. Select 2000 representative plants from the original population to maintain original genetic constitution and to avoid genetic drift. Harvest and thresh the selected single plants separately. Examine seed colour, shape and size etc and reject the seeds of those plants, which are not true representative of a variety. Make two parts of seed from each of the selected plants. One part of the seed is to be used for evaluation in plant to progeny rows and the remaining part is kept for the remnant nucleus bulk of the plants finally selected on the basis of progeny rows evaluation results. Grow the selected single plant progenies (SPPs) in blocks. Each block must contain 50 SPPs (one row each of 4m length) along with 2 rows of parental variety in each block to be used for comparison. Examine the progeny rows periodically and compare the characters of SPPs with parental variety critically with respect to seedling vigor, leaf characteristics, plant height, branching, angle of branching, days to 50 per cent flowering, capitula/plant, seeds/capitulum, 1000-seed weight etc. Remove all the off-type plants as and when detected and reject the progenies which exhibits variation from the parental lines. Complete monitoring inspection of nucleus seed production by a team. The progenies which meet all the standards mentioned in the descriptor (true to type) and give higher yield than the population mean ± SE are identified for producing the nucleus bulk. The reserve part of the seed of all the progenies so identified is bulked as the nucleus seed. This completes one cycle of the nucleus seed production. Test, if possible, the oil content of the progenies and further discard the progenies, which are out side the range of the variety. This process may be followed at least once in 2-3 cycles. Follow the grow out test to ascertain the genetic purity. The nucleus seed with 100 per cent genetic purity is further multiplied for the production of breeder seed.

Since in cross pollinated crops like niger, a breeder has to select a large number of plants so that the gene pool is properly represented, the above procedure become very laborious and difficult to practice. For all practical purposes, the breeders generally select a large number of true to the type plants from the central part of the breeder seed production plot and bulk the seed of the selected plants to use as nucleus seed.

Breeder and other classes seed production: The production practices for the breeder, foundation and certified seed are the same as outlined. Grow at least five border rows of genetically pure seed of the same variety. Maintain a minimum isolation distance of 1000 m for breeder and foundation stages and 500 m for certified seed and strictly avoid time isolation. Do not spray any insecticide during flowering stage as it will kill the pollinators and thereby reduce the seed yield. In case it is warranted, spray selective insecticide in the evening. Harvest and stack the bundles for sun drying on a clean threshing floor. A considerable care is required in harvesting and threshing to prevent mechanical mixtures and weed seeds. Report the periodical information of breeder seed production in various proforma.

Seed certification standards: Physical purity (%) for both Foundation (FS) and Certified Seed (CS) is 98; Inert matter (%) for the both FS and CS is 2; Other Distinguishing Varieties (Max. No./kg) for FS is 10 and for CS is 20; Other crop seeds (Max. No./kg) for FS is 10 and for CS is 20; Total weed seeds (Max. No./kg) for FS is 10 and for CS is 20; Minimum Germination (%) for both FS and CS is 80; Moisture (%) (a) Ordinary Container for both FS and CS is 9, (b) Waterproof Container for both FS and CS is 5. Field standards: Minimum inspection for both FS and CS is 3; Different plants (%) for FS is 0.10 and for CS is 0.20; Off-types (%) for FS is 0.10 and for CS is 0.20; Seed borne diseases for FS is 0.05 and for CS is 0.10.

Problems in seed production: The self-incompatibility makes the maintenance of the single plant progenies at nucleus seed production stage very difficult so as to ascertain the purity of source seed. Under optimum conditions of fertilization, niger tends to lodge because of its soft hollow stem which adversely affect the seed production. Niger is completely cross pollinated on account of sporophytic self-incompatibility. The pollination is exclusively entomophyllous which increases the chances of out crossing, hence inadequate isolation reduces quality of seed. Cuscuta weed is a menace in niger seed production. Initially the weed spread through seed contamination and soon becomes soil borne if not controlled effectively. Once the weed becomes soil borne it is very difficult to control it and the whole area becomes unsuitable. Timely lifting and/or non-lifting of seed has been a problem discouraging the seed production (Patil *et al.*, 2012).

Maintenance of genetic purity: Niger is completely out crossing with pollination exclusively by insects which itself is a big problem in the maintenance of genetic purity (Ranganatha *et al.*, 2012b). Niger is highly prone to mechanical mixture due to its very light, small seed and shattering habit which is another factor to affect genetic purity. Therefore, great care is to be taken to avoid mechanical mixture at all the stages from seedling to final processing of seed. Following precautionary measures shall be taken to maintain the genetic purity. Use source seed with 100% genetic purity and restrict selection of only true to the type plants. Any selection will change the gene frequencies in the original population and consequently the identity of the variety. Apply phorate 10 G @ 10 kg/ha (soil incorporation) and also put a line of insecticide around the seed plot to control seed removal by ants. Follow strict rouging at vegetative and flower initiation stages by the team. Take utmost care to clean threshing sheets/bags/containers/equipments used in sowing, harvesting, threshing and processing operations.

Grow out test: The grow out test is conducted in the area where crop can express the maximum characters without any variation. Take a sample of 100 g from the seed lot to estimate the genetic purity of the seed on the basis of morphological characters. Grow 800 plants of the submitted sample *vis-a-vis* the same population of authentic sample under recommended practices. The submitted sample for grow out test is drawn simultaneously with the samples for other tests. The permissible limit of off-types in niger is 0.5 per cent. Make a comparison at all the stages according to the expression of the characters. Examine each and every plant throughout the growing season with emphasis on the marker characters and time of their expression. Tag the off-types and count the total population along with off-types. Reject or accept the sample as per the prescribed standards. Niger has orthodox seed storage behavior and when properly dried can be stored for 2 to 3 years under ordinary conditions without losing viability. The seed multiplication ratio in niger is high and the seed rate is very low. Consequently the actual requirements for quality seed are very low. Large scale nucleus and breeder seed production shall be taken up in favourable seasons, irrespective of indents. The excess seed produced can be kept as buffer stock. It will cover the risk of crop failures and will maintain regularity in seed chain. On account of the nominal charges for seed storage, this will also be cost effective compared to the annual seed production. It will also avoid risk of genetic drift and varietal deterioration due to mechanical mixture, lack of proper isolation distance etc. Besides, the existing weakness in seed chain at foundation and certified stages, the surplus seed can also be directly distributed to the farmers. Estimated requirements of the quality seed in India: Nucleus seed- 0.15q, 0.03ha; breeder seed-10.5q, 2.0 ha; foundation seed-375.0 q, 80.0 ha; certified seed - 20000.0q, 4000.0 ha area.

CROP PROTECTION

Insect pests, diseases and weeds impose a serious threat to niger crop production (Srivastava *et al*., 2009). Niger is a crop of dry areas grown mostly by tribals in interior places due to which desired attention was not accorded on the biotic and abiotic stresses. The crop is gaining importance and studies are being made on insect pests and disease (Rajpurohit, 2011).

Insect pests: Number of insect pests have been recorded on niger of which seven are major ones and others are of minor importance. Grasshoppers, *Pyrgomorpha bispinosa-conica* and *Chrotogonous trachypterus* were found damaging seedlings. Niger caterpillar, *Condica conducta;* green semilooper, *Thysanoplusia orichalcea;* niger green bug, *Taylorilygus pallidulus* and *Spodoptera litura* cause damage to crop from seedling stage till harvest. Tobacco caterpillar, *Helicoverpa armigera* and niger capsule fly, *Dioxyna sororcula* appear from vegetative stage with peak population during flowering stage. The yield losses due to various pests range from 10 to 40 per cent.

Niger caterpillars are green with purple markings, feed on leaves and defoliates. For management: use 40-50 bird perches/ha; apply phorate 10G @ 10 kg/ha as basal application; spray NSKE 5% or neem based insecticide (Nimbecidine 5 ml/l); two sprays of chlorpyriphos 20 EC @1.5 ml/l or quinalphos 25 EC @1.5 ml/l or triazophos 40 EC @1 ml/l. Niger capsule fly maggots feed on seed and pulp inside the capitula. For management: install light trap one per ha; spray quinalphos 25 EC @1.5 ml/l or acephate 75 SP @1.5g/l. Cutworms (*Agrotis ipsilon*) moth hides under dried twigs during day time and lay eggs on leaves. Larvae attack the plants at ground level. For management: keep grass bundles or crop refuge in cluster in field for the caterpillars to hide during evening and collect the caterpillars early in the morning and kill; crop rotation; apply phorate 10 G @10 kg/ha as basal application; spray NSKE 5% or neem based insecticide; two sprays of chlorpyriphos 20 EC@ 1.5 ml/l or quinalphos 25 EC @1.5 ml/l. Bihar hairy caterpillar (*Spilosoma obliqua*) remain gregarious underneath leaves in early stages and cause serious loss in yield at third and fourth instar. For management: collection and destruction of egg masses and early instars of caterpillars; spray NSKE 5% or neem based insecticide (Nimbecidine 5 ml/l); two spraying of any one of the insecticides chlorpyriphos 20 EC @ 1.5 ml/l or triazophos 40 EC @1 ml/l or quinalphos 25 EC @ 1.5 ml/l or acephate 75 SP @1.5 g/l or indoxacarb 15.8 EC @ 0.5 ml/l. Semilooper (*Plusia orichalcea*) feeds on the leaves and defoliates. Control as in case of hairy caterpillar. For management of aphids (*Uroleucon carthami*), spray NSKE 5% or neem based insecticide; spray crop at bud initiation stage with dimethoate 30 EC @1.5ml/l or quinalphos 25 EC @1.5 ml/l or triazophos 40EC @ 1 ml/l or imidacloprid 17.8% SL @ 0.25ml/l. Surface grasshopper (*Chrotogonus* sp.) usually active in early stage of the crop; dusting with phosalone 4% or malathion 5% dust @ 25 kg/ha can control the pest.

Diseases: Niger crop suffers from relatively less number of diseases. However, the important diseases are Cercospora leaf spot (*Cercospora guizoticola*), powdery mildew (*Sphaerotheca* sp.), *Alternaria* blight (*Alternaria* sp.), Ozonium wilt (*Ozonium texanum* var. *parasiticum*), collar rot (*Sclerotium rolfsii*), *Macrophomina* rot and blight (*Macrophomina phaseiolina*); Damping off (*Rhizoctonia solani*), Rust (*Puccinia guizotiae*); Bacterial leaf spot (*Xanthomonas campestris* pv. *guizotiae*) and *Cuscuta* as *Phanerogamic parasite* (Kolte, 1985). Cercospora disease is prevalent in all the niger growing areas and causes yield reduction. The disease is severe under warm and humid weather (Rajpurohit, 2011). Disease appears as small straw to brown coloured spots with gray centre on the leaves, spots may coalesce causing defoliation. Seed treatment with thiram (0.2%) + carbendazim 50WP (0.1%) and two foliar sprays with carbendazim 50WP (0.1%) + mancozeb (0.25%) can manage the disease. *Alternaria* spots are brown to black with concentric rings. Use of resistant varieties like JNC-6, IGP-76, Deomali, GA-11, ONS-8 (Hegde, 2005), seed treatment with thiram (0.2%) + carbendazim 50WP (0.1%) and spray with mancozeb (0.25%) + carbendazim 50WP (0.1%) at 15 days interval, two sprays with zineb or dithane M-45 (0.3%), spraying mancozeb (0.2%) at 15 days interval as the disease starts appearing can effectively manage the disease (Saharan *et al.*, 2005). The powdery mildew is caused by *Sphaerotheca* sp. in Ethiopia whereas, it is known to be caused by *Oidium* sp. (*Erysiphe cichoracearum* DC) in India. The disease occurs in *rabi* as well as *kharif* season but it is more severe in *rabi*. Small powdery spots appear on leaves, which gradually spread on the lamina and stem resulting in defoliation. Foliar spray of wettable sulphur (0.2%) or carbendazim (0.1%) or karathane (0.1%) reported effective against the disease. *Macrophomina* infected roots are light blackish to black in colour, which are covered with black sclerotia and are brittle. The blackening extends from ground level upward on the stem giving black colour to stem. The recurrence of the disease takes place through seed and soil borne inoculum, later spread is through workers, tools and insects. Deep ploughing in summer, crop rotation, seed treatment with thiram (0.2%) + carbendazim (0.1%), application of *Trichoderma viride* @ 2.5 kg/ha mixing with 50 kg FYM in the field before sowing can effectively manage the disease.

Collar rot (*Sclerotium rolfsii* Sacc.) first reported from Dharwad, Karnataka (Siddarmaiah *et al.*, 1979). The tissues of collar region become soft and depressed. White fungus grows on the diseased part and forms mustard seed like sclerotia. The diseased plants turn yellow and dry. Damping off (*Rhizoctonia solani*), the fungus attacks stem of the seedling at ground level, makes water soaked soft and incapable of supporting the seedling which falls over and dies. On older seedling elongated brownish black lesions appear which increase in length and width girdling the stem and causing root rot which are black and brittle. The disease is favoured by cold and wet weather. The disease can also be reduced by drenching the plants with captan 50WP @ 0.25 per cent.

Cuscuta weed (*Cuscuta chinensis* / *C. hyalina*): Dodder a parasitic weed is the major menace of niger in some parts of the country like Odisha, Andhra Pradesh and parts of Madhya Pradesh (Tosh *et al.*, 1977). Infested plants are stunted, pale yellow with small flowers. Hand weeding at 15 days after sowing (DAS) and if necessary, second weeding at 30 DAS (before top dressing of nitrogen) is effective. Taking short duration crops such as cowpea and French bean before niger may exhaust weed seed bank in the soil resulting in less weed population. The *Cuscuta* is managed by using the niger seed *Cuscuta* free areas or it should be thoroughly cleaned before sowing (Ranganatha *et al.*, 2014). *Cuscuta* seed can be separated from niger seeds by sieving with 1 mm sieve + 10 brine solution seed treatment. Tosh *et al.* (1977) reported that chlorpropham as granular formulation at 4.0 kg/ha at 6 days after sowing and pronamide at 2.0 kg/ha at 20 DAS selectively controlled *Cuscuta* infestation without any phytotoxic effect in niger. Similarly pendimethalin (1.0-1.5 kg/ha) was found effective in controlling *Cuscuta* in niger. Application of thiobencarb at 0.75 kg/ha and anilofos at 0.50 kg/ha significantly reduced the weed dry matter and increased the seed yield of niger. When this herbicides were integrated with hand weeding at 30 or 45 DAS, seed yield were substantially increased. Pre-emergence application of oxadiazon @ 0.75 kg/ha, pendimethalin @ 1.0 kg/ha and alachlor@ 1.0 kg/ha was found effective in controlling weeds and increasing seed yield.

Abiotic stresses: Niger is generally planted as a rainfed crop in *kharif* as well as *rabi* seasons. The niger plant has a deep root system which endows it with high degree of drought resistance in deep soils. The plant has the potential to tolerate physical and physiological moisture stress of the soil and at the same time possess the ability to thrive on poor soil. A rainfall between 500-800 mm is optimum, but a well distributed rainfall of 400 mm will produce a good seed yield. The growth of niger may be depressed with a rainfall over 2000 mm, but the plant can withstand high rainfall during the vegetative phase. On account of this, niger is suitable crop for hill regions of high rainfall and humidity.

Niger is capable of growing better in waterlogged conditions. Niger roots show exceptional resistance to water logging due to the existence of acrenchyma, which varies with the degree of soil saturation. Moderate temperature between 18 and 30°C suits to the niger plant, but the rate of growth and flowering are adversely affected by temperature above 30°C causing forced maturity. On the lower side, temperature below 9°C adversely affect the plant growth. Frost kills the plants, particularly at seedling stage but the older plants are least affected. The tolerance of the niger crop to high salinity, high boron and low oxygen levels have been reported. Increasing salinity from 0-4 mmhos/cm depressed seedling emergence by less than 10 per cent and at 8 mmhos/cm up to 50 per cent.

IMPACT ASSESSMENT

The AICRP has contributed to the development of technologies across different agroecological situations. The demonstration of these technologies under real farm situations is done through frontline demonstrations. The productivity of niger is low, around 300 to 350 kg/ha in India. Niger productivity has increased by 86 per cent during 2012-13 and production by 10 per cent even after a reduction of 41 per cent in the area over 1965-66 (Ranganatha *et al*., 2014). Despite the maximum area (86.9 thousand ha) and production (29.8 thousand tonnes) in Madhya Pradesh, Andhra Pradesh has the maximum seed yield of 750 kg/ha during 2012-13. There is wide gap between the national average (304 kg/ha) and the achievable yield (700 kg/ha) of this crop as has been shown in frontline demonstrations. To reduce this gap, a strong extension work is needed for the popularization of technologies among the growers. The highest yield under rainfed condition has been reported by several research centres particularly Chhindwara, Igatpuri, Semiliguda and Kanke.

The frontline demonstration continues to carry out the impact of assessment of the potential yield and yield gap between improved technologies. The impact assessment of newly released cultivars to analyse the yield gap between latest technologies and farmer's practice through 1335 demonstrations was conducted. The frontline demonstration revealed that on an average double yield and profit (104%) was obtained by use of improved technology over farmer's practice at Chhindwara and Shadol of Madhya Pradesh.

FUTURE PERSPECTIVE

Hybrid technology which has tremendous potential to increase the productivity should be developed. Genetic/cytoplasmic genetic male sterility systems are to be developed for exploitation of heterosis. Self-compatible types also need to be identified. Production and supply of good quality seeds of improved varieties/hybrids in adequate quantities should be ensured for stability and higher productivity. Characterization and evaluation of germplasm should be standardized and descriptors should be developed. Since niger has an allelopathic and mycorrhizal association, it will be interesting to identify the substance associated with the weed suppression effect. Possibility of efficient genotypes for biofertilizers should be investigated. Major chunk of oilseeds production come from drylands, any possibility of extending the irrigation even to a limited extent coupled with conserving and utilising the rain water should be explored as the niger is efficient utiliser. The seed treatment and other plant protection techniques conducive for IPM on the basis of forecasting of pest and disease situation in different agroecological situations need to be popularized. Low cost production technologies for small and marginal farmers should be developed. Contingency plans should be prepared for capitalizing the full potential of available opportunities and made available to the extension agencies. Adoption of preharvest and postharvest technologies at farm level should be encouraged to reduce the losses and improve the quality. Research on development of value added diversified products should receive priority for enhancing the value of produce and profitability of the farmers. Liberalized trade with adequate policy support to make India an exporter of niger and their byproducts. Hence, effective pricing, processing and market intervention mechanisms are needed. Need reorientation of the policy towards establishment of processing industries in niger production zones on the lines of cooperative sugar mills. Strong Transfer of Technology programmes based on the concept of niger village is to be developed. Further, linkage between research organizations, extension agencies including departments of agriculture and farming community to be strengthened. To optimise the use of resources to reduce the risk, remunerative cropping systems should be developed for different agroecological situations by integrating the improved nutrient, pest and disease management practices.

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Genetic parameters and correlations for seed yield and morphological characters in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]

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ABSTRACT

The present investigation was carried out during *rabi* season of 2007-08 with 60 germplasm accessions of Indian mustard from China, India and Australia and 5 check varieties. The material was grown in an augmented block design to assess heritability, genetic advance for seed yield and other morphological characters and their *inter se* relationships. Significant mean sum of squares indicated genotypic differences for all the characters investigated except protein content. Estimates of heritability and genetic advance were high for secondary branches/plant, siliqua length, 1000-seed weight, seed yield/plant and harvest index indicating dominant role of additive gene action in their inheritance. Thus, selection would be effective for their improvement in early segregating generations. Seed yield/plant had significant and positive correlations with secondary branches/plant, main shoot length and siliquae on main shoot. The genetic correlations of seed yield with these characters were also positive and of moderate to high strength suggesting that for yield enhancement in Indian mustard greater emphasis in the selection programme should be laid on these component characters.

Keywords: *Brassica juncea*, Correlations, Genetic parameters, Indian mustard

Development of high yielding varieties of Indian mustard is foremost to enhance productivity of the crop and a continuous process. Knowledge of genetic parameters is vital for the improvement of target character and selection to be effective and interrelationships among yield and its attributes is highly useful in selecting characters, which are not easily observed or genotypic values of which are modified by the environmental effects. Thus, any morphological character(s) that is associated with yield would be useful in the yield enhancement. The information of interrelationship between characters also helps the breeders to know the nature, extent and direction of selection pressure among characters. Although several reports are available on genetic variability and correlations of agro-morphological characters in Indian mustard yet it is pertinent to study these parameters in new set of breeding materials/germplasm since estimates of genetic parameters for any character and pattern of correlations is influenced by genotypes, environment and their interactions. A few studies reported association analysis in indigenous germplasm of Indian mustard (Chauhan *et al.,* 2000; Misra *et al.,* 2007). However, information on such aspects involving indigenous and exotic germplasm of Indian mustard is lacking. In view of the aforesaid, the present investigation was undertaken with the objectives to estimate heritability and genetic advance for seed yield and other morphological characters and their relationships.

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MATERIALS AND METHODS

The materials for the present investigation comprised 60 germplasm accessions from China (8), India (27), Australia (25) and 5 check varieties (Bio-902, Bio-772, PCR-7, Rohini and Varuna) of Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] grown in an augmented block design with 4 blocks during *rabi* season of 2007-2008. Each block comprised 15 accessions and 5 checks. There were 3 rows of 5 m length for each accession in a block. The row spacing was 30 cm and plant spacing within a row was maintained at 10 cm by thinning. A fertilizer dose of 40:40:20 kg/ha (N: P_2O_5: K_2O) was applied at the time of sowing and 40 kg N/ha was applied after first irrigation (36 days after sowing). Second irrigation was given at 72 days after sowing. Plant protection measures were adopted as and when required. Days to maturity was recorded on plot basis. At the time of harvest, 10 random competitive plants were taken from the middle row to record plant height (cm), primary branches/plant (no.), secondary branches/plant (no.), main shoot length (cm), siliquae on main shoot (no.), siliqua length (cm), seeds/siliqua (no.), 1000-seed weight (g) and seed yield/plant (g). Oil and protein content were recorded on a composite sample of 10 plants taken for recording observations using Near Infrared Reflectance Spectroscopy. The mean data for different characters were subjected to analysis of variance of an augmented block design. The data were analyzed using software SPAD (IASRI, New Delhi). Genetic advance expressed as percentage of mean and heritability (in broad-sense) were computed following Lush (1949) and Hanson (1963), respectively. The genotypic and phenotypic correlation coefficients were calculated on the basis of adjusted and unadjusted means, respectively, using the formula given by Johnson *et al.* (1955).

RESULTS AND DISCUSSION

Analysis of variance indicated significant mean sum of squares due to genotypes for seed yield and other morphological characters investigated except protein content, thereby suggesting presence of genetic variability in the experimental materials.

Genetic parameters: Estimates of heritability and genetic advance were high for secondary branches/plant, siliqua length, 1000-seed weight and seed yield/plant (Table 1). The results revealed the dominant role of additive gene action in the inheritance of these characters and also indicating that selection would be effective for their improvement in early segregating generations. Moderate to high heritability associated with moderate to high genetic advance for siliquae on main shoot and main shoot length indicated role of both additive and non-additive gene action in their genetic control. Such characters could be amenable for improvement through selection in advance generations when non-additive component of variance is considerably reduced. High heritability but low genetic advance was recorded for oil content and days to maturity. The low genetic advance for these traits might be due to low variability in the experimental materials. Therefore, simple selection would not be effective for their improvement. Pant and Singh (2001) also observed low to moderate heritability and low genetic advance for oil content and days to maturity. But Jindal and Labana (1985) reported high heritability for oil content. The results of the present investigations were in agreement with those of previous studies where high heritability and genetic advance were recorded for 1000-seed weight, plant height, siliqua length, secondary branches/plant and seed yield/plant (Sikarwar *et al.*, 2000; Mahla *et al.*, 2003). However, earlier Reddy and Reddy (1990) reported low heritability and genetic advance for seed yield.

Table 1 Heritability (in broad-sense), actual genetic advance (Ga) and as percentage of mean (Gs) for seed yield and morphological characters in Indian mustard

Character	Heritability (%)	Ga	Gs
Days to maturity	75.9	307.2	2.2
Plant height (cm)	87.7	2787.5	16.9
Secondary branches/plant (No.)	89.4	846.3	71.4
Main shoot length (cm)	69.1	1156.4	18.6
Siliquae on main shoot (No.)	75.8	1034.9	22.5
Siliqua length (cm)	87.7	81.4	22.9
1000-seed weight (g)	96.1	198.0	52.0
Seed yield/plant (g)	78.9	828.3	55.1

Correlations: Genotypic and phenotypic correlations were in the same direction. The genotypic correlations were classified as low ($r<0.30$), moderate ($r=0.31-0.65$) and high ($r>0.65$). Genotypic correlation were, in general, higher than phenotypic correlations except association of secondary branches/plant with siliquae on main shoot and seed weight; main shoot length and siliqua length where genetic correlations were lower than the phenotypic correlations. Kumar *et al.* (1999) also recorded higher genotypic correlations than phenotypic correlations whereas Kardam and Singh (2005) recorded opposite trend. Days to maturity showed positive genetic correlations of moderate strength with plant height (r_g=0.487) and 1000-seed weight (r_g =0.399). The associations of plant height with main shoot length, siliqua length and biological yield were positive and significant. It also had positive correlations of moderate strength at genotypic level with main shoot length, siliqua length, biological yield and 1000-seed weight. Misra *et al.* (2004) also reported positive correlation of plant height with main shoot length. The correlations of secondary branches/plant with siliqua length (r_p=-0.343*) and 1000-seed weight (r_p=-0.508**) were negative and significant. However, their associations with siliquae on main shoot and biological yield/plant were positive and significant. The genetic association among these characters followed the similar pattern with reduced magnitude (Table 2). Singh *et al.* (2006) recorded positive association of secondary branches/plant with siliquae on main shoot but negative with main shoot length. Main shoot length showed highly significant and positive correlation with siliquae on main shoot, siliqua length, 1000-seed weight and biological yield/plant. Genetic correlations of main shoot length with these characters were higher than the phenotypic correlations except that of main shoot length with siliqua length. Similar trend of association was reported earlier (Misra *et al.*, 2004 and Singh *et al.*, 2006). Highly significant and positive relationship was recorded between siliquae on main shoot and biological yield/plant

(r_p=0.634**). At genotypic level also this correlation was equally strong (r_g=0.632). Siliqua length had highly positive correlation with 1000-seed weight at phenotypic and genotypic level (Table 2). Although siliqua length showed no correlation with biological yield/plant at phenotypic level but this association at genotypic level was positive and moderate. The 1000-seed weight exhibited significant and negative correlation with oil content at phenotypic and equally strong association at genotypic level.

Seed yield/plant had significant and positive correlations with secondary branches/plant, main shoot length, siliquae on main shoot and biological yield/plant. The genetic correlations of seed yield with these characters were also positive and of moderate to high strength (Table 2). Several researchers in Indian mustard also observed positive and significant association of seed yield/plant with secondary branches/plant (Misra *et al.*, 2004 and Singh *et al.*, 2006), main shoot length and siliquae on main shoot (Singh *et al.*, 2003). The discrepancy observed in pattern of correlations of some characters and their differential response at genotypic and phenotypic level could be due to genotypic differences and/or genotype x environment interactions. Since seed yield/plant had significant and positive correlations at both phenotypic and genotypic levels with secondary branches/plant, main shoot length and siliquae on main shoot, therefore, for yield enhancement in Indian mustard greater emphasis in the selection programme should be laid on these characters.

Table 2 Inter-relationships among seed yield and its contributing characters in Indian mustard

Character	PH	SB	MSL	SMS	SL	SW	BY	SY	OC
DM	0.240	-0.186	0.137	0.092	0.096	0.259	0.048	-0.040	-0.029
	0.487	**-0.276**	**0.362**	**0.159**	**0.265**	**0.399**	**0.164**	**0.004**	**-0.141**
PH		-0.088	0.599**	0.245	0.524**	0.245	0.339*	0.204	-0.238
		-0.157	**0.584**	**0.215**	**0.547**	**0.539**	**0.418**	**0.256**	**-0.220**
SB			-0.075	0.470**	-0.343*	-0.508**	0.659**	0.577**	0.149
			-0.156	**0.374**	**-0.306**	**-0.464**	**0.507**	**0.473**	**0.118**
MSL				0.429**	0.689**	0.467**	0.495**	0.519**	-0.231
				0.446	**0.663**	**0.669**	**0.559**	**0.577**	**-0.117**
SMS					-0.097	-0.258	0.634**	0.563**	-0.119
					-0.084	**-0.044**	**0.632**	**0.585**	**-0.132**
SL						0.696**	0.196	0.167	-0.234
						0.739	**0.328**	**0.256**	**-0.039**
SW							-0.016	0.057	-.403**
							0.244	**0.219**	**-0.409**
BY								0.858**	-0.152
								0.822	**-0.140**
SY									-0.135
									-0.107

Values in light and bold face represent phenotypic and genotypic correlations, respectively

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

DM: Days to maturity; PH: Plant height; SB: Secondary branches/plant; MSL: Main shoot length; SMS: Siliquae on main shoot; SL: Siliqua length; SW: 1000-seed weight; BY: Biological yield/plant; SY: Seed yield/plant and OC: Oil content

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Genetic analysis for seed yield and its contributing traits in linseed (*Linum usitatissimum* L.)

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ABSTRACT

An experiment was conducted to study the gene action in linseed through diallel analysis using 11 parents and their 55 crosses. Analysis of variance showed highly significant differences among the genotypes for all the traits. Graphical analysis displayed non-additive gene action playing major role in the expression of all the attributes. Components of variance revealed the presence of both additive as well as dominance component for days to 50 per cent flowering, days to maturity, plant height, number of seeds/capsule, 100-seed weight, seed yield/plant, harvest index and oil content. Average degree of dominance ($(\hat{H}_1/\check{D})^{0.5}$ exhibited over dominance for all the traits except test weight. High estimates of heritability with high genetic advance were reported for 100-seed weight whereas high heritability with low genetic advance was observed for days to maturity and oil content. Low heritability with high genetic advance was recorded for number of capsules/plant and primary branches/plant. Moderate heritability with high genetic advance was noticed for seed yield/plant.

Keywords: Gene action, Genetic advance, Heritability, Linseed, Variability

Linseed owing to its various uses is considered important in oilseeds economy of the country. The seed is primarily used for extracting oil which is used in various industries. In technical oil production, linseed ranks first followed by castor in the country. Every part of linseed plant is utilized commercially either directly or after processing. About 20 per cent of linseed oil produced is also used as edible oil in certain pockets of Madhya Pradesh, Bihar, Maharashtra etc. The remaining about 80 per cent of total linseed oil goes to industries. On account of the presence of poly-unsaturated fatty acid, 81 per cent of industrial linseed oil is used as an unparallel source of paint and varnishes, 11 per cent in the manufacture of linoleum and oil cloth, 3 per cent in printing ink, pad ink and remaining in soaps patent leather and other products. Discoveries of the use of linseed oil in cementing of roads and in antibiotics have given it a new importance. Therefore, it is a strong case to think of an optimum genetic balance among various components of seed.

The component of breeding value of the parents may include nature and magnitude of genetic variance, gene action of traits under improvement, their heritability and genetic advance etc. It is generally expected that there will be preponderance of additive type of gene action in linseed being a self pollinated crop, but the possibility of non-additive gene action cannot be ruled out. Therefore, additive and non-additive gene action needs to be associated in the parents and their hybrids. Yield is complex trait determined by number of meristic and metric traits. The comprehensive study of the genetic architecture of quantitative traits of economic value is essential to improve the yield potential. The present investigation aimed to generate information on the nature of gene action in linseed to suggest suitable breeding methodology for the genetic improvement of linseed.

MATERIALS AND METHODS

A set of 11 parents namely N-3, Jawahar-23, R-17, Sweta, T-397, Gaurav, Shubhra, LC 185, EC 41498, 1per76 and NP-22 and their 55 F_1s were sown in a Randomized Block Design with three replications at Oilseeds Research Farm, C.S. Azad University of Agriculture & Technology, Kanpur during *rabi* season of 2010-2011. Each genotype was sown in two rows of three meter length with row to row and plant to plant spacing of 40 cm and 10 cm, respectively. Spacing between rows was kept more than recommended for commercial cultivation, so that recording of observations would be comfortable. Recommended doses of 40 kg N, 40 kg P_2O_5 and 15 kg K_2O/ha were applied to raise a healthy crop. Three irrigations were applied and other recommended agronomic practices were followed for raising the crop. Observations on different yield contributing traits namely days to 50 per cent flowering, days to maturity, plant height, primary branches/plant, number of capsules/plant, number of seeds/capsule, 100-seed weight, seed yield/plant, harvest index and oil content were recorded on ten randomly selected plants in parents and F_1s in each replication. Data on various variables were analyzed by analysis of variance (Panse and Sukhatme, 1961). The graphical analysis was done as per Hayman (1954). The analysis was based on the variance and covariance (Vr, Wr) graph. A diallel table was prepared for each trait to calculate Vr, Wr and Vp. Related parameters were determined on the basis of the formula suggested by Hayman (1954). The significance of the components was tested by 't' test. A general approach to this method based on second degree statistics using the concepts of Ď, Ĥ, components of the variation was suggested by Yates (1947). Heritability based on the genetic components was calculated by the formula proposed by Crumpacker and Allard (1962). The expected genetic advance was calculated by the formula of Robinson *et al*. (1949).

RESULTS AND DISCUSSION

Non significant value of 't^2' in all the traits except days to 50 per cent flowering supported the validity of assumptions (Table 1). Significant variability was present among parents and their F_1 progenies with respect to all the traits under study. The graphical analysis displayed that non-additive gene action played major role in the expression of all the attributes (graphs not given). The regression coefficient 'b' deviated significantly from zero for all the traits except primary branches/plant while it deviated significantly from unity for all the traits under study. The value of 't_2' was found significant only for days to 50% flowering which indicated failure of one or more assumptions in this case. The non-significant values of 't_2' for characters under study supported the validity of the hypothesis. Components of variance showed the presence of both additive (Ď) as well as dominance components ($\hat{H}_1$) for days to 50 per cent flowering, days to maturity, plant height, number of seeds/capsule, 100-seed weight, seed yield/plant, harvest index and oil content (Table 2). Traits like primary branches/plant and number of capsules/plant showed presence of dominance component ($\hat{H}_1$) and absence of additive component (Ď). Partial dominance was observed by graphical analysis for days to 50 per cent flowering, days to maturity, plant height, primary branches/plant, 100-seed weight and oil content. Over dominance was observed for number of capsules/plant, number of seeds/capsule and seed yield/plant. On the other hand component analysis revealed that the average degree of dominance $(\hat{H}_1/\check{D})^{0.5}$ was more than unity for most of the traits except 100-seed weight, suggesting manifestation of over-dominance for these traits (Table 3). 100-seed weight showed complete dominance. It may be explained that estimates obtained through formula $(\hat{H}_1/\check{D})^{0.5}$ gave an appropriate value of the degree of dominance. Hayman (1954) suggested that in particular combinations positive, negative or complementary type of gene action and simply correlated gene distribution may seriously inflate the mean degree of dominance and convert partial dominance into apparent over dominance. Comstock and Robinson (1952) emphasized that the degree of dominance might be biased upward either by linkage or epistasis or both. Both graphical and component analysis revealed over dominance for number of capsules/plant, number of seeds/capsule and seed yield/plant. It might be a real one and could be utilized practically; however, it could be done where loci having over dominance effect tight linkage.

Table 1 Estimates of b, sb, (b -/sb), (b-1/sb) and t^2 for different characters of linseed

Character	Statistics				
	b	sb	(b-o/sb)	(b-1/sb)	t^2
Days to 50% flowering	0.418	0.131	3.191*	-4.443**	6.565
Days to maturity	0.465	0.291	1.598	-1.838	0.001
Plant height (cm)	0.468	0.128	3.656**	-4.158	0.615
Primary branches/plant	-0.043	0.037	-1.162	28.189**	1.745
Number of capsules/plant	0.250	0.154	1.623	-4.870**	5.478
Number of seeds/capsule	0.268	0.164	1.634	-4.463**	4.373
100-seed weight (g)	0.285	0.250	1.140	-2.860*	30.503
Seed yield/plant (g)	0.466	0.141	3.305**	-3.787**	4.584
Harvest index (%)	0.649	0.123	5.276**	-2.854*	3.240
Oil content (%)	-0175	0.155	-1.129	-7.581**	5.073

*, ** Significant at 0.05 and 0.01, respectively

The estimates of '$\widehat{F}$' value were positive for all the traits except plant height and 100-seed weight but the significant value was observed for harvest index. Significant estimates of $\widehat{h}^2$ were examined for primary branches/plant, number of seeds/capsule, 100-seed weight, seed yield/plant and harvest index. The significant and positive value of $\widehat{F}$ and $\widehat{h}^2$ indicated that dominant genes played a significant role in control of these attributes. The values of component 'Ê' were found non-significant for all the traits suggesting that environment does not effect on the traits. Component analysis revealed that the average degree of dominance $(\hat{H}_1/\check{D})^{0.5}$ was more than unity for most of the traits except 100-seed weight suggesting manifestation of over dominance for these traits. The ratio of $(\hat{H}_1/\check{D})^{0.5}$ was equal to unity for 100-seed weight suggesting complete dominance. Asymmetrical distribution of positive and negative alleles among the parents were recorded for all the traits as estimated value of $(\hat{H}_2/4\ \hat{H}_1)$ were less than the theoretical value (0.25). Graphical analysis also supported the asymmetrical distribution of dominant and recessive alleles in the parents.

