ISSN 0970-2776

Volume 29 Number 1 June 2012

Journal of Oilseeds Research

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

THE INDIAN SOCIETY OF OILSEEDS RESEARCH

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

MEMBERSHIP TARIFF

(w.e.f. 01.01.2007)

Life Membership		Annual Subscription		India	Abroad
Individual :	Rs.2500/- + Admn. Fee Rs.50/-	Individual	:	Rs. 300/- + Admn. Fee Rs.50/-	US$ 100 Ordinary
		Institutions	:	Rs. 2000/-	US$ 150 Institutions
		Students	:	Rs. 200/- + Admn. Fee Rs.50/-	

For subscription, please contact ☛ The General Secretary, Indian Society of Oilseeds Research, Directorate of *Oilseeds* Research, Rajendranagar, Hyderabad-500 030, A.P., India

ANNOUNCEMENT

The rating of the Journal of Oilseeds Research is **3.3**

The National Academy of Agricultural Sciences has enhanced the rating of the Journal of Oilseeds Research to **3.3** from 2011 instead of 1.0 assigned in 2007.

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

JOURNAL OF OILSEEDS RESEARCH

Previous Issue : Vol. **28**, No. 2, pp. 94-184

Vol. **29**, No. 1 June, 2012

CONTENTS

Short Communications

Review Article

Sesame improvement - Present status and future strategies

A R G RANGANATHA, R LOKESHA*, A TRIPATHI, AASFA TABASSUM, S PAROHA AND M K SHRIVASTAVA

Project Coordination Unit (Sesame & Niger), J.N.K.V.V. Campus, Jabalpur-482 004, Madhya Pradesh
*University of Agricultural Sciences, Dharwad, Karnataka

DOR-381

ABSTRACT

Sesame (*Sesamum indicum* L.) is one of the ancient oilseed crops cultivated extensively in several countries of Asia and Africa. However, the seed yield levels of sesame are continued to be low under different agro ecological niches. India has been favoured to be the centre of origin for sesame. Genetic resources have been conserved and evaluated for utilization in the sesame improvement programmes. The analysis of genetic diversity exhibited the presence of a wide variety of plant types with greater adaptability to various agro-production situations. In spite of large germplasm collections, gaps exist at secondary and tertiary gene pool levels. The wild species are utilized through inter specific hybridization for the transfer of desirable characters. Sesame being cultivated under diverse agro climatic situations, appropriate plant types have been developed through various breeding techniques to suit specific situations. The strategies for exploitation of hybrid vigour have been critically reviewed, with greater emphasis on heterosis breeding and stable cytoplasmic male sterility (CMS) system development. Sesame being sensitive to various biotic (diseases and insect pests) and abiotic stresses (drought and water logging), the approaches for resistance breeding have been presented. The role of mutations in sesame improvement has been discussed. The potentials for new markets are high, hence quality parameters have been considered for sesame improvement. Further, for the development of superior varieties of sesame, the biotechnological approaches have been emphasized. To break the yield barriers and for the quantum jumps in the productivity levels, the strategies for future improvement have been outlined based on the SWOT analysis of sesame breeding.

Keywords: Biotechnology, Hybrid, Mutation, Quality, Resistance breeding and Wilt species

General scenario

Sesame (*Sesamum indicum* L. Syn. *S. orientale* L.) is one of the oldest crops known to humans. There were archeological remnants of sesame dating back to 5,500 BC in the Indian subcontinent (Bedigian and Harlan, 1986). It is one of the crops under cultivation from ancient times (Joshi, 1961; Weiss, 1983; Bist *et al.*, 1998). Majority of the world area is found in developing countries with largest in India, Myanmar, China, Sudan, Nigeria, Ethiopia, Uganda and Turkey. In general, the paler varieties seem to be more valued, while the black varieties are prized in the Far East. Sesame is found in tropical, subtropical and southern temperate areas, particularly in Asia, South America and Africa. Asia in general and India, in particular, has been favoured to be the centre of origin (Bedigian, 2003a).

Sesame is cultivated in 7.8 million ha area with a production of 3.83 million t. world wide (Anonymous, 2010). The average yield in India has increased from 150 kg/ha during 1966 to around 400 kg/ha and the world's average productivity is 470 kg/ha. The average yield varies from a highest of 1175 kg in Egypt to a lowest of 152 kg/ha in Sudan. Asia and Africa together contribute about 95% of the total production. The comparison between China, India and Ethiopia indicated that India has the lowest yield. Sesame is grown under environment stress with low management by resource poor small holders (Cagirgan, 2006 and Bedigian, 2010). Sesame production is below expectation and the potential is higher if cultivated under favourable conditions. Sesame is grown in different seasons in India and covers all agro ecological zones. India is a leading country in export of seed; white sesame has highest market and earns a sizeable foreign exchange (₹2000 cr). Both domestic and international demand has witnessed a substantial growth.

Sesame is predominantly an autogamous crop with out crossing between 5 and 15%. The flowers are bell shaped, campanulate corolla with four anthers inserted at the base and this is called epipetalous condition. Anthesis takes place early in the morning between 6 and 9 AM and anthers are long viable (>24 hrs) and stigma remains receptive for more than 48 hrs. Sesame has a long history of autogamy with little out crossing and has been subjected to selection and recombination. Thus, majority of the traits has a history of predominance of additive genetic variance.

Sesame produces quality oil that is not only edible but also used in biomedicine. Sesame oil with 85% unsaturated fatty acids is highly stable and has reducing effect on cholesterol. The excellent nutritional, medicinal, cosmetic and cooking qualities of oil made it queen of oils. Owing to the presence of lignans and tocopherols, sesame oil has remarkable antioxidant function. The seeds are rich in quality proteins and essential amino acids. The seed is a rich source of linoleic acid, vitamins E, A, B_1, B_2, niacin and minerals. Sesame is also substitute for mother's milk.

The history of medicinal usage of sesame is intimately linked with the history of humankind. Ayurveda, the mother of all the systems of medicine has used sesame oil as a base. From the earliest times, tribal priests and medicine men used various plants to cure diseases. Over 6000 years ago, the ancient Chinese were using sesame for medicinal purposes. In India, the Ayurvedic system has been in vogue for over 3000 years. The medicinal work of Charaka Samhita and Susruta Samhita are venerated even today as a treasure on medicinal uses of the plants.

Sesame has played a major role in diverse health traditions. In this land of saints, it is amazing that our ancient people had incredible knowledge of the medicinal value of sesame. Through the ages, sesame became an integral part of the religion, culture and agriculture. Charaka, the great medical authority has said that, of all the oils, the sesame oil is the best. The oil is also used as a substitute for olive oil. The dark colour and nutty taste of unrefined oil makes it good for cooking also. The importance of sesame lies in the quality of the oil, its antiquity and use in religious rituals. For the development of superior varieties and to break the yield barriers for quantum jumps in productivity levels, the breeding strategies have been discussed in detail.

Origin and domestication

Most of the species occur mainly in the tropical Africa comprising Nigeria, Sudan, Mozambique, Angola, Congo, S.W. Africa, East Indies, Uganda, Upper Guinea and Somalia. Only seven authentic wild species have been reported to occur in India and have been confirmed by recollections from different parts. These are the cultivated *S. indicum*, its closest wild relative *S. malabaricum*, an intermediate species complex, *S. mulayanum* (all 2n=26); *S. laciniatum*, *S. prostratum*, *S. alatum* and *S. radiatum*. However, the other three species *viz*., *S. occidentale*, *S. trifoliatum* and *S. schenkii* that have been reported to occur in India could not be collected in explorations. The cultivated sesame (2n=26) is a member of the order Tubiflorae. family Pedaliaceae, which comprises 16 genera and 60 species of which several can be crossed with *S. indicum* (Ashri, 1998; Nayar and Mehra, 1968). Authentic number of Sesamum species, in existence, is still obscure as they have not been examined in detail. Even the chromosome numbers of some recognised species of African origin are yet to be confirmed. The major problem in conducting basic studies is nonavailability of seed material of an authentic specimens of the species outside the country of origin.

Weiss, (1983) presumed that sesame originated in Africa and later spread through West Asia to India, China and Japan, which became secondary centres of diversity. However, Bedigian and Harlan (1986) contested this concept based on evidence from archeology, botany and Vedic scriptures (1000 B.C.). The recovery of charred sesame seed at the Indus valley civilization site of Harappa dating back to 3050-3500 B.C. and the fact that not a single seed of sesame had been found in the Near East from earliest Islamic times, led Bedigian and Harlan to conclude that India is the centre of origin. The evidence suggests that sesame was later introduced to Mesopotamia from India and then it spread to other regions such as Babylonia, Egypt, China, Greece by the first millennium B.C. The hypothesis of earlier evidence from Mesopotamia is linguistic only and that possibly the Dravidian word for the crop *ellu* was transferred from the Indian subcontinent to Mesopotamia. Nevertheless, the coexistence of abundant distribution of *S. malabaricum*, the closest wild relative of cultivated sesame and *S. mulayanum*, the intermediate species complex, coupled with immense diversity of cultivated forms observed in the collections, further supported the findings of Bedigian and Harlan (1986) that the centre of origin is India, possibly the Western ghat region where all the wild species, including the intermediate species complex and rich diversity in cultivated forms occur.

The morphological delineations of sesame by Nohara, (1933), Ashri (1998) and Bedigian (2010) offered details of the respective geographic areas they drew from the former Soviet Union, Japan and India, respectively. The vast diversity in Sudan's Nuba Mountains (Bedigian, 1981, 1988, 1991, 2010; Bedigian and Harlan, 1983) should be viewed a micro centre or secondary centre of diversity. The molecular studies (Abdellatef *et al*., 2008; Ali *et al*., 2007; Bhat *et al*., 1999; Laurentin and Karlovsky, 2006) also characterise these differences.

Genetic studies indicate that cultivated sesame derives from wild populations native to the Indian subcontinent, i.e., the western Indian peninsula and parts of Pakistan. Bedigian (1984 through 2003b) and associates (Bedigian *et al*., 1985, 1986; Bedigian, 2010) showed that sesame's progenitor is a taxon named *S. orientale* var. *malabaricum* Nar. It displays close morphological, genetic and phytochemical affinities to the cultivar. It remained obscure even among Indian botanists. N.C. Nair named a syn. *S. mulayanum* Nair. (1963) unaware of the previous designation (Bedigian, 2003a. b; Nair pers. comm., 1979).

Sesame and the wild forms share the same diploid chromosome number, 2n= 26 (Mitra and Biswas. 1983; Thangavelu, 1994; Hiremath and Patil, 1999; Kawase, 2000; Annapurna Kishore Kumar, 2003; Annapurna Kishore Kumar and Hiremath, 2008) and the criterion of domestication, fertile hybrid products of reciprocal crosses (Harlan, 1992), were achieved (Bedigian, 1984, 1988, 2003a, b, 2010; Bedigian and Harlan, 1986). Independently, Hiremath and Patil, (1999), Kawase, (2000), Bisht *et al.*, (2004) and Annapurna (2003), Annapurna and Hiremath (2008) repeated those crosses, and each team found the offspring of these reciprocal crosses to be fertile. Agreeing with Bedigian (fieldwork, 1979, 2003a,b) and Kawase, (2000), Annapurna is convinced that they are a single taxon from side-by-side morphological comparisons of specimens named *S. orientale* var. *malabaricum* and *S.mulayanum.* Additionally, Bhat *et al.* (1999) and Nanthakumar *et al.* (2000) using RAPD markers, demonstrated proximity between *S. indicum* and the progenitor.

New results from molecular phylogeny analysis, using the two chloroplast DNA regions that have been widely used in the Lamiales: ndhF and trnLF, with material determined by Bedigian, confirm that *S. indicum* and *S. orientale* var. malabaricum are most closely related (Bedigian, 2010; Olmstead pers. comm., 2010). These tests and independent results provide unassailable evidence of the domestication of sesame.

Bedigian performed the identical tests at the same time (1984, 1988, 2003a, b 2010; Bedigian *et al.*, 1985) to assess *S. latifolium* Gillett, 2n= 32, the African progenitor proposed by Ihlenfeldt and Grabow Seidensticker, (1979). Repeated attempts to make reciprocal crosses (Bedigian, 1984, 1988, 2003a, b 2010 and Sudanese scientists M. Hassan, pers. comm.; Khidir, 1972) were unsuccessful, yielding only a few shriveled seed. Since the diploid chromosome numbers of the two species are mismatched, this is not surprising. Investigation of sesamum lignans showed qualitative differences between those two species (Bedigian, 1984, 1988, 2003a, 2006, 2010; Bedigian *et al.*, 1985) too. Whereas both lignans, sesamin and sesamolin are present in the crop as well as the designated progenitor, the absence of sesamolin in *S. latifolium* (Bedigian *et al.*, 1985; Bedigian, 2010) casts additional doubt about its proximity to domesticated sesame.

While it is accurate that most species of sesamum and genera of Pedaliaceae are native to Africa, no botanical study has ever substantiated an African progenitor from which sesame arose. Seeking a correct answer, not wedded to any view, Bedigian (2010) has reviewed the literature for decades without finding a shred of scientific work to support domestication in Africa. A distinguished deviation from the generalization that cultivars with the white seed contain higher oil, is the renowned red sesame of Kordofan grown throughout the Nuba Mountains of Sudan, prized for its high oil content, substantially greater than local white seeded cultivars (Bedigian and Harlan, 1983). A study of seed colour inheritance in sesame sums up the complex nature of the expression of this trait. Results also indicated that plants with the same seed colour might be under different genotype constitution.

Plant genetic resources

The first sesame collection was established in India in 1925. Later, large world collections were established in the Soviet Union and subsequently in Venezuela and the USA. A classification of the world collection from the Russian expeditions revealed presence of 111 types among the 500 lines. Indian cultivars comprised of 68 different types. The diversity could be summarised in terms of distinct forms of cultivars observed from various countries. This indicated the presence of a wide variety of types with greater adaptability to diversity of environments (Ashri, 1990; Ashri, 1998; Bisht *et al.*, 2004; Bedigian, 2010; Azeez *et al.*, 2011).

The variation available in the world collections from the major countries indicated that sesame from all regions often revealed remarkable similarities, which can often be directly related to the paths of human migration or exploration. These studies indicated the greater variation for specific traits from different regions. The cultivars from Russia and Transcaucasia were uniform for plant type with single stemmed; resistance to mildew and Fusarium wilt. The Central Asian region had a greater range of plant types with ecotypes adapted to wider environments. The Tadzhik area was rich in local types resistant to Fusarium. The oil content was greater in varieties from Eastern Mediterranean and lowest in the Far East (Japan) region. Tetracarpellate capsules were common in the Japanese types. Greater resemblance of collections from South America with Indian and Ethiopian cultivars.

The Indian region has been reported to be rich in diversity, especially in the cultivated forms. The seed colour varied from black to pure white. National Bureau of Plant Genetic Resources (NBPGR) has in its collection, a total of about 10,000 accessions, including a large number of duplicates. A study of the collection was undertaken with a view to form a core set and recorded wide variation and a multivariate analysis resulted in classification into discrete clusters.

Exploration and collection efforts started very early and NBPGR has been engaged in collecting diversity in the form of primitive cultivars, land races and the wild species. The collaboration with IPGRI led to collect and document the variability of adjoining regions. The indigenous collections include 4178 accessions of local cultivars, 2522 accessions of world base collection and nearly 200 accessions of the six related wild species. As a result of 22 explorations of IBPGR, a total of 1978 collections were made with passport information (Duhoon *et al.*, 2004).

Sesame introduction first initiated in 1940 was made from Cyprus and 12 others from USA. Since then, 2522 exotic collections have been introduced from over 37 countries. To broaden the genetic base of sesame, collection got impetus and an addition of 1996 accessions was made particularly from the global sesame collection of Israel, through IPGRI. Out of 2283 introductions, 674 have been received from Singapore, 493 from Israel and 372 from USA, among others Bulgaria (77), Bangladesh (71), Korea (68), Italy (65) and Japan (63). NBPGR has maintained inventories of the introductions.

In the North Eastern region of Assam, North Cachar and adjoining plains, locally called *Ahu* types and *Sali* types were collected. Both white and black seeded are common but local people prefer black types. In Central Zone, bold white types are preferred. Black seeded types were lanky with profuse branching, seed bolder and bearing high number of mostly tetralocular capsules. In the arid and semi-arid region, the local types are highly adapted to drought, brackish/saline conditions. In Deccan plateau, black types are cultivated and the white types were rare. In Southern Zone, black types were predominant and medium sized tetralocular capsules were most frequent. The distribution of variation pattern of landraces envisaged the occurrence of several distinct types in varying proportions (Ashri, 1998; Bedigian, 2010).

In spite of the large collections in India, gaps exist at the primary, secondary and tertiary gene pool levels. Collections from China and Venezuela deserve special mention in the primary gene pool, as significant diversity is either present or have been collected in these areas (Zhang *et al.*, 2000). However, important is the scarce representation of the secondary and tertiary gene pool. Of the 34 wild species in the genus Sesamum, only few are reported to occur in India *viz.*, *S. alatum, S. laciniatum, S. mulayanum, S. occidentale, S. malabaricum, S. prostratum* and *S. radiatum.* It is necessary to acquire other species of sesame, particularly from the East and West Africa to make the representation of diversity for biotic and abiotic stresses as well as for phylogenetic relationships. Trait specific germplasm may be acquired for tolerance to biotic and abiotic stresses from China, Israel, Venezuela and African countries, and bold white seed types from Egypt, Ethiopia, Korea and USA.

NBPGR regional centre at Akola has been identified as the main active collection site. A total of 6523 collections has been maintained. Thrissur and Jodhpur stations of NBPGR are serving as the duplicate sites with the holdings of 3305 and 2135 collections. It has become important for the diversity of rich countries to protect its wealth. Work has been initiated to fingerprint using RAPD and AFLP to characterize the core collection and for phylogenetic relationships (Pham *et al.*, 2009).