The ratio $(4\hat{D}\hat{H}_1)^{0.5} + \hat{F} / (4\hat{D}\hat{H}_1)^{0.5} - \hat{F}$ for all the traits except plant height and 100-seed weight was more than unity indicating the distribution of dominant alleles more frequently than the recessive alleles. The preponderance of dominant alleles was also confirmed by positive values for these traits. The proportion of dominant and recessive alleles among the parents determines the extent of genetic advance under directional selection. If the genes present in the population are dominant in nature, the extent of genetic advance will be high. On the other hand, genetic advance will be limited, if the recessive genes are predominant. The proportion of dominant genes was fairly high. This suggested the possibility of fairly high amount of genetic advance. The ratio $\hat{h}_2 / \hat{H}_2$ for primary branches/plant, number of capsules/plant, 100-seed weight and seed yield/plant indicated that more than one set of genes were associated with the expression of these traits. The correlation coefficient between the parental order of dominance and parental measurement was significant and negative for seed yield/plant suggesting that positive genes responsible for the expression of these traits were mostly dominant.

Table 2 Comparative evaluation of results on gene action and average degree of dominance for different traits in linseed

Character	Component analysis		Graphic at gene action	Average degree of dominance	
	$\hat{D}$ $\hat{H}_1$	Gene action		Wr -Vr	$(\hat{H}_1/D)^{0.5}$
Days to 50% flowering	HS < HS	NA	NA	PD	OD
Days to maturity	HS < HS	NA	A+NA	PD	OD
Plant height (cm)	HS < HS	NA	NA	PD	OD
Primary branches/plant	NS < HS	NA	NA	PD	OD
Number of capsules/plant	NS < HS	NA	NA	OD	OD
Number of seeds/capsule	HS < HS	NA	NA	OD	OD
100-seed weight (g)	HS < HS	NA	NA	PD	CD
Seed yield/plant(g)	HS < HS	NA	NA	OD	OD
Harvest index (%)	HS < HS	NA	NA	PD	OD
Oil content (%)	HS < HS	NA	NA	PD	OD

HS=Highly significant; A=Additive; CD=Complete dominance; NS=Non-significant; NA=Non-Additive; OD=Over dominance; PD =Partial dominance

High heritability (>30%) estimates were observed for harvest index, days to 50 per cent flowering, 100-seed weight, days to maturity, plant height and oil content (Table 3). It was owing to greater contribution of additive genetic component in the inheritance of these attributes. Similar findings were also observed by Ingale (1985), Kant *et al.* (2005), Pant and Mishra (2008), Kumar *et al.* (2012), Tewari *et al.* (2012) and Reddy *et al.* (2013). Moderate heritability (10 to 30%) was expressed for number of seeds/capsule and seed yield/plant. These results are in agreement with genetic analysis which indicated the greater role of non-fixable genetic variance for these traits, which includes dominance and epistasis. Low estimates of heritability were examined for number of capsules/plant and primary branches/plant. These results might be owing to high proportion of non-additive genetic variance. High genetic advance was observed for number of capsules/plant, seed yield/plant, primary branches/plant and 100-seed weight indicating the involvement of additive gene effects for the expression of these traits. Genetic gain was recorded moderate for harvest index, days to 50 per cent flowering, plant height and number of seeds/capsule. These findings indicated the presence of additive and non-additive gene effects. Therefore, the selection would be followed in later generations. Low genetic advance was observed for days to maturity and oil content. The selection in the set of material would not be much effective for these traits in early generations.

The present study revealed the significance of both additive and non-additive genetic effects in the component traits related to productivity. The genetic improvement of such traits may be based on simultaneous exploitation of both additive and non-additive components of genetic effects. For effective utilization of additive genetic effect, selective breeding may be used for the improvement of yield and its components in linseed.

Table 3 Estimation of genetic parameters and related statistics for yield and its component traits in linseed

Character	Genetic parameters and related statistics										
	$\widehat{D}$	$\widehat{H}_1$	$\widehat{H}_2$	$\widehat{F}$	$\widehat{h}^2$	$\widehat{E}$	$(\widehat{H}_2/\widehat{D})^{0.5}$	$\widehat{H}_2/\widehat{H}_1$	$4\widehat{D}\widehat{H}_1)^{0.5}+\widehat{F}$ / $(4\widehat{D}\widehat{H}_1)^{0.5}-\widehat{F}$	$\widehat{h}^2/\widehat{H}_2$	r
Days to 50% flowering	81.08**	97.22**	75.54**	26.98	2.21	0.91	1.09	0.19	1.35	0.02	0.21
	±11.63	±23.97	±20.15	±26.59	±13.48	±3.35					±0.32
Days to maturity	7.85**	10.48**	8.38**	2.88	-0.15	0.64	1.15	0.20	1.37	-0.01	0.15
	±1.48	±3.04	±2.56	±3.37	±1.710	±0.42					±0.33
Plant height (cm)	61.89**	80.76**	57.80**	-0.54	10.23	0.50	1.14	0.17	0.99	0.17	0.29
	±5.44	±11.22	±9.43	±12.44	±6.309	±0.15					±0.31
Primary branches/plant	1.25	24.73	18.47	2.52	23.74	0.19	4.44	0.18	1.58	1.28	-0.31
	±5.32	±10.98	±9.23	±12.17	±6.17	±1.53					±0.31
Number of capsules/plant	1677.0	24100.0**	19600.0**	3069	67235.16**	13.68	3.79	0.20	1.63	3.43	0.51
	±1317.28	±2714.11	±2281.60	±3010.55	±1526.25	±380.26					±0.28
Number of seeds/capsule	0.47*	2.15**	1.62**	0.61	0.74**	0.04	2.13	0.18	1.87	0.45	0.27
	±0.20	±0.41	±0.34	±0.45	±2.32	±0.05					±0.32
100-seed weight (g)	0.02**	0.02**	0.016**	-0.003	0.019**	0.00	1.02	0.18	0.84	1.22	0.43
	±0.002	±0.05	±0.004	±0.008	±0.003	±0.001					±0.30
Seed yield/plant (g)	5.35*	53.09**	46.48	10.75	175.23**	0.36	3.14	0.21	1.93	3.77	-0.70*
	±2.39	±4.94	±4.15	±5.48	±2.77	±0.69					±0.23
Harvest index (%)	35.97**	48.46**	30.45**	28.92**	26.80**	0.22	1.16	0.15	2.06	0.88	-0.50
	±4.29	±8.85	±7.44	±9.82	±4.98	±1.24					±0.28
Oil content (%)	4.53**	12.36**	11.25**	3.28	2.93	0.18	1.65	0.22	1.56	0.26	-0.25
	±1.55	±3.21	±2.70	±3.56	±1.80	±0.45					±0.32

Table 4 Mean heritability (NS) and genetic advance for different characters of linseed

Character	Mean performance	Heritability in narrow sense	Genetic Advance	Genetic advance in percentage of mean
Days to 50% flowering	74.90	52.31	14.76	19.71
Days to maturity	155.46	43.52	3.95	2.54
Plant height (cm)	75.43	42.62	14.80	19.62
Primary branches/plant	9.81	5.16	5.02	51.22
Number of capsules/plant	281.88	7.36	170.46	60.47
Number of seeds/capsule	7.30	21.69	1.37	18.77
100-seed weight (g)	0.87	45.21	0.27	31.03
Seed yield/plant (g)	14.07	10.90	7.43	52.81
Harvest index (%)	35.74	63.75	9.12	25.52
Oil content (%)	42.18	31.60	3.69	8.75

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Effect of nutrient management on growth and yield of sesame (*Sesamum indicum* L.)

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ABSTRACT

Field experiments were conducted on sesame in vertisols of Jabalpur, Madhya Pradesh during *kharif* seasons of 2009-10 and 2010-11 to determine its efficient nutrient management. Results revealed that application of 100% recommended dose of fertilizers (RDF) as 60 kg N + 40 kg P_2O_5 + 30 kg K_2O/ha superimposed with sprayings of 2% Diammonium phosphate (DAP) twice at flowering and capsule formation stages was the best nutrient management for sesame resulting in high seed yields and monetary advantages, which was comparable to 100% RDF + sprayings of 2% urea twice at flowering and capsule formation stages as well as 100% RDF + spraying of 2% DAP once at flowering stage. This nutrient management proved to be more remunerative also.

Keywords: Economics, Foliar application, Nutrient management, Sesame

Sesame (*Sesamum indicum* L.) is one of the most important crop of rainy season. It is commonly grown in the poorly fertile land with very less attention and less use of required agro-inputs particularly manures and fertilizers. Therefore its productivity is quite low in the country in general and Madhya Pradesh state in particular. In India, sesame is cultivated in 1.89 m ha area with a production of 0.73 million tonnes and productivity of 386 kg/ha. Madhya Pradesh ranks third in area and second in production by contributing 18.8 per cent and 24.3 per cent share of country's area and production, respectively. The state covers an area of 2.96 lakh ha under this crop with an annual production of 0.81 lakh tonnes and productivity of 272 kg/ha (Kumar and Varaprasad, 2012). Sesame responds very well to application of high dose of manures (Mondal *et al.*, 1992) and fertilizers (Majumdar *et al.*, 1978) in almost all growing areas of the country. But adequate and effective nutrient management is not scientifically worked out for achieving higher productivity of this crop in the state. Hence, the present investigation have been undertaken.

MATERIALS AND METHODS

Field experiments were conducted on vertisols of Jabalpur, Madhya Pradesh for two consecutive years (2009-10 and 2010-11) during *kharif* (rainy) season. The soil of the experimental site was low in organic carbon (0.44%), neutral in reaction (pH 7.4), normal in electrical conductivity (0.43 dS/m) and analyzing in low available N (198 kg/ha), medium available P (18.6 kg/ha) and high available K (323 kg/ha) contents. The rainfall generally ranges 1000 to 1500 mm during the crop season but it was 1244 in 38 rainy days in the year 2009-10 and 1611 mm in 48 rainy days in 2010-11. Nine nutrient management treatments *viz.*, T_1 - Recommended dose of fertilizers (RDF), T_2 - T_1 + one foliar spray of 2% urea at flowering (F), T_3 - T_1 + one foliar spray 2% Diammonium phosphate (DAP) at F, T_4 - T_1 + 2 foliar sprays of 2% DAP at F + Capsule formation (C), T_5 - T_1 + 2 foliar sprays of 2% DAP at F + C, T_6 - 75% RDF + 1 foliar spray of 2% urea at F, T_7 - 75% RDF + 1 foliar spray of 2% DAP at F, T_8 - 75% RDF + 2 foliar sprays of 2% urea at F+C and T_9 - 75% RDF + 2 foliar sprays of 2% DAP at F+C were tested in Randomized Block Design with three replications. Crop cv. Gujarat Til-10 was sown on July 18 and 22 in the year 2009-10 and 2010-11, respectively. Sowing was done by drilling of 5 kg seeds/ha in rows 30 cm apart. Before sowing the seeds were treated with thiram 3 g/kg of seeds. Reseeding of fresh treated seeds was done at 7 days after sowing wherever gaps of more than 10 cm existed in the rows. The thinning of overcrowded plants was also done at the same time by maintaining the plant to plant distance in rows around 10 cm. Observations on yield attributes *viz.*, plant-height, branches/plant, capsules/plant, seeds/capsule, harvest index and test weight of seeds were recorded at the time of harvesting. The seed and straw yields were recorded. Oil content of seeds was recorded to determine the oil output under each treatment. Finally, economic parameters were calculated. Data recorded on various observations were subjected to their statistical analysis. Data on all parameters were identical in both years, hence, pooled data are presented for interpretation of the results.

RESULTS AND DISCUSSION

Yield attributes: The growth and yield attributing characters of sesame *viz.*, plant-height, branches/plant, capsules/plant, test weight of seeds and harvest index were almost comparable due to the effect of different nutrient

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management, but seeds/capsule significantly differ between them (Table 1). Soil application of nutrient through 100% RDF + foliar spraying of 2% DAP twice at flowering (F) and capsule formation (C) stages - T_5 produced maximum number of seeds/capsule (21.35) closely followed by soil application of 100% RDF + foliar spraying of urea twice at F and C - T_4 (21.24) and T_1 associated with 2% urea at F stage - T_3 (21.24). Almost all nutrient management tested were able to supply adequate quantity of required nutrients to the crop, which attributed to produce similar growth parameter and yield attributing characters (Malviya, 2011; Mahajan, 2013).

Table 1 Effect of different nutrient management on growth parameters, yield attributes, yields and economics of sesame (pooled mean of *kharif* 2009-10 and 2010-11)

Nutrient management	Plant height (cm)	Branches/ plant (No.)	Capsules/ plant (No.)	Seeds/ capsule (No.)	Test weight (g)	Harvest index (%)	Seed yield (kg/ha)	Straw yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)	Cost of cultivation (₹/ha)	GMR (₹/ha)	NMR (₹/ha)	B:C ratio
T_1- Recommended dose of fertilizer (RDF)	179.5	6.12	43.23	20.93	2.78	11.03	633	5100	47.82	304	14860	27870	13010	1.87
T_2 – T_1 + one foliar application of 2% urea at flowering	179.5	6.02	43.79	20.56	2.74	11.25	652	5140	48.11	314	15036	28650	13614	1.90
T_3 – T_1 + one foliar application of 2% DAP at flowering	179.5	6.12	44.75	21.24	2.78	11.35	661	5155	48.00	319	15110	29017	13907	1.92
T_4 – T_1 + two foliar applications of 2% urea at flowering + capsule formation	179.5	6.21	45.25	21.24	2.78	11.49	674	5191	48.19	326	15212	29555	14343	1.94
T_5 – T_1 + two foliar applications of 2% DAP at flowering + capsule formation	178.5	6.27	45.81	21.35	2.74	11.55	681	5210	47.39	324	15360	29845	14485	1.94
T_6 – 75% RDF + one foliar application of 2% urea at flowering	177.5	5.77	42.89	20.68	2.72	10.88	611	5000	48.12	295	14611	26940	12329	1.84
T_7 – 75% RDF + one foliar application of 2% DAP at flowering	176.5	5.82	43.73	20.72	2.71	10.88	617	5035	47.96	297	14685	27197	12512	1.85
T_8 – 75% RDF + two foliar applications of 2% urea at flowering + capsule formation	178.5	5.82	42.55	20.58	2.72	10.91	625	5100	48.11	302	14787	27550	12763	1.86
T_9 – 75% RDF + two foliar applications of 2% DAP at flowering + capsule formation	177.5	5.87	43.07	20.59	2.73	10.91	628	5115	48.26	304	14935	27637	12702	1.85
SEm±	1.38	0.56	2.11	0.12	0.04	0.05	14.0	35.6	0.69	5.55	-	576	372	0.01
CD (P = 0.05)	NS	NS	NS	0.36	NS	NS	43.8	107.1	NS	16.57	-	1750	1120	0.03

Seed and straw yield: Based upon two years pooled data basis, application of 100% RDF coupled with foliar spraying of 2% DAP twice at flowering (F) and capsule formation (C) stages - T_5 produced maximum seeds (681 kg/ha) and straw (5210 kg/ha) yields, among all nutrient managements, but differences were not significant for straw yields. Seed yields obtained with T_4 - application of 100% RDF + foliar spray urea twice at F and C stages (674 kg/ha) and T_3 - application of 100% RDF + foliar spray of 2% DAP only once at F stage (661 kg/ha), were comparable to those obtained with T_5. But remaining nutrient management led to register significantly lesser seed yields than T_5, although they were at par to T_4 and T_3 in this regard. The variations in growth parameter and yield attributing characters were not much appreciable among different nutrient management, which resulted in to production of identical seed and straw yields. However, distinct superiority in number of seeds/capsule with T_5 attributed to produce maximum seed yields. These results are close conformity with the findings of other workers (Deshmukh and Duhoon, 2008; Malviya, 2011; Mahajan *et al.*, 2013) also.

Oil yield: Oil yield is mainly directly related with seed yield and oil content of seeds. The oil content of seeds did not differ much due to varying nutrient management, but seed yields showed variations between them. Hence, oil yields under different nutrient management followed almost same order as to seed yields.

Economic viability: The cost of cultivation was ₹4860/ha with application of 100% RDF - T_1, which slightly increased as ₹15036 to 15360/ha when one or two spraying of urea or DAP 2% was superimposed with T_1. But application of only 75% RDF superimposed by foliar spraying of urea or DAP needed an investment of ₹ 14611 to ₹14935/ha for cultivation of crop, which were at par to T_1. The nutrient management consisted with application of 100% RDF + 2 foliar spraying of urea or DAP 2% (T_2, T_3, T_4 and T_5) led to record slightly higher net monetary returns (NMR) ranging from ₹ 13614 to ₹ 14485/ha than T_1 (₹13010/ha). But nutrient management consisting with 75% RDF + foliar spray of urea or DAP 2% (T_6, T_7, T_8 and T_9) led to register slightly lesser NMR (₹ 12329 to ₹ 12763/ha) than T_1. Because of a very marginal deviation in cost of cultivation as well as gross monetary returns based on comparable seed yields due to different nutrient management, the benefit cost ratio values did not show any remarkable differences between different nutrient management. As a whole application of 100% RDF + foliar spraying of DAP 2% twice at flowering and capsule formation stages proved to be most economically viable.

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Biochemical composition of whole seed, decorticated seed and seed coat in sesame (*Sesamum indicum* L.) of different seed coat colours

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ABSTRACT

Biochemical analysis of whole seed, decorticated seed and seed coat of different coloured varieties of sesame were studied. Maximum oil content in whole and decorticated seed was recorded in white seeds (47.5 and 51%, respectively). Light brown seed coat showed maximum oil content (15.0%). Minimum free fatty acid (FFA) content in whole seed was recorded in white seeds (0.62%) and maximum in dark brown seeds (1.71%). The decorticated black seed contained minimum FFA content (2.13%), white seed coat the lowest (0.85%). Highest FFA content in the seed coat was exhibited by light brown seeds (1.96%). Minimum oxalic acid in whole seeds was in white (0.82%). The white and dark brown decorticated seeds contained minimum oxalic acid (0.88%). Seed coat of all the varieties *viz*., black (2.65%), light brown (2.15%), dark brown (2.10%) and white (1.84%) exhibited the higher oxalic acid than whole and decorticated seed. The highest protein was found in whole and decorticated seed of white (18.35 and 16.45%, respectively), whereas seed coat of all the varieties contained one-fourth protein content of the whole and decorticated seeds. White (5.60 mg/kg) and black (5.65 mg/kg) seeds were found almost at par for desirable sesamol, an antioxidant, in whole seed. The decorticated seed of black (6.35 mg/kg) and white (6.15 mg/kg) seeds of sesame exhibited the highest sesamol, whereas the maximum of 6.95 mg/kg in white seeds.

Keywords: Biochemical composition, Fibre contents, Oil content, Seed coat colours, Sesame

Sesame (*Sesamum indicum* L.) is one of the world's most important oilseed crops and has long been an ingredient in human foods and animal feed in the form of whole seed, seed oil and meal. The special flavour and its resistance to oxidative deterioration make sesame oil an excellent salad oil. Sesame seed has a high food and nutritional value, because it contains rich edible oil, nutritious protein, sufficient amount of useful carbohydrates, minerals and essential vitamins (Muralidharudu, 1995). Recently, a variety of nutraceutical uses have been discovered from sesame. In addition to lipid-soluble antioxidants such as sesamin, sesamolin, sesamol and sesaminol (Sirato-Yasumoto *et al*., 2001), sesame lignans and lignan glucosides are found to be antioxidative and health-promoting (Katsuzaki *et al*., 1994). Defatted sesame meal (40-50% protein) is an important protein source for human consumption due to the presence of sulfur containing amino acids (El-Adawy, 1995). Whole sesame seed consumption appears to increase plasma c-tocopherol and enhanced vitamin E activity, which are believed to prevent cancer and heart diseases (Cooney *et al*., 2001).

Sesame seed coat is highly rich in minerals including calcium, phosphorus, potash and other micronutrients like Zn, Fe, Mg and Mn (Gopalan *et al*., 1982). The presence of anti-nutritional factors like oxalic acid and phytic acid (in traces) in the seed coat render the calcium and phosphorus into non-available forms and impart unpleasant taste also.

The oxalic acid binds with calcium to form calcium oxalate, which is not utilized by the human body. India is the hot spot of variability in cultivated forms. Therefore any variety with high oil content, low free fatty acid as well as low antinutritional factor (oxalic acid) will be highly desirable to fetch the higher premium in the international as well as in the domestic market. The hull accounts for 10 to 20 per cent of the whole seed which contains oxalic acid (about 2%) and calcium (1-2%).

Protein rich meal obtained after oil extraction is used as animal feed but meal from dehulled and defatted seed may also be used in food products as a source of methionine. Abou Gharbia *et al*. (2000) reported that oxidative stability of sesame oil is high in case of the oil extracted from coated seeds than in those extracted from dehulled seeds. Few references are available on chemical composition of white and black sesame seed; however there is meagre information available on different coloured type of sesame seeds. In India, there is wide range of variability in chemical composition of sesame varieties. Keeping in view the above facts, it is imperative to study the biochemical analysis of whole seed, seed coat and decorticated seed of different coloured varieties of sesame.

MATERIALS AND METHODS

Varieties having different seed colours were procured from store of All India Coordinated Research Project on Sesame and Niger, Jabalpur, India. The raw seeds were

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cleaned and sieved to remove dust and small stones. 25 g of each seed varieties was taken in Petri-dish and very little water was sprinkled to moisten and kept in oven at 40°C for 2-hours in order to dehull the seed easily. The relative percentage weight of dehulled and hulled seed when done manually were: for white 84 per cent and 16 per cent, light brown 72 per cent and 28 per cent, dark brown 70 per cent and 30 per cent, and black 75 per cent and 25 per cent, respectively. Maximum hull was obtained from dark brown and light brown, whereas white seed possesses very thin seed coat and black seeded variety had brittle and thick seed coat. The raw seed, dehulled seed and hull were kept in deep freezer at -20°C until analysis. Standard methods were adopted for different quality traits. Estimation of free fatty acid in seed sample was determined by the standard AOCS method (1980). Estimation of oxalic acid in seed sample was determined by potassium permanganate method (AOCS, 1980). Estimation of protein was determined by Lowry's method. Estimation of sesamol in seed sample was done by the method of Hemalatha and Ghafoorunissa (2004). Estimation of crude fibre in seed sample was determined by AOCS (1980) and Bryant and McClements (2000). The mean data of three replicates were subjected to variance analysis and test of significance (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

The mean data for oil content on whole seed, decorticated seed and seed coat revealed that the maximum oil content was in whole seed in white seeds varieties (47.5%) followed by black (40.0%), light brown (39.4%) and dark brown (37.5%) seeds (Table 1). In decorticated seeds, oil content varies within 7% among different coloured seeds. Maximum oil content was found in white seeds (51.0%) followed by light brown (46%), black (45.5%) and dark brown (43.5%) seeds. This indicates that the oil is mainly localised in the dehulled seed (endosperm layers) and the result confirms previous findings by El-Adawy and Mansour (2000) who reported a high content of oil for the dehulled sesame seeds. The seed coat of light brown seeds exhibited the highest oil content (15.0%), which is followed by dark brown seeds (12.85%). Thus, it can be concluded that the maximum loss due to removal of seed coat occurs in light brown and dark brown seeds. The maximum quantity of oil may be retained in the decorticated white seeds even after removal of seed coat.

The mean data for free fatty acid (FFA) content on whole seed, decorticated seed and seed coat revealed that the FFA content in whole seed was minimum in white (0.62%) and maximum in dark brown seed (1.71%). The decorticated black seed contained minimum FFA content (2.13%) followed by dark brown seeds (3.03%). Seed coat of white seeds exhibited the lowest FFA content (0.85%) followed by black seed (1.81%). The highest FFA content in the seed coat was exhibited by light brown seeds (1.96%). The highest FFA content in decorticated seed and seed coat may be due to water used during dehulling. These conditions are favourable to a lipasic activity before drying in the oven. Indeed FFA was partly formed by hydrolysis of triacylglycerols, which was promoted by the presence of food moisture.

Oxalic acid on whole seed, decorticated seed and seed coat revealed that it was minimum in whole seed as recorded by white (0.82%) and a maximum in light brown seeds (1.15%). The decorticated white and dark brown seeds contained minimum level of oxalic acid (0.88%). Seed coat of black (2.65%), light brown (2.15%), dark brown (2.10%) and white (1.84%) exhibited higher oxalic acid than in whole seed and decorticated seed. Thus it can be concluded that the seed coat contains maximum oxalic acid which can be reduced by dehulling. Decortication process makes the seed less bitter and more palatable because this process reduces their level of oxalic acid and phytic acid. Dark/black seeds of sesame are generally more bitter due to the presence of higher level of oxalic acid and fibre than white ones. So, white seeded sesame is preferred in food stuff. Therefore, by dehulling process pigments located in outer epidermis of seed can be eliminated.

The highest protein content was found in whole and decorticated white seeds (18.35 and 16.45%, respectively), whereas seed coat of all varieties exhibited one fourth of protein of the whole seed and decorticated seeds. The decorticated seeds of black (6.35 mg/kg) exhibited the highest sesamol content, whereas the maximum sesamol content in the seed coat was recorded by white (6.95 mg/kg) followed by black seeds (6.60 mg/kg). The decorticated seed and seed coat contained slightly higher amount of sesamol than whole seed. This was probably due to conversion of sesamolin to sesamol during heating as explained by Yoshida *et al*. (1995) and Mohamed and Awatif (1998).

Raw seed, decorticated seed and seed coat showed variation in mineral composition, where iron was the predominant one followed by zinc and copper (Table 2). Magnesium and manganese were present in comparatively low amount. The mineral content varied significantly between seed coat and raw seed, which could be due to the recuperation or elimination of the mineral elements during the dehulling of sesame seed (Mohammed *et al*., 2011). Fibre content in seed coat is slightly higher than raw seed and decorticated seed and ash content in seed coat contained higher amount than raw seed and decorticated seed ranging from 3.0 to 4.6%. This can be considered as the potential source that could be used to meet part of the nutritional requirement for animal feed.

Table 1 Different biochemical traits in whole seed, decorticated seed and seed coat in sesame

Seeds	Oil (%)	FFA (%)	Oxalic acid (%)	Protein (%)	Sesamol (mg/kg)
Whole seeds					
White	47.5	0.62	0.82	18.35	5.60
Light brown	39.4	1.60	1.15	17.20	4.85
Dark brown	37.5	1.71	1.01	16.50	3.80
Black	40.0	1.49	0.93	17.00	5.65
SEm±	0.24	0.03	0.04	0.39	0.06
CD (P= 0.05)	0.84	0.10	0.12	1.35	0.20
Decorticated seeds					
White	51.0	2.80	0.88	16.45	6.15
Light brown	46.0	2.95	0.93	15.35	6.25
Dark brown	43.5	3.03	0.88	14.60	4.65
Black	45.5	2.13	0.91	15.15	6.35
SEm±	0.52	0.05	0.03	0.26	0.03
CD (P = 0.05)	1.80	0.17	0.09	0.92	0.10
Seed coats					
White	11.75	0.85	1.84	6.15	6.95
Light brown	15.0	1.96	2.15	6.85	6.35
Dark brown	12.85	1.95	2.10	6.00	5.85
Black	11.2	1.81	2.65	4.90	6.60
SEm±	0.20	0.02	0.14	0.46	0.04
CD (P = 0.05)	0.69	0.06	0.49	1.59	0.13

Table 2 Nutrients, fibre and ash contents in whole seed, decorticated seed and seed coat of sesame cultivars

Seeds	Fe (mg/100g)	Mn (mg/100g)	Zn (mg/100g)	Mg (mg/100g)	Cu (mg/100g)	Fibre (%)	Ash (%)
Whole seed							
White	10.6	3.4	9.0	0.4	2.2	3.2	2.9
Light brown	9.0	3.3	7.5	0.3	2.5	1.5	1.8
Dark brown	8.7	3.6	7.4	0.2	2.3	2.0	2.2
Black	9.5	3.0	8.8	0.3	2.2	2.5	3.6
SEm±	0.06	0.12	0.29	0.12	0.10	0.04	0.05
CD (P= 0.05)	0.22	0.41	0.99	0.43	0.34	0.13	0.16
Decorticated seed							
White	10.2	4.1	7.5	0.3	1.9	3.4	2.7
Light brown	7.6	3.4	7.1	0.3	2.3	2.3	1.8
Dark brown	7.5	2.8	6.2	0.2	2.1	1.7	2.6
Black	8.5	2.8	6.9	0.2	1.7	3.0	3.8
SEm±	0.12	0.34	0.28	0.01	0.10	0.17	0.05
CD (P= 0.05)	0.43	1.19	0.97	0.04	0.34	0.59	0.16
Seed coat							
White	5.1	4.0	4.2	0.4	2.1	4.6	3.5
Light brown	5.6	4.0	4.0	0.5	1.6	3.5	2.2
Dark brown	4.7	3.5	4.6	0.3	1.2	3.0	2.6
Black	3.7	3.3	4.3	0.4	1.0	3.3	4.3
SEm±	0.05	0.14	0.05	0.01	0.06	0.26	0.03
CD (P= 0.05)	0.16	0.48	0.16	0.03	0.19	0.91	0.12

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Moisture dependent postharvest physical and textural characteristics of brown sesame seed (var. TMV-4)

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ABSTRACT

Physical and textural characteristics are important in design and manufacturing of harvest and post harvest machines. Some postharvest physical and textural characteristics of brown sesame seed (var. TMV-4) were determined as a function of moisture content in the range of 4.3 per cent to 20 per cent (d.b). The axial dimensions, geometric mean diameter, surface area, volume, sphericity and aspect ratio were found to be increasing linearly for all studied moisture levels. Furthermore, the thousand seed mass, true density, porosity and the angle of repose also increased linearly whereas, bulk density decreased linearly with the increase of moisture content under study. The results showed that the static coefficient of friction on four different surfaces of plywood, mild steel, galvanized iron and glass also increased linearly for all level of moisture. The initial cracking force, average rupture force and average rupture energy decreased linearly with increased moisture content of 4.3 to 20 per cent (d.b.).

Keywords: Brown sesame seed, Moisture content, Physical characteristics, Rupture energy

Sesame (*Sesamum indicum* L.), an ancient oilseed, is one of the oldest cultivated plants in the world. It is an annual crop cultivated in tropics to temperate zones. India is a major producer of sesame, followed by China, Myanmar and Sudan (Nagaraj, 2009). The crop is mainly cultivated for its highly nutritious oil. Among all oilseeds, sesame has the highest oil content of 46-64% with 25% protein therefore it is popularly known as queen of oilseeds (Raja *et al*., 2007). Sesame oil, otherwise also referred to as gingelly oil, is one of the major sources of edible oil in India. The oil is also useful in the industrial preparation of perfumery, cosmetics, pharmaceuticals, insecticides, paints and varnishes (Warra, 2011). The postharvest physical properties of sesame seeds such as weight, diameter, surface area, bulk density are required and necessary in the design and optimal performance of the grain threshing unit. The size of grains represented by their equivalent diameter and sphericity is necessary to describe their shape (Arafa, 2007). The surface area is useful to calculate the rate of heat transfer and in the design of appropriate heating equipment. Material size is required for grading and packing (Akintunde and Akintunde, 2004) and in sieve separation and grinding operations (Darvishi, 2012). Bulk density, true density and porosity are required for the design of aeration, storage, transport and separation systems (Barnwal *et al*., 2012). In order to optimize some postharvest handling factors: threshing efficiency, pneumatic conveying and storage of sesame seed; the physical properties of seeds are essential (Gupta and Das, 1997). Information on textural properties with dependency on moisture content could be useful for the design of an efficient dehulling system, equipment for mechanical expression of oil and other processes (Sharma *et al*., 2009).

Research on physical and textural characteristics of sesame seeds is limited. Akintunde and Akintunde (2004) and Arafa (2007) analyzed physical properties of sesame seed at single level of moisture content of 3.4 and 14% (w.b.) respectively, whereas Darvishi (2012) reported the physical and mechanical properties of white sesame seed with four different moisture levels (4.5 to 15% w.b.). However, no literature is available related to brown sesame seed. Thus, keeping in view, this investigation was carried out to study some important physical and textural characteristics of brown sesame seed (var. TMV-4) as a function of moisture content.

MATERIALS AND METHODS

Sesame seed var. TMV-4 developed at Tamil Nadu Agricultural University was procured from Oilseeds Research Station, Tindivanam, Tamil Nadu, India. The seeds were cleaned and graded in CIAE (Central Institute of Agricultural Engineering, Bhopal, India) model cleaner and grader using appropriate set of sieves to remove foreign matter, broken and immature seeds. The initial moisture content of the seed was determined by standard hot air oven method with the temperature settings of 130±1°C for three hours (ASAE, 1999). The initial average moisture content of the seed was found as 4.30% (d.b.). The experimental moisture of the samples (4.3, 8, 12, 16 and 20%, d.b.) was chosen according to the prevailing processing practices and obtained with either adding or removing distilled water (Khodabakhshian *et al*., 2010a). The conditioned samples were sealed in low density polythene bags of 90 µm thickness and kept in refrigerator at 4°C for one week for uniform distribution of moisture throughout the sample. Before starting the actual experiment, required quantity of sample was taken out from the refrigerator and allowed to

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equilibrate at room temperature for two hours (Singh and Goswami, 1996).

About 50 randomly selected seeds of each sample were taken and axial dimensions were determined using digital vernier caliper (Mitutoyo Corp, Japan) of 0.001 mm accuracy. The geometric mean diameter, sphericty, grain volume, surface area and aspect ratio were calculated using the expression mentioned by Darvishi (2012).

Test seed weight was calculated by counting 1000 seeds manually and weighing them in an electronic balance having an accuracy of 0.001g (Akintunde and Akintunde, 2004). The true density of brown sesame seeds was calculated based on Kingsly *et al*. (2006) by displacement method using toluene, to avoid any possible absorption of moisture by seeds. Toluene was taken in measuring cylinder and known quantity of sesame seeds was dipped into toluene. The net volumetric displacement of toluene was recorded. Bulk density, which is the ratio of the mass of seeds to its total volume, was determined by standard test weight procedure by filling seed into 500 ml measuring cylinder to a 15 cm height striking the top level and then weighing the container with digital balance with an accuracy of 0.001g (Balakrishnan *et al*., 2011). The porosity of brown sesame seed was computed in percentage from the values of true density and bulk density using the relationship given by Mohsenin (1986). The experiments were carried out with five replications and the mean value was reported.

The static or filling angle of repose was calculated by using an open ended cylinder of 15 cm diameter and 25 cm height. The cylinder was placed at the center of a circular plate with the diameter of 35 cm. It was filled with the samples and was raised slowly until a cone on the circular plate was formed. The diameter and height of the cone were recorded. The angle of repose was calculated according to Khodabakhshian *et al*. (2010b). The static coefficient of friction was determined with respect to four surfaces *viz*., plywood, mild steel, galvanized iron and glass. These are the common materials used for the transportation, storage and handling operations. Static coefficient of friction apparatus consisted of a frictionless pulley fitted on a frame, a bottomless rectangular box, loading pan and test surfaces. A known quantity of seeds was kept in bottomless box which was placed over a test surfaces and weights were added to the loading pan until the box just began to slide (Fig. 1). Based on Subramanian and Viswanatan (2007), the static coefficient of friction was calculated. The experiments were conducted at least ten times for each level of moisture content, and the mean value was reported.

Textural characteristics such as the initial cracking force, average rupture force and average rupture energy was measured using Texture Analyzer (TA-HDi., Stable micro systems). Twenty five replications were conducted for each textural measurement. The conditioned samples were visually inspected and randomly selected prior to testing and those with visible immature seeds were discarded. The condition-set up in the texture analyzer for measuring textural properties was: Pre-test speed, 1.0 mm/s; Test speed, 0.02 mm/s; Post-test speed, 5 mm/s; Test distance, 0.3 mm; Trigger type, Auto; Trigger force, 0.10 N; Load cell 50 kg; Probe, P/5. Assuming the behavior of seed for impact loading, single seed was placed over the central point of the test surface under the probe in horizontal i.e. normal resting position. The graph was drawn between the force resisted by the test material and time. From the graph, the initial peak position was considered as initial cracking of the test material and the force related to this initial peak position was considered as initial cracking force. The average force experienced by the test material from zero to the test distance is considered as average rupture force and the area under this curve is known as average rupture energy (Sharma *et al*., 2009).

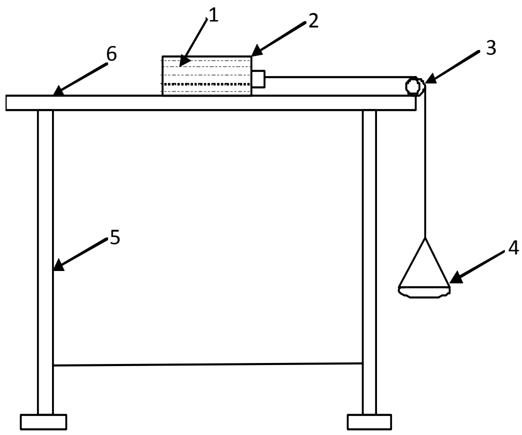


Fig. 1. Experimental setup for static coefficient of friction.
1. Test material; 2. Bottomless rectangular box; 3. Frictionless pulley; 4. Loading pan; 5. Support; 6.Testing surfaces

RESULTS AND DISCUSSION

The effect of moisture content on geometric characteristics of sesame (var. TMV-4) seeds is presented in Fig. 2a, 2b and 2c. The geometric mean diameter, surface area, volume, aspect ratio and sphericity varied between 1.63 - 1.77 mm, 7.14 - 8.21 mm^2, 1.42 - 1.86 mm^3, 0.562 - 0.583 and 0.533 - 0.559, respectively. The increasing trend in axial dimensions, with seed in moisture content was due to the filling of capillaries and voids upon absorption of moisture and subsequent swelling. The equations representing the linear relationship of geometric mean diameter, surface area, volume, sphericity as a function of moisture content of brown sesame seed are presented in Table 1. The results are in line with those reported for other agricultural materials such as cardamom (Balakrishnan *et al*., 2011), coriander seeds (Balasubramanian *et al*., 2012), flaxseed (Singh *et al*., 2012) and white sesame seed (Darvishi, 2012).