So far, no efforts have been made to conserve germplasm using *in situ* strategy in India. Nevertheless, Western Ghats hotspot for biodiversity has some of the wild species and therefore, can be proposed for in situ conservation. The National Gene Bank has 3655 accessions comprising 3153 Indian and 502 exotic collections stored, *ex situ* at -20°C. A total of 177 accessions has been cryopreserved- *S. indicum*-137; *S. alatum*-1; *S. laciniatum*-5; *S. malabaricum*-10; *S. mulayanum*-17; *S. prostaratum*-4 and *S. radiatum*-3. The cryopreserved germplasm included mainly the wild relatives and a part of the core collection.

The morphological variation observed in the accessions maintained has been documented. The Germplasm Management Unit (GMU) at Project Coordination Unit, AICRP (Sesame and Niger) Jabalpur has documented germplasm lines in four catalogues. Besides, two catalogues have been published by the NBPGR from the evaluation data of 1393 accessions. Utilization of the PGR led to the development of 58 improved varieties. Among the 58 varieties developed so far; 28 have come through straight selections. Since 1996 over 2000, diverse germplasm have been utilized for heterosis in over 4000 cross combinations. For example, one of the parents for the cvs. TC-25 and TC-289 namely EC-7 and EC-4619, respectively were exotic collections.

The diversity in cultivated types includes important land races namely Kari Ellu, Thodde Ellu, Chatko long, Turai Nuvvlu, Pyru Nuvvlu, Bhori, Gopya and Gherd from parts of Karanataka, Madhya Pradesh, Andhra Pradesh and Maharashtra. Under IPGRI programme, a joint exploration for collection was undertaken and 70 accessions were collected from 12 districts of Bangladesh. The diversity was represented by red, black and white seeded types, varying in four, six to eight capsules/axil. Red to brown seeded collections of sesame collected from the saline belt of Khulna district may have useful traits for salinity tolerance.

In sesame, dwarf and less dehiscent lines *viz.*, PI 189082, PI 189229, PI 210687, PI 481875 and PI 481876 were collected from USA. Collections with high oil content (EC 303295-314, ex. USA), early maturing, high yielding accessions (EC 310417-454, ex. Bulgaria); varieties such as Seowan; Remier and Danbackggo from Korea; Arawasa, Piritu and Aceitera from Venezuela were some of the promising introductions. Six accessions (EC 327447-452, ex. Sudan) were promising introductions for drought resistance and high oil content. Two black and high yielding accessions (Ec 355666-667) were introduced from Thailand. Further, the promising lines were identified for various economic traits like early maturity (EC-89112, JLSE-1, 6, 8, SI-938, EC-37037, EC-370392), dwarf type (EC-89112 and JS-468), high oil types (AT-13, HT-6, AT-9, SI-1930, SI-3315, TMV-4) and for phytopthora tolerance (TS-67, RJS-73 and KIS-358).

Sesame has large variability in many parts of the world and farmers have also not touched the breeder developed sesame. Many of the plant breeders and farmer selectors have different views of the ideal architecture and the diverse environments also have an effect. Evaluation of germplasm should consider the region from which the cultivars that show the greatest morphological distinctiveness are derived.

Any barrier to gene flow (altitude, rainfall, soil, temperature, social and political isolation) permits populations to fragment and accumulate genetic differences between the sub-populations (Harlan, 1970). When a location is isolated in space and time, a secondary center of diversity has time to evolve (Harlan, 1975).

Wild species and species relationships

The generic name Sesamum for sesame was taken by Hippocrates from the Arabic semsin. The genus Sesamum has a wide distribution in nature in tropical Africa, Madagascar, Arabia, India, Ceylon, tropical Australia and a few of the eastern islands of the Malayan Archipelago. Kobayashi (1981) studied the distribution of Sesamum species and their salient features (Table 1).

In India, besides cultivated sesame, two wild species S. prostratum Retz. and *S. laciniatum* Klein has been described in Hooker's flora and other Indian floras. Abraham (1945) collected wild Sesamum plants in Travancore in India and on the basis of cytological studies of cultivated sesame, the wild plants and the sterile hybrids between the wild plants and cultivated sesame, considered it to be a distinct species; hence referred to this species as *S. grandiflorum*. There is also a record of another species *S. malabaricum* from the same region in Index Kewensis. Wild sesame of Malabar was considered as a variety of the cultivated sesame and designated it as *S. orientale* var. *malabaricum*. They also used this type in breeding new varieties.

A new species, *S. latifolium* Gillett, from East Africa was described and the species has been included in the flora of Tropical East Africa. Also examined the three species *S. schenckii* Aschers, *S. grandiflorum* Schinz and *S. gibbosum* Bremek and Oberm. Further, it was found that in leaves, flower and fruit characters the three species were very much alike and the minor differences were not sufficient for specific distinction and hence, suggested that the three species were synonymous. Flora of Tropical Africa gives the description of *S. schenckii* only. The flora of Tropical East Africa, mentions that *S. sabulosum* A. Chev. is a syn. of *S. alatum* Thonn; *S. baumii* Stapf is a syn. of *S. angustifolium* (Oliv.) Engl., *S. macranthum* Oliv. is syn. with *S. angolense* Welw. Much work has not been done on the taxonomy and classification of *Sesamum*. The basic chromosome number of only few species has been reported and others need to be authenticated. A thorough cyto-taxonomic examination of numerous species of the genus may result in further reduction of the number of species recorded in *Sesamum* genus. Prabhakaran (1996) also summarized genetic diversity of wild *Sesamum* from South Indian region through collections.

Interspecific hybridization: *S. indicum* crosses with *S. malabaricum* has been reported successfully and pollen fertility was up to 93.6%. The reciprocal cross was also reported with low crossability. Furthermore, *S. indicum* crossability with *S. prostratum* and *S. laciniatum* was reported with low pollen fertility. The 2n= 26 of *S. indicum, S. alatum, S. grandiflorum, S. malabaricum, S capense* and *S. mulayanum* inter-specific hybrid was reported. Further, inter specific crosses among 2n=32; *S. lacinatum, S. prostratum* are fertile, but *S. angolense, S. latifolium, S. prostratum* and *S. latifolium* are sterile. Also crosses between 2n= 64; *S. radiatum* x *S. occidentale; S. occidentale* x *S. radiatum*, are fertile with bivalents. However, crosses between *S. indicum* x *S. prostratum* and *S. indicum* x *S. latifolium* are sterile. Among 2n=26; *S. indicum* x *S. radiatum* reciprocal and *S. indicum* x *S. occidentale* crosses were attempted by some workers. Also between 2n= 32 and 2n=64; *S. occidentale* x *S. lacinatum* reciprocal and *S. occidentale* x *S. prostratum* crosses are attempted. Ramalingam *et al.* (1994) reviewed crossability relationships and homology in sesame.

The scope for utilization of few wild species for transfer of desirable characters like hardiness, profused flowering, resistance to phyllody and drought tolerance into cultivated sesame is possible. Interspecific hybridization among different chromosomal groups was carried out (Ramanujam, 1944; Ramanujam and Joshi, 1951). It is evident that (i) post fertilization barrier exists in 2n = 26 group speciesm (ii) partial barrier to get F_1 in crosses occurs between 2n=26 and 2n=32 groups which might be due to endosperm embryo imbalance, (iii) both the pre and post-fertilization barriers prevail in 2n=26 and 2n=64 groups and (iv) post-fertilization barrier occurs in crosses between 2n=32 and 2n=64 groups.

Cytogenetical work could throw light on the inter-relationships between species of sesame. A high frequency of bivalents and pollen fertility was observed in hybrids of *S. indicum* x *S. malabaricum* which suggests strong genomic similarity between these species, whereas the low frequency of bivalents and high frequency of univalents (0-16) in hybrids of *S. indicum* x *S. prostratum* and *S. indicum* x S. laciniatum suggests the distinct nature of *S. indicum* genome from the other two species. Thus, these observations corroborates the earlier observations (Ramalingam *et al.*, 1994). On the basis of high crossability and chromosome pairing in F_1, it is suggested that *S. indicum* is closer to *S. malabaricum* than *S. laciniatum* and *S. prostratum*. Failure of fruit setting in other crosses indicated their distant relationships. This indicates the post fertilization barriers and it is therefore, inferred that in vitro techniques could be attempted to overcome these barriers (Ashri, 1998; Bedigian, 2010).