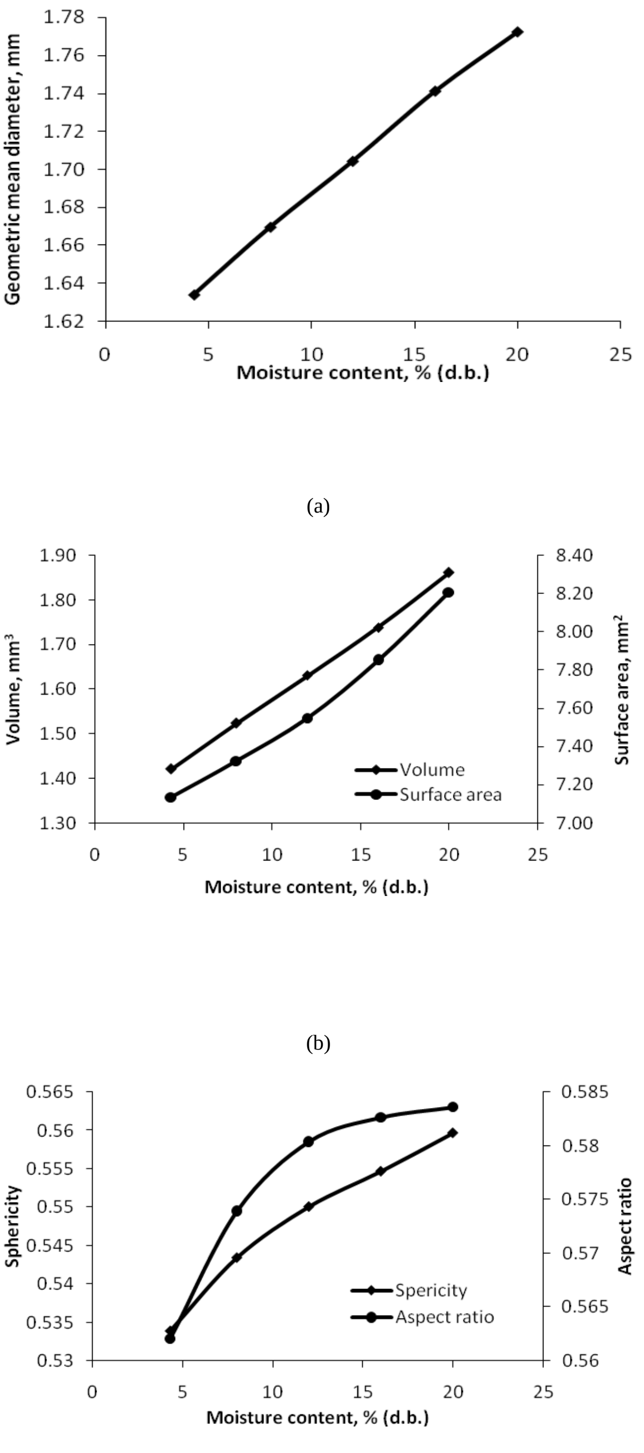


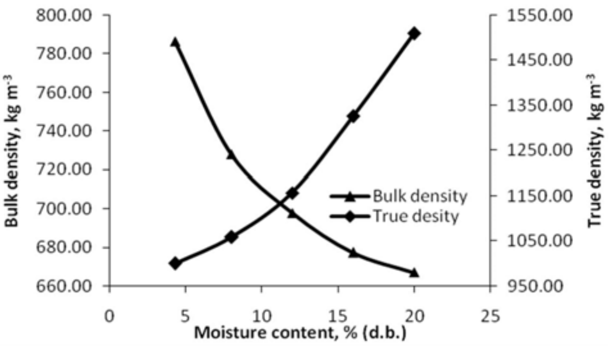
Fig. 2. Effect of moisture content on geometric characteristics of brown sesame seed (var. TMV-4)

Table 1 Regression equations and coefficient of determination (R^2) for physical and textural characteristics of brown sesame seed (var. TMV-4) as a function of moisture content (M, % d.b.)

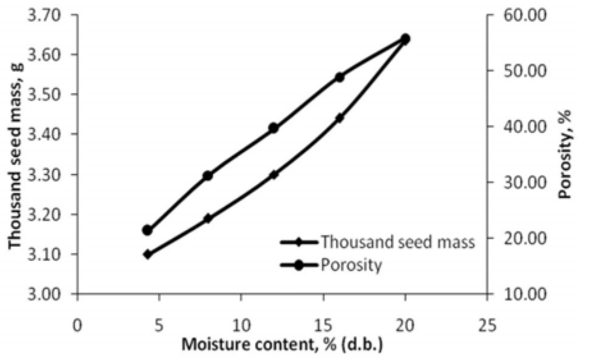
Parameters	Regression Equation	R^2
Geometric mean diameter, mm	0.0088 M + 1.5976	0.9989
Surface area, mm^2	0.0678 M + 6.7959	0.9861
Volume, mm^3	0.0278 M + 1.2995	0.9993
Aspect ratio	0.0013 M + 0.5608	0.8319
Sphericity	0.0016 M + 0.5292	0.9707
Thousand seed mass, g	0.0336 M + 2.9278	0.9795
Bulk density, kg/m^3	-7.3105 M + 799.56	0.9005
True density, kg/m^3	32.697 M + 815.97	0.9616
Porosity, %	2.1936 M + 13.006	0.9949
Angle of repose, degrees	0.5011 M + 12.331	0.9682
Initial cracking force, N	-2.9713 M + 64.551	0.9694
Average rupture force, N	-4.0612 M + 98.285	0.9626
Average rupture energy, N mm	-0.3224 M + 7.8090	0.8990
Static coefficient of friction		
Ply wood	0.0115 M + 0.3350	0.9971
Mild steel	0.0112 M + 0.3256	0.9956
Galvanized iron	0.0105 M + 0.3132	0.9974
Glass	0.0087 M + 0.2959	0.9963

The effect of moisture content on gravimetric properties of brown sesame (var. TMV-4) seeds is shown in Fig. 3a and Fig. 3b. Thousand seed mass increased linearly as moisture content increased from 4.3-20 per cent (d.b.). The mean value of thousand seed mass ranged from 3.10-3.64 g. Similar trend of linear increase in the thousand seed mass with the increase in seed moisture content has been reported by Singh and Goswami (1996) for cumin seed and Coskuner and Karababa (2007) for flaxseed. The bulk density of brown sesame seed in the moisture range of 4.3 to 20 per cent (d.b.) exhibited linear decreasing trend. In other words, the increase in mass because of moisture gain in the sample was smaller than the accompanying volumetric expansion of the bulk. The range of bulk density at different moisture levels was recorded between 786.50 and 667.09 kg/m^3. The negative linear relationship of bulk density with moisture content was also observed by Karababa (2006), Visvanathan *et al*. (1996), Altuntas *et al*. (2005), Khodabakhshian *et al*. (2010a) and Darvishi (2012) for popcorn kernels, neem nut, fenugreek, sunflower seeds and white sesame seeds, respectively.

The true density of var.TMV-4 brown sesame seed varied from 1000.22 to 1509.67 kg/m^3, while Darvishi (2012) reported decreasing trend of true density in white sesame seed in the range of 1140 to 943.5 kg/m^3. These trends are also in line with the results for other oil seeds reported by Khodabakhshian *et al*. (2010a) for sunflower seeds and Coskuner and Karababa (2007) for flaxseed. As it was found, the porosity of particulate material depends on both bulk and true density; therefore the variation of porosity is directly affected by these parameters. The porosity was increased linearly with moisture content. The porosity of brown sesame seed ranged from 21.37-55.81 per cent. Higher porosity values provide better aeration and water vapor diffusion during deep bed drying. The linear increasing trend of porosity with moisture was observed for some other agricultural materials such as cumin seed (Singh and Goswami, 1996) and flaxseed (Coskuner and Karababa, 2007). The regression equations and their respective coefficients of determination (R^2) for the measured gravimetric properties of seed as a function of moisture content are presented in Table 1. As the coefficient of determination (R^2) was adequately high, it seems that the moisture content had remarkable influence on the measured parameters.



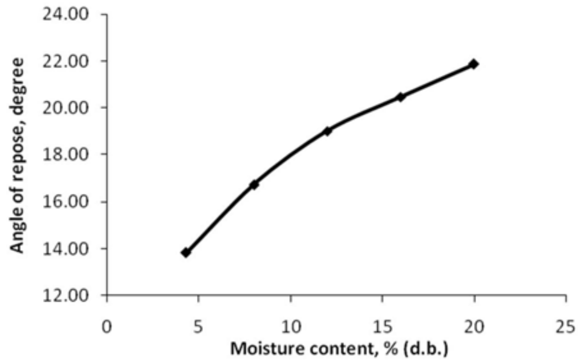
(a)



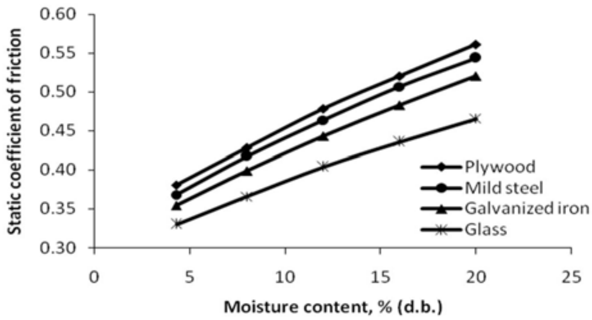
(b)

Fig. 3. Effect of moisture content on gravimetric characteristics of brown sesame seed (var. TMV-4)

The angle of repose of brown sesame seed showed a linear increasing trend with moisture (Fig. 4a). The angle of repose ranged between 13.83 to 21.85 degrees. A similar increasing trend of angle of repose with moisture content for different plant materials was reported by Gupta and Das (1997) for sunflower seed, Darvishi (2012) for white sesame seed and Subramanian and Viswanatan (2007) for millets. Coefficient of static friction for brown sesame seed at various surfaces such as plywood, mild steel, galvanized iron and glass are presented in Fig 4b.



(a)

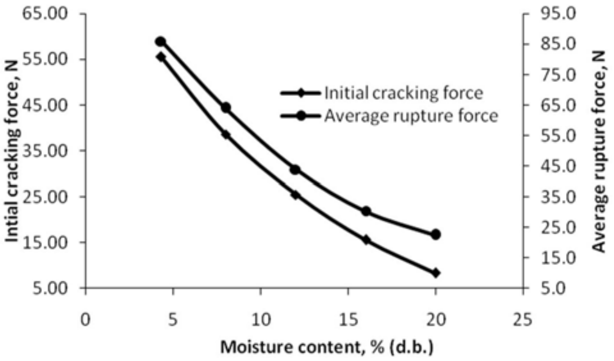


(b)

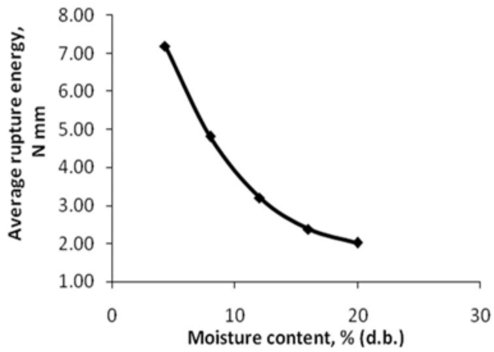
Fig. 4. Effect of moisture content on frictional characteristics of brown sesame seed (var. TMV-4)

As seen from the figure, the coefficient of static friction increased linearly with moisture content for seed against all the contact surfaces studied. The static coefficient of friction of brown sesame seed against various surfaces increased from 0.33 to 0.56. The highest friction coefficient of seed was observed for plywood surface followed by mild steel, galvanized iron and glass. The values of the coefficient of static friction were found lower against glass surface at all moisture levels. This may be due to the smoother and more polished surface of glass sheet compared to the other test surfaces. Previous studies also reported an increase in the static coefficient of friction with increase in moisture content for flaxseed (Singh *et al*., 2012), pomegranate seeds (Kingsly *et al*., 2006), neem nut (Visvanathan *et al*., 1996), sunflower seed (Gupta and Das, 1997), white sesame seed (Darvishi, 2012). The regression equations and their respective coefficients of determination (R^2) for the measured frictional properties of brown sesame seed as a function of moisture content are presented in Table 1.

The variation of textural characteristics of brown sesame seed at different moisture levels are given in Fig. 5a and 5b. It was observed that initial cracking force, average rupture force and the average rupture energy decreased linearly with the increase in moisture level.



(a)



(b)

Fig. 5. Effect of moisture content on textural characteristics of brown sesame seed (var. TMV-4)

The average values ranged between 55.57-8.35 N, 85.9 - 22.5 N and 7.19 - 2.02 N mm, respectively. The decreasing trend might be due to externally applied force which creates shear stresses in internal tissues causing rupture of the cotyledon, and because there is a definite cellular arrangement in the cotyledon tissues, a greater or lesser force may be required to cause rupture (Peterson *et al*., 1995). Similar type of observations as a function of moisture content was recorded by Sunflower (Gupta and Das, 2000; Sharma *et al*., 2009) canola and wheat (Bargale *et al*., 1995) and white sesame seed (Darvishi, 2012).

Conclusions

- The average geometric mean diameter, surface area, volume, aspect ratio and sphericity varied between 1.63 - 1.77 mm, 7.14 - 8.21 mm^2, 1.42 - 1.86 mm^3, 0.562 - 0.583 and 0.533 - 0.559, respectively.
- Bulk density of brown sesame seed was found to decrease from 786.50 to 667.09 kg/m^3 but true density and porosity increased with moisture content.
- Increase in moisture resulted in linear increase in angle of repose for brown sesame seed varied from 13.83-21.85 degrees when moisture increased from 4.3 to 20 per cent (d.b.).
- The static coefficient of friction against different materials (plywood, mild steel, galvanized iron and glass) increased with increase in moisture content.
- The initial cracking force, average rupture force and the average rupture energy decreased linearly with all studied moisture level.
- Changes in moisture content of brown sesame seeds exhibited profound impact on its physical and textural characteristics.
- The present study provides basic useful data about physical and textural properties of brown sesame seeds for designing postharvest processing machines.

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Interaction and tolerance to *Alternaria brassicae* in Indian mustard (*Brassica juncea*) genotypes

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ABSTRACT

The biochemical changes were observed in leaves of Indian mustard tolerant (EC-399301, EC-399296, EC-399299, PHR-2) and susceptible (Varuna) genotypes infected with Alternaria blight (AB) caused by *Alternaria brassicae* at critical stage (75 days after sowing) of disease development. The presence of metabolites in infected *B. juncea* leaves such as glucosinolate (µ moles), phenol (mg/g), sugar (mg/g), protein (mg/g), carotenoids (µg/g) and chlorophyll (mg/g) were highly associated with the fungal infection. As compared to the susceptible check Varuna, level of glucosinolate, sugar, carotenoids and chlorophyll were decreased in tolerant hosts' leaves after pathogen infection. Although, the phenol and protein content in tolerant and susceptible genotypes were increased in AB infected leaves than healthy leaves. Our findings are discussed within the context of *A. brassicae-B. juncea* interaction and tolerance to this pathogen. The results indicated that factors conditioning the host response to *A. brassicae* might be the outcome of complex biochemical changes operated in host genotypes.

Keywords: Alternaria blight, Biochemical changes, Genotypes, Indian mustard

Rapeseed-mustard (*Brassica* species) crops ravaged by the devastating Alternaria blight disease which is caused by *Alternaria brassicae* (Berk) Sacc. resulted up to 47 per cent yield losses (Kolte *et al*., 1987). Biochemical defense mechanism consists of the presence or absence of a meticulous chemical substance or a group of substances in a host plant which interferes with the growth and development of a pathogen. Preformed antifungal compounds that occur constitutively in healthy plants are probable correspond to inherent chemical barriers to infection and may protect plants beside show aggression by a wide range of probable pathogens. The biochemical constituents may be present before infection or may be produced by the interaction of host and pathogen (post-infection). Upon being infected by pathogens, a complex variety of defense responses are developed by plants. In addition to the pre-formed biochemical defenses, a number of defense responses are induced in plants in response to infection by pathogens (Yamunarani *et al*., 2004). The synthesis of new proteins that can have direct or indirect action on the course of pathogenesis is a ubiquitous response of many plants to pathogen attack. Moreover, proteins/enzymes, some metabolites such as phenols, sugars, free amino acids, proline, ascorbic acid and carotenoids also impart vital role in disease resistance. Therefore, they may be responsible for the resistance by good value of their higher levels in resistant cultivars (Parashar *et al*., 1987) at the critical stage 75 days after sowing for the development of Alternaria blight (Meena *et al*., 2004). Hence, the present investigation was conducted to study the *A. brassicae - B. juncea* interaction and tolerance in Indian mustard genotypes.

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MATERIALS AND METHODS

Four tolerant (EC-399301, EC-399296, EC-399299, PHR-2) and a highly susceptible (Varuna) Indian mustard genotypes were identified on the basis of their performance under different geographical conditions under All India Coordinated Research Project on Rapeseed- Mustard (2007-2011). The plants of these genotypes were sown and spray-inoculated using an atomizer at 60 days after sowing (DAS) by single conidia culture spore suspension with 2×10^5 conidia/ml of *A. brassicae* local isolate. All the biochemical parameters were analyzed at two stages i.e., pre-inoculation (60 DAS) and post-inoculation (75 DAS). Healthy and infected fresh leaf samples for biochemical analysis were collected randomly from the plants. Healthy and infected leaf samples were analyzed for different biochemical parameters *viz*., total soluble sugars, total soluble proteins, total phenols, total chlorophyll and total carotenoids to study the biochemical changes associated with the development of disease and to study the relationship of disease development with biochemical constituents (Table 1). Total sugar content was estimated by phenol-sulphuric acid method while total soluble proteins were estimated by Lowry's method. Total phenol was estimated by Folin Ciocalteu reagent method. Total chlorophyll was estimated as per Arnon (1949) and total carotenoids content was determined using the same extract as used for chlorophyll (Lichtenthaler and Wellburn, 1983).

RESULTS AND DISCUSSION

Total soluble sugars: Higher amount of total sugars were present in healthy leaf samples of tolerant genotypes at pre-inoculation stage and the lowest in diseased leaf samples of susceptible cultivar Varuna (Table 2). Similar results showing higher sugar content in tolerant genotypes have been obtained in leaf blight of Barley (*Hordeum vulgare*) (Singh *et al*., 2009), downy mildew and white rust of *B. napus* (Singh, 2000) and charcol rot disease of bean (Baraka *et al*., 2004). Our results are supported by the observations obtained by Bhargava and Khare (1988) who reported that total and reducing sugars are more in resistant and low in susceptible cultivars of chickpea against Alternaria leaf blight. The reduction in sugar content after infection may be due to rapid hydrolysis of sugars during pathogenesis through enzymes (hydrolases) secreted by pathogens and subsequent utilization by pathogens for their development. Moreover, sugars are precursors of phenolics which are highly toxic to microorganisms. These may be the probable reasons for higher sugar content in resistant genotypes. The higher content of sugar in resistant cultivars indicates clearly that it provides resistance to them. The decrease in total sugars is expected due to deficiency in photosynthetic pigments, the magnitude of which has been reported to be directly proportional to the rate of photosynthesis. The co-existence of free sugars and phenols results in glycosylation of phenols by sugars forming phenolic glycosides which are more soluble in cell sap and thus are involved more efficiently in resistance expression. Singh (2004) also reported that total sugar content decreased in all the infected plant parts of different *Brassica* spp. studied and total sugar was found lower at all stages of infection due to *A. solani* as compared to healthy ones.

Table 1 Alternaria blight severity on *B. juncea* genotypes

Genotype	Alternaria blight severity (%)	
	Leaves	Siliquae
EC-399301	10.0 (18.4)	5.0 (12.9)
EC-399296	6.3 (14.4)	7.1 (15.4)
EC-399299	7.9 (16.3)	2.7 (9.4)
PHR-02 (TC)	3.3 (10.5)	1.7 (7.2)
Varuna (SC)	44.2 (41.2)	15.8 (23.5)
CD (P=0.05)	3.2	3.4

TC - Tolerant Check SC - Susceptible Check

Total soluble proteins: In the present investigation, total soluble proteins were reported to be highest in the diseased samples (leaves and pods) of susceptible genotype (Varuna) at pre-harvest stage while the lowest were recorded in healthy samples of moderately resistant genotypes (PHR 2 and EC 399299) at pre-inoculation stage. The results are in accordance with Mogle and Mayee (1981) who observed considerable reduction of amino acids in leaf proteins from virus tolerant and virus susceptible varieties of apple and pearl millet infected with downy mildew, respectively. Saud *et al*. (2000) reported the decrease of protein content in guava after infection with *Aspergillus niger* while Ghosh *et al*. (2003) found that the healthy leaves of mulberry plants possessed more proteins than the infected ones.

In our experiment on changes in protein content with progression of stages, it was found that with increase in infection of *A. brassicae* the protein content increased. The results are in conformity with the results of Junqueira *et al.* (2004) who reported an increase of protein content in corn plants infected by the maize bushy stunt phytoplasma. During the host pathogen interaction, amino acids act as substrate for the pathogen or they may have a fungistatic effect through their involvement in metabolic reactions associated with disease resistance e.g., the synthesis of specific proteins related to the infection.

Total phenols: Phenolics confer resistance to infection by microbes, presumably by inactivation of fungal enzymes or viral nucleoproteins. These compounds accumulate around the sites of injury or microbial penetration at concentrations that are sufficient to inhibit many pathogens of the host. These compounds are widely distributed in higher plants and are involved in their resistance mechanism to parasitic fungi and bacteria. Accumulation of phenolic compounds including ortho-dihydric phenols (OD phenols) in host-parasite reaction is a general phenomenon of disease resistance and the rate of accumulation and breakdown of phenolic compounds determine the degree of resistance. These compounds have long been correlated with the resistance of plants to infectious agents (Singh, 2000). In our studies, higher amount of total phenols was observed in diseased samples (leaves and pods) as compared to healthy leaves and pods and phenol content was higher in moderately resistant varieties at pre-harvest stage. The lowest phenols were recorded at pre-inoculation stage in the healthy samples of highly susceptible genotypes. The results are in agreement with the findings of Singh (2000) who observed higher phenol content in diseased plant parts of resistant varieties.

The accumulation of phenolic compounds in infected host tissues may be related to their release from glycosidic esters by the enzymatic activity of host or pathogen. Some workers have implicated o-dihydroxy phenol concentration as a resistance factor because they become highly reactive upon oxidation and may form substances toxic to pathogens or inactivate enzymes including hydrolytic enzymes produced by plant pathogenic fungi. Studies have shown that qualitative and quantitative changes in phenolic compounds occur after infection with various pathogens in crop plants and it was also found that the accumulation of phenolics was much higher in resistant cultivars than in susceptible ones. The post-infection increase in phenolic content could be due to a number of factors including enhancement of synthesis, translocation of phenolics to the site of infection and hydrolysis of phenolic glycosides by fungal glycosidases to yield free phenols and the increase in level of phenolic compounds in infected leaves may be due to translocation of phenolics to the site of infection (Parashar *et al*., 1987). The results obtained clearly showed that higher amount of phenols in resistant genotype made it resistant.

Table 2 Different biochemical parameters in Indian mustard leaves due to Alternaria blight infection

Biochemical Parameters/ Genotype	Glucosinolate (µ moles)		Sugars (mg/g)		Protein (mg/g)		Phenols (mg/g)		Carotenoids (µg/g)		Chlorophyll (mg/g)	
	H	I	H	I	H	I	H	I	H	I	H	I
EC 399301	15. 7	9.4	13.3	8.5	53.2	69.9	2.9	4.1	7	2.7	0.8	0.5
EC 399296	18.7	11.3	10.1	6.3	43.6	50.6	3.5	4.9	3.7	2	0.6	0.4
EC 399299	13.9	8.7	10.9	9.8	31.9	32.9	3.1	4.3	7.3	5	0.7	0.7
PHR 2	10.3	6.5	9.7	6.8	33.4	30.7	4.1	4.5	4.3	2.3	0.6	0.3
Varuna	11.2	9.8	9.9	12.8	31.4	54.5	1.2	2.6	3.7	2	0.5	0.4
CD (P=0.05)	0.7		1.08		1.51		0.21		1.0		0.1	
Correlation with ABL	-0.357	0.280	-0.206	0.887	-0.340	0.334	-0.957	-0.960	-0.363	-0.301	-0.585	-0.123
Correlation with ABS	-0.061	0.541	-0.229	0.713	-0.165	0.464	-0.899	-0.817	-0.524	-0.483	-0.624	-0.234

H= Healthy; I= Infected; ABL= Alternaria blight on leaf; ABS= Alternaria blight on siliquae

Accumulation of phenols plays a natural role in inducing resistance in different plants. The presence of higher concentration of phenols in the leaf tissue provides a chemotoxic barrier against the pathogens. Our results are also in agreement with the findings of Yadav *et al*. (1996) who reported the inheritance of phenols in relation to white rust resistance in Indian mustard. Our results are also supported by Singh (2000) who reported the increase in phenol content after infection in *Brassica* species against downy mildew and white rust of mustard. One of the widely accepted explanations of how the phenol system and related oxidative enzymes operate in diseased plants is that following infection by pathogens, the plant releases various phenolic compounds whose oxidation products such as quinones, are toxic to the invading pathogens and pests (Dogan *et al*., 2007).

Chlorophylls and carotenoids: Present investigations on total chlorophyll content revealed that higher content was observed in healthy leaves and pods of moderately resistant cultivars as compared to diseased leaves and pods (Table 2). The highest chlorophyll content was recorded at pre-inoculation stage in the healthy samples of moderately resistant genotypes (EC 399301, EC 399299 and PHR 2) and the lowest was found in the diseased samples of highly susceptible genotypes (Varuna) at pre-harvest stage. Many workers have attributed various reasons for the phenomenon of reduction of chlorophyll. Borah *et al*. (1978) working with red rust of tea suggested that the reduction in content of chlorophyll a and b might be due to inhibition of synthesis rather degradation of pre-existing pigments. The loss of chlorophyll content due to *A. solani* has been reported by Choulwar and Datar (1991).

The results also corroborate with those observed by Nema (1991) in betelvine leaves that the reduction in total chlorophyll, chlorophyll a and chlorophyll b was more pronounced in highly susceptible cultivars. The loss of chlorophyll in diseased leaves and pods under the present investigation may be due to interference by pathogen in the normal chlorophyll synthesis or breakdown of chlorophyll due to activation of enzymes that degrade chlorophyll (Rathore *et al*., 2001). Significant differences in chlorophyll content of all cultivars were observed which decreased upon infection. Singh (2004) reported that chlorophyll content decreased in all the infected plant parts of all *Brassica* spp. A considerable decrease in the chlorophyll content was observed in infected leaves of Withania somnifera which could be the consequence of disorganisation of the chloroplast membrane system and breakdown of the chloroplast envelope during infection (Pati *et al*., 2008).

The carotenoids content was found to increase with increase in infection and the increase was more prominent in the diseased samples of highly susceptible varieties. The highest total carotenoids content was found in the diseased samples of highly susceptible genotypes at pre-harvest stage and the lowest was recorded at pre-inoculation stage in the healthy samples of moderately resistant genotypes. Our results corroborate with those of Mali *et al*. (2000) who reported that the reduction in carotenoids content was more in susceptible genotype than in resistant genotypes of moth bean following YMV infection. The results indicated that factors conditioning the host response to *A. brassicae* might be the outcome of complex biochemical changes operated in host genotypes.

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Assessment of avoidable yield losses due to insect pests in castor (*Ricinus communis* L.)

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ABSTRACT

Field experiments were carried out to evaluate the avoidable yield losses caused by insect pests on three castor cultivars (DCH-519, DCH-177 and 48-1) during *kharif* and *rabi* seasons of 2012-13 and 2013-14. Semilooper, tobacco caterpillar, hairy caterpillar, capsule borer and leafhopper were recorded as major pests. However, the pest succession varied with the season. The results revealed that significantly lower infestation of insect pests was observed in protected plots over unprotected plots. Higher mean seed yield of 1996 kg/ha and 1596 kg/ha was recorded from protected plots, while seed yield of 1421 kg/ha and 750 kg/ha was recorded from unprotected plots during *kharif* 2012-13 and 2013-14, respectively. During *rabi* season, higher mean seed yield of 1050 kg/ha and 927 kg/ha was recorded in protected plots, while unprotected plots recorded seed yield of 542 kg/ha and 375 kg/ha during 2012-13 and 2013-14, respectively. The mean avoidable yield losses due to insect pests on castor cultivars ranged from 17.2 to 63.3 per cent during *kharif* season, while the loss was higher (22.5 to 89.4%) during *rabi* season. Among the cultivars, DCH-519 revealed minimum avoidable yield losses due to insect pests in both *kharif* and *rabi* seasons.

Keywords: Avoidable yield loss, Castor, Cultivars, Insect pests, Pest succession

Castor (*Ricinus communis* L.) is an industrially important oilseed crop of India. The crop is attacked by a number of insect pests which impose a great limitation in realizing the potential productivity. Among the insect pests, semilooper, tobacco caterpillar, leafhopper and capsule borer are of greater economic importance (Lakshminarayana *et al*., 2013). The magnitude of the insect pests problem is quite high in Southern India where castor is grown mainly as rainfed crop, while it is low in Gujarat and Rajasthan under irrigated conditions (Lakshminarayana, 2005). Development of Integrated Pest Management strategies for each agro-ecological zone to exploit full yield potential is the need of the day. Information on crop losses is prerequisite to determine the relative importance of pests and to provide a sound base for an integrated management schedule. Yield loss in castor due to defoliation by semilooper and capsule damage by capsule borer was worked out in South India (Anonymous, 2006; Rao *et al*., 2012). However, information on the yield loss due to insect pest complex as a whole in castor is scanty. Hence, the present study was undertaken with the main objective of generating data on the avoidable yield losses caused by insect pests during *kharif* and *rabi* seasons in castor.

MATERIALS AND METHODS

Field experiments were conducted at Research Farm, Directorate of Oilseeds Research, Hyderabad during *kharif* and *rabi* seasons of 2012-13 and 2013-14 with three castor cultivars *viz.*, DCH-519, DCH-177 and 48-1 under protected and unprotected conditions. Each cultivar was sown (Ist fortnight of July and October during *kharif* and *rabi* seasons, respectively) in two plots, each of size 100 m^2 with a spacing of 90 cm x 90 cm. All agronomic practices were followed as per the recommendations except for insect-pest management. Unprotected plots were kept free from insecticides and subjected to the natural infestation of the insect pests. Whereas, protected plots were treated with foliar application of monocrotophos 0.04% at 15-20 days intervals starting from seedling stage to the maturity stage of the crop. In each treatment, the plot was divided in to four blocks (each block of 25 m^2, considering each as one replicate) and the observations of insect pests were taken from five randomly selected plants in each block at fortnightly intervals. In each harvest, the data on total number of capsules and number of capsules damaged by the capsule borer was recorded from each block and then per cent capsule damage was worked out. Mean insect numbers and per cent damage across sampling intervals were determined to provide a single index of pest population for making comparison across treatments. The final pooled mean data was analyzed and presented. The yield was recorded on each block individually by spike order (at the time of harvest of each primary, secondary and tertiary) which was converted to kg/ha for statistical interpretations. Treatment effects were analyzed using Factorial Randomized Block Design with four replications. Following ANOVA, differences between datasets were determined using least significant difference at P=0.05 using

AGRES statistical software. The avoidable yield loss was calculated using the following formula:

Per cent avoidable yield loss =

$$\frac{\text{Yield in protected crop - Yield in unprotected crop}}{\text{Yield in protected crop}} \times 100$$

RESULTS AND DISCUSSION

Data on the incidence of major insect pests and yield losses caused by them were assessed in three castor cultivars (DCH-519, DCH-177 and 48-1) during *kharif* 2012-13 and 2013-14 is presented in Tables 1 and 2. Semilooper (*Achaea janata*), tobacco caterpillar (*Spodoptera litura*), hairy caterpillar (*Euproctis fraterna*), capsule borer (*Conogethes punctiferalis*) and leafhopper (*Empoasca flavescens*) were recorded as major insect pests during *kharif* season. Incidence of semilooper and tobacco caterpillar was noticeable throughout the crop season. Capsule borer and leafhopper were observed during reproductive stage and remained active till crop maturation. Hairy caterpillar recorded as major pest during *kharif* 2013-14 and its incidence appeared during reproductive stage and continued throughout the growing season. Significantly less population of the insect pests on all three cultivars was registered in protected crop than in unprotected crop (Table 1). The mean population of semilooper (0.9 and 0.6 larvae/plant), *S. litura* (0.08 and 1.2 larvae/plant), leafhopper (19.3 and 12.4 leafhoppers/3 leaves/plant) and capsule borer (6.2 and 7.1% capsule damage) was low in protected plots as compared to unprotected plots (4.2 and 2.4 semilooper larvae/plant; 0.3 and 4.0 *S. litura* larvae/plant; 68.0 and 52.2 leafhoppers/3 leaves/plant; 8.1 and 15.8% capsule damage) during *kharif* 2012-13 and 2013-14, respectively. Similarly, mean population of hairy caterpillar recorded during *kharif* 2013-14 was low in protected plots (0.3 larvae/plant) as compared to untreated plots (0.9 larvae/plant).

Table 1 Population of insect pests on castor under protected and unprotected conditions during *kharif* (2012-13 and 2013-14)

Kharif (2012-13)

Cultivar	Semilooper (larvae/plant)[$]		*Spodoptera litura* (larvae/plant)[$]		Leafhopper (No./3 leaves/plant)[$]		Capsule damage (%)[#]	
	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
DCH-519	0.7 (1.1)	3.4 (1.9)	0.03 (0.7)^{a}	0.1 (0.8)^{a}	15.6 (4.0)	45.3 (6.7)	7.0 (15.3)	9.7 (18.1)
DCH-177	0.9 (1.2)	4.5 (2.2)	0.1 (0.8)^{a}	0.3 (0.9)^{b}	24.6 (4.9)	87.0 (9.2)	7.2 (15.6)	8.6 (17.0)
48-1	1.1 (1.3)	4.8 (2.3)	0.1 (0.8)^{a}	0.6 (1.0)^{b}	17.7 (4.3)	71.7 (8.5)	4.5 (12.1)	6.1 (14.3)
Mean	0.9 (1.2)^{a}	4.2 (2.1)^{b}	0.08 (0.8)^{a}	0.3 (0.9)^{b}	19.3 (4.4)^{a}	68.0 (8.1)^{b}	6.2 (14.3)^{a}	8.1 (16.5)^{b}

	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±
Plant Protection (P)	*	0.20	0.10	*	0.05	0.02	*	0.99	0.47	*	1.54	0.72
Cultivars (C)	NS	-	0.11	*	0.06	0.03	*	1.22	0.57	*	1.88	0.88
Interaction (PxC)	NS	-	0.16	*	0.08	0.04	NS	-	0.81	NS	-	1.25

Kharif (2013-14)

Cultivar	Semilooper (larvae/plant)[$]		*Spodoptera litura* (larvae/plant)[$]		Hairy caterpillar (larvae/plant)[$]		Leafhopper (No./3 leaves/plant)[$]		Capsule damage (%)#	
	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
DCH-519	0.7 (1.1)	2.8 (1.8)	0.9 (1.2)	4.6 (2.3)	0.2 (0.8)	0.7 (1.1)	6.2 (2.6)^{a}	20.2 (4.5)^{b}	6.8 (15.0)	16.6 (24.0)
DCH-177	0.2 (0.8)	2.3 (1.7)	1.2 (1.3)	3.6 (2.0)	0.3 (0.9)	0.7 (1.1)	16.4 (4.1)^{b}	81.1 (9.0)^{d}	7.9 (16.1)	17.2 (24.4)
48-1	0.8 (1.1)	2.0 (1.6)	1.4 (1.4)	3.7 (2.0)	0.3 (0.9)	1.3 (1.3)	14.7 (3.9)^{b}	55.2 (7.4)^{c}	6.7 (15.0)	13.7 (21.6)
Mean	0.6 (1.0)^{a}	2.4 (1.7)^{b}	1.2 (1.3)^{a}	4.0 (2.1)^{b}	0.3 (0.9)^{a}	0.9 (1.2)^{b}	12.4 (3.5)^{a}	52.2 (7.0)^{b}	7.1 (15.4)$_{a}$	15.8 (23.3)^{b}

	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±
Plant Protection (P)	*	0.15	0.07	*	0.17	0.08	*	0.11	0.05	*	0.53	0.25	*	2.26	1.06
Cultivars (C)	NS	-	0.09	NS	-	0.10	NS	-	0.06	*	0.65	0.30	NS	-	1.30
Interaction (PxC)	NS	-	0.13	NS	-	0.14	NS	-	0.09	*	0.91	0.43	NS	-	1.84

* - Significant; NS- Non Significant [$]Figures in the parentheses are square root transformed values; [#]Figures in parentheses are arc sin transformed values

In a column means followed by the same alphabet do not differ significantly by LSD (P=0.05)

Significantly higher seed yield was recorded in protected plots over unprotected plots during both *kharif* 2012-13 and 2013-14 (Table 2). The data revealed that a higher mean seed yield of 1775 to 2275 kg/ha with an average of 1996 kg/ha and 1484 to 1776 kg/ha with an average of 1596 kg/ha was recorded from protected plots, while the mean seed yield of 1075 to 1813 kg/ha with an average of 1421 kg/ha and 286 to 1298 kg/ha with an average of 750 kg/ha was recorded from unprotected plots during *kharif* 2012-13 and 2013-14, respectively. The avoidable yield losses due to insect pests on different cultivars of castor ranged from 20.3 (DCH-519) to 44.5 per cent (DCH-177) with an average of 29.1 per cent and 12.5 (DCH-519) to 83.9 per cent (DCH-177) with an average of 50.9 per cent during *kharif* 2012-13 and 2013-14, respectively. On basis of pooled results of *kharif* 2012-13 and 2013-14, the avoidable yield losses due to insect pests on different cultivars of castor ranged from 17.2 (DCH-519) to 63.3 per cent (DCH-177) with an average of 39.5 per cent.