Table 1 Distribution and salient features of sesamum species

Sesamum species	2n	Occurrence	Crossability with *S. indicum*	Salient features
S. indicum	26	Wide spread from tropical to temperate zone	F1s highly fertile	Cultivated, erect, simple or branched, leaves variable, corolla companulate, whitish to pink, nectary, sessile, seed coloured to white, smooth, edible
S. indicum	52	India, U.S.A., Japan, Venezuela		Autotetraploid
S. malabaricum	26	India, (Malabar coast), Africa,	Some sterility observed, fertile in crosses with S. indicum	Wild, partially cultivated
S. mulayanum	26	Indian subcontinent	F1s highly fertile	Wild, similar to *S. indicum* in plant morphology, corolla pink, fertile in crosses with *S. indicum*
S. laciniatum	32	India (Kerala, Tamil Nadu, Deccan hills), Africa	Shriveled seeds	Wild, partially cultivated, prostrate, occurs in rocky habitat, dark pink corolla, simple, serrate leaves
S. prostratum	32	India (Kerala, Tamil Nadu, Maharashtra, Madras), Africa	F1s sterile, amphidiploids, viable seeds,	Partially cultivated, prostrate, occurs in rocky habitat, dark pink corolla, simple, serrate leaves
S. alatum	26	Nigeria, Sudan, Mozambique, India	Fruit normal, seeds healthy	Wild, erect, branched, leaves foliolate, corolla pink to carmine, nectary sessile, seed winged, blackish
S. radiatum	64	India, (Maharashtra), Africa, Upper Guinea, Sri Lanka	Shriveled seeds	Partially cultivated, erect, simple or branched, leaves entire, corolla violet-purple, nectary sessile, short capsule, seed blackish, smooth rugose,
S. schenckii (*S. grandiflorum*)	26	S.W. Africa, India (Travancore), East Indies,	F1s with end period fertility F2s reported	Wild, erect, intermediate, leaves 5-7, partite, corolla purple, seed winged,
S. capense	26	South Africa	Shriveled nonviable seeds	Wild, erect, branched, leaves foliate, corolla violet purple, nectary sessile, seed winged, blackish,
S. angolense	32	Angola		Wild, erect, simple or branched, leaves entire, corolla violet purple, nectary sessile, long capsule, seed blackish, rugose,
S. angustifolium	32	Congo, Mozambique, Uganda		Partially cultivated, erect, simple or branched, leaves entire, corolla rosed, nectary sessile, long capsule,
S. occidentale	64	Africa, Sri Lanka, India		Partially cultivated
S. mombazense	unknown	Congo,		Wild, erect, branched, leaves entire, corolla purple, long capsule,
S. antirrhinoides	unknown	Angola		Wild, erect, branched, leaves entire, corolla purple, nectary stipitate, seed narrowly winged
S. schinzianum	unknown	S.W. Africa (Damaraland), East Indies		Wild, erect, branched, leaves oblong-lanceolate, corolla palerosed, long capsule, nectary stipitate, seed large
S. pedaloides	unknown	Angola		Wild, erect, branched, leaves entire, sessile, seed narrowly winged
S. calycium	unknown	Angola, Mozambique		Partially cultivated, erect, branched, leaves lanceolate entire, corolla rosed, nectary sessile, small capsule,
S. baumii	unknown	Angola		Partially cultivated, erect, slender, leaves entire, corolla pale rosed, nectary subsessile, seed rugose
S. heudelotii	unknown	Upper Guinea		Wild, prostrate, leaves lanceolate oblong, fruit unknown
S. repens	unknown	Lower Guinea		Wild, prostrate, leaves sessile entire, corolla rosed, long capsule, seed flat
S. marlothii	unknown	S.W. Africa, East Indies, Australia.		Wild, erect, lower leaves 3-foliolate, nectary sessile, seed blackish
S. rigidum	unknown	Angola		Wild, erect, branched, leaves entire, corolla pale rosed, seed oblique flat or convex
S. brasiliense	unknown	Brazil		Partially cultivated
S. biapiculatum	unknown	Congo		Wild
S. caillei	unknown	New Guinea,		Wild
S. digitaloides	unknown	Africa		Wild
S. denterii	unknown	Africa		Wild
S. latifolium	unknown	East Africa		Wild
S. lepidotum	unknown	Africa		Wild
S. microcarpum	unknown	Africa		Wild
S. sabulosum	unknown	Sudan		Wild
S. somalense	unknown	Somalia		Wild
S. talbotii	unknown	Nigeria		Wild
S. thonnerii	unknown	Africa		Wild
S. triphyllum	unknown	Africa, East Indies		Wild
S. trifoliatum	unknown	India		Wild
S. ligitaoides	unknown	Africa		Wild
S. auriculatum	unknown	Crete		Partially cultivated
S. indicatum	58	India		Partially cultivated, experimental, amphidiploid of *S. orientale* (n=13) x *S. prostratum* (n=16)
Ceratotheca (C. sesamoides)	32	Africa		Partially cultivated, related genus to Sesamum
Anthadenia (A. sesamoides)	unknown	Africa		Partially cultivated, related genus to Sesamum
Volkameria (V. sesamoides)	unknown	Africa		Partially cultivated, related genus to Sesamum

Development of ideal plant types for different situations

Sesame is an ancient oil seed plant endowed with certain desirable characters. Nevertheless, systematic intensive work has not been done. This is mainly because sesame is a crop of developing countries where funds are scarce and continuous breeding efforts are not pursued. Further, sesame is not mandated to any of the CGIAR International institutes. The potentials of sesame have been amply demonstrated in tropical Venezuela (Mazzani 1985), in South Korea where sesame is a high input crop (Kang, 1994) and in summer, production areas in India (Sharma, 1994) and in China (Zhao, 1994).

The objectives are higher yield, improved plant architecture and resistance to diseases and insect-pests, whereas specific objectives vary with the regional requirements. In developing countries, sesame is grown with low inputs, while in developed countries, such as the United States and South Korea, it is grown with reasonable or high inputs. Sesame fits into various cropping systems either as a main or second crop and also it is grown often as intercrop. Nonshattering cultivars are needed for combine harvest in developed countries and moderate types are adjustable elsewhere (Ashri, 1998; Bedigian, 2010).

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, but these characters are critical for the confectionery which is increasing globally with the growing health concerns. In Venezuela, growers had to switch cultivars in recent years when the main market changed from oil to confectionery use. In India, white seeded is preferred for export and domestic use in Northern plains and plateau region. Whereas brown or black seeded are preferred by domestic consumers in Eastern coast and black seeded in the South coastal region.

Specific breeding objectives in sesame are as follows:

Seed characters: Large or medium large, well filled, shape and colour to satisfy market demands, especially for confectionery. Seed coat rough or brittle, easily removable by dry decortication; short (a few months) seed dormancy appropriate; higher oil content, above 50%; higher lignan content for longer shelf life.

Seedling characters: Fast, vigorous germination and emergence with strong hypocotyl elongation to ensure better emergence; rapid growth in the early stage to overcome weeds and to result in better stand establishment; ability to germinate and withstand lower temperature in early stage of growth in temperate areas.

Roots: Rapid root growth, deep tap root penetration with a well distributed secondary root system.

Leaves: Medium to broad at the base and narrow lanceolate toward the apex to permit maximum light penetration; short petioles; abscission early and complete at maturity for clean threshing.

Stem: Moderately branched, under low input conditions, short internodes with corresponding adjustment of capsule angle.

Growth habit: Determinate with uniform and short flowering or moderately determinate with a prolonged ripening period according to the farming system. Under high input conditions, the first would be preferable

Flowers: To start 20-30 cm from the soil surface; number of flowers per leaf axis - one.

Capsules: Setting start from base. Bicarpellate (4 locules) for larger seed size, long capsule, one per leaf axil, upright angle, appressed, full seed set, without aborted ovules. effective seed retention, suitable for machine harvest or through delayed capsule indehiscence type.

Physiological characters: Neutral day length response and thermo-insensitivity; improved harvest index; higher efficiency in nutrient uptake; tolerance to waterlogging, drought, salinity, and other abiotic stresses; potential to respond to application of fertilizers and/or irrigation; high and stable seed yield under a wide range of environments (Rajan, 1981).

Higher oil content will be an important objective. In addition to increasing seed yield, increasing oil yield simultaneously is very essential. Modification of the fatty acid composition is needed for specific market niches. Further, protein content and amino acid modifications may be considered. Higher lignan content could expand the use of sesame oil as an antioxidant. The value addition through the development of varieties with sweet taste and low anti nutritional factors (oxalic acid and/or phytic acid) present in the seed coat will be desirable for global competitiveness.

Introduction

The use of introductions directly or after minimal selection was common. Subsequent efforts for specific need required programmes based on recombination. In sesame, introduction sometimes followed by mass or single plant selection was efficient. The Venezuelan cultivar Morada, selected from an introduction from Zaire (Republic of Congo), proved well adapted to Tanzania. The introductions from which some improved varieties selected in Venezuela were originated in China, Congo, Nicaragua, Colombia, and Ethiopia. The improved sesame cultivars grown in Ethiopia originated as introductions from India, Uganda, Sudan and Egypt and the popular cultivars in Ethiopia were introductions. The Mexican cultivar Yori 77 performed better in Northern Australia (Inrie, 1995). Early Russian introduced from Texas to South Korea served as a basis for the intensive cultivation of sesame (Ashri, 1998; Bedigian, 2010).

It appears that no recommendations can be given on the promising geographical sources of introductions on a national basis. Ashri *et al.* (1991) and Ashri (1994) showed that oil content and protein content in South Korea could predict performance in Israel and vice versa. It is observed that introductions can be useful in breeding. In some cases, introductions may be adopted directly or used as the source of genes. Two major traditional sesame growing countries, China and India, have enhanced their germplasm introduction and collection efforts (Zhao 1994; Duhoon *et al.*, 2000) and some of the commercial cultivars are direct introductions.

Selection

Phenotypic selection within the local germplasm has been practised. Both mass and single plant selection has been important in developing improved varieties. Mass selection was aimed at the elimination of the less desirable genes leading to better adaptation. Single plant selection has produced successful varieties and there is scope for selection, when new variability is created. In India, 85 varieties are released (Table 2) so far and among this, 28 were developed by selection from local material, 32 by pedigree method, 4 by induced mutations and 21 by other methods (Ranganatha *et al.*, 2012). In China out of 36 varieties, 17 were developed by selection from local material, 18 by pedigree method, and one from induced mutation (Zhao, 1994). In South Korea out of 18 varieties, one variety was developed through direct introduction, one by selection from introduced material and three from local material, eight by pedigree method and five by induced mutations (Kang *et al.*, 1993). At Venezuela, 19 varieties have been developed, out of this seven are from introductions, six by pedigree method and three by other methods (Ashri, 1998). The breeding efforts at South Korea increased seed yield levels from 650 kg/ha (suweon21, pungnyeon) to 1000 kg/ha (pangsan, seedun).

Hybridisation

The genetic variability has to be generated from planned crosses. Pedigree method has been used in hybridisation. Backcross, multiple crosses, bulk populations and population improvement with or without male sterility are less common. The crosses were usually between two cultivars, but sometimes more complex crosses are effected. Modifications of the pedigree method, such as single seed descent have been initiated. Pathirana (1995) compared breeding progress in five crosses using pedigree, bulk, single seed descent and modified single seed descent methods. Further, concluded that the bulk method, which is less expensive, could be used with the same amount of success as the other methods. Srinivas *et al.* (1992) compared the effectiveness of the bulk and single capsule descent methods and found that the bulk method was superior to the single capsule descent in four crosses, but was less successful in two crosses, where the parents were closely related. Early generation testing was studied by Ranganatha *et al.* (1994a) and Pathirana (1995) and concluded that it was ineffective. The results indicated that simple bulk methods may be used with equal success like pedigree, SSD or early generation testing (Ranganatha and Virupakshappa, 1993; Ranganatha *et al.*, 1994b). Ashri (1981, 1995) created a highly heterogeneous population by bulking F_2 seed from crosses of a wide range of cultivars with the determinate mutant. Seeds of advanced generations of this population were shared with researchers in many countries. The back cross has been used in a limited way in sesame. It has been used to incorporate desirable traits such as indehiscence and transfer of male sterility genes into adapted types. Its use will no doubt expand as better and more productive cultivars are developed with identification of additional sources of useful loci.

Inheritance studies

The genetic control of various traits in sesame was studied by various researchers (Nohara, 1933; Langham, 1945a, 1945b, 1946, 1947a, 1947b). The studies on inheritance mechanisms in sesame were also reviewed by Joshi (1961), Weiss (1971, 1983), Brar and Ahuja (1979), Ashri (1998) and Bedigian (2010). The research attention has been devoted to yield components, heritability, and related biometrical research. The reports reviewed by Brar and Ahuja (1979) dealt with monogenic or digenic traits with major genes. Polygenic control was cited only for five out of 71 traits. The known modes of genetic control for some characters that influence yield, as reviewed by Brar and Ahuja (1979) are as follows.

Branched *vs.* unbranched, one gene (Nb, nb); Normal *vs.* fasciated stem, single or duplicate genes (F_1, f_1, F_2, f_2); Single *vs.* multiple (2-3) flowers and capsules/leaf axil, one gene (T, t); Fertility *vs.* complete male and female sterility, one gene (Sc, sc); Fertility *vs.* male sterility, one gene (Ms, ms); Bicarpellate *vs.* quadricarpellate capsules, one gene (Tc tc); Dehiscent *vs.* indehiscent capsules, one gene with pleiotropic effect (Id, id), or two complementary genes.; Normal *vs.* paper shell capsule, two complementary genes (P_1, p_1, P_2, p_2); Capsule length, polygenic.; Photoperiod response, polygenic; resistance to *Alternaria* - monogenic dominant; resistance to phyllody - digenic with complementary gene interaction (cultivated) or duplicate dominant genes (wild); The traits whose mode of inheritance was elucidated can serve as marker in crosses and can be used in linkage studies (Table 3). The linkage was reported and in plants that are *idid,* the cotyledons and leaves are cupped, apparently a pleiotropic effect or an extremely close linkage.

Table 2 Selected released varieties of sesame in India

Variety	Pedigree	Breeding method	Year of release	Days to maturity	Oil content (%)	Average yield	Salient Feature, Recommended areas
TMV-3	Local x Malabar wild	Pedigree	1948	80-82	48-50	600-650	Black seed, rainfed and irrigated areas of Tamil Nadu and Karnataka, Tolerant to leaf minor
TMV (Sv)-7	SI 250 X ES22		2009	85-90	50-52	Rainy season 750 Summer 820	Tamil Nadu, AP, Karnataka, Cosmopolitan variety suited for all seasons, brown testa, tolerant to root rot, suitable for confectionery
T-4	T-10 x T-3	Pedigree	1960	85-90	48-51	600-650	White seed, for alluvial soils of UP
Amrit	XU-2 X Krishna	Pedigree	2006	80-85	43-46	750-850	Light brown seed, rainy season rainfed, winter season, summer irrigated, AP, TN, CG, WB and MP
TC-25	EC-7 x TS-24-1	Hybridization and selection	1978	80-85	50-53	750-800	White seed, Punjab, Vidarbha region (MS), MP and Rajasthan
Pratap (C-50)	Selection from local collection of Kota district	Pure line	1968	95-100	48-52	600-650	Dull white seed, heavy soils of Rajasthan, resistant to *Macrophomina*
RT-351	NIC-8409 x RT-127	Pedigree	2010	85-90	48-50	750-900	Rajasthan, Gujarat, UP, Maharashtra, Haryana, Punjab HP, Karnataka and J&K, Tolerant to *Macrophomina*, leaf curl, phyllody, moderately resistant to Cercospora and capsule borer
Purva-1	Selection from local material of Gujarat	Pure line	1968	95-100	48-50	700-750	Reddish brown seed, , Gujarat, Moderately resistant to powdery mildew
Gujarat Til-2	Gujarat Til-1 x TC-25	Pedigree	1994	88-92	48-52	750-800	White seed, Gujarat, Moderately resistant to *Macrophomina*
E-8	Selection from local material of Northern Karnataka	Pure line	1989	95-100	47-50	550-600	Creamy white seed, Northern Karnataka, Resistant to powdery mildew and bacterial leaf blight
Thilathara	CST-785 x B-14	Hybridization and selection	2006	84-88	48-52	600-650	Blackish brown seed, rainy season, Onattukara region of Kerala Summer rice fallows, Resistant to powdery mildew
JLT-408	Padma x Yuzi-8	Pedigree	2010	80-85	51-53	700-800	White seed, rainy season, Assured rainfall zone of Khandesh and adjoining areas of Vidharba, Marathwada region, Moderately tolerant to leaf roller/ capsule borer, Tolerant to gallfly, Moderately resistant to phyllody, Cercospora, *Alternaria Macrophomina* and powdery mildew
Madhavi	Selection from local material	Pure line	1978	75-80	46-48	650-700	Light brown seed, Andhra Pradesh
Hima	No.5039 x AT-1	Pedigree	2006	75-80	48-50	Rainy season 700-750 Summer 1100-1200	Shiny white seed, Late rainy season, winter season and semi-winter season, Andhra Pradesh field tolerance to *Alternaria* leaf spot
TKG-22	HT-6 x JLT-3	Pedigree	1995	82-85	50-54	600-700	White seed, Eastern UP, MP, Bihar, Orissa, West Bengal and NE states, Tolerant to *Phytophthora* blight

Table 3 Genetics of important traits in sesame

Trait	Number of genes		
	Monogenic	Digenic	Polygenic
Growth habit	1	-	-
Seedling traits	4	1	-
Leaf traits	11	2	1
Stem traits	5	1	1
Flower traits	23	7	-
Capsule traits	7	2	1
Seed traits	4	2	-
Photoperiodism	4	-	1
Seed composition	1	2	1
Physiological	1	2	-

Figures given comprise only indicative samples of literature

Of these, in five cases there are separate reports on monogenic or digenic control for the same trait, in different genetic backgrounds. Seed colour is controlled by several loci, one of which is epistatic. The homozygous recessive xx prevents pigment formation and exhibits white seeds. Yukawa *et al.* (1996) investigated the structure and expression of two seed-specific cDNA clones encoding stearoylacyl carrier protein desaturase (SACPD).

Seed yield and yield components

Sesame seed yield and harvest index are often low. Higher seed yield is a major breeding goal and many researchers (Weiss 1971 and 1983; Brar and Ahuja 1979; Tu *et al.*, 1991; Ray and Sen 1992; Inrie 1995; Ashri, 1998; Bedigian, 2010) evaluated the relative importance and/or the genetic control of the different yield components and harvest index. The studies were conducted by Kang, 1994 and Baydar, 2005 to determine the ideal sesame plant type or ideotype for different situations. The low amounts of solar radiation, often caused during the monsoon period due to short days and cloudy skies, could be partly responsible for the lower yield. Inrie, (1995) stressed that yield is the product of intercepted photosynthetically active radiation and conversion efficiency. Cultivar differences in leaf area were found (Kang, 1994). When the yield components and the sink is considered, they should be viewed in conjunction with the prevailing agronomic practices such as pure or mixed stand, low or high plant density and low or high inputs. For example, plant stand density would affect branching, while planting date will affect the height of the first capsule. The number of capsules/leaf axil is controlled by a single gene (T=1 capsule/axil and tt=2 or more capsules). Rheenen, (1981a) showed that cultivars with one capsule/axil and cultivars with three capsules/axil are grown in the same regions, neither types taking over the whole area. It may be concluded that the problem is in the production of the photosynthate-the source and not the number of capsules-the sink (Durga *et al.*, 1997). Similarly, Rheenen (1981b and 1981c) found that cultivars with long *vs.* short capsule and cultivars with four *vs.* multilocular capsules were cultivated in the same area and none of these types had a competitive yield advantage.