Table 2 Avoidable yield losses due to insect pests in castor during *kharif* (2012-13 and 2013-14)

Cultivar	*Kharif* 2012-13				*Kharif* 2013-14				Pooled Mean			
	Yield (kg/ha)			% avoidable loss	Yield (kg/ha)			% avoidable loss	Yield (kg/ha)			% avoidable loss
	Protected	Unprotected	Mean		Protected	Unprotected	Mean		Protected	Unprotected	Mean	
DCH-519	2275	1813	2044[a]	20.3	1484[b]	1298[c]	1391[a]	12.5	1880	1556	1718	17.2
DCH-177	1938	1075	1507[b]	44.5	1776[a]	286[e]	1031[b]	83.9	1857	681	1269	63.3
48-1	1775	1375	1575[b]	22.5	1528[b]	666[d]	1097[b]	56.4	1652	1021	1337	38.2
Mean	1996[a]	1421[b]	1709	29.1	1596[a]	750[b]	1193	50.9	1796	1086	1441	39.5
	F-test	CD at 5%	SEm±	-	F-test	CD at 5%	SEm±	-	F-test	CD at 5%	SEm±	-
Plant Protection (P)	*	212	99	-	*	106	50	-	*	126	59	-
Cultivars (C)	*	260	122	-	*	130	61	-	*	155	73	-
Interaction (PxC)	NS	-	172	-	*	183	86	-	*	219	103	-

* - Significant; NS- Non Significant

The incidence of insect pests during *rabi* season was found similar as *kharif* season and semilooper, tobacco caterpillar, hairy caterpillar, leafhopper and capsule borer were recorded as major insect pests during *rabi* season. However, variation in pest succession was observed during *rabi* season. Leafhoppers appeared in seedling stage and remained active till crop maturation. Tobacco caterpillar, semilooper and hairy caterpillar also appeared in seedling stage and remained active till vegetative stage. Capsule borer was observed during reproductive stage and continued throughout the season. The incidence of pests was found significantly lower in protected plots as compared to the untreated plots during both the years (Table 3). The mean population of leafhopper (27.4 and 14.1 leafhoppers/3 leaves/plant), *S. litura* (0.03 and 0.4 larvae/plant), semilooper (0.4 and 0.2 larvae/plant), hairy caterpillar (0.3 and 0.1 larvae/plant) and capsule borer (1.0 and 8.5% capsule damage) was low in protected plots as compared to unprotected plots (88.8 and 53.8 leafhoppers/3 leaves/plant; 0.3 and 1.7 *S. litura* larvae/plant; 1.2 and 1.2 semilooper larvae/plant; 1.8 and 1.2 hairy caterpillar larvae/plant; 2.5 and 14.1% capsule damage) during *rabi* 2012-13 and 2013-14, respectively.

Higher seed yield of 988 to 1100 kg/ha with an average of 1050 kg/ha and 686 to 1064 kg/ha with an average of 927 kg/ha was recorded in protected crops during *rabi* 2012-13 and 2013-14, respectively. Castor cultivars under unprotected conditions recorded minimum seed yield of 525 to 888 kg/ha with an average of 542 kg/ha and 0 to 762 kg/ha with an average of 375 kg/ha during *rabi* 2012-13 and 2013-14, respectively. Among the cultivars, yield of 48-1 and DCH-519 was maximum (1100 kg/ha and 1064 kg/ha) in protected conditions during *rabi* 2012-13 and 2013-14, respectively. Seed yield of DCH-177 was higher in protected conditions (988 kg/ha and 1030 kg/ha during *rabi* 2012-13 and 2013-14, respectively), while DCH-177 under unprotected conditions suffered heavy loss due to insect pests especially due to leafhopper resulted minimum seed yield of 213 kg/ha during *rabi* 2012-13 and complete failure of crop during *rabi* 2013-14. Among the castor cultivars, yield of DCH-519 was maximum under unprotected conditions (888 kg/ha and 762 kg/ha during *rabi* 2012-13 and 2013-14, respectively) (Table 4). The avoidable yield losses due to insect pests on different cultivars of castor ranged from 16.5 (DCH-519) to 78.4 per cent (DCH-177) with an average of 49.1 per cent and 28.4 (DCH-519) to 100 per cent (DCH-177) with an average of 58.5 per cent during *rabi* 2012-13 and 2013-14, respectively. Pooled means of the two years data revealed that the avoidable yield losses due to insect pests on different cultivars of castor ranged from 22.5 (DCH-519) to 89.4 per cent (DCH-177) with an average of 54.1 per cent.

The insect pest complex of crops has undergone a tremendous change during the last two decades due to change in cropping pattern, introduction of high yielding cultivars and insecticide application pattern (Kooner *et al.*, 2006). Some major pests have become insignificant, while others continue to remain serious. On the other hand, some species, which were of minor importance in the past, have become dominant pests, and others that were never reported have appeared. This kind of shift in the pest complex necessitates the continuous monitoring and review of the pest complex and their succession for developing effective pest management strategies. The incidence of major pests in castor recorded in the present study revealed that semilooper, *S. litura*, capsule borer and leafhopper continue to remain as major pests during *kharif* and *rabi* seasons. Similar findings were also reported by Lakshminarayana (2005) and Lakshminarayanamma *et al*. (2013). However, the status of red hairy caterpillar (*Amsacta* spp.) reported by

Basappa (2007) differed from the present study in which the pest was not observed during both *kharif* and *rabi* seasons. Similarly hairy caterpillar (*Euproctis fraterna*) reported as minor pest (Lakshminarayana, 2005) was observed as major pest in both seasons.

Reliable information on crop loss due to insect pests to establish the increased yield is obtainable when these agents are controlled at acceptable economic cost. Crop loss estimates are thus regarded as the best way to indicate to the farmer that the opportunities are gained when sound plant protection measures are applied (Kooner *et al*., 2006; Duraimurugan and Tyagi, 2012). Earlier, seed yield loss of 31.0 to 40.8 per cent due to defoliators *viz*., semilooper and *S. litura*, 12.9 to 20.3 per cent due to sucking pests (Anonymous, 1992) and 48.6 to 52.0 per cent due to capsule borer (Anonymous, 1991) were reported. The present study confirmed the significant impact of insect pests on castor yield which effected mean avoidable yield loss of 17.2 to 63.3 per cent during *kharif* and 22.5 to 89.4 per cent during *rabi*. The results also indicate that the cultivar DCH-519 revealed minimum seed yield loss due to insect pests in both *kharif* and *rabi* seasons as compared to other cultivars. This is in confirmation with the report of Lakshminarayana and Raoof (2005) who reported that the yield losses in castor varied widely with variety/hybrid. Therefore, the present study gives information on major insect pests of castor and avoidable yield losses due to the insect pests in different crop growing seasons. The information would enable us for developing effective pest management strategies and to harness best yield potential in castor.

Table 3 Population of insect pests on castor under protected and unprotected conditions during *rabi* (2012-13 and 2013-14)

Rabi (2012-13)

Cultivar	Leafhopper (No./3 leaves/plant)$^{\$}$		*Spodoptera litura* (larvae/plant)$^{\$}$		Semilooper (larvae/plant)$^{\$}$		Hairy caterpillar (larvae/plant)$^{\$}$		Capsule damage (%)$^{\#}$	
	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
DCH-519	20.3 (4.5)	78.3 (8.8)	0.0 (0.7)	0.4 (0.9)	0.6 (1.0)	1.4 (1.4)	0.2 (0.8)	1.6 (1.4)	1.4 (6.7)^{b}	4.1 (11.6)^{bc}
DCH-177	33.7 (5.8)	93.3 (9.6)	0.0 (0.7)	0.1 (0.8)	0.2 (0.8)	0.9 (1.2)	0.6 (1.0)	2.1 (1.6)	0.7 (4.7)^{a}	1.1 (6.0)^{a}
48-1	28.3 (5.3)	95.0 (9.7)	0.1 (0.8)	0.3 (0.9)	0.4 (0.9)	1.3 (1.3)	0.13 (0.8)	1.8 (1.5)	0.9 (5.3)^{ab}	2.4 (8.9)^{c}
Mean	27.4 (5.2)^{a}	88.8 (9.4)^{b}	0.03 (0.7)^{a}	0.3 (0.9)^{b}	0.4 (0.9)^{a}	1.2 (1.3)^{b}	0.3 (0.9)^{a}	1.8 (1.5)^{b}	1.0 (5.6)^{a}	2.5 (8.8)^{b}

	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±
Plant Protection (P)	*	0.79	0.37	*	0.06	0.03	*	0.14	0.07	*	0.12	0.06	*	1.09	0.51
Cultivars (C)	NS	-	0.46	*	0.07	0.04	NS	-	0.08	*	0.15	0.07	*	1.33	0.62
Interaction (PxC)	NS	-	0.64	NS	-	0.05	NS	-	0.12	NS	-	0.10	*	1.89	0.88

Rabi(2013-14)

Cultivar	Leafhopper (No./3 leaves/plant)$^{\$}$		*Spodoptera litura* (larvae/plant)$^{\$}$		Semilooper (larvae/plant)$^{\$}$		Hairy caterpillar (larvae/plant)$^{\$}$		Capsule damage (%)$^{\#}$	
	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected	Protected	Unprotected
DCH-519	9.1 (3.1)^{a}	34.2 (5.9)^{c}	0.4 (0.9)^{a}	1.4 (1.4)^{c}	0.3 (0.9)^{ab}	0.9 (1.2)^{c}	0.1 (0.8)^{a}	0.2 (0.8)^{a}	10.9 (19.1)^{bc}	16.3 (23.7)^{d}
DCH-177	18.5 (4.3)^{b}	92.1 (9.6)^{d}	0.6 (1.0)^{ab}	2.9 (1.8)^{d}	0.2 (0.8)^{ab}	2.1 (1.6)^{d}	0.2 (0.8)^{a}	2.2 (1.6)^{c}	7.6 (16.0)^{ab}	-
48-1	14.6 (3.8)^{ab}	35.1 (5.9)^{c}	0.3 (0.9)^{a}	0.8 (1.1)^{b}	0.1 (0.8)^{a}	0.5 (1.0)^{b}	0.1 (0.8)^{a}	1.2 (1.3)^{b}	7.0 (15.3)^{a}	11.9 (20.0)^{c}
Mean	14.1 (3.7)^{a}	53.8 (7.1)^{b}	0.4 (0.9)^{a}	1.7 (1.4)^{b}	0.2 (0.6)^{a}	1.2 (1.3)^{b}	0.1 (0.8)^{a}	1.2 (1.4)^{b}	8.5 (16.8)^{a}	14.1 (21.9)^{b}

	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±	F-test	CD at 5%	SEm±
Plant Protection (P)	*	0.45	0.21	*	0.11	0.05	*	0.11	0.05	*	0.05	0.02	*	1.99	0.94
Cultivars (C)	*	0.55	0.26	*	0.13	0.06	*	0.13	0.06	*	0.06	0.03	*	2.44	1.15
Interaction (PxC)	*	0.77	0.36	*	0.19	0.09	*	0.18	0.09	*	0.09	0.04	*	3.45	1.62

* - Significant; NS- Non Significant $^{\$}$Figures in the parentheses are square root transformed values; $^{\#}$Figures in parentheses are arc sin transformed values

Table 4 Avoidable yield losses due to insect pests in castor during *rabi* (2012-13 and 2013-14)

Cultivar	*Rabi* 2012-13				*Rabi* 2013-14				Pooled Mean			
	Yield (kg/ha)			% avoidable loss	Yield (kg/ha)			% avoidable loss	Yield (kg/ha)			% avoidable loss
	Protected	Unprotected	Mean		Protected	Unprotected	Mean		Protected	Unprotected	Mean	
DCH-519	1063^{a}	888^{a}	976^{a}	16.5	1064^{a}	762^{b}	913^{a}	28.4	1064^{a}	825^{b}	945^{a}	22.5
DCH-177	988^{a}	213^{c}	601^{b}	78.4	1030^{a}	0^{d}	515^{b}	100	1009^{a}	107^{d}	558^{c}	89.4
48-1	1100^{a}	525^{b}	813^{b}	52.3	686^{b}	362^{c}	524^{b}	47.2	893^{b}	444^{c}	669^{b}	50.3
Mean	1050^{a}	542^{b}	797	49.1	927^{a}	375^{b}	651	58.5	989^{a}	459^{b}	724	54.1
	F-test	CD at 5%	SEm±	-	F-test	CD at 5%	SEm±	-	F-test	CD at 5%	SEm±	-
Plant Protection (P)	*	151	71	-	*	93	44	-	*	57	27	-
Cultivars (C)	*	185	87	-	*	114	53	-	*	69	33	-
Interaction (PxC)	*	262	123	-	*	161	76	-	*	98	46	-

* - Significant; NS- Non Significant

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Factors influencing oilseed growers for enrolling as members of Karnataka Co-operative Oilseed Growers Federation Limited, Raichur Regional Union, Karnataka

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ABSTRACT

The study was conducted purposively in the selected organization Karnataka Co-operative Oilseed Growers Federation Limited (KOF) and factors influencing on enrolling as member of KOF was judged by selecting top three Oilseed Growers Co-operative Societies (OGCS) from Raichur Regional Union (RRU) based on highest volume of business. From selected OGCS 45 members and 45 non members were selected to collect primary data. The data on primary source were analysed using Simple Ranking and Garret analysis. Factors influencing majority of respondents for enrolling as members of society were hope of reducing market risk (mean score 57.82) and no commission charge (mean score 53.31). Further majority of non-members had not registered in the society due to non availability of credit facility from society (mean score 55.77), personal relation built with commission agents over the year (mean score 54.31) and indebtedness to commission agent (51.71) as opined by non-member respondents.

Keywords: KOF, RRU, OGCS, Society

Co-operative is a way of life as per *Rig veda*, a mythological Indian Scripture. Co-operative society is an organization of group of people with collective responsibilities (Kale *et al.*, 2004). Co-operative societies in India play an important role in development of agriculture, banking, credit, agro-processing, storage, marketing, dairy, fishing and housing etc. Co-operative has inherent advantages in tackling the problems of poverty alleviation, food security and employment generation (Adis *et al.*, 2007). The co-operative movement started in India in the last decade of 19^{th} century with two objectives in view, i.e. to protect the farmers from the hands of private money lenders and to improve their economic condition (Kale *et al.*, 2004). Madras province was the birth place for this cooperative movement that has slowly gained the movement in the later stages.

By and large, the oilseed growers in India have been caught in the hard clutches of private traders, brokers and money lenders (Anilkumar *et al.*, 2013). Apart from the financial handicap which has placed growers in pathetic conditions, many time the vagaries of monsoon make their condition much more miserable, discouraging even the most enthusiastic growers. The common method followed by middlemen is to flood the market with oilseed during the harvest season that would consequently lead to price slash so low as to cause despair to the real farmers. This is followed by another strategy of creating artificial scarcity by withholding the stock that artificially inflates the price. Thus traders, hoarders and stockists join hand to reap enormous profit at the loss of producers. In the entire marketing process the consumers too at large have to undergo the agony of paying more prices for the oil than normally warranted. To lessen these problems, oilseed grower's cooperative marketing was established at the village and taluk level to handle a variety of farm produce (particularly cereals and pulses) but unfortunately majority of oilseed growers stay away from the society. To address this issue, no concerted efforts were made especially for oilseed growers (Jogindra, 2004). As a result, their problems have remained more or less unsolved, unanswered and call for greater attention. In the light of this fact, the study was undertaken to know reasons for not enrolling as a members of society and their suggestions for further improvement of the society.

MATERIALS AND METHODS

The study was conducted purposively in the selected Raichur Regional Union (RRU). The union covers Raichur, Gulbarga, Bidar, Koppal and Yadgir districts of Northeast Karnataka region. The sample size consisted of 90 respondents (45 members and 45 non-members) selected from top three Oilseed Growers Co-operative Societies (OGCS) of Raichur Regional Union (RRU) based on highest volume of business. The societies are Devadurga and Lingasaguru from Raichur district and Yelaburga from Koppal district. Interview schedule was used to collect the primary data. To collect in-depth information observation and guidance methods were also employed. Data analysis and interpretation of the data was done using simple statistical tools like Henry Garrett Ranking method. The following formula was used for calculating the Henry Garrett Ranking Method.

$$\text{Per cent position} = \frac{100*(R_{ij}-0.50)}{N_j}$$

Where, R_{ij} is Rank given for i^{th} item by j^{th} individual
N_j is Number of items ranked by j^{th} individual

The per cent position of each rank was converted to score by referring to tables given by Garret and Woodworth. Then for each factor, the score of individual respondents were summed up and divided by the total number of respondents (Jennifer, 2004). The mean score for all the factors were ranked, following the decision criteria that higher the value stands in first place and so on.

RESULTS AND DISCUSSION

Result in the Table 1 clearly revealed that the average age of members was relatively higher when compared to non-members. The average family size of members was 9.37 and in non-members it was 7.40. The education level of the respondent families differed among the members and non-members. However, most of the respondents had primary and secondary level of education. Only 11 per cent of members were illiterate and in case of non-members it was 18 per cent. The average land holdings was also higher in the members (7.85 ha) than that of non-members (5.08 ha) and compared to non-members the area under irrigated condition was relatively higher in members.

Majority of respondents enrolled as members in the society by giving more importance to remunerative price paid by society (57.82), no commission charge (53.31) and adequate transport facility provided by society (52.55) followed by getting guidelines and technical assistance from society (52.35), difficulty in marketing of produce (52.20), to get quality inputs from society (52.13) and correct weighment by society (51.04) were other reasons for becoming the members of society (Table 2). Further no loading and unloading charges, better storage facility and immediate payment were the very minor reasons expressed by members for becoming the members of society. Similarly, Jogindra (2004) reported that remunerative price paid by society and to get quality inputs from society are the major reasons expressed by members for becoming the members of society in Rajasthan.

Majority of respondents stayed away from society and not registered for membership of society due to lack of credit facility from society (55.77) followed by personal relation with traders and commission agents established over the years (54.31), indebtedness to commission agents (51.71), traders and commission agent treat well (51.53), cash requirement during off-season (50.95), to avoid market problems (50.86), low price offered by OGCS (49.44), not aware of society (49.17), other fellow farmers in the village did not sell through OGCS (47.46) and not producing oilseeds (46.00) (Table 3). In view of the above obtained results society should put effort to provide credit, meet cash requirement in off-season, increase price and to do publicity and propaganda of OGCS at village level similar suggestion were expressed by respondents as revealed in Table 4. Similar suggestions were given by Bahadhur (2006) to efficient organization of dairy cooperatives in Nagaland.

Table 1 General characteristics of sample respondents

Particulars	Member n = 45	Non-member n = 45
Average age (Years)	46.86	42.77
Family size (No.)		
(i) Male	3.97 (42.35)	3.30 (44.59)
(ii) Female	2.37 (25.27)	2.33 (31.54)
(iii) Children	3.03 (32.38)	1.77 (23.87)
Average	9.37 (100.00)	7.40 (100.00)
Education level (No.)		
(i) Illiterate	11 (24.44)	18 (40.00)
(ii) Primary	13 (28.88)	15 (33.33)
(iii) Secondary	19 (42.22)	8 (17.77)
(iv) College	2 (4.44)	4 (8.88)
Average	45 (100.00)	45 (100.00)
Land holding (ha)		
(i) Irrigated		
(ii) Dry land	2.69 (34.27)	2.39 (47.15)
Average	7.85 (100.00)	5.08 (100.00)

Figures in the parenthesis indicate percentage to the total

Table 2 Reason for becoming the members of OGCS (n= 45)

Ranks scale & Factors		I 81	II 70	III 63	IV 57	V 52	VI 47	VII 42	VIII 36	IX 29	X 18	Total	Total Score	Mean Score	Rank
Better storage facilities	f	3	2	5	4	3	5	2	6	7	8	45	2134	47.42	IX
	fx	243	140	305	228	156	235	84	396	203	144				
Remunerative price	f	7	5	4	6	7	2	7	2	3	2	45	2602	57.82	I
	fx	567	350	252	342	364	94	294	216	87	36				
Immediate payment	f	4	6	2	3	5	2	6	4	7	6	45	2102	46.71	X
	fx	324	420	126	171	260	94	252	144	203	108				
No commission charge	f	8	4	5	6	2	5	4	3	5	3	45	2399	53.31	II
	fx	648	280	315	342	104	235	168	108	145	54				
Provide guidelines & technical assistance for better production of oilseeds	f	8	4	5	3	4	2	7	6	2	4	45	2356	52.35	IV
	fx	648	280	315	171	208	94	294	216	58	72				
Adequate transportation facilities	f	5	8	3	5	4	6	3	5	2	4	45	2365	52.55	III
	fx	405	560	189	285	208	282	126	180	58	72				
No loading & Unloading charges	f	2	5	7	6	8	3	2	6	1	5	45	2235	49.66	VIII
	fx	162	350	441	342	416	141	48	216	29	90				
Will provide good quality input	f	3	6	4	8	6	5	4	3	4	2	45	2346	52.13	VI
	fx	243	420	252	456	312	235	168	108	116	36				
Correct weighment	f	5	3	8	4	5	5	3	2	7	3	45	2297	51.04	VII
	fx	405	210	504	228	260	235	126	72	203	54				
Difficulties in marketing of produce	f	4	7	6	4	5	6	2	4	3	4	45	2349	52.20	V
	fx	324	490	378	228	260	282	84	144	87	72				
Total	f	45	45	45	45	45	45	45	45	45	45				

x = Scale value, f = number of respondents, fx = Score

Table 3 Reason for not becoming the members of OGCS (n= 45)

Ranks scale & Factors		I 81	II 70	III 63	IV 57	V 52	VI 47	VII 42	VIII 36	IX 29	X 18	Total	Total Score	Mean Score	Rank
Not aware of societies	f	5	2	5	4	3	3	2	6	8	7	45	2213	49.17	VIII
	fx	405	140	305	228	156	141	84	396	232	126				
Lack of credit facilities	f	7	5	4	6	3	2	7	2	7	2	45	2510	55.77	I
	fx	567	350	252	342	156	94	294	216	203	36				
No high marketable surplus	f	4	6	2	3	7	2	4	6	5	6	45	2136	47.46	IX
	fx	324	420	126	171	364	94	168	216	145	108				
Other fellow farmers in the village not selling through the OGCS	f	6	2	5	7	2	5	2	3	5	3	45	2070	46.00	X
	fx	486	140	315	399	104	235	84	108	145	54				
Personal relation with the commission agent/ traders build over the years	f	8	4	5	6	4	7	2	3	2	4	45	2444	54.31	II
	fx	648	280	315	342	208	329	84	108	58	72				
Cash requirement during offseason	f	5	8	3	5	4	2	3	5	6	4	45	2293	50.95	V
	fx	405	560	189	285	208	94	126	180	174	72				
To avoid market problems	f	2	8	7	6	5	3	2	6	1	5	45	2289	50.86	VI
	fx	162	560	441	342	260	141	48	216	29	90				
Price offered by OGCS are low/ not competitive	f	3	6	4	8	5	2	4	3	4	6	45	2225	49.44	VII
	fx	243	420	252	456	260	94	168	108	116	108				
Indebtedness to commission agent	f	3	5	8	4	5	5	7	2	3	3	45	2327	51.71	III
	fx	243	350	504	228	260	235	294	72	87	54				
Traders and commission agent treat well	f	4	7	6	4	2	6	5	4	3	4	45	2319	51.53	IV
	fx	324	490	378	228	104	282	210	144	87	72				
Total	f	45	45	45	45	45	45	45	45	45	45				

x = Scale value, f = number of respondents, fx = Score

Table 4 Suggestion from the members for the further improvement of the society (n= 45)

Ranks scale & Factors		I 81	II 70	III 63	IV 57	V 52	VI 47	VII 42	VIII 36	IX 29	X 18	Total	Total Score	Mean Score	Rank
Immediate cash payment	f	8	2	5	4	3	5	6	2	7	3	45	2439	54.20	II
	fx	864	140	305	228	156	235	252	72	203	54				
More working hours	f	4	5	7	6	3	2	7	2	7	2	45	2038	45.30	X
	fx	324	350	441	342	156	94	294	216	203	36				
More number of staff	f	2	6	5	3	4	2	6	4	7	6	45	2053	45.62	IX
	fx	162	420	215	171	208	94	252	144	203	108				
Increase procurement centers	f	5	4	8	6	2	5	4	3	5	3	45	2272	50.50	V
	fx	405	280	504	342	104	235	168	108	145	54				
Better price for their produce	f	8	4	5	3	4	2	7	6	2	4	45	2409	53.44	III
	fx	648	280	315	171	208	94	294	216	58	72				
To enhance credit facilities	f	9	4	3	5	4	6	3	5	4	2	45	2498	55.52	I
	fx	729	280	189	285	208	282	126	180	116	36				
Quick transport facilities	f	6	5	7	2	8	3	2	4	6	2	45	2147	47.70	VII
	fx	486	350	441	114	416	141	48	144	174	36				
Better coordination	f	8	6	4	3	6	5	4	3	4	2	45	2143	47.62	VIII
	fx	648	420	252	171	312	235	168	108	116	36				
Provide adequate storage facilities	f	7	3	8	4	4	6	3	2	5	3	45	2372	52.70	IV
	fx	567	210	504	228	208	282	126	72	145	54				
Supply of good quality inputs	f	8	3	6	4	3	6	2	6	3	4	45	2203	48.96	VI
	fx	641	210	378	228	156	282	84	216	87	72				
Total	f	45	45	45	45	45	45	45	45	45	45				

x = Scale value, f = number of respondents, fx = Score

To analyze the constraints faced by member farmers and their suggestions for further improvement of society, major observation during preliminary visits by the researcher were put before the sample respondents and were asked to rank them. The suggestions (Table 4) were analyzed by using Garrett ranking (Jennifer, 2004). The results indicated that majority of the members (55.52) wished to have enhanced credit facilities from society followed by immediate cash payment (54.20), better price for their produce (53.44), providing adequate storage facility (52.70), increase of procurement centers (50.50), supply of good quality inputs (48.96), quick transportation facility (47.72), better coordination from OGCS (47.62), more number of staff (45.62) and more working hours (45.30). The federation should take note on the suggestions made by members to improve its service to the oilseed growers.

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Evaluation of a mobile phone based agro-advisory programme on sunflower (*Helianthus annuus* L.)

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ABSTRACT

The increasing penetration of mobile phone networks and handsets in India presents an opportunity to make useful information on agriculture more widely available to farmers. The present study was conducted with 240 farmers growing sunflower (*Helianthus annuus* L.) in two districts in Andhra Pradesh State, India during 2011-12. The taluks and villages were selected based on highest area under sunflower and the presence of farmers with IKSL (IFFCO Kisan Sanchar Limited) sim cards. The farmers were selected by random sampling method. The study used ex-post facto and pre- and post- experimental research designs. An improvised Bennett's hierarchy, a logic model was used for evaluation. The results indicated significant differences in knowledge and adoption scores of pre- and post-dissemination groups indicating the impact of the system. Mobile phones based advisories can create awareness and make knowledge accessible to farmers and to some extent mobilize communities to adopt best practices. To further improve knowledge, adoption of improved practices and impart required skills to farmers training sessions and demonstrations need to be organized after the broadcast of advisories.

Keywords: Adoption, Audio messages, Impact, Listening behaviour, Sunflower

Farmers need information on a variety of topics, at a variety of stages, before adopting a new technology (De Silva and Ratnadiwakara, 2008; Mittal *et al.*, 2010). Farmers have different types of information needs during each stage of the process, ranging from weather forecasts, pest attacks, inputs, cultivation practices, pest and disease management and prices and they need to access a wide range of information related to production technologies, post harvest processes, remunerative markets, credit and weather (Glendenning *et al*., 2010). Despite a wide range of reform initiatives in agricultural extension in the past decades, the coverage of, access to and quality of information provided to small holder farmers is uneven and the main sources of information to farmers till today are neighbours, input dealers, radio, TV, news paper and extension worker. Considering this poor reach of extension, the information and communication technologies (ICTs) can play an important role in their endeavour of reaching the unreached farmers. Among the various ICT tools, the increasing penetration of mobile phone networks and handsets in India presents an opportunity to make useful information more widely available and offers several advantages over other alternatives in terms of cost, geographic coverage and ease of use (Aker and Mbiti, 2010). Mobile phone networks with a subscriber base of more than 920 million and overall tele-density of 61.38 can play a significant role in technology transfer. Mobile telephony has been widely accepted mode of delivering information not only in India but also in other South Asian and African countries (Mittal, 2011).

In spite of several mobile based initiatives for providing access to timely and quality information to farmers, the rigorous impact evaluation of these initiatives were very few. In order to measure the impact of mobile phone-based applications and services in the agricultural sector on farmers' knowledge, adoption and welfare, rigorous impact evaluations are needed (Aker, 2011). To bridge this gap, Directorate of Oilseeds Research (DOR) has initiated mobile phone based agro-advisories to oilseed farmers with the collaboration of IFFCO Kisan Sanchar Limited. IFFCO Kisan Sanchar Limited (IKSL) is a tri-lateral joint venture between the Indian Farmers Fertilizer Cooperative Limited (IFFCO), Airtel and Star Global Resources Limited. IKSL provides voice-based agricultural information to empower rural farmers and reinforce the cooperative through the mobile network. IKSL distributes airtel SIM cards branded 'Green SIM' to its IFFCO members and other farmers. DOR has developed the content for agro-advisories on sunflower and in collaboration with IKSL disseminated them to the farmers of Andhra Pradesh, India. The present study was undertaken to evaluate the impact of mobile phone based agro-advisory programme on sunflower with the following specific objectives to assess the information needs of sunflower farmers, evaluate the listening behavior of farmers and determine the impact of the advisories in terms of knowledge, opinions, adoption behavior and economic welfare of farmers.

MATERIALS AND METHODS

Sampling: Two districts *viz.*, Mahabubnagar and Prakasham from Andhra Pradesh State, India were selected for the study. Three taluks from each district and three villages from each taluk were selected based on the highest area under sunflower crop. Two hundred and forty registered farmers with 'green sim cards' were selected by random sampling method from 18 villages. The study used an expost facto and experimental designs for survey and evaluation of impact of mobile phone advisory system, respectively. Before the start of the season (July-September, 2011), interviews were conducted with farmers to assess their information needs, level of knowledge, adoption and economics of sunflower cultivation. During *rabi*, 2011-12 and *kharif* 2012, knowledge on sunflower production technologies was disseminated through audio messages. At least two messages were disseminated in a week during the season. After the end of the each season during March-April and October-November, 2012, data were collected on farmers listening behavior, their opinions on messages, their knowledge, adoption and economics. The details of messages disseminated are as follows:

Category of message	Audio messages (no.)		Farmers interviewed (no.)
	rabi	*kharif*	
Pre-sowing	6	6	240
Sowing and production	12	12	240
Plant protection	6	6	240
Harvest and post harvest management	4	4	240
Total	28	28	-

Measurement of variables: The information needs of farmers on sunflower cultivation were assessed on a three point continuum ranging from high, medium to low. Listening behavior was measured by three sub-components: listening frequency, listening pattern and listening response. Opinions of farmers were obtained on six sub-components: timeliness of the messages, relevance, audio quality, message treatment, content adequacy and usefulness. Knowledge was characterized by the information gained by the farmers on various aspects of sunflower cultivation hearing through the mobile phone messages and measured by asking 25 questions. Adoption refers to use of an idea/practice on sunflower cultivation after listening to audio messages from mobile phones and measured by recording the practices adopted by the farmers after listening to messages. The economics of sunflower cultivation were worked out by recording the cost of cultivation (COC), gross monetary returns (GMR) and benefit cost ratio (BCR).

Evaluation process: An improvised Bennett's hierarchy, a logic model (Taylor and Sara, 1996; Taylor, 1999; McCawley Paul, 2013) was used for evaluation. The model consists of situations/priorities at level 1, inputs, outputs-activities, outputs-participation at level 2, 3 and 4, respectively and outcomes: short-term, medium-term and long-term at level 5, 6 and 7, respectively. Suitable indicators were identified for each level (Fig. 1) and measured. An interview schedule was developed in local language and validated by field data. The data were collected by personal and telephone interviews of farmers. SAS software was used to analyze descriptive statistics such as frequency, mean, per cent and the differences in knowledge, adoption and economics of pre- and post-dissemination groups were tested by paired 't' test.

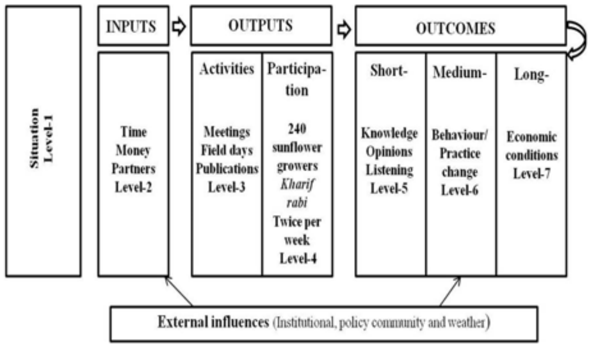

Fig. 1. Logic model applied to evaluation of mobile advisory system

RESULTS AND DISCUSSION

Situation-level 1: The existing situation of the farmers was assessed by understanding the information needs in sunflower cultivation. Among 240 farmers interviewed, 160 farmers (66.67%) felt high information need on improved sunflower cultivars followed by market prices (60.42%), management of tobacco caterpillar (*Spodoptera litura*) and borer (*Helicoverpa armigera*) (54.17), information on weather (53.33%) and information on biological control agents (50.00%). Farmers had low information need on harvesting (43.75%), chemical seed treatment (42.50%) and method of sowing (41.67%) (Table 1). The results are in congruence with that of Mittal *et al*. (2010), who reported that information regarding seeds is the most frequently accessed information by farmers followed by mandi prices, plant protection and fertilizer application.

Inputs-level 2: The total money spent on the programme was ₹ 3.75 lakhs and there were 1,511 people involved, which includes seven scientists from DOR, two technical persons each from IKSL and DOR and 2000 sunflower farmers, five organizations: DOR, IKSL, Airtel (service provider) and two NGOs *viz*., Research in Environment Education and Development Society (REEDS) and Rythu Mitra Sangam (RMS) (Table 2).

Outputs-level 3 & 4 (Activities and Participation): The activities allotted to and completed by seven scientists were screening of content/scripts for messages, organizing meetings/farmers' days and discussion with farmers on sunflower production technologies. The activities of technical persons of DOR were identifying the farmers, registrations, providing green sim cards and explaining about the broadcast of the messages. Further, the technical persons were also involved in evaluation of responses, record keeping, tabulation of scores, arranging for meetings and distribution of pamphlets. The NGOs (REEDS and RMS) were involved in facilitating the identification of farmers, building rapport, distribution of sim cards, arrangements for meetings and creating awareness about the dissemination of messages. The activities of technical persons of IKSL were recording of the OBD messages and disseminating through service provider. Among 1500 registered participants, 240 farmers were selected for the survey. The activities of these farmers were registration with DOR, listening to the messages, attending the meetings/farmers days and providing responses during the interviews for data collection.

Table 1 Situation analysis for assessing the information needs of sunflower farmers in the region (n = 240)

Information need	High	Medium	Low
Suitable cropping system	98 (40.83)*	82 (34.17)	60 (25.00)
Suitable intercropping systems	110 (45.83)	95 (39.58)	35 (14.58)
Recommended improved cultivars	160 (66.67)	60 (25.00)	20 (08.33)
Seed treatment with biological control agents	120 (50.00)	68 (28.33)	52 (21.67)
Seed treatment with chemicals	60 (25.00)	78 (32.50)	102 (42.50)
Method of sowing	80 (33.33)	60(25.00)	100 (41.67)
Thinning in sunflower	95 (39.58)	85 (35.42)	60 (25.00)
Critical stages for moisture stress	60 (25.00)	75 (31.25)	105 (43.75)
Fertilizer management	105 (43.75)	80 (33.33)	55 (22.92)
Sources of various fertilizers	80 (33.33)	90 (37.50)	70 (29.17)
Utility of Boron application	115 (47.92)	100 (41.67)	25 (10.42)
Utility of S application	105 (43.75)	86 (35.83)	49 (20.42)
Manual weed management	28 (11.67)	40 (16.67)	172 (71.67)
Herbicide application	110 (45.83)	85 (35.42)	45 (18.75)
Management of sucking insect pests	115 (47.92)	90 (37.50)	35 (14.58)
Management of foliage eating insect pests	130 (54.17)	79 (32.92)	31 (12.92)
Management of alternaria	98 (40.83)	96 (40.00)	46 (19.17)
Management of powdery mildews	100 (41.67)	85 (35.42)	55 (22.92)
Management of SND	90 (37.50)	81 (33.75)	69 (28.75)
Supplemental pollination	115 (47.92)	95 (39.58)	30 (12.50)
Harvesting	40 (16.67)	95 (39.58)	105 (43.75)
Value addition by use of sunflower heads	115 (47.92)	95 (39.58)	30 (12.50)
Value addition for producing honey	90 (37.50)	120 (50.00)	30 (12.50)
Market prices	145 (60.42)	80 (33.33)	15 (06.25)
Information on weather	128 (53.33)	70 (29.17)	42 (17.50)

* Figures in parenthesis are percentages

Table 2 Investments in terms of human resources, partners and finances in the programme

Human resources	No./ Value (₹)
Scientists from DOR	7
Technical persons from IKSL for OBD recordings	2
Technical persons for dissemination	2
Registered participants	1,500
Total	1,511
Partners	
IFFCO Kisan Sanchar Limited	
Service provider (Airtel)	
local NGOs (REEDS and RSS)	
Money spent	
Procurement of green sim cards	15,840
Publication of pamphlets	7,000
Transportation charges for registration and discussions with farmers	15,000
Cost for recording of messages	10,000
Cost for the service providers for dissemination	25,000
Salaries of scientists and technical persons	300,000
Total	372,840

Outcomes- level 5 (short term)

Listening behaviour: Only 20.0 per cent of the farmers listened to all the 25 messages and majority of farmers (34.58%) listened to 8-15 messages. Majority of the farmers (70.35%) listened to messages and 26.25 per cent of the farmers listened to messages, simultaneously doing some work either at field or home. Few have taken notes (1.67%) or recorded the messages (1.25%). Majority of the farmers (84.17%) have only listened to the messages without discussing with friends or family members and negligible per cent of farmers had sought additional information by calling back either DOR staff or the IKSL help line (2.50%). Overall, majority of the farmers (66.67%) were in the below average listening behaviour category (Table 3).