Kim and Lee (1981) in South Korea found that out of 1401, local landraces examined, 75% had one bicarpellate capsule/axil (4 locules); 20% had one quadricarpellate capsule/axil and 5% had three bicarpellate capsules/axil. Similarly, in Venezuela, 17 improved cultivars studied, about half were unbranched and the others were mixed in the three maturity groups, short, medium and late. In South Korea, where sesame is grown with high inputs, improved cultivars were released with one capsules/axil. There are various reports on correlations of the yield components, path coefficients and heritabilities, *e.g.* Lee and Chang (1986), Osman (1989), Ashri (1998) and Bedigian (2010). Their findings vary and are valid only for the particular genotype and environment and it is difficult to draw generalised conclusions.

Seed shattering

A limitation of sesame is that the capsules dehisce upon maturity and shatter the seeds. Mutations for seed retention were critical in the domestication of seed producing crops. The mechanisms involved differ, but generally, they are controlled by few major genes. Thus, it is possible that such a desirable mutation occurred in sesame, but was not noticed, or it was noticed but disregarded by growers, or that it did not occur. An indehiscent spontaneous mutant was discovered in 1942 by Langham (1946) in Venezuela, which was reported to be monogenically controlled. Later, digenic control was encountered in some crosses (Nafie 1980) and also modifiers (Ashri and Ladizinski 1964). In the homozygous recessive *idid* plants, the capsules are indehiscent due to structural changes in the mesocarp (Ashri and Ladizinski 1964). The *idid* plants have reduced seed set, lower seed yield, higher susceptibility to diseases and other undesirable features. Despite efforts by many researchers, the desired indehiscence could not be separated from the undesirable side effects, suggesting pleiotropism. The capsules of the *idid* indehiscent plants proved too difficult to thresh. Therefore, Culp (1960) proposed to breed indehiscent plants with the papershell trait (monogenic), but that also did not eliminate the difficulties.

Mutations for improved seed retention could affect capsule opening or produce stronger placenta. The need for good seed retention is considered even in some developing countries where manual labour is becoming scarce at harvest time and is essential for mechanized harvesting. For this reason, the FAO/IAEA has sponsored a research programme on induced mutations. The objective of the programme was to obtain non-shattering mutatnts. The participants reported inducing four indehiscent mutations in three Turkish cultivars (Cagirgan 1996, 1997), but their breeding value and undesirable effects are unknown. Semi-shattering mutants were also induced in Thailand (Maneekao *et al.*, 1997). The Sesaco company in the United States, founded by Langham and associates concluded that the crop must be harvestable by combine. They embarked on large scale breeding efforts with the *idid* allele and with stronger placenta, but these approaches proved unsuccessful. Sesaco breeders then developed cultivars whose capsules are more appressed, pointing upward, dehisce only part way from the tip and retain most of their seeds even when inverted due to stronger placenta attachment. The Sesaco cultivars S17 to S22 are of this type.

A recessive mutant (*gsgs*) termed seamless; whose capsules do not dehisce was observed by Langham and Langham (Ashri 1998; Bedigian, 2010). Capsules of *gsgs* plants appear to have only one carpel, although they have 4 rows of seeds. Unfortunately, in this mutant the stamens often abort and the plants have lower seed set. In addition; it was difficult to break open the capsules to seperate the seeds. Improved *gsgs* lines were developed; however their yield potential remained too low. Continued search for productive mutants by treating diverse cultivars with various mutagens and doses, should be a long-term effort. Large M_2 populations should be screened at maturity for seed retention. The *idid* materials might be mutagenized to eliminate the undesirable effects. However, since the latter are probably pleiotropic manifestations of the *idid* genotype, the probability of success is low.

Mechanization

At present, the majority of the sesame is harvested manually in the world. In several international meetings, there was a controversial prediction that unless sesame is mechanized in the next few decades, its world production will decrease significantly. In some lines, the seeds abscise from the placenta and in other lines, they are attached. The original placenta attachment discovered in Venezuela in 1956 was very fragile. Yermanos (1984) felt that it was too weak to provide shatter resistance. This character had been incorporated into Kinman lines and was present in S03 and S07. Through crossing lines with different placenta attachment genes and selection pressure, the placenta attachment has been strengthened enough to hold the seed to the combine. The lines primarily from Thailand, Myanmar and China have a hole in the membrane in the lower part of the capsule. In working towards a capsule split to expose the membrane, this lower hole can allow the seed to exit. This character of a hole at the bottom has been bred. The plant characters of consideration for mechanization are, height of plant, height of first capsule, branching and lodging resistance.

Plant types for stress intensive agriculture

Traditionally, sesame is grown extensively in drylands. It has a lot of inherent and acquired tolerance for the vagaries of monsoon and climate and hence, emerged as a potential choice for risk and uncertainties in tropical agriculture. The crop experiences moisture stress to varying degrees in different stages of crop growth. Sesame during its evolution and domestication acquired large number of agronomically inferior characters, which were essential for the sesame plant species survival. In the light of the advent of superior plant types for stress intensive conditions, the situation warranted the breeders to come in aid of the sesame. The efforts in reconstruction of plant types have led to the isolation of desirable types. The essential features of the plant types recommended for stress intensive agriculture are as follows. (a) medium/long duration (90-105 days), however, very late types are undesirable. (b) branching types (2-4 branches). (c) high degree of tolerance to leaf spots, powdery mildew and moderate tolerance to phyllody. (d) moderate tolerance to Antigastra and gall fly. (e) better adaptability and high regenerative growth after moisture stress. (f) fairly good tolerance to waterlogging. (g) medium/tall plant type. (h) less number of immature capsules and (i) fairly good synchrony in maturity. In the traditional areas in India, cultivars like Phule til-1, TC-289, JT-7, Gauri, Rajeshwari, DSS-9, CO-1 and types with introgression of local germplasm are recommended. The straight derivatives of exotic types should be advocated only after testing for the adaptability. Hence, indigenously bread stocks, possessing these features are the choice to the farmers.

Plant types for input intensive agriculture

A three-fold increase in average productivity was recorded in West Bengal, Andhra Pradesh, Tamil Nadu and Odisha in the nontraditional areas. Still higher potentials are demonstrated and also realised elsewhere (high yield range of 15-20 q/ha). At present, considerable area is coming up in different states in winter and summer seasons. The present day local type is a total misfit for input intensive agriculture due to the poor response to higher levels of management. The agronomic features of the plant types for input intensive agriculture are as follows. (a) short duration (75-85 days). (b) dwarf plant types. (c) photo and thermoinsensitivity. (d) higher response to added inputs and irrigation. (e) short internodal length and higher number of effective capsules. (f) perfect synchrony in maturity and (g) high harvest index. In the non-traditional areas for input intensive agriculture cultivars like RT-125, RT-127, TKG-21, TKG-22, TKG-55, Madhavi and HT-2 are the appropriate choice for the farmers. Selection of appropriate types for rainy, winter and summer seasons in different agroclimatic regions will enhance the productivity to a great deal, Hence, popularization of these ideal plant types is the pre-requisite for realizing a breakthrough in sesame productivity in different agro-production situations.

Exploitation of hybrid vigour in sesame

Hybrids combine characters from two parents with high adaptability associated with resistance to various biotic and abiotic stresses, low genotype x environment interactions and uniformity in yield. This concept led to the development of hybrids for exploitation of hybrid vigour. Male sterility in sesame was reviewed by Yermanos and Osman (1981), Weiss (1983), Osman (1985), Ashri (1998) and Bedigian (2010). The earlier accounts described sterility (male and female) or incomplete male sterility or only during the early part of the growing season. The genetic male sterility allele originated as a spontaneous mutation in Venezuela. Sesame lines with the male sterility allele were supplied by Mazzani, Venezuela to Yermanos at the University of California (Osman and Yermanos 1982). The male sterility proved to be monogenic and recessive (ms) in environments tested (Osman and Yermanos 1982; Yermanos 1984; Wang *et al.*, 1993; Tu *et al.*, 1995). When pollinated, the male sterile plants indicated seed yield that are comparable to male fertile plants (Osman and Yermanos 1982); The anthers of the male sterile plants are green and translucent, which facilitates identification of the male sterile plants in the bud stage, three to four days before anthesis. Gao *et al.* (1992) reported that in msms plants, the non-vacuolated microspores break down at the tetrad stage. China developed first genetic male sterile hybrid. The hybrid technologies for exploitation of heterosis are : (a) manual emasculation and pollination; (b) use of chemical hybridizing agents; (c) development of genetic male sterile line and (d) development of the cytoplasmic genetic male sterile line.