Table 3 Listening behaviour of the surveyed farmers

Variable		Frequency (%)
1. Listening frequency		
a. listened to all 28 messages		48 (20.0)
b. Listened to all 19-27 messages		64 (26.67)
c. Listened to all 10-18 messages		83 (34.58)
d. Listened to fewer than 10 messages		45 (18.75)
2. Listening pattern		
a. Listening and simultaneously doing some work		63 (26.25)
b. Only listening		170 (70.83)
c. Listening and taking notes		04 (01.67)
d. Recording		03 (01.25)
3. Listening response		
a. Only listening		202 (84.17)
b. Discussion with friends		26 (10.83)
c. Discussion with family members		18 (07.50)
d. Seeking additional information with IFFCO/DOR		06 (02.50)
Overall listening behaviour (a + b + c)		
	Low	160 (66.67)
	Medium	60 (25.00)
	High	20 (8.33)
Mean: 6.80	SD: 2.52	Range: 3-11

Opinions of farmers: Half of the farmers (50.00%) thought that the messages were presented in time coinciding with the crop growth and 40 per cent of the farmers felt, messages were late. The farmers, who had sown the crop early in *rabi* during second fortnight of September in Prakasham district felt, the messages were late. Majority of the farmers (57.92%) reported that the content of the messages was highly relevant, quality of audio was good (70.83%), messages were highly technical (44.58%), content was adequate (40.83%) and highly useful (61.66%). Overall, 74.58 per cent of the farmers had medium opinion of the mobile phone based messages followed by 18.75 per cent and 6.67 per cent with low and high opinion respectively (Table 4). Xiaolan Fu and Shaheen Akter (2012) reported that more than 75 per cent of the farmers view mobile phone assisted services useful, quality of the services and the speed of services delivery have been improved significantly as a result of mobile phone intervention.

Table 4 Opinions of farmers on mobile phone based audio messages

Variables	Categories	Frequency (%)
a. Timeliness of the messages		
	Coinciding with the crop growth	120 (50.00)
	Early	24 (10.0)
	Late	96 (40.0)
b. Relevance		
	Highly relevant	139 (57.92)
	Somewhat relevant	83 (34.58)
	Irrelevant	18 (07.50)
c. Audio quality		
	Good	170 (70.83)
	Fair	48 (20.0)
	Poor	22 (09.17)
d. Message treatment		
	Less technical	65 (27.08)
	Moderately technical	68 (28.33)
	Highly technical	107 (44.58)
e. Content adequacy		
	Adequate	98 (40.83)
	needs more details	86 (35.83)
	not at all adequate	56 (23.33)
f. Content usefulness		
	Very useful	148 (61.66)
	Little useful	70 (29.17)
	Not useful	22 (9.17)
Overall opinion (a+b+c+d+e+f)		
	Low	45 (18.75)
	Medium	179 (74.58)
	High	16 (6.67)
Mean = 11.13	SD = 3.12	Range = 6-17

Knowledge of farmers: About 66.67 per cent of the farmers were in moderate knowledge category before hearing the audio messages over mobile phones (answered 15 to 22 questions) and this increased to 70.42 per cent after hearing the messages over mobile phones (answered 18 to 23 questions). The farmers in low knowledge category decreased from 16.25 per cent (answered <15 questions) to 8.33 per cent (answered <18 questions) and in high knowledge category increased from 17.08 per cent (answered more than 22 questions) to 21.25 per cent (answered more than 23 questions) in pre- and post-dissemination groups, respectively. The mean scores, range of scores for knowledge were higher in post-dissemination group than those of pre-dissemination group and the paired t value was significant between the groups (17.48, $p < 0.01$) (Table 5). The mobile phone based audio messages have helped in increasing the knowledge of sunflower farmers. Kumar and Padmaiah (2012) reported significant improvements in knowledge of castor growers due to mobile phone based agro-advisories. Pawan Kumar (2011) reported that the information obtained through mobile phones improved soil health, which resulted in increased agricultural productivity and farm income.

Table 5 Farmers' knowledge on sunflower production technologies

Knowledge categories	Pre-dissemination	Post-dissemination
Low	39 (16.25)*	20 (08.33)
Medium	160 (66.67	169 (70.42
High knowledge	41 (17.08)	51 (21.25)
Mean	32.71	38.6
SD	3.16	4.71
Range	26-42	26-47
Paired 't' value	17.486 ($p < 0.01$)	

*Figures in parenthesis are percentages

Outcomes-level 6 (medium term): Behaviour/Practice change: Farmers in low adoption category decreased from 17.50 to 10.42 per cent in pre- and post-dissemination groups, respectively and that of high adoption category increased from 15.83 to 22.08 per cent indicating the impact of mobile phone based dissemination. The mean adoption scores increased from 28.27 to 31.10 in pre- and post-dissemination groups, respectively. The paired t value was significant (14.5, $p < 0.01$) between pre- and post-dissemination scores (Table 6).

Table 6 Farmers' adoption of sunflower production technologies

Adoption categories	Pre- dissemination	Post- dissemination
Low	42 (17.50)*	25 (10.42)
Medium	160 (66.67)	162 (67.50)
High	38 (15.83)	53 (22.08)
Mean	28.27	32.1
SD	2.55	3.51
Range	26-39	26-44
Paired 't' value	14.17 ($p < 0.01$)	

*Figures in parenthesis are percentages

Outcomes-level 7 (long term): Economics: The seed yield increased marginally during *kharif* (750 kg/ha) and *rabi* (1250 kg/ha) seasons in post-dissemination group (Fig. 2), but statistically significant differences were not observed between pre- and post-dissemination groups. The COC and GMR increased slightly, but the BCR remained almost same for pre-(*kharif*: 1.85, 2.57) and post-dissemination (*rabi*: 1.89, 2.58) groups (Fig. 3). This indicated that the increase in GMR was not reflected in higher BCR due to increase in COC. Aker and Mibiti (2010) reported that mobile phone coverage and adoption had positive impacts on agricultural and labour market efficiency and welfare in certain countries. Jenson (2007) indicated that adoption of mobile phones by fishermen and wholesalers was associated with a dramatic reduction in price dispersion, complete elimination of waste and near-perfect adherence to the law of one price. Both consumer and producer welfare increased. Mobile phones allowed fishermen to get timely price information and decide on the best place to land and sell their daily catch. Abraham (2007) observed that widespread use of mobile phones increased the efficiency of markets by decreasing risk and uncertainty for fishermen in Kerala.

External factors: External factors will have either supporting or antagonistic effects on the outcomes of the programme. Particularly, the decision to adopt a technology/practice depends on many external factors such as institutional, policy environment and community. The institutional factors like timely availability of required inputs in the markets, their quality and cost affects the adoption decision of farmers. Even though the knowledge scores were higher (mean: 38.6), the adoption scores were lower (mean: 32.1) due to these external factors. The policy of the State regarding minimum support price to sunflower may act as a trigger for adoption of new techniques, which may influence the adoption scores. The farmers might have been exposed to information on sunflower from other community sources, which were not accounted in the study. Apart from this, other factors such as the climatic conditions influence the adoption decisions of the farmers. During *kharif* there was prolonged dry spells after sowing of the crop, hence farmers had not taken the risk of higher investment in nutrient management particularly boron and sulphur application, which may be one of the reason for low adoption scores.

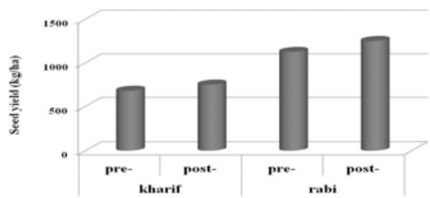

Fig. 2. Seed yield of sunflower for pre- and post-dissemination groups

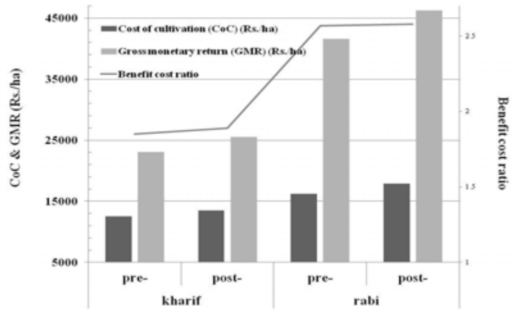

Fig. 3. Economics of sunflower cultivation for pre- and post-dissemination groups

This study has clearly bought out the use of mobile phone networks for dissemination of agricultural knowledge as one of the powerful means of increasing access to quality information to farmers who may not be reached by the extension programmes. With the increased availability, access and ownership of mobile phones in India, mobile based agro-advisories would play a significant role in reducing the information gap and information asymmetry between the farmers. It can be concluded that mobile phones based advisories can create awareness and make knowledge accessible to farmers. To some extent mobilize communities to adopt best practices and make research findings easily available to farmers in a simple and understandable language. To improve knowledge and adoption of improved practices, training sessions and demonstrations should be organized immediately after the broadcast of advisory in order to impart the required skills. Other formats such as question-answer, quizzes and pull based advisories may also be combined to create and sustain the interest of farmers in the advisories and improve their uptake.

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Frontline demonstrations in Chhindwara district of Madhya Pradesh : An impact analysis

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ABSTRACT

Madhya Pradesh is one of the potential States for castor cultivation with highest productivity after Gujarat. Several technologies and crop management options have been developed by Directorate of Oilseeds Research (DOR) and All India Coordinated Research Project (AICRP) on castor centres, that can significantly increase the yield, but adoption of these technologies by farmers has been far less than anticipated. Realizing the importance of extending these technologies for improving the yields at farmers' level, frontline demonstrations (FLDs) were conducted to show the productivity potential and profitability of improved production and protection technologies by AICRP Castor Chhindwara centre, Madhya Pradesh. The present study assessed the impact of these FLDs in enhancing the yield of castor and the socio-economic factors contributing to the adoption of improved technology by farmers. The results indicated that the mean seed yield and the additional net returns were higher in FLD farmers plots compared to non-FLD farmers. Adoption of farmer was highly correlated with socio-economic characteristics such as knowledge level, farm size and training programmes attended. The major contributing factors for adoption of improved practices were knowledge level and exposure to demonstrations.

Keywords: Adoption, Castor, Frontline demonstrations, Socio-economic characteristics

In Madhya Pradesh, castor is being cultivated as shade crop and intercrop with vegetables and on commercial scale it is being grown as sole crop under irrigated and rainfed conditions. Presently, it is cultivated in an area of 6000 ha in the state with one of the highest productivity (1667 kg/ha) only after Gujarat (2012-13). Castor crop has high potential for cultivation in Chhindwara, Damor, Mandla, Seoni, Dindori, Betul, Khandwa and Hoshangabad districts of Madhya Pradesh due to presence of suitable weather conditions and high cost of cultivation of competing crops such as cotton.

Several technologies and management options have been developed by Directorate of Oilseeds Research (DOR) and All India Coordinated Research Project (AICRP) on castor centres, that can significantly increase the yield, but adoption of these technologies by farmers has been far less than anticipated. Realizing the importance of extending these technologies for improving the yields at farmers' level, frontline demonstrations (FLDs) were conducted to show the productivity potential and profitability of improved production and protection technologies by AICRP Castor Chhindwara centre, Madhya Pradesh. Around 75 FLDs were conducted during the period from 2007 to 2012. The present study was conducted in Chhindwara and Amaravathi districts, Maharashtra with the objectives to document the profile characteristics of castor farmers, to understand the knowledge level and extent of adoption of improved practices and to examine the influence of socio-economic characteristics on knowledge and adoption levels of farmers.

MATERIALS AND METHODS

The improved technology (IT) included the recommended variety, recommended agronomic practices, recommended dose of fertilizers and need based plant protection. The IT was demonstrated on 0.40 ha plot in comparison with farmers' practice (FP) of using local varieties and imbalanced fertilizer application, in order to provide farmers an opportunity to compare, evaluate and choose themselves the best practice based on their own criteria.

Six villages *viz*., Linga, Bethul, Bordy, Baigaudi, Kundalikala and Amarwadi where FLDs were conducted during 2007 to 2012 were selected. The FLD and non-FLD castor farmers were randomly selected from the same and adjoining villages, respectively. The final sample of the study was 81 with 41 FLD and 40 non-FLD castor farmers. For realizing higher yields, 10 improved castor management practices *viz*., land preparation, improved cultivars, time of sowing, fertilizer application, timely inter culture and weeding, plant protection measures, irrigation, timely harvesting and threshing were identified with the help of castor researchers. Farmers knowledge and adoption levels were assessed on above mentioned 10 man practices in the study area. A summated rating scale with a score range 0-10 was used to measure farmers' knowledge as well as adoption levels. Knowledge and adoption scores were categorized into low, medium and high levels based on mean and standard deviation. A semi-structured interview schedule was

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employed to collect the data from the selected respondents. Key informants of the respective villages and the scientists of RARS, Chhindwara helped in data collection. The data were tabulated and analyzed using statistical tools *viz.*, mean, percentage, Mann-Whitney U test, correlation and step-wise regression for drawing meaningful conclusions.

Mann-Whitney U test was utilized to assess the significance of difference between FLD and non-FLD farmers with respect to their adoption behaviour towards recommended castor production technologies as follows:

$$U = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 (n_1 < n_2)$$

Where n_1 and n_2 number of observations in samples one and two and R_1 is sum of the ranks of the observations in sample1. When $n_1 > n_2$ replaces R_1 with R_2

When either n_1 or n_2 are larger than 20 the distribution U approaches normal distribution. The significance for the large sample obtained by

$$z = \frac{U - (n_1 n_2 / 2)}{\sqrt{n_1 n_2 (n_1 + n_2 + 1)/12}}$$

The association between adoption levels and size of land holdings were analysed by Chi-Square test of Independence is:

The chi-square statistic for the r x s contingency table

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{s} (O_{ij} - E_{ij})^2 / E_{ij}$$

$$E_{ij} = E(O_{ij}) = \frac{R_i x C_j}{N}$$

Where $E(O_{ij})$ is the expected frequency of cell containing observe frequency O_{ij}.

RESULTS AND DISCUSSION

The profile characteristics of selected respondents in Table 1 indicated that majority of the FLD and non-FLD castor farmers were middle aged (35-55 years) and with middle to high school education. Majority of FLD (45.9%) and non-FLD farmers (50%) belonged to medium level of land holding category. Majority of FLD (36.6%) and non-FLD farmers (40%) had 10-20 years experience in agriculture. But all the farmers had less than 10 years experience in castor cultivation. Majority (85%) of FLD farmers attended the training programme on castor once as compared to 25 per cent of non-FLD farmers. Majority of FLD farmers (85.4%) were members in an organization as compared to only 2.5 per cent of non-FLD farmers.

Table 1 Distribution of FLD and non-FLD farmers based on the profile characteristics

Particulars	Frequency and (%)	
	FLD	Non-FLD
a) Age (years)		
Young (<35)	1 (2.4)	6 (15.0)
Middle (35-55)	25 (61.0)	28 (70.0)
Old (>55)	15 (36.6)	6 (15.0)
b) Education		
Illiterate	8 (19.6)	2 (5.0)
Primary school	11 (26.8)	3 (7.5)
Upper Primary school	11 (26.8)	8 (20.0)
High school	11 (28.8)	20 (50.0)
Inter & above	0	6 (15.0)
c) Land holdings (ha)		
Marginal (<1.0)	2 (4.9)	0
Small (1.0-2.0)	11 (26.8)	0
Medium (2.0-5.0)	18 (43.9)	20 (50.0)
Large (>5.0)	10 (24.4)	20 (50.0)
d) Experience in agriculture (years)		
<10	5 (12.2)	11 (27.5)
10-20	15 (36.6)	16 (40.0)
21-30	11 (26.8)	13 (32.5)
21-40	6 (14.6)	0
>40	4 (9.8)	0
e) Experience in castor (years)		
<10	41 (100)	40 (100.0)
>10	0	0
f) Yield		
Low	10 (24.4)	10 (25.0)
Medium	25 (61.0)	23 (57.5)
High	6 (14.6)	7 (17.5)
g) Knowledge		
Low	7 (17.1)	7 (17.5)
Medium	16 (39.0)	23 (57.5)
High	18 (43.9)	10(25.0)
h) Adoption		
Low	13 (31.7)	0 (0)
Medium	19 (46.3)	30 (75.0)
High	9 (22.0)	10(25.0)
i) Training programmes attended on castor		
One	0 (0)	30 (75.0)
Two	35 (85.4)	10 (25.0)
Three	3 (7.3)	0 (0)
More than three	3 (7.3)	0 (0)
j) Number of crops grown per year		
One	3 (7.3)	5 (12.5)
Two	32 (78.0)	30 (75.0)
Three	6 (14.6)	5 (12.5)
k) Member or office bearer		
Non-member	3 (7.3)	39 (97.5)
Member	35 (85.4)	1 (2.5)
Office bearer	3 (17.3)	0 (0)
l) Frequency of contact with researchers		
Not contacted	2 (4.9)	33 (82.5)
Once in crop cycle	38 (92.7)	4 (10.0)
More than once in crop cycle	1 (2.4)	3 (7.5)
m) Frequency of extension agency contact		
Once in crop cycle	39 (95.1)	4 (10.0)
No contact	2 (4.9)	36 (90.0)
n) Frequency of contact with others		
Occasioned	1 (2.4)	1 (2.5)
Regular	39 (95.1)	4 (10.0)
Rare	1 (2.4)	35 (87.5)

F=Frequency; Figures in parenthesis are percentages

Majority (92.7%) of FLD farmers had at least contacted the researchers once as compared to 10 per cent of non-FLD farmers. In case of extension agency contacts, 95 and 10 per cent of FLD and non-FLD farmers had one time contact during crop growth period. However, in non-FLD farmers, about 90 per cent of them had two times contact.

Impact of FLDs demonstrations: The mean seed yield of FLD farmers increased by 52 per cent with additional net returns of ₹ 39,860/ha as compared to non-FLD farmers. The BC ratio was 4.6 and 3.4 for FLD and non-FLD farmers, respectively (Table 2). Similar results of yield enhancement under frontline demonstrations were reported in potato (Mishra *et al*., 2009) and bajra (Anil Kumar *et al*., 2010). Majority of FLD farmers (42.5%) were in high knowledge category, whereas as majority of non-FLD farmers were in medium knowledge category. Majority of FLD (45%) and non-FLD farmers (82.5%) were in medium adoption category. More than 22 per cent of FLD farmers and 17 per cent of non-FLD farmers were in high adoption category (Table 3).

Table 2 Castor productivity potentials and economics of FLDs under real farm situations

Mean yield* (kg/ha)		% mean	Mean cost of cultivation (₹/ha)		Mean Gross returns (₹/ha)		Additional returns	BCR	
IT	FP		IT	FP	IT	FP		IT	FP
4183	2741	52	27459	24081	125435	82238	39860	4.6	3.4

Mean of 41 FLDs and 40 non-FLDs, IT=Improved technology, FP=Farmers practice

Table 3 Distribution of castor farmers based on the level of knowledge and extent of adoption

Category	Level of knowledge			Extent of adoption		
	FLD	Non-FLD	Total	FLD	Non-FLD	Total
Low	7 (17.5)	7 (17.5)	14 (17.5)	13 (32.5)	0 (0)	13 (16.25)
Medium	16 (40)	26 (65)	42 (52.5)	18 (45)	33 (82.5)	51 (63.75)
High	17 (42.5)	7 (17.5)	24 (30)	9 (22.5)	7 (17.5)	16 (20)
Total	40 (100)	40 (100)	80 (100)	40 (100)	40 (100)	80 (100)

Figures in parenthesis are percentages

Strong association was observed between the knowledge levels of FLD and non-FLD farmers (χ^2=7.21, p = 0.027 and contingency coefficient = 0.30). Mann-Whitney U test (U=602.5 Z=-2.103 p=0.35) indicated that there were significant differences in knowledge levels of FLD and non-FLD farmers. Similarly, strong association was observed in the extent of adoption of improved practices by FLD and non-FLD farmers (χ^2=17.01, p=0.001 and contingency coefficient = 0.42). There were significant differences in the extent of adoption of FLD and non-FLD farmers (U=492.5, Z = -3.17, p = 0.01). This might be due to the fact that most of the participating farmers had correct technological information and knowledge about improved technologies.

Influence of knowledge and adoption of farmers on castor productivity: The basic assertion is that acquisition of knowledge and adoption behavior is influenced by the socio-economic characteristics. Accordingly, correlation and regression analyses were done to know the influence of socio-economic characteristics. Adoption behavior of farmers was highly correlated with knowledge level (r=0.61), training programmes attended with respect to castor cultivation (r=0.33). Productivity is highly correlated with knowledge level of farmers (r=0.40), social participation (0.33) and family labour engaged (r=0.44) and peer groups (r=0.42) (Table 4). A step-wise regression analysis indicated knowledge level on castor (t=7.31 p=0.00) and FLD dummy (t=-3.92; p=0.00) were found to be significant. Standardized beta coefficients indicated that adoption of a technology was mostly influenced by the knowledge level (Table 5). Step wise regression analysis of yield on socio-economic variables indicated that FLD dummy (t=4.01; p=0.00), area under castor cultivation (t=-3.02; p=0.00), adoption (t=3.91; p=0.00) and family labour engaged (t=2.22; p=0.05) significantly influenced productivity of castor (Table 6). In order to increase castor productivity these variables may be manipulated positively.

The major constraints perceived by farmers were non-availability of quality seeds, high cost of labour and shortages at critical periods, poor marketing for the produce, fluctuating market prices affecting the decision to plant castor, increasing cost of inputs, yield losses due to incidence of wilt and low awareness on improved production technologies.

Table 4 Correlation between socio-economic characters, yield and adoption

Characteristics	Yield	Adoption
Adoption	0.368	
Age	0.217	0.119
Education	-0.215	0.185
Farm Size	-0.118	0.347**
Area under castor	0.026	0.180
Knowledge	0.399**	0.607**
Experience in castor cultivation	0.206	-0.105
Training progarammes attended on castor	0.038	0.334*
No. of crops grown per year	0.079	0.029
Member or office bearer	0.325(**)	0.014
Information sources on castor	0.134	-0.032
Family labour engaged	0.412(**)	-0.097
Frequency of contact with researchers	0.171	-0.166
Frequency of extension agency contact	-0.456(**)	0.194
Experience in agriculture	0.153	-0.077
Frequency of contact with others	-0.422(**)	0.182

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

Table 5 Influence of socio-personal characteristics of farmer on adoption of improved technologies

Variate	Unstandardized coefficients		Standardized coefficients	t-value	Sig.
	B	Std. Error	Beta		
(Constant)	2.730	0.509		5.361	0.000
Farm size	0.055	0.029	0.232	1.857	0.068
Area under castor	-0.850	0.471	-0.219	-1.803	0.076
Knowledge level	0.634	0.087	0.647	7.312	0.000
FLD dummy	-0.980	0.250	-0.349	-3.924	0.000

Table 6 Influence of socio-personal characteristics of farmer on castor yield

Variate	Unstandardized coefficients		Standardized coefficients	t-value	Sig.
	B	Std.Error	Beta		
(Constant)	1296.016	523.978		2.473	0.016
Family labour engaged	382.055	171.967	0.216	2.222	0.030
Area under castor cultivation	-766.518	253.256	-0.265	-3.027	0.001
Level of adoption	252.382	64.493	0.346	3.913	0.000
FLD dummy	819.289	204.134	0.392	4.013	0.000

The FLDs have shown the potential of IT to step-up the productivity significantly and increasing the income of farmers. In order to scale-up the demonstrations and speed up the dissemination of improved technologies in the region, there is need to forge necessary partnerships involving extension agencies, State Department of Agriculture and input agencies. Knowledge and extent of adoption of improved practices significantly influences the yield. Hence, efforts should be directed to increase the knowledge and adoption of farmers through various approaches. Providing training to farmers on castor production technologies is an important step in this direction.

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GJG-31: A high yielding and better quality Spanish bunch type groundnut (*Arachis hypogaea* L.) variety for Gujarat state

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ABSTRACT

A Spanish bunch type groundnut genotype GJG-31 is a hybrid derivative of the cross GG-2 x PBS-21065. It has recorded an overall mean pod yield of 3483 kg/ha, which was higher than the check varieties *viz*., GG-2 (2545 kg/ha), GG-4 (2812 kg/ha), GG-6 (2965 kg/ha) and TG-26 (2887 kg/ha). Thus, this genotype expressed an overall improvement of 36.86 per cent, 24.07 per cent, 17.47 per cent and 20.64 per cent in pod yield over the check varieties GG-2, GG-4, GG-6 and TG-26, respectively. This genotype was also tested in trials of All India Coordinated Research Project i.e. Initial Varietal Trial-Spanish Bunch-I and II during summer seasons of 2008 and 2009, respectively, where the performance was better than the local check variety GG-6 (14.46%) and zonal check variety TG-26 (11.79%). However, it was comparable with check varieties *viz.,* TAG-24, TG-37A and Dh-86. The kernel yield (2460 kg/ha) of GJG-31 was also higher than the check varieties *viz*., GG-2 (1822 kg/ha), GG-4 (2115 kg/ha), GG-6 (2174 kg/ha) and TG-26 (2159 kg/ha). GJG-31 recorded average 100-kernel weight of 40.77 g, average 100-pod weight of 115.3 g and average shelling out-turn of 70.62 per cent. GJG-31 was found free from peanut bud necrosis disease incidence as disease was not appeared in this variety. Due to its consistent superior performance, GJG-31 has been released for general cultivation in the summer bunch groundnut growing areas of Gujarat state.

Keywords: GJG-31, Groundnut, Spanish bunch, Variety

Groundnut (*Arachis hypogaea* L.) is an important crop for food and oil in tropical and subtropical regions. Gujarat is the leading groundnut growing state of the country, which contributes nearly ⅓ area and production of India. In general, the yield level in groundnut is quite high during summer season as compared to *kharif* season mainly due to cultivation under assured irrigated conditions. The summer groundnut varieties released so far in the state possess small pod size and hence they are less preferred for the cultivation. Under the circumstances, a variety with high yield potential, bold kernels and good quality traits is highly required. Therefore, GJG-31, a high yielding variety was developed by the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh in the year 2010 for the general cultivation during summer season in Gujarat state.

The Spanish bunch groundnut variety GJG-31 was developed by hybridization (GG-2 x PBS-21065) followed by pedigree method of selection. From the segregating populations, a Spanish bunch type high yielding and bold seeded genotype was isolated and evaluated. The genotype was tested in all station trials at Junagadh, Kodinar, Anand and Vyara during summer 2006 to summer 2009. Further, the genotype was also nominated for evaluation under AICRP trials during summer, 2008 and summer, 2009 in zone-II (Southern Rajasthan and Gujarat). The variety was screened for reaction to insect pests (thrips, jassids and *H. armigera*) and diseases (tikka, rust, stem rot and peanut bud necrosis disease incidence) under field conditions during summer 2006 to summer 2009. The recommended packages of practices were followed while conducting the trials to raise the healthy crop. The yield data was analyzed by Randomized Block Design as suggested by Panse and Sukhatme (1985).

Based on performance of the variety GJG-31 in the state trials of four consecutive years, it had proven its superiority in all the years. The mean pod yield of GJG-31 was 3483 kg/ha as compared to the checks *viz*., GG-2 (2545 kg/ha), GG-4 (2812 kg/ha), GG-6 (2965 kg/ha) and TG-26 (2887 kg/ha), which was 36.86 per cent, 24.07 per cent, 17.47 per cent and 20.64 per cent higher than the checks *viz*., GG-2, GG-4, GG-6 and TG-26, respectively (Table 1). The mean pod yield in the AICRP (Groundnut) trials revealed that the testing genotype had recorded the highest pod yield of 2787 kg/ha as compared to the check varieties, TAG-24 (2762 kg/ha), TG-37A (2741 kg/ha), TG-26 (2493 kg/ha), Dh-86 (2715 kg/ha) and GG-6 (2531 kg/ha). The variety GJG-31 has performed better than TG-26 (11.79 %) and GG-6 (14.46 %), but it was comparable with check varieties TAG-24 (0.92 %), TG-37A (1.68 %) and Dh-86 (2.65 %) (Table 2).

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Table 1 Yield performance of groundnut variety GJG-31 in the state trials

Year/Season	Name of trial	Locations	Pod yield (kg/ha)					SEm ±	CD (P=0.05)	CV%
			GJG-31	GG-2 (C)	GG-4 (C)	GG-6 (C)	TG-26 (C)			
Summer, 2006	PET-SB	Junagadh (1)	3872	2708*	3477	3605	3584	176	506	9.6
Summer, 2007	SSVT-SB	Junagadh (1)	5262	4255*	4117*	4282*	3962*	204	602	8.1
Summer, 2008	LSVT-SB	Junagadh	2373	2072	1644*	1887	1944	210	621	18.3
		Kodinar	4491	3205	4063	4282	4630	192	566	8.2
		Anand	3312	2487*	2806*	2804*	3172	164	485	9.7
		Vyara	1625	912*	764*	1060*	1384	128	376	17.9
		Average (4)	2950	2169	2319	2508	2782	-	-	-
		% increase over check	-	36.01	27.21	17.62	6.04	-	-	-
Summer, 2009	LSVT-SB	Junagadh	3583	2632*	-	2399*	2008*	196	581	12.18
		Kodinar#	1192	858	-	1088	1037	79	NS	13.19
		Anand	4025	3257	-	3778	3787	238	707	11.18
		Vyara	2801	1375*	-	2593	1514*	166	494	16.18
		Average (3)	3470	2421	-	2923	2436	-	-	-
		% increase over check	-	43.33	-	18.70	42.45	-	-	-
Overall Average (9)			3483	2545	-	2965	2887	-	-	-
Overall Average (6)			3489	-	2812	-	-	-	-	-
Overall % increase over the checks			-	36.86	24.07	17.47	20.64	-	-	-
Top ranking of GJG-31 over the checks			-	9/9	6/6	9/9	9/9	-	-	-
Total No. of Freq. in top Non-significant groups			9/9	3/9	2/6	3/9	5/9	-	-	-

*= Indicates significant the variety GJG-31 at 5% level of significance in comparison to respective check
= the data were not considered in calculation of average due to below state average yield, C - Check
PET-SB= Preliminary Evaluation Trial-Spanish Bunch; SSVT-SB= Small Scale Varietal Trial-Spanish Bunch; LSVT-SB= Large Scale Varietal Trial-Spanish Bunch

Table 2 Yield performance of groundnut variety GJG-31 in the AICRP trials in Zone II, India

Season/Year	Name of trial	Locations	Pod yield (kg/ha)						SEm ±	CD (P=0.05)	CV %
			GJG-31	TAG- 24 (NC)	TG- 37A (ZC)	TG-26 (ZC)	Dh-86 (ZC)	GG-6 (LC)			
Summer, 2008	IVT-SB-I	Junagadh	2755	2258*	2769	2472	2399	2176*	146	416	13.6
		Anand	3652	4251	3365	3364	3702	2762*	190	542	12.9
		Jalgaon	3548	3414	2850	2561	3365	-	175	353	8.6
		Udaipur	2620	2327	2717	2217	2483	-	194	390	12.9
		Average (4)	3144	3063	2925	2654	2987	2469	-	-	-
		% increase over check	-	2.65	7.41	18.46	5.26	29.77	-	-	-
Summer, 2009	IVT-SB-II	Junagadh	2722	2396	2624	2313	2300	2506	225	453	14.4
		Anand	2460	2321	2230*	2210*	1959*	2678	180	363	13.9
		Jalgaon	2181	3351	3091	3091	3548	-	203	408	12.3
		Udaipur	2360	1777	2278	1715	1960	-	188	378	14.6
		Average (4)	2431	2461	2556	2332	2442	2592	-	-	-
		% increase over check	-	-	-	4.24	-	-	-	-	-
Overall Average (8)			2787	2762	2741	2493	2715	2531	-	-	-
Overall % increase over check			-	0.92	1.68	11.79	2.65	14.46	-	-	-
Top ranking of GJG-31 over the checks			-	6/8	5/8	7/8	6/8	3/4	-	-	-
Total No. of Frequency in top Non-sign. groups			5/8	4/8	4/8	2/8	5/8	2/4	-	-	-

*=Indicates significant the variety GJG-31 at 5% level of significance in comparison to respective check
IVT-SB-I= Initial Varietal Trial-Spanish Bunch-I; IVT-SB-II = Initial Varietal Trial-Spanish Bunch-II

Ancillary observations of economic attributes of GJG-31 along with the checks are presented in Table 3. Average kernel yield of GJG-31 was 2460 kg/ha, which was 35.01 per cent, 16.31 per cent, 13.16 per cent and 13.94 per cent higher over the check varieties *viz.*, GG-2 (1822 kg/ha), GG-4 (2115 kg/ha), GG-6 (2174 kg/ha) and TG-26 (2159 kg/ha), respectively. GJG-31 exhibited more 100-kernel weight (40.77 g) over all the check varieties i.e., GG-2 (32.83 g), GG-4 (34.34 g), GG-6 (35.35 g) and TG-26 (36.33 g). Average 100-pod weight of GJG-31 was also high

(115.3 g) as compared to the check varieties *viz.*, GG-2 (92.1 g), GG-4 (86.8 g), GG-6 (85.9 g) and TG-26 (82.3 g). The average shelling out-turn of the testing genotype was less than GG-4 and TG-26 while, it was comparable with the check varieties GG-2 and GG-6.

The testing variety GJG-31 was screened for pests and diseases during summer 2006 to summer 2009. Tikka, rust and stem rot were not appeared throughout testing period. The testing genotype was found free from PBND incidence (Table 4). Due to its consistent superior performance for high pod yield, kernel yield, oil yield, haulm yield with better quality characteristics, the newly developed variety GJG-31 has been released by 6th Combined Joint Agricultural Research Council Sub-Committee Meeting held at Junagadh (Gujarat) during 20-22 April, 2010 for summer groundnut growing areas of Gujarat State (Anonymous, 2010).

Table 3 Ancillary observations of economic attributes of variety GJG-31 along with checks

Character	GJG-31	GG-2 (C)	GG-4 (C)	GG-6 (C)	TG-26 (C)
Pod yield (kg/ha)	3483	2545	2812	2965	2887
Kernel yield (kg/ha)	2460	1822	2115	2174	2159
Haulm yield (kg/ha)	6408	5736	6574	6116	3856
Oil yield (kg/ha)	1211	888	1039	1040	1030
Shelling out-turn (%)	70.62	71.61	75.22	73.34	74.79
Oil content (%)	49.24	48.74	49.15	47.82	47.74
100-pod weight (g)	115.3	92.1	86.8	85.9	82.3
100 kernel weight (g)	40.77	32.83	34.34	35.35	36.33
Maturity days	117	117	116	115	117
Protein content (%)	29.86	30.65	29.60	29.04	27.04
Sugar content (%)	10.84	10.71	9.65	10.31	11.42
Count (No. of kernels/30 g wt.)	67.5	93.5	92.0	99.0	105.0

C=Check

Table 4 Mean rating of incidence of insect-pests and diseases at Junagadh (Summer 2006 to Summer 2009)

Diseases/Insect Pests	Entries				
	GJG-31	GG-2 (C)	GG-4(C)	GG-6(C)	TG-26(C)
I. Diseases					
Tikka score (0-9)			Disease was not appeared		
Rust score (0-9)			Disease was not appeared		
Stem rot incidence (%)			Disease was not appeared		
II. Pests					
PBND incidence (%)	0.00	3.77	1.50	5.08	5.26
Leaf damage by thrips (%)	42.5	37.1	46.3	40.1	58.8
Average. no. of jassids/3 leaves/plant	2.2	3.3	2.8	3.2	2.9
Leaf damage by *H. armigera* (%)	44.4	59.5	51.8	50.0	27.8

C=Check

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Genetic evaluation of physiological traits affecting water use efficiency in sunflower (*Helianthus annuus* L.)

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ABSTRACT

The present investigation was undertaken to evaluate 41 (26 restorer and 15 maintainer) genotypes of sunflower for physiological traits affecting water use efficiency under different environments. The traits studied were canopy temperature, leaf area index, photosynthetic rate and leaf water potential. Among the four stress treatments, W_1 (control) irrigating during entire grown cycle yielded the maximum value for all the parameters, except canopy temperature, followed by W_4, W_3 and W_2 (withholding of irrigations in different growth stages). In genotypes under study, the estimates of heritability and genetic advance were observed maximum for leaf area index followed by leaf water potential indicating the predominant additive gene effects for these parameters. Hence, these traits can be improved to a considerable extent by limited selection cycles. Estimation of GCV and PCV values were higher for leaf area index as compared to other traits indicating high genetic variability for leaf area index. Pooling of physiological and genetic parameters indicated that leaf water potential and photosynthetic capacity can be adopted for breeding of suitable crop varieties for changing climatic scenario.

Keywords: Genetic parameters, Physiological parameters, Sunflower, Water use efficiency

The water stress is one of the major causes for crop losses worldwide, reducing average yields to 50 per cent or even more. Possible global climate change scenario suggests a future increase in the risk of drought. Therefore, breeding crop varieties for improved water use efficiency is of utmost importance. Production experiences have shown that irrigation scheduling, done in a manner to fulfill crop water requirement, is mostly desirable in order to achieve high yields and economically viable production. When water is limited, alternative strategies must be sought to reduce irrigation water use and to improve its efficiency. Among these strategies deficit irrigation is getting particular significance during last decades since it aims to optimize agricultural output while saving water for other purposes. A strategy for drought stress breeding depends on the intensity, frequency and timing of drought occurrence. Under typical conditions in North India, rainfall is too low and agriculture is dependent on supplemental irrigations. Since water availability is highly unpredictable and flowering period of sunflower is highly sensitive to drought, tolerance to water stress at flowering must be developed to minimize the damaging effect of drought.

The first approach, to develop water stress tolerant line, is to screen high yielding germplasm accompanied by superior yield contributing traits. It is likely that this germplasm also contain extensive variation for stress tolerance traits. Spring season sunflower in Punjab is grown in the month of January/February to May/June. The high temperature particularly in the month of April to June coincides with the reproductive and seed filling stages of the crop which requires frequent irrigation. Therefore, there is need to develop germplasm and hybrids which require less water during crop season.

There are many reports on variability and association studies in sunflower; however, limited work has been done on physiological parameters in spring season sunflower. Genetic analysis of physiological characters, under different water stress environments in sunflower is not much widely discussed. Hence, the present study was planned with the objective to genetically analyze various physiological traits affecting water use efficiency under varied water regime.

The study was undertaken at Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana. The experimental material comprised of 41 genotypes of sunflower comprising 15 maintainer lines and 26 restorer lines planted during spring 2010 in a Randomized Complete Block Design with three replications. The treatment includes four irrigation regimes *viz.*, W_1: (Irrigation level 01) Irrigating the plots during the entire growth cycle to maintain the soil water content near to field capacity; W_2: (Irrigation level 02) Withholding of 2nd irrigation i.e., before button stage and there after complete withholding of irrigations after soft dough stage (30-40 DAS); W_3: (Irrigation level 03) Withholding of irrigation at 50 per cent flowering stage and soft dough stage thereafter complete withholding of irrigations after hard dough stage (60-65 DAS); W4: (Irrigation level 04) Withholding of irrigation at anthesis completion stage and there after complete withholding of irrigation after soft dough stage (65-70 DAS). Withholding of 2nd irrigation means 2nd irrigation was withheld; however remaining irrigation (i.e., 3rd, 4th, etc.) was provided. Complete withholding of irrigation stands for no irrigation was made after soft dough stage. The remaining irrigation regimes were provided in similar manner. The data was recorded on canopy temperature (CT) (°C), leaf area index (LAI), photosynthetic capacity (PS) and leaf water potential (LWP) (mpa). Leaf water potential was recorded by leaf water potential meter (Water Potential System - WESCOR - 4357526011) in one intact plant in each replication of all genotypes. The unit of measurement was Mega-Pascal's (Mpa). Leaf area index was measured using canopy analyzer (Sunscan-typeSS1) in each row of all inbred lines, under field conditions. The temperature of plant canopy was measured by Infrared thermometer in intact plants of each plot. The unit of measurement was degree centigrade (°C). Photosynthetic capacity was worked out by Flaurometer reading of PS II activity by chlorophyll fluorometer (Model-0530P).

In plants water deficit has shown to decrease both growth and yield. Selection of suitable plants from germplasm using specific physiological traits is a viable way forward for crop improvement for water stress tolerance (Reynolds *et al*., 2005). Therefore, in the present study the emphasis was laid down to evaluate the lines for various physiological parameters. The canopy temperature ranged from 25.61 to 27.74°C in control (W_1), whereas in W_2, W_3 and W_4 it varied from 26.06 to 29.90°C, 27.72 to 30.40 °C and 32.65 to 35.50°C, respectively (Fig. 1a). Where no water stress was given, the genotypes P-87-R (25.88°C), P-89-R (25.94°C), 234-B (25.96°C) and 50-B (25.61°C) recorded lower canopy temperature while the same genotypes recorded higher canopy temperature in W_4, where water stress was given at anthesis completion and soft dough stage. Maximum increase in canopy temperature was observed in W_2 for the genotypes 49-B (26.33 to 29.38°C) and 234-B (25.96 to 28.62°C), whereas genotypes P-61-R (27.56 to 29.28°C) and 11-B (26.73 to 28.02°C) exhibited maximum increase for canopy temperature in W_3. The overall effect of water stress was least in P-93-R and P-75-R while all other genotypes recorded increased canopy temperature under all the water stress levels. It is evident from the results that canopy temperature, in general, increases with the increasing water stress during different stages of plant growth and a balance has to be kept between lower canopy temperature and irrigation frequency to keep the yield losses to minimum.

Photosynthesis in higher plants is known to decrease with decreasing relative water content (RWC) and leaf water potential (Lawlor and Cornic, 2002). According to Lawson *et al*. (2003) drought mainly limits photosynthesis through stomatal closure and metabolic impairment. Drought stress can affect growth of plant organs resulting in the alteration of physiological features of the plant and this has been observed in present study as well. The photosynthetic capacity (Fv/Fm ratio) ranged from 0.69 to 0.77 in W_1, whereas in W_2, W_3 and W_4 substantial decrease was recorded and varied from 0.57 to 0.73, 0.59 to 0.71 and 0.62 to 0.74, respectively. It was observed that the genotypes P107RP2, P69R, 3376R, P75R and 40B exhibited least reduction in photosynthetic capacity while significant reduction in the photosynthesis was reported for the genotypes P61R, P93R, P111R, 10B and 53B (Fig. 1b) which reveals that these genotypes are more susceptible to water stress. Decrease in photosynthetic capacity due to down regulation of PS II activity has been earlier reported by Germ *et al*. (2005) and Ashraf *et al*. (2007). However, maintenance of photo-synthetic capacity under water stress has also been discussed by Chaves *et al*. (2002).

Leaf area index is an integrative measure of carbon and water balance in plants and is one of the major components of plant productivity (Cowling, 2003). Leaf area is the value as an index of plant growth and in addition related to accumulation of dry matter, plant metabolism and yield. Accurate estimation of leaf area index is required because of the importance of canopy structure in gas, water, carbon and energy exchange. In W_1, the range for leaf area index was 0.4 to 1.5, whereas in W_2, W_3 and W_4 it was 0.2 to 0.8, 0.2 to 1.0 and 0.3 to 1.3, respectively (Fig. 1c). In W_4, most of the genotypes recorded very less reduction in leaf area index followed by W_3 and W_2. The overall effect of water stress on leaf area index was least in 95C1R, P107RP1 and 44B whereas the maximum effect was observed in P112R, P119R, 40B, RHA297 and P100R. According to previous studies by Bajaj *et al*. (2007) genotypes interact differentially in different environments with respect to leaf area index and seed yield. Leaf area was found to be positively correlated with seed yield. The average leaf area index was significantly higher in W_1 (0.66) as compared to W_2 (0.37), W_3 (0.42) and W_4 (0.56) which can be attributed to lesser water availability in different stress environments at different crop growth stages. Reduction in leaf area index due to water stress has also been observed by Moriondo *et al*. (2003). Reduction in leaf area index was less in W_4 because water stress was imposed after the vegetative growth of plants. In W_2 and W_3 more reduction in leaf area index can be mainly attributed to stress imposed before flowering when vegetative growth was very essential.

Leaf water potential was significantly higher under W_1 (-2.56 mpa) as compared to W_2 (-3.16 mpa), W_3 (-3.17 mpa) and W_4 (-3.02 mpa) in all genotypes. In W_1 the range for leaf water potential was -2.83 mpa (P61R) to -2.35 mpa (304B), whereas in W_2, W_3 and W_4 it ranged between -3.96mpa (P93R) to -2.55 mpa (P107RP1), -3.73 mpa (11-B) to -2.40 mpa (P107RP1),-3.64 mpa (P94R) to -2.56 mpa (P61R), respectively (Fig. 1d). The effect of water stress was significant in all treatments in all genotypes except P-107-R-P1, P-110-R and 304-B. Constant availability of water maintained high leaf water potential in W_1 and it reduced in W_2, W_3 and W_4 as per irrigation scheduling.

Canopy temperature showed maximum heritability of 81.75 per cent in control plots (W_1) (Table 1) followed by 71.7 per cent (W_2), 50.88 per cent (W_3) and 49.03 per cent (W_4). However, genetic advance has shown showed opposite trend with changing water stress and was ranged from 1.34 (W_4) to 0.12 (W_1). PCV and GCV was found highest in controlled treatment (W_1) 13.68 and 7.77 followed by 11.94 and 4.88 in W_3, 10.15 and 7.04 in W_4 and 4.78 and 3.20 in W_2. For photosynthetic capacity, heritability was highest in W_3 (52.59%) while the minimum was recorded to be 48.11 (W_4). In the same manner, genetic advance also shifted with changing stress environments i.e., 0.49 (W_1) followed by 1.34 (W_4), 1.17 (W_3) and 0.23 (W_2). Regarding PCV and GCV, the inter-environmental range was 15.23 and 13.58 (W_1) to 10.15 and 7.04 (W_4). Leaf area index recorded highest heritability (91.12%) in W_1 followed by 86.82 per cent (W_4), 78.84 per cent (W_3) and 50.26 per cent (W_2). Similarly the genetic advance changed with varying water stress i.e., 0.55 (W_1) followed by 0.42 (W_4), 0.31 (W_3) and 0.14 (W_2). The PCV and GCV were found to be highest in W_1 (i.e., 45.17 and 44.89) and minimum in W_2 (3.17 and 1.58). Leaf water potential ranged from 86.59 per cent (W_1) to 60.45 (W_2). In contrast to other parameters genetic advance was found to be maximum in W_2 (0.47) followed by W_4 (0.42) and W_3 (0.38). PCV and GCV were highest in W_2 (13.08 and 10.13) while the lowest was recorded in W_4 (6.85 and 3.06).

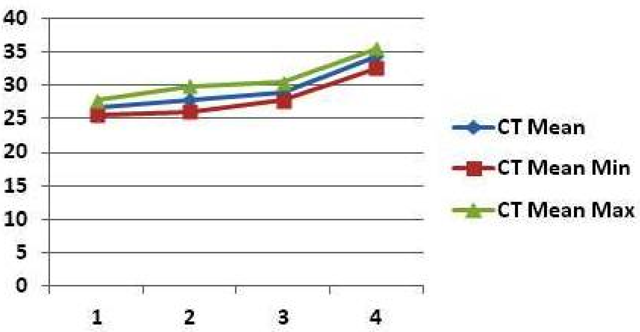

Fig.1a. CT (Canopy Temperature)

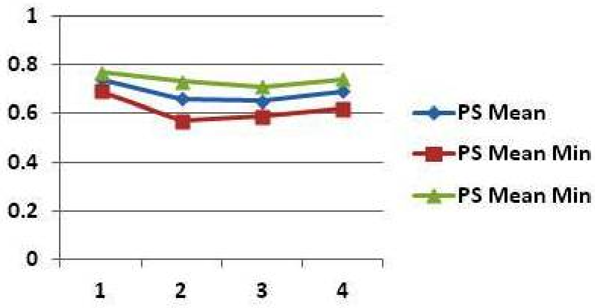

Fig.1b. PS (Photosynthetic capacity)

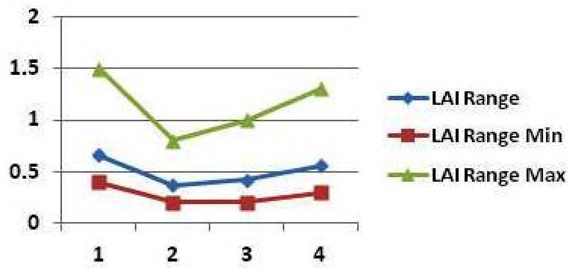

Fig.1c. LAI (Leaf Area Index)

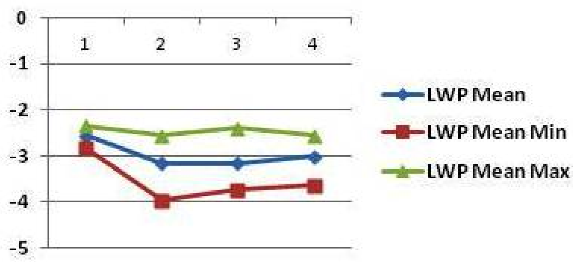

Fig.1d. LWP (Leaf water potential)

Note: X and Y axis denotes the units of parameters and four stress treatments, respectively

Fig.1. Status of physiological parameters under different water stress environments

Heritability estimates along with genetic advance is more useful than heritability value alone predicting the resultant effect for selecting the best genotypes. Maximum heritability and genetic advance was observed for leaf area index followed by leaf water potential indicating the presence of sufficient amount of additive gene effects. Hence, this trait can be improved to a considerable effect by limited selection cycles. Photosynthetic capacity recorded minimum heritability and genetic advance showing dominance gene action. Therefore heterosis breeding can be rewarding to improve the photosynthetic capacity of genotypes. Estimation of GCV and PCV values for leaf area index were almost similar as compared to other traits indicating environment is contributing fewer roles and selection would be more effective. It is evident from this study that significant reduction in yield and its components takes place due to water stress. Photosynthetic capacity, leaf area index and leaf water potential were observed to be significantly reduced while canopy temperature increased with increasing water stress. The W_2 and W_3 have shown maximum reduction in these physiological parameters as compared to W_4. The results indicate that irrigation at button stage, 50 per cent flowering, soft dough stage and hard dough stage are crucial for crop growth cycle whereas withholding of irrigation at anthesis completion stage does not affect the yield related characters to that extent. A total of eight genotypes have been identified as more water use efficient genotypes with respect to canopy temperature, photosynthetic capacity and leaf area index (Table 2).

The results indicated a better scope for selection for leaf area index. The lower variability coefficients for leaf water potential and photosynthetic capacity indicates that there was less genetic variation for these traits in the materials evaluated, which calls for search of variation in other materials for development of variability for these parameters. Since no intensive work on genetic analysis for physiological parameters has been done before, this was a novel study to evaluate these traits *viz.*, canopy temperature, leaf area index, photosynthetic rate and leaf water potential for variability coefficients. The reporting will have long term implication in breeding of suitable crop varieties for drought and water stress resistance.

Table 1 Genetic evaluation of physiological parameters

	Canopy temperature					Photosynthetic capacity			
	h^2 (%)	GA	PCV%	GCV%		h^2 (%)	GA	PCV%	GCV%
W_1	81.75	0.12	13.68	7.77	W_1	60.12	0.49	15.23	13.58
W_2	71.7	0.23	4.78	3.20	W_2	49.38	0.19	10.53	5.98
W_3	50.88	1.17	5.13	3.66	W_3	52.59	0.03	11.94	4.88
W_4	49.03	1.34	4.13	2.89	W_4	48.11	0.07	10.15	7.04
	Leaf Area Index					Leaf Water Potential			
	h^2 (%)	GA	PCV%	GCV%		h^2 (%)	GA	PCV%	GCV%
W_1	91.12	0.55	45.17	44.89	W_1	86.95	0.38	8.54	7.96
W_2	50.26	0.14	3.17	1.58	W_2	60.45	0.47	13.08	10.13
W_3	78.14	0.31	45.02	39.79	W_3	70.54	0.38	9.12	3.44
W_4	86.82	0.42	41.79	38.94	W_4	70.59	0.40	6.85	3.06

W_1 - Control; W_2 - Second environment; W_3 - Third environment; W_4 - Fourth environment; h^2 (%)-Heritability; GA - Genetic advance; PCV - Phenotypic coefficient of variance; GCV - Genotypic coefficient of variance

Table 2 Promising genotypes selected for various water stress environments

Environments	CT	PS	LAI	LWP
W_1	P87R, P89R	P107RP2, P69R	95C1R	P61R, 304B
W_2	234B	P75R, 40B	P107RP2, P89R	P93R, P107RP1
W_3	P89R, P93R	3376R	P91R	11B, P94R
W_4	P107RP2	P69R, 40B	P93R	304B

CT: Canopy Temperature; PS: Photosynthetic capacity; LAI: Leaf Area Index; LWP: Leaf Water Potential

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Genetic architecture of yield contributing traits in linseed (*Linum usitatissimum* L.)

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ABSTRACT

Fifty two accessions of linseed were evaluated during *rabi* 2009-10 and 2010-11 to know the genetic variability, direct and indirect contribution of some metric traits on seed yield under Randomized Block Design. The results revealed that high heritability along with high genetic advance as per cent of mean was observed for number of capsules/plant, seed yield/plant and number of secondary branches/plant while high heritability coupled with low genetic advance was noticed for days to maturity and days to 50 per cent flowering. Seed yield was significant and positively correlated with number of capsules/plant, 1000-seed weight and number of secondary branches/plant. Path coefficient analysis indicated that number of capsules/plant and 1000-seed weight showed positive direct effect on seed yield/plant. These traits having positive direct effect on seed yield can be considered as a suitable selection criteria for evolving high yielding linseed genotypes.

Keywords: Correlation, Genetic advance, Heritability, Linseed, Path analysis, Variability

Linseed is a valuable oilseed crop that provides the source of omega-3 fatty acid, which is essential for human beings. It is used in manufacturing the paint, soap, varnish, linoleum pad and printing ink. India's total production of linseed is around 1.49 lakh tons from an area of 2.96 lakh ha with low productivity of 502 kg/ha (Anonymous, 2014). Primary objective of linseed breeder is to increase the seed yield. Generally, yield represents the final character resulting from many developmental and biochemical processes which occur between germination and maturity. Before yield improvement can be realized, the breeder needs to identify the cause of variability in seed yield in any given environment, since fluctuations in environment generally effects yield through its components. Knowledge of heritability and genetic advance of the characters is a pre-requisite for the improvement through selection. The study of relationship among quantitative traits is important for assessing the feasibility of joint selection of two or more traits. Positive correlations between two desirable traits make the job of the plant breeder easy for improving both traits simultaneously. On the other hand, negative correlation expressed between two desirable traits make it impossible to achieve a significant improvement in both traits. However, simple correlation do not give an insight into the true biological relationship of these traits with seed yield. The path coefficient analysis described by Dewey and Lu (1959) allows partitioning of correlation coefficient into direct and indirect contribution of various traits towards dependent variable and thus helps in assessing the cause effect relationship as well as effective selection. Hence, this study is aimed to analyze and determine the traits having interrelationship with seed yield utilizing the correlation and path analysis.

Fifty two genotypes of linseed collected from different places of Uttar Pradesh and other states of the country were grown at Oilseeds Research Farm, C. S. Azad University of Agriculture & Technology, Kanpur during *rabi* 2009-10 and 2010-11 in a Randomized Block Design with three replications. Each genotype was planted in a single row of 5m length with row to row distance of 30 cm. Recommended package of practices was followed to raise a good healthy crop. Five plants were randomly selected in each genotype replication wise to record the observations on nine metric traits *viz.,* plant height (cm), days to 50 per cent flowering, days to maturity, number of primary branches/plant, number of secondary branches/plant, number of capsules/plant, number of seeds/capsule, 1000-seed weight (g) and seed yield/plant (g). The data were statistically analyzed using average of five plants. The phenotypic and genotypic coefficient of variations was calculated as per Burton and Devane (1953). Heritability and genetic advance were estimated according to Johnson *et al.* (1955) and Allard (1960). Phenotypic and genotypic correlations were worked out according to Robinson *et al.* (1951).

The range of variation for different characters indicated the existence of wide variability among the genotypes (Table 1). Highest range was observed for number of capsules/plant followed by seed yield/plant and number of secondary branches/plant. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) revealed similar pattern of variability, the earlier being little higher, it showed that environment did not exert masking influence on the expression of genetic variability. Similar results were observed by Ram *et al.* (2010). Number of capsules/plant exhibited maximum GCV and PCV followed by seed yield/plant and number of secondary branches/plant. Thus, appreciable amount of variability was present among the genotypes for all these traits and selection could be effective for further improvement of these characters. On the contrary, moderate estimates of GCV and PCV were recorded for number of primary branches/plant, 1000-seed weight, plant height and number of seeds/capsule. This indicates little improvement could be expected under selection for these characters. However, low estimates of variability were recorded for days to 50 per cent flowering and days to maturity indicating the limited scope of selection for these traits.

The estimates of heritability were very high for all the traits under study. Heritability in conjunction with genetic gains was more effective and dependable in predicting the improvement through selection (Johnson *et al.*, 1955). High heritability coupled with high genetic advance as per cent of mean was recorded for number of capsules/plant, seed yield/plant, number of secondary branches/plant and number of primary branches/plant indicating that these characters can be improved through direct selection since the additive gene action is being involved in the inheritance of these traits. Similarly high heritability with high genetic advance for seed yield has been reported by Tewari *et al.* (2012). High heritability with low genetic advance was observed for days to maturity, days to 50 per cent flowering and number of seeds/capsule which might be due to preponderance of non-additive gene effects. Hence, it could be suggested that improvement of these traits might be difficult through selection.

The genotypic correlations in most of the cases were higher than the phenotypic correlation indicated that genetic factors played a major role in determining these correlation (Table 2). Comparatively low phenotypic values might be attributed due to differential interaction of genotypes with the environment. High significant and positive correlation was observed between seed yield and number of capsules/plant at both phenotypic and genotypic level (0.647** and 0.697**) followed by 1000-seed weight (0.560**and 0.594**), number of secondary branches/plant (0.521**and 0.546**) and number of primary branches/plant (0.323*and 0.392**) at both phenotypic and genotypic levels. Similar results were observed by Kant *et al.* (2008). Number of capsules/plant showed significant and positive association with number of primary branches/plant and number of secondary branches/plant at both phenotypic and genotypic levels, whereas number of secondary branches showed significant and positive association with number of primary branches/plant. Similarly the association of days to maturity with plant height and days to 50 per cent flowering was found significant and positive. Significant positive association was also observed between plant height and days to 50 per cent flowering.

Table 1 Estimates of variability, heritability and genetic advance for various characters in linseed

Character	Mean	Range	PCV (%)	GCV (%)	Heritability (%)	GA	GA as per cent of mean
Days to 50% flowering	84.47	70.0-103.0	12.76	12.46	95.4	21.17	25.06
Plant height (cm)	65.67	51.0-104.6	18.49	17.79	92.6	23.16	35.27
Days to maturity	142.71	111.0-169.0	12.07	11.94	97.8	34.71	24.32
No. of primary branches/plant	5.36	3.0-9.3	28.22	24.46	75.1	2.34	43.66
No. of secondary branches/plant	20.06	10.0-34.3	33.58	32.93	96.2	13.36	66.55
No. of capsules/plant	110.30	45.3-251.3	42.10	41.36	96.5	92.28	83.67
No. of seeds/capsule	8.16	4.3-10.0	16.33	14.17	75.3	2.07	25.37
1000-seed weight (g)	6.68	4.3 – 9.3	20.40	19.48	91.2	2.56	38.37
Seed yield/plant (g)	5.17	1.9-10.2	39.31	37.75	92.2	3.86	74.66

PCV=Phenotypic Coefficient of Variance; GCV=Genotypic Coefficient of Variance; GA=Genetic Advance

Number of capsules/plant had the highest direct and positive effect on seed yield/plant followed by 1000-seed weight and number of secondary branches/plant there by indicating that the genetic correlation between number of capsules/plant and seed yield/plant explains the true relationship between these two characters since number of capsules/plant not only showed the highest correlation with seed yield but also had maximum direct effect on this dependent character (Table 3). Similar results were also observed for 1000-seed weight and number of secondary branches/plant. On the contrary number of primary branches correlated with seed yield/plant but had low direct effect on the dependent character. Low and positive direct effect of number of primary branches was complemented by its high indirect effect through number of capsules/plant and number of secondary branches/plant to produce a significant and positive correlation with seed yield. The effects of remaining yield contributing characters were negligible except number of capsules/plant which had indirect effect via number of secondary branches/plant. The results are in agreement with the earlier findings of Rao (2007). Hence, selection of these characters would be effective in increasing the seed yield in linseed genotypes. The value of residual effect of undefined factors was low (0.209). Thus number of capsules/plant, 1000-seed weight and number of secondary branches/plant were the most important component of traits of seed yield and need emphasis while selecting high yielding genotypes in linseed.

Table 2 Correlation coefficients between seed yield and yield contributing characters in linseed

Character	Traits	Days to 50% flowering	Plant height (cm)	Days to maturity	No. of primary branches/plant	No. of secondary branches/plant	No. of capsules/ plant	No. of seeds /capsule	1000-seed weight (g)	Seed yield /plant (g)
Days to 50% flowering	P	-	0.608**	0.649**	0.003	0.136	0.067	-0.202	-0.044	0.125
	G		0.650**	0.677**	0.001	0.141	0.077	-0.204	-0.055	0.125
Plant height (cm)	P		-	0.640**	0.146	0.242	0.163	-0.260	-0.016	0.237
	G			0.672**	0.169	0.257	0.174	-0.303	-0.012	0.251
Days to maturity	P			-	0.206	0.251	0.245	-0.162	0.048	0.209
	G				0.239	0.261	0.248	-0.187	0.055	0.218
No. of primary branches/plant	P				-	0.518**	0.373*	0.059	0.032	0.323*
	G					0.575**	0.435**	0.137	0.023	0.392**
No. of secondary branches/plant	P					-	0.378**	0.056	0.123	0.521**
	G						0.386**	0.072	0.138	0.546**
No. of capsules/plant	P						-	0.069	0.198	0.647**
	G							0.102	0.220	0.697**
No. of seeds/capsule	P							-	0.070	0.144
	G								0.081	0.138
1000-seed weight (g)	P								-	0.560**
	G									0.594**
Seed yield/plant (g)	P									-
	G									

*,** Significant at 5% and 1% level of probability, respectively; P=Phenotypic correlation coefficients, G=Genotypic correlation coefficients

Table 3 Direct and indirect (genotypic) effects of different contributing traits towards seed yield in linseed

Character	Days to 50% flowering	Plant height (cm)	Days to maturity	No. of primary branches/plant	No. of secondary branches/plant	No. of capsules/ plant	No. of seeds/ capsule	1000-seed weight (g)	Genotypic correlation coefficient with seed yield
Days to 50% flowering	0.092	0.114	0.112	0.000	0.057	0.037	-0.018	-0.026	0.125
Plant height (cm)	0.060	0.175	0.111	0.004	0.068	0.084	0.022	-0.006	0.251
Days to maturity	0.062	0.118	0.166	0.005	0.059	0.119	0.141	0.025	0.218
No. of primary branches/plant	0.000	0.029	-0.040	0.021	0.152	0.208	0.010	0.011	0.392
No. of secondary branches/plant	0.013	0.043	-0.043	0.012	0.263	0.185	0.005	0.064	0.546
No. of capsules/plant	0.007	0.031	-0.41	0.009	0.103	0.479	0.008	0.102	0.697
No. of seeds/capsule	-0.022	-0.053	0.231	0.003	0.019	0.049	0.074	0.037	0.138
1000-seed weight (g)	-0.005	-0.002	-0.00*	0.000	0.037	0.106	0.006	0.462	0.594

Residual effect- 0.209

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Assessment of different herbicides on weed suppression and yield of groundnut (*Arachis hypogaea* L.)

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ABSTRACT

Experiment was conducted at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar to evaluate the performance of quizalofop ethyl sponsor sample to its market sample available for weed suppression and its impact on groundnut yield during *kharif* 2012. The major weed flora in the experimental plots were *Echinochloa colona* (39.2%), *Eleusine indica* (28.0%), *Parthenium hysterophorus* (7.5%) and *Mollugo stricta* (3.7%) and *Digera arvensis* (3.7%). It was found that among the herbicides, post-emergence application of quizalofop ethyl sponsor sample at 50 g a.i./ha was found to be most effective weed management practice in reducing the density and dry weight of weeds with higher weed control efficiency, higher yield (981 kg/ha) and yield attributes being at par with its market sample applied at 50 g a.i./ha. The reduction in kernel yield in unweeded check was 77.6% compared to best weed management practices (quizalofop ethyl sponsor sample @ 50 g a.i./ha). Post emergence application of imazethapyr @ 150 g a.i./ha was found more effective in suppressing broad leaf weeds in groundnut.

Keywords: Groundnut, Herbicides, Weed management, Yield

Groundnut (*Arachis hypogaea* L.) is a valuable oilseed and accounts for 33 per cent area and 45 per cent production in India. India ranks first among groundnut growing countries in the world with 6.74 m ha area and 7.99 m t production (Bhale *et al*., 2012). Weed management in groundnut has great importance as this crop suffers heavily due to weed competition in the early stage because of its short structure and initial slow growth. Unmanaged weeds in groundnut crop results in yield loss as high as 70 to 75 per cent (Gnanamurthy and Balasubramaniyan, 1998). The critical period of crop weed competition in groundnut was observed to be 40 to 60 days after sowing (Singh and Patel, 1992).

Generally weeds are controlled through hand weeding in groundnut, which is very expensive, laborious and sometimes damaging to the crop plant (Dubey *et al*., 2010). Mechanical weeding is economical but the timely operation is important. Due to continuous rains during *kharif*, groundnut grown in this season do not allow timely mechanical weeding. Herbicides on the other hand give timely and effective control of weeds and from very beginning compared to mechanical weed control. A lot of herbicides such as trifluralin, pendimethalin, alachlor, fluchloralin etc when applied alone or supplemented with one hand weeding have been found to be effective for weed management in groundnut. Mostly these herbicides are applied as pre-plant incorporation or pre-emergence while for the control of latter emerged weeds, only imazethapyr is available in the market which is applied as post-emergence thus there is need for the new herbicide molecules which could control grassy weeds at later stage. Hence, a sponsor sample of quizalofop ethyl (5% EC) has been developed for control of grassy weeds. It is a selective herbicide, absorbed mainly by the leaves and inhibits the activity of acetyl CoA carboxylase (ACCase). Furthermore, this herbicide is a new perception as compared to available sample of quizalofop ethyl 5% EC in market. The present study has been undertaken to evaluate the performance of sponsor sample of quizalofop ethyl 5% EC as compared to its market sample for control of grassy weeds and to find out an appropriate dose of this herbicide and its impact on groundnut.

A field experiment was conducted during *kharif* season of 2012 at Norman E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar to know the response of quizalofop ethyl herbicides on weed density, yield and economics of groundnut. The soil of the experimental plot was sandy loam in texture with pH 7.3, organic carbon 0.77% and available N, P, K were 193, 14.3 and 200 kg/ha, respectively. The experiment was laid out in Randomized Block Design with three replications comprising seven different weed control treatments *viz.*, two different doses of quizalofop ethyl sponsor sample (SS) and market sample (MS) 5% EC applied at 37.5 and 50 g a.i./ha, imazethapyr 10% SL @ 150 g a.i./ha as standard check, weed free and weedy check. Quizalofop ethyl and imazethapyr were post-emergence herbicides which were applied at 2-3 leaf stage of weeds using knapsack sprayer fitted with a flat fan nozzle with the spray volume of water 500 l/ha. Groundnut cultivar "Chandra" was sown in lines on June 28, 2012 in a plot size 5x3 m^2. All the recommended package of practices except weed control was adopted in the

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experimental plot during the experiment. Seeds of grassy, sedges and broad leaved weeds were spread uniformly in the experimental field to ensure sufficient population of these weeds in study plots. Fertilizer at 20 kg N/ha, 30kg P/ha and 45kg K_2O/ha was applied in each plot through urea, single superphosphate and muriate of potash at the time of sowing of groundnut.

Observations on weed density were recorded at 60 days after herbicide application (DAA) by randomly placing a quadrate of 0.25×0.25 m at two places in each plot. The weeds inside each quadrate were uprooted, cleaned and dried. After drying, weight and weed control efficiency was calculated by using the formula WCE = (weed biomass in unweeded control - weed biomass in managed treatment)/ weed biomass in unweeded control x 100. Yield and yield component of groundnut were recorded at harvest. The data were analyzed following analysis of variance technique and mean separation were adjusted by the multiple comparison test. Regression analysis was also carried out between pod yield and weed dry weight, weed control efficiency at 60 DAS and yield attributing characters.

Major weeds in the experimental plots at 60 DAA were *Echinochloa colona* (39.2%), *Eleusine indica* (28.0%), *Panicum maximum* (5.6%), *Digitaria sanguinalis* (1.9%) and *D. aegyptium* (1.9%). Among broad leaf weeds, *Parthenium hysterophorus* (7.5%), *Mollugo stricta* (3.7%), *Digera arvensis* (3.7%), *Phyllanthus niruri* (2.8%) and *Commelina benghalensis* (1.9%) were more rampant. However, among the sedges *Cyperus iria* was present contributing 3.8 per cent of the total weed density.

Result revealed that herbicide had lowered the density of all the weeds at 60 days compared to weedy check. Quizalofop ethyl at all the doses resulted into significantly less population of grassy weeds over rest of the herbicidal treatments (Table 1). These results are in conformity with Dixit *et al.* (2012). Among different weed species, *P. maximum* was most effectively reduced by all the herbicides and its population was brought to zero by quizalofop ethyl 5% EC. Quizalofop ethyl was significantly superior to imazethapyr 10% SL in reducing the density of all the weed species except *P. hysterophorus* where imazethapyr was more effective. Differences among sponsor and market sample were non-significant at similar doses with regards to above parameters. Highest weed control efficiency (WCE) was obtained with sponsor sample of quizalofop ethyl 5% EC @ 50 g a.i./ha.

Table 1 Effect of quizalofop ethyl 5% EC on weed suppression in groundnut at 60 days after herbicidal application

Treatment	Dose (g a.i. /ha)	Grassy weeds			Broad leaf weeds			Weed dry weight (g/m^2)	WCE (%)
		E. colona	*E. indica*	*P. maximum*	*P. hysterophorus*	*M. stricta*	*P. niruri*		
Quizalofop ethyl 5% EC (sponsor sample)	37.5	0.5 (1.3)	0.5 (1.3)	0.0 (0.0)	2.4 (10.7)	1.8 (5.3)	1.1 (2.7)	91.6	82.6
Quizalofop ethyl 5% EC (sponsor sample)	50.0	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	2.4 (10.7)	1.8 (5.3)	0.7 (2.7)	63.9	87.8
Quizalofop ethyl 5% EC (market sample)	37.5	1.1 (2.7)	0.0 (0.0)	0.0 (0.0)	2.5 (12.0)	2.0 (6.7)	1.1 (2.7)	99.4	81.1
Quizalofop ethyl 5% EC (market sample)	50.0	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	2.4 (10.7)	2.0 (6.7)	0.5 (1.3)	77.0	85.3
Imazethapyr 10% SL	150	2.4 (10.7)	3.7 (40.0)	0.5 (1.3)	0.0 (0.0)	2.0 (6.7)	0.0 (0.0)	267.0	49.2
Weed free check	-	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0	100.0
Weedy Check	-	4.0 (56.0)	3.7 (40.0)	2.2 (8.0)	2.4 (10.7)	1.8 (5.3)	1.6 (4.0)	525.2	0.0
LSD (P=0.05)		0.8	0.6	0.6	0.3	0.5	NS	73.8	-

All the weed control treatments have significantly positive impact on yield attributes and kernel yield of groundnut (Table 2). Yield attributes except 100-kernel weight were significantly influenced by different treatments. Weed free treatment recorded significantly highest kernel yield in groundnut followed by quizalofop ethyl 5% EC (SS) @ 50 g a.i./ha. The results generated gains support from the other reports (Solanki *et al*., 2005). Quizalofop ethyl @ 50 g a.i./ha recorded higher value of yield attributing characters *viz.*, plants (no./m^2) and pods (no./plant) which were at par with quizalofop ethyl (MS) at 50 g a.i./ha and superior to standard check imazethapyr 150 g a.i./ha. Highest kernel yield (981 kg/ha) was obtained from quizalofop ethyl (SS) @ 50 g a.i./ha. The possible reason for this might be the higher weed control efficiency without phytotoxicity leading to higher values of yield contributing characters *viz.*, plants (no./m^2) and kernel/pod. Regression analysis revealed that the groundnut yield changed to various degree with different weed control efficiency and dry weight (Fig. 1). Crop yield and weed control efficiency at 60 DAA were positively correlated. One per cent increase in weed control efficiency caused increase in grain yield by 9.602 kg/ha. However, the dry matter accumulation by weeds was negatively correlated with grain yield. Regression analysis ($y = 1166 - 1.828 x$) also indicated that one g/m^2 increase in dry matter accumulation by weeds causes reduction in grain yield by 1.828 kg/ha. Every increase of plant (no./m^2), pods (no./plant) and 100 kernel weight (g) by harvest would results in 141.2, 168.2 and 110.5 kg/ha enhance in kernel yield, respectively.