Manual emasculation and pollination

The flower of sesame is bell-shaped, campanulate with 2-3 cm long corolla with five epipetalous stamens, hence, removal of petals ensures emasculation easier. The anther dehices depending upon season and location; anthers are long viable (24 hrs); the stigma has very long viability (>48 hrs). Floral biology is such that out crossing per cent ranges between 5 and 15%. However, a split corolla line identified has very high out crossing to the tune of 70%, thus, makes outcrossing easier and can be maintained by selfing. Long flowering duration, high pollen density and one healthy male flower can pollinate 3-4 female flowers. High number of seeds/capsule (60) and low seed rate makes manual hybrid production easier. As the emasculated female line does not have any pollen in the flowers, the insect activity is minimal in female line, makes hand pollination system easy for production of hybrid seed. Still, other schools considers manual production of hybrid is laborious, time-consuming and uneconomical. The yield potential of hybrid is very high and in India, potential yield of 20-25 q/ha has been observed, whereas in China hybrids recorded yield of 25-30 q/ha.

Gemetocides

Manual emasculation of female line is time consuming, hence, use of a gametocide is considered as means of hybrid seed production. However, it has been observed that the application of a gametocide normally adversely affects ovule fertility and many of the morphological traits *viz.*, plant height, number of branches, capsules/plant, seeds/capsule and seed yield of male sterility induced female plants. It is therefore, important that while selecting gametocide and dose it must least affect the ovule fertility and plant morphology adversely (Sudhir Kumar and Reddy, 2005). Application of sodium 2, 3 dichloro isobutyrate 1000 mg/kg bud initiation stage followed by two sprays at 10 days interval was found effective. Whereas, application of Mandok 0.05% at bud initiation followed by two sprays at 10 days interval produced better pollen sterility in the female line without affecting ovule fertility. Chemical emasculation of sesame by growth regulators such as dalapon, FW 450 (2, 3 dichloro methyl propionic acid sodium salt) and sodium 2, 3-dichloropropionate was reviewed by Osman (1985). In China, Zhao (1994) reported that the gametocides caused hypertrophy of the tapetal cells with FW450 also found effective. However, found the best time for application to be just after PMC formation, this treatment is not applicable for indeterminate lines. Annamalai-I variety of sesame was treated with 1% EMS for 2 hrs and selected plants with > 60% sterility were advanced. Out of 15200, only three plants *viz.*, MS8A, MS14A, and MS15A were comparatively more stable for male sterility, however, these lines were weak for morphological and yield associated traits. The sib mated progenies produced more male fertile plants revealing departure from 1:1 ratio indicating that male sterile line have not attained stability for the trait. Physical and other chemical mutagens have been reported by various workers.

Development of a genetic male sterile line

Male sterility is expressed under homozygous recessive conditions and msms lines are maintained by crossing with heterozygous male fertile plants. The male fertile plants not linked with genetic marker are rogued at flowering stage, but, the marker linked plants are removed on expression of the character at seedling stage. However, effort for the development of stable male sterile lines through mutagenesis is in progress. Breeding lines containing the above *ms* allele has been distributed by Mazzani and Yermanos. Male sterility trait reported in a line of Venezuela, has been utilized into the materials adapted to diverse conditions, *e.g.* California (Yermanos and Osman, 1981) and China (Wang *et al.*, 1993; Wang *et al.*, 1995; Tu *et al.*, 1995). This male sterility gene has been used in production of hybrids in China.

Development of the cytoplasmic genetic male sterile line

Development of the cytoplasmic genetic male sterile line is a stable means for production of hybrid. The crossing between *S. malabaricum* and *S. indicum* followed by genomic substitution of *S. indicum* resulted in development of CGMS lines (Prabhakaran *et al.*, 1996 and Bhuyan and Sharma, 2003). The CGMS lines were developed through substitution of nuclear genome in genotypes TMV-3, TMV-4, TMV-6 and Co-1 and developed CMS T3, CMS T4, CMST6 and CMS7. Out of 70, hybrids tested Co-1/TNAU-11 indicated a standard heterosis of 182.6% for seed yield. Identification of a suitable pollen parents for exploitation of heterosis for producing standard hybrid is essential. Male sterility has been obtained in the cross of *S. malabaricum* x *S. indicum*, however, not in the reciprocal cross (Thangavelu, 1994), suggesting that inter specific crosses may produce genetic cytoplasmic male sterility.

Cross CMS CI/Payur-1,CMS T4/Payur-1 and CMS T4/Si 1525 exhibited high heterosis for seed yield followed by the number of capsules and oil content, while cross CMS CI/ Payur-1 and CMS T6/Payur-1 revealed heterosis for capsules. However, CMS T6/Si 1528 and CMS T4/SVPR-1 revealed high heterosis for test weight. In another study, CMS T6 / SVPR 1 revealed high heterobeltiosis for phenological traits. The characters days to flowering and maturity showed negative heterosis indicating development of early maturing hybrids. Several crosses revealed heterosis for seed yield, oil content, test weight and number of capsules. Heterosis to the tune of 152% was observed for seed yield followed by 1000 seed weight, number of branches and capsules.

Hybrid seed production technologies

The slow progress in increasing the yield of cultivars and the high yield increments (50%) of some hybrids have strengthened the sesame hybrid approach. Cross pollination through insects of male sterile plants presents no problem and each female plant can produce thousands of seeds. Tu (1993) calculated that seed produced on one ha of field can supply sufficient F_1 seed for 60-80 ha. Further, estimated that in China's conditions, F_1 hybrid could be produced economically by using the available genic male sterility and manually rouge out the male fertile plants from the female rows. The hybrid cultivar Yeti No. 9 (ms 86-1 x Danback) developed by Tu was covered by 6000 ha. in 1995 in China. Another approach being tested in China, farmers who grow small plots of sesame are supplied with the seed of the parents and trained to produce their own hybrid seed. The self labour, reduces the cost of the hybrid seed, and the increased F_1 yield, could make this option attractive to small holders. In India, it is proposed to produce hybrid sesame by hand emasculation and pollination because stable male sterile lines have not been developed (Thangavelu, 1994b; Manivannan and Ganesan, 2001).

For hybrid seed production by hand emasculation and pollination, one school considers prices are the limiting factor. The hand emasculation and subsequent pollination can be followed to produce the hybrid seed. The cost of hybrid seed production by this method is of concern. Manivannan and Ganesan (1993) estimated that an average of 2500 flowers may be produced from 440 plants/40 M^2. Male flowers collected from 10 m^2 may be enough as a pollen parent. The effective flowering period extended upto 15-18 days. The estimated production of hybrid seed was 2.5 to 3 kg/40 m^2 with the cost of about ₹ 200/kg seed. The estimated cost of hybrid seed produced by hand emasculation and pollination at Jalagon (AICORPO, 1993) involving hybrids Tapi x HT-24, ATPT-85-6 x Tapi and Tapi x CST-785 was worked out to be ₹ 1218/kg seed. In China, two hybrids were cultivated by hand emasculation and pollination method with a yield of about 3000 kg/ha. The number of capsules, seeds/capsule, 1000 seed weight seed yield and oil content are the important traits as they revealed a high degree of heterosis and also observed economic traits for hybrid production. Seed yield, number of seeds/capsule and 1000 seed weight with high *sca* indicated possibilities for exploitation of heterosis.

For production of hybrid seed, emasculation of appropriate flower bud is done in previous evening by holding the corolla between the index finger and thumb and smoothly slipping out by a gentle pull. As the stamens are epipetalous, they get themselves simultaneously removed along with the corolla. On an average, an individual can emasculate 2500 to 3500 flowers in a period of three hours. The following morning, healthy and robust flowers of a male parents are collected by smooth slipping of the corolla column and brushed on stigma of the emasculated flowers. Four flowers of a female parents can be pollinated by a single male flower. The process of dusting is attended between 6 and 9 AM. During this period, dusting of 800-1000 flowers could be completed. The care is taken to emasculate and pollinate all the flowers produced on a particular day. Any left-over flowers that missed emasculation are removed. The per cent of capsule set is as high as 80 (Manivannan and Ganesan, 1993). At Riverside (California), experience showed that emasculation and pollination could be done simultaneously in the green house and in the field (Yermonos, 1980). Seed set was also reported to be high (Osman, 1985).

Although sesame is largely self-pollinated, substantial levels of heterosis have been reported for certain hybrid combinations from various countries. High yield of F_1 hybrid, than those of the better parent have been reported by Murthy (1975), Brar and Ahuja (1979), Mazzani *et al.*, (1981), Osman and Yermanos (1982), Yermanos (1984), Osman (1989), Zhan *et al.*, (1990), Tu (1993), Murthy (1994), Durga *et al.*, (1994), Quijada and Layrisse (1995), Ashri (1998), Solanki and Gupta (2000), Duhoon (2001), Sumathi and Muralidharn (2009) and Bedigian (2010). Several sources of genetic male sterility are reported in sesame (Ashari, 1998; Bedigian, 2010). All these originated as mutations and are controlled by recessive gene(s).

In Venezuela, the preliminary trials with F1 hybrids were conducted by Mazzani *et al.* (1981). Further, evaluated a hybrid in the semi-commercial field which excelled at five locations. The F_1 seed were produced using male sterility. Commercial production of hybrid was tested in China. High heterosis encouraged to produce hybrids, but the lack of male sterility was a constraint; therefore, it was also suggested that F_2 populations of certain combinations would be useful with low inbreeding depression. Zhao (1994) reported that there was residual heterosis in F_2.