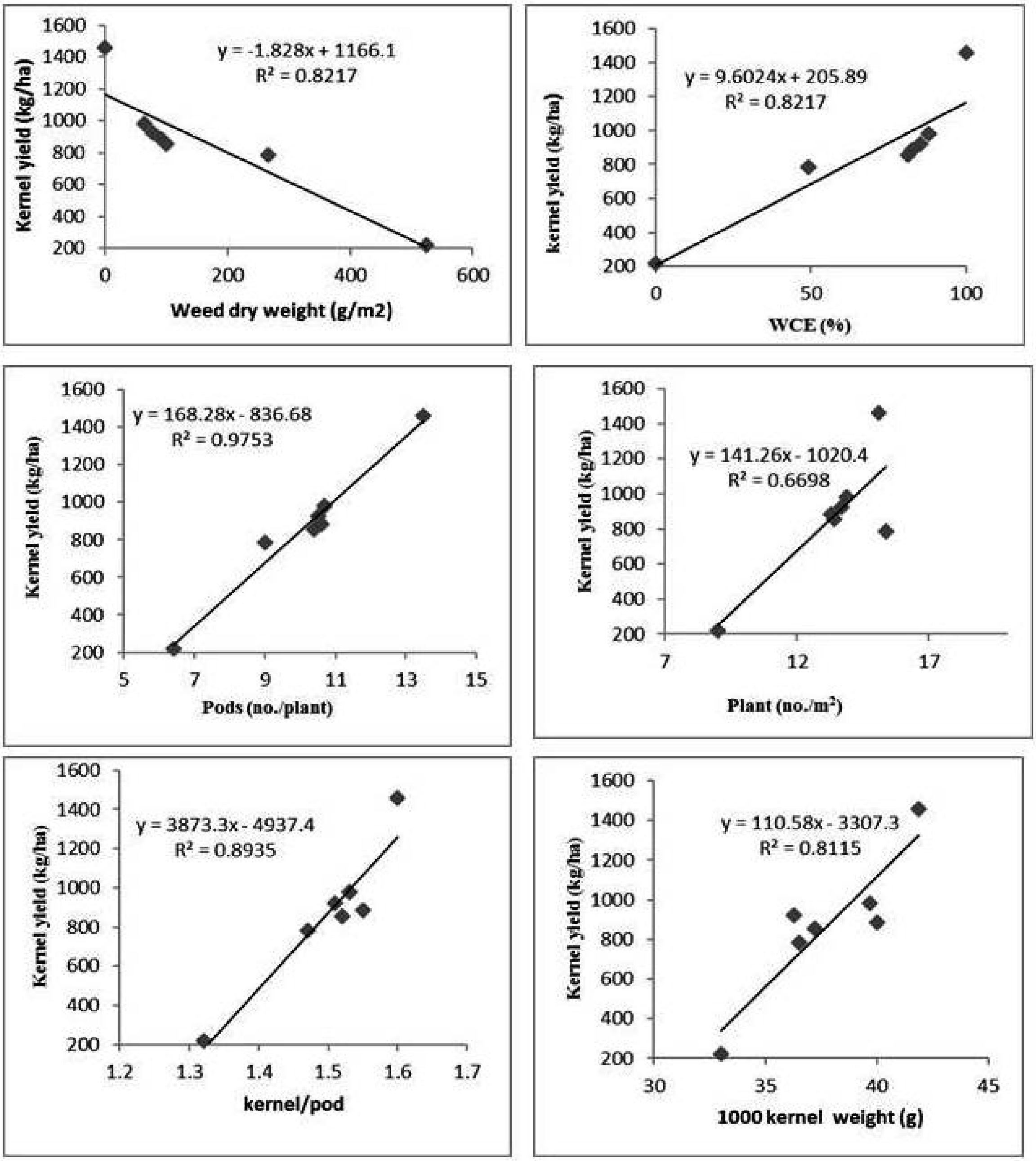

Fig. 1. Relationship between grain yield and weed control efficiency, weed dry weight at 60 DAA and yield attributes at harvest

Table 2 Effect of various treatments on yield and yield attributing characters

Treatment	Dose (g a.i./ha)	Plant (No./m^2)	Pods (No./plant)	Kernel/ pod	100-kernel weight (g)	Kernel yield (kg/ha)
Quizalofop ethyl 5% EC (sponsor sample)	37.5	13.3	10.6	1.55	40.0	884
Quizalofop ethyl 5% EC (sponsor sample)	50.0	13.9	10.7	1.53	39.7	981
Quizalofop ethyl 5% EC (market sample)	37.5	13.4	10.4	1.52	37.2	857
Quizalofop ethyl 5% EC (market sample)	50.0	13.7	10.5	1.51	36.3	924
Imazethapyr 10% SL	150	15.4	9.0	1.47	36.5	783
Weed free check	-	15.1	13.5	1.60	41.9	1459
Weedy check	-	9.0	6.4	1.32	33.0	220
LSD (P=0.05)		2.6	1.7	0.13	NS	136

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Effect of integrated nitrogen management on growth and yield of sesame (*Sesamum indicum* L.)

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ABSTRACT

A field experiment was conducted during *kharif* season of 2011 in vertisols at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani to study the effect of integrated nitrogen management on growth and yield of sesame varieties. The results indicated that variety AKT-101 was superior over Phule Til-1 in producing higher growth, yield attributes and yield. Among different integrated nitrogen management practices, application of recommended dose of fertilizer (60:40 N: P_2O_5 kg/ha) had the highest growth, yield attributes and yield of sesame which was at par with the application of 25% N through vermicompost + 75% N through urea. Gross monetary returns and net monetary returns were higher in recommended dose of fertilizer than integrated nitrogen levels. Among different varieties, AKT-101 recorded highest gross and net monetary returns.

Keywords: Integrated nitrogen management, Nitrogen, Sesame, Varieties

Sesame (*Sesamum indicum* L.) is an ancient and important oilseed crop of India. The average productivity of sesame is very low (378 kg/ha), which is mainly due to its cultivation on marginal and submarginal lands with poor fertility under rainfed conditions. Integration of organics and inorganics has been found to be quite promising not only in maintaining higher productivity but also in providing greater stability in crop production (Nambiar and Abrol, 1992). Popularizing the use of organics to reduce the dependence on chemical fertilizer and to contribute the pollution free environment is the greatest need of the hour. Farm yard manure and vermicompost have been advocated as good organic manure for the use in integrated nutrient management programme in field crops (Shroff and Devasthali, 1992). Therefore, there is an urgent need to develop a system using organic and inorganics on a complementary basis, which may enhance the efficiency and simultaneously reduce the requirements of inorganics. In this contest, the present study was planned to find out suitable variety and nutrient combinations to realize the higher and sustain the production of sesame during *kharif* season.

A field experiment was conducted during *kharif* season of 2011 at Department of Agronomy, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. It was laid out in Split-Plot Design in vertisols with two varieties *viz.*, Phule Til-1 and AKT-101 as main plot treatments and five integrated nitrogen levels *viz.*, recommended dose of fertilizer (60:40 N: P_2O_5 kg/ha), 25% N through vermicompost + 75% N through urea, 50% N through vermicompost + 50% N through urea, 25% N through FYM + 75% N through urea and 50% N through FYM + 50% N through urea as sub-plot treatments and replicated thrice. The soil was clayey in texture, slightly alkaline (pH 7.72) in nature containing low available nitrogen (210 kg/ha), medium in available phosphorus (15.21 kg/ha) and high in available potassium (580 kg/ha). A basal dose of 40 kg/ha P_2O_5 through SSP was applied as a basal at the time of sowing. However, N was applied @ 60 kg/ha as per treatments. Crop was planted with the spacing of 45 x 10 cm. The recommended dose of fertilizer (RDF) was 60 kg N and 40 kg P_2O_5/ha. The sowing was done on 11th July and harvested on 24th October, 2011. Standard package of practices were adopted for raising the crop. The observations were recorded on growth and yield attributes. Data on various variables were analyzed by analysis of variance (Panse and Sukhatme, 1967). Total rainfall received during experimental period was 536 mm distributed over 36 rainy days.

The growth and yield attributes and yield of sesame varieties varied significantly among themselves. AKT-101 performed better than Phule Til-1 in recording significantly higher growth attributes *viz.*, plant height (96.42 cm), number of branches/plant (3.77), number of functional leaves/plant (67.80) and yield attributes *viz.*, number of capsules/plant (58.69) and seed yield/plant (6.23 g) over Phule Til-1. Similarly, sesame variety AKT-101 produced significantly higher seed yield (1047 kg/ha), straw yield (2154 kg/ha), biological yield (3201 kg/ha) and oil content (45.78%) over Phule Til-1. It might be due to higher growth attributes which resulted in better development of capsules, good seed filling and consequently higher yield. Similar findings were also reported by Sumathi and Jaganadham (1999) and Kathiresan (2002). The significant differences were not observed in 1000-seed weight of Phule Til-1 and AKT-101. Phule Til-1 recorded highest harvest index (32.84) over AKT-101. Sesame variety AKT-101 recorded significantly higher gross monetary returns (₹ 53426/ha), net monetary returns (₹ 37626/ha) and B:C ratio (3.38) over Phule Til-1 (Table 1).

Performance of sesame varied significantly due to different integrated management treatments. The results revealed that the application of RDF (60:40 N:P_2O_5 kg/ha) recorded highest growth attributes and yield attributes *viz*., plant height (99.10 cm), number of branches/plant (4.10) and number of functional leaves/plant (68.05), number of capsules/plant (61.28), seed yield/plant (6.53 g), seed yield (1115 kg/ha) and straw yield (2512 kg/ha) which was at par with the application of 25% N through vermicompost + 75% N through urea and significantly superior over rest of the treatments. This may be because of higher photosynthetic activity and effective translocation of photosynthates to sink, which resulted in better development of capsules, good seed filling and consequently higher yield. Similar findings were also reported by Ahamed *et al*. (2001). Application of recommended dose of fertilizer (60:40 N: P_2O_5 kg/ha) recorded higher gross and net monetary returns and B:C ratio, though this was at par with the application of 25% N through vermicompost + 75% N through urea (Table 1). The interaction effects of sesame varieties and integrated nitrogen management were found non-significant in influencing the yield of sesame crop.

From above investigation it can be concluded that sesame variety AKT-101 was superior and application of RDF (60:40 N:P_2O_5 kg/ha) was more beneficial for getting higher yield and returns. Further, substituting 25% N requirement through vermicompost was equally effective in realizing higher yield.

Table 1 Growth, yield attributes, seed yield and economics of sesame varieties as influenced by integrated nitrogen management practices

Treatments	Growth attributes			Yield attributes and yield								Economics		
	Plant height (cm)	No. of branches /plant	No. of functional leaves/ plant	No. of capsules /plant	Seed yield /plant	Seed yield kg/ha	Straw yield kg/ha	Biological yield kg/ha	Harvest Index	1000 seed weight (g)	Oil content (%)	GMR (₹/ha	NMR (₹/ha)	B:C ratio
Varieties (V)														
V_1-Phule Til-1	87.49	3.04	60.76	53.25	5.03	922	1885	2807	32.84	3.39	45.20	47042	31262	2.98
V_2- AKT-101	96.42	3.77	67.80	58.69	6.23	1047	2154	3201	32.70	3.50	45.78	53426	37626	3.38
SEM±	1.38	0.10	0.66	0.58	0.13	18	21	39	--	0.04	0.04	935	935	--
CD (P=0.05)	4.14	0.32	1.99	1.73	0.40	55	62	117	--	NS	0.14	2801	2801	--
Integrated Nitrogen Management (N)														
N_1- RDF (60:40 N:P_2O_5 kg/ha)	99.10	4.10	68.05	61.28	6.53	1115	2512	3627	30.74	3.52	46.46	57005	39335	3.22
N_2- 25% N through Vermicompost + 75% N through Urea	95.42	3.70	66.73	58.33	5.93	1035	2247	3282	31.53	3.48	45.91	52873	33350	2.70
N_3- 50% N through Vermicompost + 50% N through Urea	92.49	3.33	64.03	56.20	5.55	977	2014	2991	32.66	3.45	45.50	49857	28242	2.30
N_4- 25% N through FYM + 75% N through Urea	87.13	3.06	61.93	53.20	5.25	922	1724	2646	34.86	3.41	45.46	46960	25937	2.23
N_5- 50% N through FYM + 50% N through Urea	85.13	2.83	60.33	50.76	4.90	874	1607	2481	35.22	3.36	44.11	44453	19838	1.80
SEM±	3.26	0.07	1.08	1.29	0.28	29	18	47	--	0.16	0.44	1464	1464	--
CD (P=0.05)	9.78	0.23	3.26	3.87	0.85	86	61	142	--	NS	1.32	4383	4383	--
Interaction (V x N)														
SEM±	4.92	0.11	1.54	1.82	0.40	40	86	126	--	0.23	0.62	2043	2042	--
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	--	NS	NS	NS	NS	--

GMR = Gross monetary returns; NMR= Net monetary returns; NS- Non-significant

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Water production function and optimal irrigation programme for drip irrigated castor (*Ricinus communis* L.)

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ABSTRACT

Water shortage for crop production necessitates adequate knowledge of the crop water production function to make decisions on water allocation for optimum returns from castor crop under surface drip irrigation. The study was conducted in *rabi* 2009-10 at Agricultural college farm, Rajendranagar, Hyderabad. The different drip irrigation schedules at 40, 60 and 80 per cent pan evaporation replenishment levels either kept constant throughout the crop life or combinations at vegetative, flowering and development stages were compared with surface check basin at (0.8 IW/CPE ratio) irrigation. The results showed that drip irrigation at 0.6 Epan replenishment up to flowering and 0.8 Epan later on registered comparable seed yields with drip irrigation scheduled at either at 0.6 or 0.8 Epan and was significantly superior over other treatments and the best fit water production function was quadratic ($R^2 = 0.99$). The optimum quantity of water (ETc) for maximum net returns under prevailing prices (water and castor @ ₹10 and 30 ha/mm and kg/ha, respectively) was 381.4 ha mm with a resultant seed yield of 3611 kg/ha. The gross returns, net returns and net return/rupee invested varied from ₹ 72194 to 144447/ha, ₹ 36808 to 108018/ha and 1.040 to 3.049, respectively.

Keywords: Castor, Optimum drip irrigation, Pan evaporation, Water Production function

Traditionally in Andhra Pradesh the castor is raised under rainfed conditions on marginal soils with low productivity (0.677 t/ ha). Raising castor during *rabi* (winter) season under irrigation using high yielding varieties and hybrids is a new dimension in castor production with promise that provides greater stability and higher productivity (>3 t/ha) (Tiwari, 2012). However, castor growing under conventional surface irrigation recorded a seasonal water requirement of 1178 mm/ha (Patel *et al*., 1998). But shortage of water supply for irrigation is being increasingly felt due to pressures from depleting groundwater levels, rising alternative demands, water quality degradation and economics. Therefore, farmers are switching over to drip irrigation to improve irrigation application efficiency, water productivity and seed yields. This condition of limited water supply for crop production necessitates adequate knowledge of the crop water production function to make decisions on resource allocation in terms of quantity and timing for maximizing returns. Such information is lacking for castor (Vaux and Pruitt, 1983). Hence, the present study was undertaken to determine water production function for castor and further utilize it for economic ramification.

The field experiment was conducted at College Farm, College of Agriculture, Acharya N. G. Ranga Agricultural University, Hyderabad (17.19°N, 78.23°E and 543 m altitude) in *rabi* season of 2009-10 on a sandy clay soil. The soil was low in N, medium in P and high in K status and alkaline in reaction (pH 8.03). The soil water retention capacity at -0.03 and 1.5 MPa was 0.254 and 0.130 $cm^3\ cm^{-3}$. The available water was 12.4 cm/m depth of soil. Bulk density of the soil was 1.43 g/cm^3. The source of irrigation water was bore well with C_3S_1 water quality. There were seven irrigation treatments based on surface drip method of irrigation and irrigation scheduling levels in the form of pan evaporation replenishment. The evaporation replenishment factor *viz.*, 0.4, 0.6 and 0.8 was either kept constant throughout the crop life or was combinations of the above at vegetative, flowering and capsule development stages besides a treatment of surface check basin irrigated crop at 0.8 IW/CPE ratio with IW = 50 mm (Table 1). The eight irrigation treatments were laid out in Randomized Block Design with three replications. The integral dripper lines of 16 mm diameter were laid out along the crop rows at 1.2 m spacing with emitters spaced at 0.5 m having a flow rate of 4 L/hour. The application rate was 6.66 mm/hour. Flow meters were used to measure flow rates to each individual treatment according to designated pan evaporation replenishment factor. The total depth of irrigation water applied in drip irrigated treatments varied between 227 mm (0.4 Epan) to 453 mm (0.8 Epan). Whereas in surface check basin irrigated crop it was 450 mm applied in 9 irrigations of 50 mm depth each. Effective rainfall received during experimental period was 46.8 mm. Castor evapotranspiration (ETc) was calculated using the water balance equation (Praveen Rao, 2011).

Table 1 Castor seed yield, crop evapotranspiration (ET_c) and water productivity (WP) as influenced by different irrigation treatments

Treatment	Seed yield (kg/ha)	Crop ETc (mm)	Water productivity (kg/m^3)
I_1 = Drip irrigation at 0.4Epan throughout crop life	1859.2	239.3	0.777
I_2 = Drip irrigation at 0.6Epan throughout crop life	3805.0	334.6	1.137
I_3 = Drip irrigation at 0.8Epan throughout crop life	3950.0	428.1	0.923
I_4 = Drip irrigation at 0.4Epan up to flowering and 0.6Epan later on	2850.0	285.6	0.998
I_5 = Drip irrigation at 0.4Epan up to flowering and 0.8Epan later on	2775.0	330.4	0.840
I_6 = Drip irrigation at 0.6Epan up to flowering and 0.8Epan later on	4280.5	399.9	1.070
I_7 = Drip irrigation at 0.4Epan up to 50 DAS, 0.6Epan from 51-95 DAS and 0.8Epan 96 DAS - maturity	2910.5	342.5	0.848
I_8 = Surface check basin irrigation at 0.8 IW/CPE ratio with an IW of 50 mm throughout crop life	2550.0	445.9	0.571
SEm±	161.5	-	0.033
CD (P=0.05)	495.8	-	0.101

$$ETc = I + P \pm DSW - Dp - Ro \quad \ldots\ldots\ldots\ldots.. \quad (1)$$

where I is the amount of irrigation water applied (mm), P the precipitation (mm), DSW the soil water content change (mm) in the 0.60-m soil profile, Dp the deep percolation (mm), and Ro the amount of runoff (mm). Since the amount of irrigation water was controlled, runoff was assumed to be zero. Monitoring soil water content in the experimental plots revealed that Dp was negligible below 0.60 m in depth. On the other hand water ETc was estimated by monitoring soil moisture before and after each irrigation using delta probe in the effective crop root zone depth of 1.0 m. Water productivity was calculated using the following formula (Praveen Rao, 2011).

$$\text{Water productivity} = \text{Seed yield (kg/ha)}/ET_c\ (m^3/ha)\ldots.(2)$$

The crop in all the treatments was harvested in three pickings based on the physiological maturity of the primary, secondary and tertiary spikes and the final picking was on 5th April 2010. Hybrid 'PCH 111' was planted on 7th November 2009 by adopting a row-to-row spacing of 1.2 m and plant to plant distance of 0.5 m in plots of 18.0 m x 7.2 m. A fertilizer dose of 60 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha was applied both for surface and drip irrigated castor crop. Total phosphorus was applied as basal in all the treatments. The N and K was applied in 3 equal splits at 30, 60 and 90 days after sowing in surface irrigated crop. Whereas, in drip irrigated crop the N and K was applied through fertigation using fertilizer injector at weekly intervals up to 100 days after sowing. The source of NPK fertilizers were single super phosphate, urea and muriate of potash (white crystalline form), respectively.

Drip irrigation scheduling at 0.6Epan up to flowering and 0.8Epan later on (I_6) registered higher seed yield but it was statistically on par with I_2 (drip irrigation scheduling at 0.6Epan throughout the crop life) and I_3 (drip irrigation scheduling at 0.8Epan throughout the crop life) and significantly superior over other irrigation treatments *viz*., I_1, I_4, I_5, I_7 and I_8 (Table 1). The crop in I_2 and I_6 also registered higher water productivity in comparison to other treatments. Lowest seed yield/ha was recorded under I_1, wherein irrigations were scheduled with drip at 0.4Epan throughout the crop life. Expectedly lowest water productivity was observed in surface irrigated crop. In general water productive efficiency decreased with increase in water supply. These data were further used for developing water production functions (linear and quadratic) and best-fit quadratic function was utilized for working out the economically viable levels of water requirement for maximizing returns as:

$$W_{opt} = (b_1 - P_w/P_y)/2b_2 \quad \ldots\ldots\ldots.. \quad (3)$$

Where, W, P_w and P_y is seasonal crop evapotranspiration, price of water and yield, respectively (Table 2).

Linear: $Y = 880.36 + 63926\ ET_c$ $\quad R^2 = 0.30$ F value = 2.6

Quadratic: $Y = -9535 + 68.603\ ET_c - 0.0895\ ET_c^2$
$R^2 = 0.99$ F value = 35.7

Where, Y, castor seed yield (kg/ha); ETc seasonal crop evapotranspiration (mm); R^2, coefficient of determination; and F, variance ratio for testing R^2 in both the functions.

The test statistics (R^2 and F-value) of linear production function indicated that it was statistically not significant. The explained total variation (R^2) in seed yield was very low i.e., 30.0 per cent. On the other hand the test statistics and R^2 were significant for quadratic production function. The explained total variation in seed yield was 99.0 per cent, suggesting that in the present study it was the best fit was obtained with quadratic form as water production function i.e., the castor seed yield increased with increase in crop evapotranspiration, but the increase in seed yield was not proportional to the crop evapotranspiration (Fig. 1). The maximum yield (Y_{max}) was bracketed within the administered water levels. The predicted maximum castor seed yield (Y_{max}) of 3611.3 kg/ha was obtained with 383.25 mm of water. The water production function did not emerge through the origin and the value of regression constant (a) was negative, indicating that some minimum amount of crop ET_c (182.5 mm) was required to be expended to realize the economic yield in castor grown in *rabi* season.

The optimum quantity of water (ETc) level that will maximize the net return under prevailing prices considered (₹ 10.0 ha/mm and ₹ 30.0/kg of castor seed yield), worked out to be 381.4 ha mm with the resultant seed yield of 3611 kg/ha. This optimum level represents one point on the derived demand curve (Fig. 1). Thus economic optimum levels of water under different appraised prices of output and input showed that the optimum level of irrigation water was inversely related to increase in the price of water (P_w), whereas it (W_{opt}) had a direct positive relationship with the price of castor seed yield (Table 2). The increase in price of water from ₹ 7.5/mm to ₹ 15.0/mm under a given price of seed yield, say ₹ 20/kg, is associated with only 2.1 mm decrease in the demand of water. Similar trends were noted with net returns and net return per rupee invested. The gross returns, net returns and net return/rupee invested varied from ₹ 72194 to 144447/ha, ₹ 36808 to 108018/ha and 1.040 to 3.049, respectively.

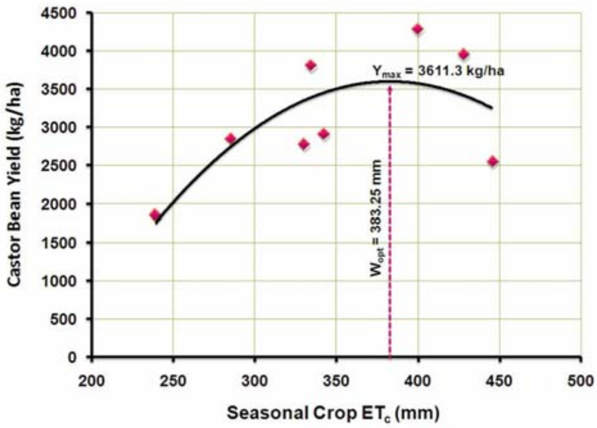

Fig. 1 Quadratic crop water production function for castor

Table 2 Economic returns of castor at optimum levels of water under spectrum of appraised prices

Price of water (P_w) (₹/mm)	Price of yield (P_y) (₹/kg)	Price ratio ($P_r=P_w/P_y$)	Optimum water (mm)	Optimum yield (kg/ha)	Gross returns (₹/ha)	Cost of water (₹/ha)	Cost of cultivation (₹/ha)	Discounted cost of drip (₹/ha)*	Net returns (₹/ha)	Net returns/rupee invested
7.5	20	0.3750	381.16	3610	72218	2858	19800	9900	39659	1.218
	30	0.2500	381.86	3611	108333	2863	19800	9900	75769	2.326
	40	0.1875	382.21	3611	144447	2866	19800	9900	111881	3.435
10.0	20	0.5000	380.46	3610	72211	3804	19800	9900	38707	1.155
	30	0.3333	381.39	3611	108330	3813	19800	9900	74816	2.232
	40	0.2500	381.86	3611	144444	3818	19800	9900	110926	3.309
12.5	20	0.6250	379.76	3610	72203	4747	19800	9900	37756	1.096
	30	0.4166	380.92	3610	108324	4761	19800	9900	73862	2.143
	40	0.3125	381.51	3611	144440	4768	19800	9900	109971	3.190
15.0	20	0.7500	379.06	3609	72194	5685	19800	9900	36808	1.040
	30	0.5000	380.46	3610	108317	5706	19800	9900	72910	2.059
	40	0.3750	381.16	3610	144436	5717	19800	9900	108018	3.049

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In vitro evaluation of fungicides and bio-control agents against sunflower collar rot (*Sclerotium rolfsii*)

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ABSTRACT

The efficacy of different fungicides against *Sclerotium rolfsii* was tested using poison food technique under in vitro conditions and through seed treatment in screen house. Efficacy of fungicides in vitro against *S. rolfsii* showed that carboxin, vitavax power and hexaconazole completely inhibited mycelial growth up to 100 per cent at 100 ppm concentration. Thiram inhibited 95.8 per cent and propiconazole inhibited 98.1 per cent at 1000 ppm. Captan inhibited 80.6 per cent at 1000 ppm while, carbendazim only inhibited 18.5 per cent at 1000 ppm. Pencycuron have failed to show antifungal activity against *S. rolfsii* even at 1000 ppm. Evaluation of bio-agents against *S. rolfsii in vitro* revealed that *Trichoderma harzianum* showed maximum antifungal activity with 70.1 per cent inhibition of mycelial growth followed by *T. viride* (63.1%) and *Bacillus* spp. (53.7%). Seed treatment with fungicides and soil treatment with bio-agents significantly reduced the disease incidence of collar rot. Maximum collar rot control was found by carboxin (73.9%) followed by vitavax power (69.9%) and thiram (69.4%) by seed treatment under screen house conditions. For the bio-agents, *T. harzianum* showed maximum control of the disease (40.8%) followed by *Bacillus* spp. (36.9%) and *T. viride* (34.6%) in comparison to control.

Keywords: Bio-agents, Collar rot, Fungicides, *Sclerotium rolfsii*, Sunflower

Sunflower (*Helianthus annuus* L.) harbours a large number of biotrophic and necrotrophic diseases leading to heavy loss in yield (Mehta *et al*., 2005). Among the necrotrophic soil borne pathogens, collar rot caused by *Sclerotium rolfsii* Sacc. is the most important in Haryana conditions, where the warm and humid conditions prevail during the growing seasons for the development of this disease in sunflower. The wide host range, prolific growth and ability to produce persistent sclerotia contribute to the economic losses associated with this pathogen (Kokub *et al*., 2007). Once the pathogen is established in the soil, it is extremely difficult to manage due to its survival as saprophytic nature in soil or elsewhere. Among the various methods, the use of microorganisms as bio-control agents has reported to provide a very promising alternative and less hazardous method for plant disease control (Papavizas, 1985). *Bacillus* (Nair *et al*., 2002) and *Pseudomonas* (Mark *et al*., 2006) have been reported to suppress the various soil borne diseases of different crops. *Trichoderma* species have been extensively used and investigated for their bio-control ability as they suppress pathogens by various mechanisms (Reino *et al*., 2008).

The effect of eight fungicides on the growth of *S. rolfsii* was studied using poisoned food technique. Different concentrations *viz.*, 100, 200, 400, 500 and 1000 ppm were used. A 0.2 per cent stock solution was prepared for each fungicide and the required concentration was achieved through dilution technique. The double strength potato dextrose agar (PDA) medium was prepared and sterilized at 15 psi for 20 minutes. An equal volume of chemical solution and PDA was mixed in a sterilized conical flask to achieve the final concentration and 20 ml of the solution was poured aseptically to each of the 90 mm sterilized Petri-plates. Upon solidification, each plate was centrally inoculated with five mm disc of mycelium obtained from 7 days old culture of *S. rolfsii* and incubated at 27±1ºC for seven days. Four replications were maintained for each treatment in Completely Randomized Design (CRD). PDA medium without any of the fungicide served as control. The chemicals tested were thiram, captan, carbendazim, carboxin, carboxin + thiram, hexaconazole and propiconazole. Colony diameter of the fungus of each treatment along with control was measured (mm) and recorded after every 24 h, till the test fungus occupied the full Petri-plate in the controlled treatment. The per cent inhibition of mycelial growth over control was calculated by using the formula:

$$I(\%) = \frac{C-T}{C} \times 100$$

where

I = Per cent inhibition of mycelium
C = Radial growth of *S. rolfsii* mycelium in control
T = Radial growth of *S. rolfsii* mycelium in treatment

The antagonistic effect of four bio-agents on the growth of *S. rolfsii* was studied using dual culture technique. The bioagents were *Trichoderma harzianum, T. viride, Pseudomonas fluorescens* and *Bacillus* spp. The fungus was cultured on PDA, while the bacteria were cultured on Nutrient Dextrose Agar (NDA) but the antagonistic effects of the bio-agents were studied on PDA. Fifteen ml of PDA medium was poured into sterile Petri-plates and allowed to solidify. From seven days old culture of *S. rolfsii,* five mm mycelial disc was cut from the margin of the actively growing colony with a sterile cork borer and placed near the periphery on one side of the PDA plate, while an antagonistic fungi were placed on the other side of the PDA plate just opposite to the first disc i.e. at an angle of 180º. Similarly, antagonistic bacteria obtained from three days old culture were streaked five centimeter long on the PDA medium at the two centimeter mark from the periphery of the Petri-plate. Simultaneously, five mm mycelial disc of *S. rolfsii* were cut from the margin of the actively growing colony with a sterile cork borer and placed near the periphery on opposite side of the bacterial streak i.e. at an angle of 90º. All the plates were incubated at 27±1 ºC for five days. Each treatment replicated four times as CRD and appropriate controls were maintained. The extent of antagonistic activity by fungal and bacterial antagonists was recorded on fifth day by measuring the growth of *S. rolfsii* in dual culture plate and control plate. The per cent inhibition of *S. rolfsii* was calculated. The best treatments of both the fungicides and bio-agents evaluated *in vitro* were also tested for their efficacy under screen house conditions in pots.

The antagonistic effect of the promising fungicides and bio-agents evaluated *in vitro* were further evaluated under the screen house conditions. These fungicides were carboxin (2g/kg seed), vitavax power (2g/kg seed) and thiram (3g/kg seed), while the bio-agents were *Trichoderma harzianum* (20g/kg soil), *Trichoderma viride* (20g/kg soil) and *Bacillus* spp. (1x10^5 cfu). Soils were pre-inoculated with inoculum of *S. rolfsii* @ 20g/kg soil in the earthen pots of 12 inches diameter. For the fungicides, seeds of hybrid HSFH-848 and 64A57 were treated 72-h prior to planting. For the bio-agents *T. harzianum* and *T. viride* were initially grown on sterilized rice straw medium by inoculating with seven days old culture and incubated for 10 days at 27±1ºC to allow maximum establishment of the fungus mycelium. Prior to planting of these hybrids HSFH-848 and 64A57, soils were inoculated with the respective bio-agents (20 g/kg soil). In case of *Bacillus* spp. (1x10^5 cfu) of bacterial suspension was added to pots during time of planting of the seeds. A total of seven plants per pot for each replication were maintained with four replications as CRD. Untreated seeds sown in pre-inoculated soil only with *S. rolfsii* served as control. The first observation was recorded 15 day after in terms of seed germination (%) and 30 days after disease incidence (%) was recorded as:

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100$$

Carboxin (Vitavax™) had highest per cent inhibition for mycelial growth at 50 ppm (98.8%) and further completely inhibited the mycelial growth (100%) at 100 ppm (Table 1). Vitavax power showed the similar results with 97.8 and 100 per cent mycelial growth inhibition at 50 and 100 ppm, respectively. Hexaconazole recorded 92.2 per cent growth inhibition at 50 ppm and complete inhibition at 100 ppm. Tiwari and Ashok (2004) have also reported the similar findings for carboxin and hexaconazole, while Kulkarni *et al*. (1986) reported that carboxin showed 100 per cent inhibition even at 50 ppm and Hegde *et al*. (2010) reported that hexaconazole (0.025%) and vitavax power (0.025%) showed 100% inhibition at the respective concentrations. Thiram and propiconazole have shown impressive result in inhibition of mycelial growth. Thiram inhibited 70.8 per cent at 50 ppm and 95.8 per cent at 1000 ppm. Datta and Das (2002) reported 70.3 per cent inhibition of mycelial growth and 96.5 per cent inhibition of sclerotial production in *S. rolfsii* by thiram (0.1%). Propiconazole inhibited 86.7 and 98.1 per cent at 50 and 1000 ppm, respectively. Captan recorded maximum inhibition of mycelial growth of 80.6 per cent at 1000 ppm. Rout *et al.* (2006) reported for 100 per cent inhibition of mycelial growth by captan @ 0.3%. On the other hand, for carbendazim, 18.5 per cent inhibition has been observed @ 1000 ppm, while pencycuron have failed to inhibit the mycelial growth even at 1000 ppm. No report for pencycuron has been put forward as an effective fungicide against *S. rolfsii*. Similarly, captan and carbendazim were found to be least effective among the fungicides tested (Sharma and Singh, 1989). The present findings for efficacy of propiconazole and carbendazim in controlling mycelial growth *in vitro* in this study were supported by Bhuiyan *et al*. (2012).

Biological control, especially using fungal antagonists against fungal plant pathogens has gained considerable attention and appears to be promising as a viable supplement or alternative to chemical control (Papavizas, 1985). In the present investigation, four bio-agents *viz., T. viride*, *T. harzianum*, *P. fluorescens* and *Bacillus* spp. were tested for mycelial inhibition of *S. rolfsii in vitro* (Table 2). *T. harzianum* showed maximum antifungal activity with 70.1 per cent inhibition of mycelial growth followed by *T. viride* (63.1%) and *Bacillus* spp. (53.7%). *Pseudomonas fluorescens* inhibited only 33.3 per cent of the mycelial growth of *S. rolfsii.* These above results are in agreement with Karthikeyan *et al.* (2006) who demonstrated culture filtrates of *T. viride* inhibiting the growth of pathogen as well as sclerotial germination to a greater extent. In dual culture assay, Henis *et al*. (1983) observed *T. viride* pq1 inhibited the growth of *S. rolfsii,* parasitized and lysed the mycelium of *S. rolfsii.* Ganesan *et al*.(2007) reported that *T. harzianum* showed around 57 per cent of inhibition against *S. rolfsii.*

Table 1 *In vitro* effect of different fungicides on per cent growth inhibition of *S. rolfsii*

Fungicides	*Per cent inhibition at different concentrations (ppm)					
	50	100	200	500	1000	Mean
Thiram	70.8 (57.4)	73.1 (61.6)	84.2 (67.0)	88.3 (74.9)	95.8 (80.4)	82.4 (68.2)
Captan	33.3 (35.2)	48.6 (44.2)	55.6 (48.2)	65.3 (53.9)	80.6 (63.8)	56.7 (49.1)
Carbendazim	6.6 (14.8)	11.5 (19.8)	13.9 (22.5)	16.3 (23.7)	18.5 (25.5)	13.4 (21.3)
Carboxin	98.8 (83.5)	100 (90.0)	100 (90.0)	100 (90.0)	100 (90.0)	99.8 (88.7)
Carboxin + Thiram (Vitavax power)	97.8 (81.5)	100 (90.0)	100 (90.0)	100 (90.0)	100 (90.0)	99.2 (88.3)
Hexaconazole	92.2 (73.9)	100 (90.0)	100 (90.0)	100 (90.0)	100 (90.0)	98.4 (86.8)
Propiconazole	86.7 (68.8)	88.3 (69.7)	92.5 (79.3)	95.4 (79.3)	98.1 (82.1)	92.2 (75.3)
Pencycuron	0.50 (4.9)	0.50 (4.9)	0.50 (4.9)	0.5 (4.9)	0.5 (4.9)	0.5 (4.9)
Mean	60.8 (52.5)	65.0 (58.8)	68.3 (61.1)	70.7 (63.3)	74.2 (65.8)	
	Treatment (T)		Concentration (C)		T x C	
CD (P=0.05)	(2.2)		(1.7)		(4.9)	

*Mean of four replications. The values in parentheses are angular transformation.

Table 2 *In vitro* effect of different bio-agents on per cent growth inhibition of *S. rolfsii*

Treatments	*Mycelial Inhibition (%)
Trichoderma viride	63.1 (52.6)
T. harzianum	70.1 (56.9)
Pseudomonas fluorescens	33.3 (35.3)
Bacillus spp.	53.7 (47.2)
CD (P=0.05)	(4.0)

In the present investigation, *T. harzianum* showed 8 mm of zone of inhibition, while *T. viride* had 6 mm and *Bacillus* spp. showed 10 mm of zone of inhibition. Very less sclerotia were formed at the periphery of the Perti-plate. Therefore, reduction in sclerotial production by the antagonist may reduce the inoculum potential and subsequently disease incidence. Prasad *et al*.(1999) reported in-line that sclerotial production was reduced significantly by antagonist *Trichoderma* and *Gliocladium* species. It may be due to the penetration of antagonistic hyphae into hyphae of pathogen at the place of contact as confirmed by Mukherjee *et al*.(2001). The antagonistic organisms act on the pathogen by different mechanisms *viz*., competition, lysis, antibiosis, siderophore production and hyper parasitism (Vidyasekaran, 1999).

Sunflower seeds are prone to attack by several soil and seed-borne fungi during germination, emergence and growth. The affected seeds may rot before emergence or get killed following emergence. Seed germination was significantly increased when seeds were treated with fungicides and bio-agents, however, all the three fungicides found to be superior over the bio-agents as these showed significant difference in seed germination (Table 3). Fungicide carboxin @ 2g/kg seed recorded highest per cent germination followed by thiram @ 3g/kg seed and vitavax power @ 2g/kg seed in both the hybrids, while among bio-agents *T. harzianum* recorded maximum germination followed by *Bacillus* spp. and *T. viride*. Furthermore, treated seeds have significantly recorded low disease incidence for collar rot. Fungicides have proven to be superior over bio-agents as seeds treated with fungicides significantly controlled the collar rot disease and maximum control was shown by carboxin, controlling 72.9 per cent disease in 64A57 and 73.5 per cent in HSFH-848. On an average, vitavax power reduced disease incidence by 69.9 per cent and thiram by 69.4 per cent. In case of bio-agents, on an average, *T. harzianum* showed maximum control of the disease by 40.8 per cent followed by *Bacillus* spp. (36.9%) and *T. viride* (34.6%). The present findings for fungicides were also communicated for same fungus in different crops by Datta and Das (2002) in tomato; Hedge *et al*. (2010) for *Stevia rehaudiana*. Prasad *et al*. (1999) also obtained similar results for *Trichoderma* spp. where *T. viride* reduced collar rot incidence by 42-65 per cent, while *T. harzianum* reduced the incidence by 45.5-66.8 per cent. Successful bio-control of *S. rolfsii* by infesting fields with cultures of *Trichoderma* spp. has been reported in the literature (Patibanda *et al*., 2002).

T. harzianum and carboxin showing their maximum antifungal activity *in vitro* and under screen house conditions need to be tested under field conditions for their use in integrated disease management strategy against this pathogen.

Table 3 Efficacy of promising seed treating fungicides and bio-agents on inhibition of *S. rolfsii* under screen house conditions

Treatments	64A57			HSFH-848			
	Germination (%) 15 DAS	Disease incidence (%) 30 DAS	Disease control (%)	Germination (%) 15 DAS	Disease Incidence (%) 30 DAS	Disease control (%)	Mean disease control (%)
Carboxin (2g/kg)	76.5 (60.9)	11.5 (19.8)	72.9	74.8 (59.8)	12.5 (20.7)	73.5	73.3
Vitavax power (2g/kg)	72.5 (58.4)	13.3 (21.3)	68.9	73.5 (59.0)	13.8 (21.7)	70.9	69.9
Thiram (3g/kg)	74.5 (59.7)	13.0 (21.1)	69.5	71.5 (57.7)	14.5 (22.4)	69.3	69.4
T. harzianum (20g/kg)	71.0 (57.4)	25.2 (30.1)	40.9	70.3 (56.9)	27.9 (31.9)	40.8	40.8
T. viride (20g/kg)	67.5 (55.2)	28.9 (32.5)	32.2	66.8 (54.8)	29.8 (33.0)	37.0	34.6
Bacillus spp. ($1x10^5$ cfu)	67.8 (55.4)	27.7 (31.7)	35.0	68.5 (55.8)	28.9 (32.5)	38.9	36.9
S. rolfsii	62.8 (52.4)	42.6 (40.7)	-	61.5 (51.6)	47.3 (43.4)	-	-
CD (P=0.05)	(1.9)	(2.1)	-	(1.9)	(2.5)	-	-

*Mean of four replications. The values in parentheses are angular transformation.

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Checklist of insect pests and natural enemies associated with groundnut (*Arachis hypogaea* L.) ecosystem in Anaimalai tract of Tamil Nadu

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ABSTRACT

Fixed and roving surveys were conducted at Coconut Research Station, Aliyarnagar and Anaimalai tract of Coimbatore district, Tamil Nadu to study the insect pests and natural enemy complex of groundnut ecosystem. Results of the study revealed the occurrence of 32 species of insect pests and 13 species of natural enemies. Among the insect pests, only five *viz.*, *Helicoverpa armigera, Spodoptera litura, Scirtothrips dorsalis, Empoasca kerri* and *Aphis craccivora* were considered as major pests. Nine insect pests were considered as minor, while 18 were noticed as spot occurrence. The leafminer, *Liriomyza trifolii* population was noticed only during *kharif* season. Among the 13 species of natural enemies, coccinellid beetles *viz., Coccinella transversalis* and *Cheilomenes sexmaculatus* were dominant.

Keywords: Biodiversity, Groundnut, Insect pests, Natural enemies

Any agro-ecosystem is characterized by an array of pest and natural enemy complex which is decided by the microclimatic conditions of that location. Biswas and Das (2011) reported about 40 insect pests of major and minor importance in groundnut ecosystems of Bangladesh. Sridhar and Mahto (2000) documented 37 insect and mite species besides six natural enemies in groundnut ecosystem. About 29 insect pests and 20 natural enemies have been catalogued by Sahayaraj and Raju (2003) in Tuticorin and Tirunelveli districts of Tamil Nadu. Most groundnut insect pests are sporadic in occurrence and distribution. Although many insect species are reported to feed on groundnut, only few cause economic yield loss. With respect to the study area concerned, groundnut is cultivated during two seasons (*kharif* and *rabi*) and a very few farmers take up planting during summer coinciding with the monsoon spell characteristic of this Anaimalai tract. Anaimalai tract has become a major coconut belt and the area under groundnut has substantially reduced over the years. As a result there had been vast changes in the pests and natural enemy fauna inhabiting groundnut. A complete catalogue of the pest and natural enemy complex pertaining to Anaimalai tract comprising of Pollachi (North), Pollachi (South) and Anaimalai blocks has been made for three consecutive years from 2010 to 2012.

Fixed survey was done in the Coconut Research Station, Aliyarnagar (10º29' N and 76º58' E) while roving surveys were undertaken in different groundnut growing regions of Anaimalai tract *viz.,* Kullegoundanur, Thengaparai, Pongaliyur, Vedasandur, Mudaliyarpathi, Thundukadavupathy, Kaliyapuram and Periapodhu. Random sampling was made manually with the help of insect nets and pit fall traps, and the collected insects (pests and natural enemies) were preserved according to standard procedures for further identification. For fixed plot survey, groundnut var. TMV 7 was sown in Coconut Research Station, Aliyarnagar in one acre area and regular sampling was done at weekly intervals using insect nets, besides visual observations starting from sowing to harvest. The observations on insect pests and natural enemies were recorded on one hundred plants randomly selected from the specified sampling area. The crop was sampled during seedling, vegetative, flowering, peg formation, pod development and pod maturity stages. Those insects that occurred from seedling stage until harvest and causing proportionate damage (more than 10%) were categorized as major pests, while those that caused minimal damage (less than 10%) were designated as minor pests. Those insects that were noticed feeding the plant occasionally during the entire study period were designated as spot occurrence. Those insect species that showed their presence without causing any disturbance to the plant were considered as visitors. Based on the visible damage caused by the insect pests, the role of the pests was also recorded. The natural enemies that were spotted during the study period were also recorded.

The groundnut crop registered 32 species of insect pests and 13 species of natural enemies during the study period (Table 1). Among the insect pests, only five *viz., Helicoverpa armigera*, *Spodoptera litura*, *Scirtothrips dorsalis*, *Aphis craccivora* and *Empoasca kerri* were considered as major pests and were found at Coconut Research Station, Aliyarnagar as well as farmers fields. Nine pests were designated as minor pests, while the remaining were considered as spot occurrence.

Major pests: The gram pod borer, *H. armigera* was noticed feeding on the growing buds, flowers as well as leaves. The young larvae feed in congregations making characteristic scratch marks on the upper leaf surface which are indications of their incidence. The older larvae are nocturnal in habit and defoliate mostly during night times while resting near the base of the plant during day time. Though, they have been reported to feed the young pods also (Wightman and Ranga Rao, 1993), damage of such nature was not prominent in the study area. The tobacco caterpillar, *Spodoptera litura* was found to defoliate during the vegetative stage and was noticed up to harvest.

The sucking pests *viz.*, aphids, thrips and leafhoppers were noticed throughout the crop period since early vegetative stages. But their populations have not crossed the Economic Threshold Level (ETL) and symptoms of Y shaped yellowing was noticed only after 90 days. The leafhopper population was found to reach higher numbers only during maturity stages (Subbarayudu, 1996). Wightman and Ranga Rao (1993) suggested insecticidal sprays against leafhopper population only when more than 10% of the entire leaves show hopper burn symptoms. In the present studies also, hopper burn symptoms manifested only during the fourth month when the crop was about to be harvested. The aphids always occur in colonies sucking sap from terminal buds and flowers. Most often, coccinellids and syrphids were noticed along with these colonies and help in natural predation. In general, four species of thrips are noticed in groundnut ecosystem *viz.*, *Scirtothrips dorsalis* Hood, *Thrips palmi* Karny., *Frankliniella schultzei* (Trybom) and *Caliothrips indicus* (Bagnall) (Wightman and Ranga Rao, 1993). Of these, the first two species were noticed in groundnut ecosystem of Anaimalai tract. Due to their rasping and sucking type of mouth parts, their feeding results in white patches on the upper leaf epidermis while necrotic patches are noticed on the lower surface of the leaves. Though their presence was noticed up to two months, their damage could be considered serious only if they show up in high numbers during seedling stages where such high numbers may lead to stunting and drying up of the whole foliage.

Minor pests: Generally, the leafminer, *Aproaerema modicella* (Deventer) is considered as a major pest of groundnut in several groundnut growing regions (Singh and Oswalt, 1992). But the same was noticed as a minor pest in Pollachi tract. Another leafminer *viz.*, the serpentine leafminer, *Liriomyza trifolii* (Burgess) registered higher per cent of leafmining (up to 16.5% leaflets) during *kharif* 2012, but their presence was negligible during the remaining seasons. Further, leafminer damage was noticed only during the first 25 to 30 days of the crop and the later stages of the crop did not exhibit damage by this pest. The blister beetle, *Mylabris pustulata* Thunb. was noticed feeding the groundnut flowers in higher numbers to the tune of 2-3 nos./15 m^2 plot during *kharif* 2011 and 2012. However their presence was not noticed during *rabi* seasons. Their presence was mostly noticed during early morning and late evening hours. A similar occurrence of the blister beetle adults feeding the groundnut flowers has been reported during 2011-12 from Saurashtra region of Gujarat (Harish *et al.*, 2012). The authors have attributed this sudden occurrence to climate change and uneven distribution of rainfall. But the extent of damage by blister beetles in terms of yield reduction needs to be studied in detail. Likewise, the spiraling whitefly, *Aleurodicus dispersus* Russell which was noticed sparsely (less than 10% of leaflets) during 2010-11 and reached noticeable levels (47.5% of leaflets) during *kharif* 2011-12. But relatively higher population was noticed only during later stages of the crop i.e., pod formation or maturity stages. Again, their status needs to be ascertained through repeated observations in the future. Groundnut is also prone attack by storage pests during storage. Storing groundnut as pods may deter most storage pests except the groundnut bruchid, *Caryedon serratus* Olivier which attacks pods. The other storage pests including the *Corcyra cephalonica* (Stainton) and *Tribolium castaneum* (Herbst.) attack the damaged kernels and are hence termed secondary storage pests. In the present studies, the aforementioned storage pests were also noticed in lesser numbers and hence were of minor importance.

Spot occurrence: Besides the major and minor pests enlisted above, several insect pests were noticed as spot occurrence. The groundnut bud borer, *Anarsia ephippias* (Meyrick) which has been recorded as a minor pest in North India (Wightman and Ranga Rao, 1993) was noticed as a spot occurrence and was found to bore into the terminal buds and shoot tips. The leaf roller, *Archips* sp. was noticed in the farmers fields in specific pockets during 2010 and 2011 and their presence was not noticed during 2012. The grasshopper, *Atractomorpha crenulata* (Fab.) was noticed in groundnut during vegetative stages, but caused no defoliation and hence their role could not be ascertained. Similarly, the eurybrachid, *Eurybrachis tomentosa*, *Icerya purchasi* and *Monolepta signata* were also present in groundnut crop only as spot occurrence. The pulse beetle, *Callosobruchus maculatus* and *C. chinensis* which are serious pests of stored leguminous seeds, have also been noticed during the vegetative stage of the crop. Again, they could only be termed as visitors as they caused no damage to groundnut.

Table 1 Insect pest complex of groundnut ecosystem in Anaimalai tract of Tamil Nadu

Scientific name	Common Name	Order	Family	Crop stage (s)	Status of the insect pest	Role of the insect
Aleurodicus dispersus Russell	Spiralling whitefly	Homoptera	Aleyrodidae	F, PF, PM	Minor	Sucking pest
Anarsia ephippias (Meyrick)	Bud borer	Lepidoptera	Gelechiidae	V	SO	Consumes terminal buds
Aphis craccivora Koch.	Aphid	Homoptera	Aphididae	V, F, PF	Major	Sucking pest
Aproaerema modicella Deventer	Groundnut leafminer	Lepidoptera	Gelechiidae	V	Minor	Mines leaves
Archips sp.	Leaf roller	Lepidoptera	Tortricidae	V	SO	Defoliator
Atractomorpha crenulata (Fab.)	Green grasshopper	Orthoptera	Acrididae	V	SO	YTD
Bemisia tabaci Gennadius	Whitefly	Homoptera	Aleyrodidae	V	Minor	Sucking pest
Caliothrips indicus Bagnall	Thrips	Thysanoptera	Thripidae	V	Minor	Sucking pest
Callosobruchus chinensis L.	Cowpea weevil	Coleoptera	Bruchidae	V	SO	Visitor
Callosobruchus maculatus (F.)	Cowpea weevil	Coleoptera	Bruchidae	V	SO	Visitor
Caryedon serratus Olivier	Groundnut bruchid	Coleoptera	Curculionidae	S	Minor	Primary storage pest
Catantops pinguis (Stal.)	Short horned grasshopper	Orthoptera	Acrididae	V	SO	Visitor
Chrysodeixis sp.	Golden twin spot moth	Lepidoptera	Noctuidae	V	SO	Defoliator; Collected from light trap
Cofana sp.	White leafhopper	Homoptera	Cicadellidae	V	SO	Sucking pest
Corcyra cephalonica (Stainton)	Rice moth	Lepidoptera	Pyralidae	S	Minor	Secondary storage pest
Empoasca kerri Pruthi	Green leafhopper	Homoptera	Cicadellidae	V, F, PF	Major	Sucking pest
Euborellia stali (Dohrn.)	Earwig	Dermaptera	Carcinophoridae	PM	SO	Collected in pit fall trap
Eurybrachis tomentosus (Fabr.)	Eurybrachid	Homoptera	Eurybrachidae	V	SO	YTD
Helicoverpa armigera Hub.	Gram pod borer	Lepidoptera	Noctuidae	V, F, PF	Major	Defoliator; Consumes flowers, buds, etc.
Heteracris annulosa Walker	Short horned grasshopper	Orthoptera	Acrididae	V	SO	Visitor
Hieroglyphus banian (Fab.)	Rice grasshopper	Orthoptera	Acrididae	V	SO	Visitor
Icerya purchasi Maskell.	Cottony cushion scale	Homoptera	Margarodidae	V	SO	YTD
Latoia lepida (Cramer)	Castor slug caterpillar	Lepidoptera	Limacodidae	V	SO	Defoliator; Adult collected in light trap
Liriomyza trifolii (Burgess)	Leafminer	Diptera	Agromyzidae	V	Minor	Mines leaves
Monolepta signata Olivier	Flea beetle	Coleoptera	Chrysomelidae	V	SO	YTD
Mylabris pustulata (Thunb.)	Blister beetle	Coleoptera	Meloidae	F	Minor	Flower feeder
Myllocerus discolor	Ash weevil	Coleoptera	Curculionidae	V	SO	Defoliator
Nezara viridula (L.)	Green stink bug	Hemiptera	Pentatomidae	V	SO	Sucking pest
Proutista moesta (Westwood)	Derbid	Homoptera	Derbidae	V	SO	Sucking pest
Scirtothrips dorsalis (Hood)	Thrips	Thysanoptera	Thripidae	V	Major	Sucking pest
Spodoptera litura Fab.	Tobacco caterpillar	Lepidoptera	Noctuidae	V, F, PF, PM	Major	Defoliator
Tribolium castaneum (Herbst.)	Red flour beetle	Coleoptera	Tenebrionidae	S	Minor	Secondary storage pest

SE: Seedling stage; V: Vegetative stage; F: Flowering stage; PF: Pod formation stage; PM: Pod maturity stage; S: Storage; SO: Spot Occurrence; YTD: Yet to be determined

Natural enemies: With regard to natural enemies of groundnut ecosystem, number of predators and parasitoids were noticed (Table 2). Among them, the coccinellids, *Coccinella transversalis* Fab. and *Cheilomenes sexmaculatus* (Fab.) were in higher proportions and were always noticed among aphid colonies aiding natural predation. Three species each of dragonflies and damselflies were also noticed which are generalist predators.

Thus, it could be observed from the above studies that, groundnut crop of Anaimalai tract is not severely affected by defoliators and sucking pests. However, the occurrence of certain minor pests *viz.*, spiraling whitefly and blister beetle need to be viewed with caution as their occurrence in larger numbers will heavily reflect on the yield of the crop.

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Table 2 Natural enemy complex of groundnut ecosystem in Annamalai tract of Tamil Nadu

Scientific name	Common Name	Order	Family	Status of natural enemy	Pests upon which the natural enemy feeds
Brumoides suturalis Fab.	Three striped lady beetle	Coleoptera	Coccinellidae	Predator (G)	Aphids, nymphs of jassids
Coccinella transversalis Fab.	Transverse lady beetle	Coleoptera	Coccinellidae	Predator (G)	Aphids, nymphs of jassids
Scymnus latemaculatus Motsch.	Coccinellid	Coleoptera	Coccinellidae	Predator (G)	Aphids, nymphs of jassids
Micraspis discolor Fab.	Lady bird beetle	Coleoptera	Coccinellidae	Predator (G)	Aphids, nymphs of jassids
Cheilomenes sexmaculatus Fab.	Six-spotted lady beetle	Coleoptera	Coccinellidae	Predator (G)	Aphids, nymphs of jassids
Ischnura aurora (Braeur)	Golden Dartlet	Odonata	Coenagrionidae	Predator (A)	Generalist predator
Agriocnemis pygmaeae (Rambur)	Wandering wisp	Odonata	Coenagrionidae	Predator (A)	Generalist predator
Ceriagrion coromendalianum (Fab.)	Narrow winged damselfy	Odonata	Coenagrionidae	Predator (A)	Generalist predator
Neurothemis tullia (Drury)	Pied paddy skimmer	Odonata	Libellulidae	Predator (A)	Generalist predator
Diplacodes trivialis (Rambur)	Chalky percher	Odonata	Libellulidae	Predator (A)	Generalist predator
Orthetrum sp.	Dragonfly	Odonata	Libellulidae	Predator (A)	Generalist predator
Syrphus sp.	Roverfly	Hymenoptera	Syrphidae	Predator (G)	Aphids, nymphs of jassids
Chrysoperla carnea Stephens	Common green lacewing	Neuroptera	Chrysopidae	Predator (G)	Generalist predator

G: Grub stage; A: Adult stage

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Productivity potential and profitability of castor (*Ricinus communis* L.) with sprinkler irrigation

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ABSTRACT

In Andhra Pradesh, Amrabad Mandal in Mahabubnagar district was inhabited predominantly by Chenchus. They depend on forest produce for their livelihood. The area under castor gradually came down in these villages due to erratic rains and inadequate irrigation. Farmers felt the need for an efficient water management system for castor. Castor crop was re-introduced in to these villages with sprinkler irrigation with Tribal Sub Plan. The productivity potential and profitability of castor increased with sprinkler system as compared to flood irrigation. The factors for ready adoption of sprinklers were delineated such as limited availability of water, controlling of irrigation depth increased crop yield and converting rainfed area to irrigated area. Adoption of sprinkler irrigation have changed the economic dependence on money lenders, improved the input use in castor and increased the gross monetary returns to the Chenchu farmers.

Keywords: Castor, Chenchus, Irrigation, Reconnaissance, Sprinklers

Nallamala forest ranges spread across five districts *viz.*, Mahabubnagar and Nalgonda in Telangana region, Kurnool in Rayalaseema region and Prakasham and Guntur in Andhra region of Andhra Pradesh. In Mahabubnagar district, Nallamala forest area covers two assembly segments namely Achampet and Kollapur. Achampet consists of five Mandals *viz.*, Amrabad, Balmoor, Lingala, Achampet and Uppununthala. Among them, Amrabad is fully surrounded by the Nallamala ranges and consists of 18 Gram panchayats and 34 villages including Pentas, Gudem and Thandas. The people of this Mandal belongs to various caste groups *viz*., forward caste, other backward caste, scheduled caste and three types of scheduled tribes namely Chenchu, Lambada and Yerukala. Majority of Chenchu farmers are dependent upon the forest products like gum, honey, fruits, seed, leaves, tubers etc. for their livelihood, while Lambada and Yerukala tribes reside in Thandas villages and depend mainly on agriculture and other ancillary activities.

Lands were provided to tribal people (including Chenchus) by the Integrated Tribal Development Agency (ITDA), Sunnipenta-Srisailam (Kurnool) and supported agricultural development. But, the rainfed agriculture has become burdensome to many of the Chenchu farmers and they reverted back to depend upon forest products. However, most of the forest areas in Nallamala are prone to de-forestation and thus the dependency of Chenchus on the forest products for their livelihood has become unsustainable. With this background, the present study was conducted with the objectives to identify the problems related to castor production in the selected villages, to assess the felt needs as perceived by the Chenchu farmers to know the reasons for preferring the sprinkler irrigation and to study the impact of sprinkler irrigation on castor productivity and profitability

The study was conducted in the three villages *viz*., Jangamreddypalle, Petranchenu and Macharam, Amrabad mandal, Mahabubnagar district in Telangana. A baseline survey was conducted in the villages to assess the felt needs of farmers through focus group discussions (FGD). Reconnaissance survey was conducted to assess the problems encountered by the Chenchus in castor production. It was found that frequent droughts hinder castor productivity. In order to provide assured irrigation to castor crop, Directorate of Oilseeds Research, Rajendranagar, Hyderabad has provided technical and logistical support for establishing micro-irrigation facility (sprinklers) under Tribal Sub Plan (TSP) during 2011-12 for farmers with tube wells. Fifty six farmers were selected random from three villages, the data on effect of sprinklers on castor yields were collected through structured interview schedules and FGD. The data were tabulated and analyzed using descriptive statistics.

The results of reconnaissance survey on problems in castor production are shown as a problem tree in Fig.1. It is clear from the Fig.1, that uneven distribution of rains, inadequate irrigation sources, low nutrient status and water holding capacity of soil led to gradual reduction in castor yield. In order to combat the problem of water scarcity, there is a need for a new method of efficient water management in agriculture (Karamani *et al*., 2006). Low exposure to extension agency and lack of castor cultivation trainings led to low knowledge on castor production and reduced yields. Farmers perceived low profits due to high cost of inputs, non-availability and high cost of labour and low market price for castor seeds.

Establishment of sprinkler irrigation and bore wells were the most important needs of the Chenchu farmers, followed by tractor and tractor-drawn implements. Accessibility to agricultural inputs and support for diversified agriculture to allied activities were the subsequently ranked needs of the farmers. Among all, Nalligorru (Local weeds collecting bullock drawn implement) which was the least preferred felt needs of the Chenchu farmers of the selected villages.

Limited water resources and there by less area under irrigation were identified as the major factors associated with adoption of sprinkler irrigation. Similar reasons were reported by Caswell and Zilberman (1985). Other factors perceived by them in that order were increasing yields with sprinklers, controlling of irrigation depth to cover more area and reduction of production cost, avoiding water loss in sandy loam soils, minimum chance of crop failure, easy to manage, can be used even on undulated topography, reduction of sucking pests and change of micro-climate. Meena and Dheertaj Singh (2013) reported that water security was the major factor for adoption of drip system in Rajasthan.

Information given in Table 1 pertains to the impact of sprinkler irrigation on castor productivity and profitability. The additional net returns realized by the farmers was ₹2854 and ₹4200/ha as a result of adoption of sprinkler irrigation in castor at Jangamreddy Palli and Macharam, respectively. The seed yield increased by 16 and 18 per cent in Jangamreddy Palli and Macharam villages, respectively. The mean increase in seed yield and additional net returns as a result of sprinkler was 17 per cent and ₹ 3473/ha, respectively. The BC ratio with sprinkler was 2.56 as against farmers' practice of flood irrigation (2.39).

The dependency on money lenders was reduced because of income generated from the castor crop; most of the money generated was utilized for household purpose, agriculture (purchase of seed, fertilizers and pesticides), re-payment of hand loans, children education and performing festivals. The water scarcity, sandy loam soil and poor irrigation management led to the need for alternate irrigation systems. The sprinkler irrigation introduced in castor in the study area proved its worth as there was significant enhancement in castor productivity and profitability.

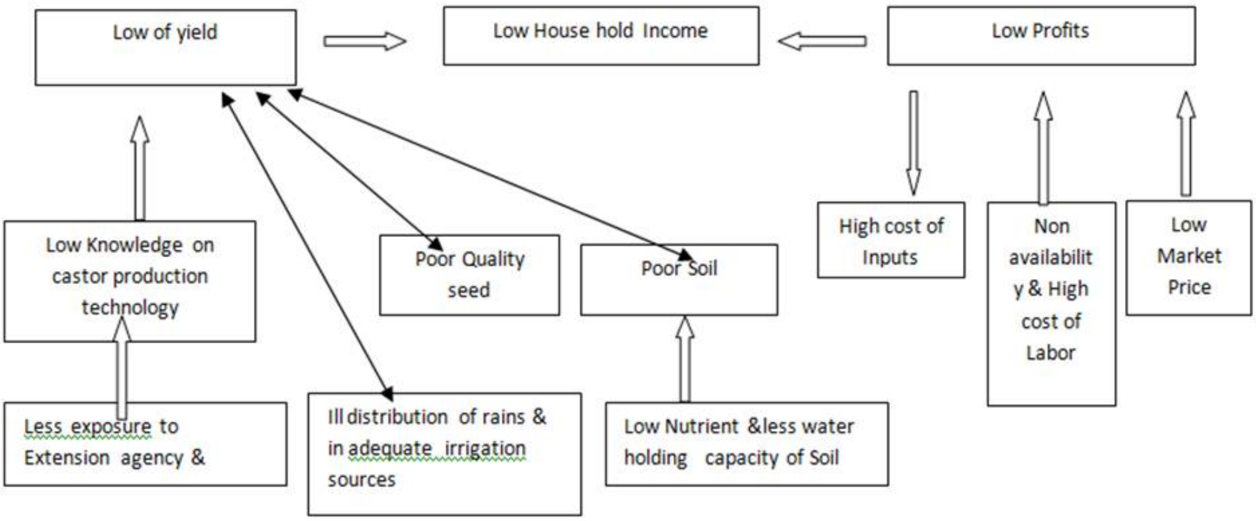

Fig. 1. Problem tree of low castor production in tribal villages

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Table 1 Effect of sprinkler irrigation on castor productivity and profitability during *rabi* 2012-13*

Village	No. of Demons.	Mean seed yield (kg/ha)		% increase	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Addl. Net returns (₹/ha)	BCR	
		IT	FP		IT*	FP	IT	FP		IT	FP
Jangamreddy Palli	19	871	754	16	11917*	11361	26130	22620	2854	2.19	1.99
Macharam	15	1250	1060	18	12500	11000	37500	31800	4200	3.00	2.89
Mean	34	1038	889	17	12174	11177	31140	26670	3473	2.56	2.39

IT=Improved Technology (sprinklers; castor hybrid DCH), FP=Farmers' practice (flood irrigation), BCR=Benefit Cost Ratio
*Acute drought year (rainfall was less than normal (District mean-605mm) depleted the ground water levels in *rabi*.

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Resource-use management of castor (*Ricinus communis* L.) growers in Andhra Pradesh

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ABSTRACT

A study was conducted to assess the resource-use management (RUM) behaviour of castor growers in Mahabubnagar district of Andhra Pradesh with 120 randomly selected castor growers through a pre-standardized scale. It was found that the respondents with large size of land holdings had medium to high level of RUM behaviour, while respondents with small and medium size of land holdings had low to medium level. Overall, there was low to medium level of RUM behaviour as exhibited by the castor growers. The respondents had low to medium level of management towards land, cropping system, seed, soil-moisture and nutrients, while medium to high level of management towards weeds, pests, diseases and irrigation. Seed, soil-moisture and nutrient were the primary indicators contributed towards both productivity and profitability of castor cultivation. Strategies for efficient management of these indicators are to be popularized through need-based extension efforts to improve the productivity and profitability of castor under rainfed conditions of Andhra Pradesh.

Keywords: Andhra Pradesh, Castor growers, Resource-use management

Successful management of a farm depends upon the optimum use of resources, so that the farm can survive and prosper. A farmer has to weigh the merits and demerits of available farm resources to plan for maximum output from the best contribution of the resources. It is nothing but resource-use management (RUM) and assessment of RUM behaviour of the farmers, not only provides indication of reasons for the success or failure of any farm but also implications for the agricultural scientists, extension personnel and policy makers to plan their efforts in order to educate the farmers to get maximum benefit out of effective resource-use management.

Castor is one of the important non-edible oilseed crops grown in Andhra Pradesh. The crop has been cultivated under rainfed and poor management conditions in the state with very low productivity (Raghavaiah *et al.*, 2006). There exists a wide gap between actual and potential yield levels of castor in Andhra Pradesh due to the improper resource-use management behaviour of the castor growers (Prasad, 2002; Ramanjaneyulu and Padmaiah, 2003; Padmaiah, 2007). The castor production constraints can be overcome through efficient RUM behaviour (Ramanjaneyulu and Padmaiah, 2003). Thus, there is a need to improve the RUM behaviour of castor growers under rainfed situations in order to overcome production constraints and increase castor productivity, for which, "assessing the actual RUM behaviour of the castor growers", is obviously, a pre-requisite. With this aim, a study was conducted in Mahabubnagar district of Andhra Pradesh. The results of the study are presented here under.

Andhra Pradesh is the predominant castor growing state in India under rainfed conditions, whereas Mahabubnagar is the major castor producing district in Andhra Pradesh (Hegde and Damodharam, 2007) and hence was the locale of the study. A total of 120 castor growers were randomly selected as the respondents of the study. Post-survey stratification revealed that 42 farmers with small (with land holdings less than 2 ha area), 48 with medium (with land holdings of 2-5 ha area) and 30 with large (with land holdings of more than 5 ha area) size of land holdings constituted the respondents of the study. To assess the RUM behaviour of castor growers in all castor-growing ecosystems of the country, a scale was constructed with 52 statements under 9 indicators (Table 2) and was standardized. The response of the farmers in the pre-standardized scale was collected through personal interview method in a four point continuum. The data were collected during January-March 2009, tabulated and analyzed using statistical techniques like mean, standard deviation (SD), Chi-square test, simple correlation and multiple regression.

It was found that respondents with large size of land holdings had medium to high level of resource-use management (RUM) behaviour, while respondents with small and medium size of land holdings had low to medium level (Table 1). Overall, there was low to medium level of RUM behaviour exhibited by the castor growers. The Chi-square test revealed that there was also significant difference between the three categories of castor growers with respect to distribution according to their RUM behaviour. Thus, effective extension efforts are needed to improve the RUM behaviour of farmers with small and medium size of land holdings.

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Table 1 Distribution of respondents according to their RUM behaviour (N=120)

Level of RUM	Categories of farmers (%)			Total (%)
	Small	Medium	Large	
Low	42.9	35.4	6.7	30.8
Medium	50.0	52.1	60.0	53.3
High	7.10	14.5	33.3	15.9
Total	100.0	100.0	100.0	100.0
Mean	116	127	163	132
SD	48	51	50	53
Chi-square		16.5**		

**- Significant at 1% level of probability

The respondents had low to medium level of management towards land, cropping system, seed, soil-moisture and nutrients (Table 2). Their behaviour towards the management of weeds, insect-pests, diseases and irrigation could be explained as medium to high. Based on the mean values of the scores of individual indicators of RUM, the importance given by the respondents for managing the different indicators are as follows: seeds, nutrients, soil-moisture, land, diseases, insect-pests, cropping system, weeds and irrigation. Effective extension efforts are needed to improve the low to medium level of RUM behaviour of the respondents towards land, cropping system, seed, soil moisture and nutrients.

Regression analysis revealed that the management of cropping system, seed, soil-moisture, nutrient, insect-pests and diseases significantly contributed to castor productivity at 1 per cent level of probability (Table 3). Among the significant indicators, seed management, soil-moisture management and nutrient management were found to be the primary indicators that contributed towards castor productivity. Similarly, among the different indicators of RUM, cropping system, seeds, soil-moisture, insect-pests and diseases contributed significantly towards profitability of castor at 1 per cent level of probability, whereas nutrient management contributed significantly at 5 per cent level of probability. Among the significantly contributed indicators, seed, soil-moisture and nutrient were found to be the primary indicators contributed towards profitability of castor cultivation. These results imply that efficient management of seed, soil-moisture and nutrient will enhance the castor productivity and profitability and hence such strategies are to be popularized among the castor growers.

Table 2 Distribution of respondents according to indicators of RUM (N=120)

Level of Management (%)	Indicators of RUM								
	Land	Cropping system	Seeds	Soil-moisture	Nutrient	Weed	Insect-pests	Diseases	Irrigation
Low	34.2	29.2	34.2	30.8	29.2	0.0	3.3	17.5	0.0
Medium	52.5	63.3	52.5	52.5	54.2	61.7	80.0	63.3	95.0
High	13.3	7.5	13.3	16.7	16.7	38.3	15.8	19.2	5.0
Mean	22	10	39	23	24	4	13	14	4
SD	13	6	24	5	11	1	5	3	2

Table 3 Indicators of RUM contributing to castor productivity and profitability

RUM indicators	Castor productivity			Castor profitability		
	Beta Coefficients					
	Unstandardized		Standardized	Unstandardized		Standardized
	Beta value	Std.error	Beta value	Beta value	Std.error	Beta value
Constant	-77.8	53.9	-	-6.537	4.52	-
Land	0.17 NS	0.38	0.00	0.01 NS	0.03	0.01
Cropping-system	5.69**	2.05	0.10	0.48**	0.17	0.10
Seeds	3.72**	0.85	0.29	0.31**	0.07	0.29
Soil-moisture	17.50**	3.20	0.27	1.47**	0.27	0.27
Nutrients	5.87**	2.75	0.20	0.49*	0.23	0.20
Weeds	1.14 NS	7.32	0.00	0.10 NS	0.61	0.00
Insect-pests	8.72**	3.07	0.13	0.73**	0.26	0.12
Diseases	3.50**	1.45	0.04	0.29**	0.12	0.04
Irrigation	2.76 NS	7.14	0.02	0.23 NS	0.60	0.02

NS=Non-significant; **=Significant at 1% level of probability; *= Significant at 5% level of probability

Educational status of the respondents and their farm size had influenced RUM behaviour positively at 1 per cent level of probability, whereas annual income and social status influenced positively at 5 per cent level of probability. Farming experience of the respondents had negative but significant relationship with RUM behaviour of the respondents. Hence, it could be implied that young castor growers with higher education, large size of land holdings, higher annual income and higher social status may be used as resource-persons to influence RUM behaviour of castor growers.

Castor growers with large size of land holdings had higher RUM behaviour than that of the small and medium categories. The respondents had low to medium level of management towards land, cropping system, seed, soil moisture and nutrients. Effective extension efforts are needed to improve the low to medium level of RUM behaviour of the respondents towards land, cropping system, seed, soil-moisture and nutrients and overall RUM behaviour of farmers with small and medium size of land holdings. Seed management, soil-moisture management, and nutrient management were the primary indicators that contributed to productivity and profitability in castor cultivation. Hence, strategies for efficient management of these indicators are to be popularized among the castor growers. Young castor growers with higher education, large size of land holdings, higher annual income and higher social status may be used as resource or contact persons to influence RUM behaviour of castor growers.

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10. **Introduction** part should be brief and limited to the statement of the problem or the aim and scope of the experiment. The review of recent literature should be pertinent to the problem. Key words of the article should be given in the beginning.
11. Relevant details should be given of the **Materials and Methods** including experimental design and the techniques used. Where the methods are well known, citation of the standard work in sufficient. Mean results with the relevant standard errors should be presented rather than detailed data. The statistical methods used should be clearly indicated.
12. **Results and Discussion** should be combined, to avoid repetition.
13. The results should be supported by brief but adequate tables or graphic or pictorial materials wherever necessary. Self-explanatory tables should be typed on separate sheets, with appropriate titles.
14. The tables should fit in the normal layout of the page in portrait style. All weights and measurement must be in SI (metric) unit. Tables and illustrations (up to 20% of text) should not reproduce the same data.
15. The discussion should relate to the limitations or advantages of the author's experiment in comparison with the work of others. All recent relevant literature should be discussed critically.
16. Line-drawings should be clearly drawn (7 inch or 17 cm width) in black waterproof ink on smooth, tough paper, minor points of style should be noted carefully. Photographs should be large, unmounted, glossy prints of good quality. They should be clear and relevant to the subject. Colour photographs may be sent for better identification and legibility of different parts of the object. All figures should have legends (types). Original artwork should accompany 2 copies. Repetition in graphic and tabular matter should be avoided.
17. For citing **References** a recent issue or the present journal may be referred, ensuring that all the references cited in the text are referred in the end under References section of the article. Each citation should have the name(s) of the author(s), initials (without full stops, but comma after each full name), year of publication (with full stop), full title of the article (with full stop), name of the journal (in italics with comma but without abbreviations), volume number (in bold), preferably the issue (within parentheses and colon) and complete page range (not merely the first page and full stop). Complete name of publisher and place of publication of books should be given in case of books. For proceedings or other publications complete details should be given.
18. All articles are sent to referees for scrutiny and authors should meet criticism by improving the article, indicating the modifications made (in separate sheet, 2 copies).
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20. For **writing,** authors are requested to consult the recent issue of **Journal of Oilseeds Research**, either this issue or the immediate past issue. The language and spellings are followed as per British style, but not in American style.
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