Generally, high level of heterosis was noticed, when the parents of hybrids were from divergent origins. There were also marked differences in the F_1 hybrid vigour between reciprocals (Ray and Sen, 1992; Tu, 1993), thus, a cytoplasmic component may be involved. General and specific combining ability were assessed in different hybrid combinations by various authors; their relative impact varied. Some authors considered additive gene action to be more important (Ibrahim *et al.*, 1983; Dharmalingam and Ramanathan, 1993; Inrie, 1995), while others considered the nonadditive components to be more important (Imrie, 1995; Quijada and Layrisse, 1995). The impact of additive *vs.* nonadditive genes is expected to vary from one hybrid combination to the other.

In view of the difficulties encountered in producing hybrid seed with the available genic male sterility, F_2 hybrids with residual heterosis were proposed in China (Zhao, 1994), but this approach was not adopted (Y. Li, pers. commun.). It is a problem, because of the loss of uniformity and the reduced vigour of the F_2 hybrid (Sodani and Bhatnagar, 1990). Use of the split corolla mutant, which reduces selfing as the maternal line is an alternate approach for the production of hybrid seed. If the crossing blocks are in isolated areas without other flowering plants around, insect pollinators will produce a high percent of out-crossed seed. Even if the cross pollination rate is only 50%, the yield increase will be considerable, provided the parents have high combining ability. An advantage of this system is that the split corolla maternal parent can be maintained by selfing.

Resistance breeding

Cultivars resistant to diseases, insect-pests, and abiotic stresses would be important, specially because in developing countries other means of control are scarcely used. *Macrophomina* is destructive and wide-spread. Phyllody, caused by phytoplasma transmitted by leaf hoppers, induces vegetative proliferation of the flower buds and is destructive. Screening is difficult since it depends on field conditions, vector population and disease infestation levels. The development of methods for inoculation and rapid disease identification, as well as better screening approach is also required.

Biotic Stresses

Sesame suffers from various diseases caused by fungi, bacteria, phytoplasma and virus. The IDM is structured to use of resistant varieties, cultural practices, surveillance and need based chemical control of the regions (Table 4).

Table 4 Host plant resistance against major diseases

Disease	Causal organism	Status of resistance
Stem and root rot	*Macrophomina phaseolina*	4 and 5, Cultivated and wild species
Phytophthora blight	*Phytophthora parasitica*	4 and 5, Cultivated and wild species
Alternaria leaf blight	*Alternaria sesami*	4 and 5, Cultivated and wild species
Phyllody	*Phytoplasma*	4 and 5, Cultivated and wild species
Wilt	*Fuarium oxysporum*	5, Cultivated species
Cercospora leaf spot	*Cercospora sesami*	4 and 5, Cultivated and wild species
Powdery mildew	*Leveillula taurica*	4 and 5, Cultivated and wild species
Bacterial leaf spot	*Pseudomonas syringae*	4, Genetic variation reported
Bacterial blight	*Xanthomonas campestris*	4, Genetic variation reported
Leaf curl	*Tobacco mosaic virus*	6

4:Partial resistance in germplasm; 5:Resistance present in wild species; 6:Not known

Phyllody and powdery mildew are the major diseases. No source of resistance is currently available in the varietal germplasm. However, wild *Sesamum* species have shown resistance to insect-pests and diseases (Parani *et al.*, 1996, Ashri, 1998). *S. malabaricum* has been reported to be resistant to shoot webber, powdery mildew and phyllody. Resistance to phyllody and *Phytophthora* blight has also been reported in *S. alatum* and *S. radiatum*. Among 11 major diseases of sesame, for nine diseases germplasm exhibited partial resistance and for five diseases, wild species recorded high resistance. As varietal replacement can provide a spatial and temporal discontinuity against the pathogen, use of resistant varieties has been the main approach. The use of resistant varieties is the cheapest and effective means of controlling diseases (Lee *et al.*, 1985a). However, in sesame levels of resistance/ tolerance is very low (Table 5). There are lines varying from tolerant/resistant to extreme susceptibility to root rots, bacterial leaf blight and drought.

Table 5 Resistant/tolerant reaction of varieties to major diseases

Variety	Pb	Msr	Bls	Blb	Alt	Cer	PM	Phyll	Lc
JT-21				+		+			
TKG-22	+								
TKG-55	+	+							
JTS-8	+		+		+				
RT-46		+							
RT-54		+			+				
RT-103		+	+					+	
RT-125		+	+					+	
RT-127		+		+			+	+	
Sekhar								+	+
Gautama					+				
Usha					+				
TSS-6					+			+	

Pb: *Phytophthora* blight; Msr: *Macrophomina* stem/root rot; Bls: Bacterial leaf spot; Blb: Bacterial leaf blight; Alt: *Alternaria* leaf spot; Cer: *Cercospora* leaf spot; PM: Powdery mildew; Phyll: Phyllody; Lc: Leaf curl

Antigastra occurs regularly in the sesame growing areas and damage the crop in all the stages. The pest has been reported to cause up to 50% yield loss. Partial resistance was found for leaf webber and capsule borer in germplasm as well as in wild species. RT-46, RT-54, RT-103, RT-125, RT-127, TKG-21, TKG-55, TKG-22, Usha, Sweta Til, Tapi, Krishna, N-32, JTS-8, MT-75, Hima, SI-250 and TMV-3 varieties showed field tolerance against leaf roller/capsule borer. RT-46, Sweta Til, RT-103, RT-125, OMT-26, RAUSS-17-4 and N-32 varieties have shown tolerance against gall fly. RT-46, RT-103, Sweta Til, RT-127 and N-32 for *Antigarstra* and *Asphondylia*. MT-75 and showed tolerance against bud fly and RT-127 for gall fly and mites, respectively.

Abiotic stresses: Sesame faces various stresses such as waterlogging, fluctuations in temperature, photoperiod, salt concentration and drought. The climatic factors such as precipitation, humidity and soil factors will influence the growth. Sesame is considered to be a drought resistant than many other crops. Resistance to drought is associated with tropical origin and high root shoot ratio. However, during the plant establishment phase, it is susceptible to moisture stress. Drought resistance has shown negative correlation with the resistance to the toxicities of potassium chloride, permeability and rate of water absorption. Varieties having low water absorption rates in conditions of high temperature were tolerant to water stress. A comparison of dehiscent and indehiscent types showed that water conductance under irrigated conditions in dehiscent types was higher than in indehiscent types. Thus, there were greater leaf water deficits in shattering than in nonshattering types due to faster transportation in hot weather. Thus, indehiscent types seem to be better suited to water stress. Single stem types are reported to have more rapid root elongation than branching types, but root spread in branching types is greater. The root/shoot ratio is generally higher in dry region types. Therefore, root depth and elongation rate, rather than the root/shoot ratio may be used as selection criteria. Among the wild species, *Sesame angustifoluim* is drought resistant as it shows a high per cent of the capsule set (89%) during the dry season. The adaptive features of this species are fleshy roots, small linear leaves, a large number of stomata located only at the adaxial surface; hairiness and high capsule set in the dry season. This species has the potential of donating valuable genes for resistance to drought.

Sesame normally requires fairly high temperature. Temperature for optimum growth from seedling to flowering and fruiting is in the range of 27-33°C. Considerable genotypic variation to temperature has been found. Temperatures of 40°C or above at flowering will affect fertilization and seed set. On the other hand, if temperature falls below 20°C for long time, germination and seedling growth are delayed and these processes are inhibited at temperatures below 10°C. However, lots of genotypic differences were noticed.

Sesame is very sensitive to waterlogging; however, varieties show tolerance to the considerable extent. Some wild types with resistance to waterlogging have been reported. Some varieties from Venezuela have been reported tolerant to varying duration. Sesame is believed to be susceptible to salt concentration; however, variability among cultivars has been reported. Sesame variety TMV-1 has been found to be tolerant to sea water. Since, a lot of variability is reported, there is scope for breeding varieties suitable for high salt concentrations. Sesame has been reported sensitive to boron. Phosphorus concentration was found to change the salt tolerance.

There appears to be negative linkages between the yield and stress tolerance. Attempts have been made to understand the response of plants to stress. The genes have been identified that are down regulated in response to stress. The response of genes is monitored following a change in the environmental conditions, be it dehydration, salinity, heat and cold. It is expected that gene knockout and RNAi techniques will help in understanding the role of other unknown genes. The studies should involve approaches to understand the basis of stress tolerance and an integrative approach towards stress tolerant transgenic plants.

Mutation breeding

Sesame has a wide range of genetic variability; however, certain desirable traits have not been found including resistance against major diseases and better seed retention. These needs promoted investigators to initiate mutation programmes. FAO Expert Consultations (Ashri, 1981, 1985 and 1987) recommended that induced mutations be used to enhance the genetic variability, that can be easily identified in large populations, *e.g.* resistance to major diseases, insect-pests, seed retention and plant architecture.

Sesame has been treated with radiations, mainly gamma-rays and chemical mutagens, mainly with ethyl methane sulfonate and also with sodium azide. Sesame seeds proved less sensitive physiologically to the various mutagenic agents; therefore higher doses can be used (Ashri 1982). The higher doses result in additional undesirable mutations that may cause masking effect on the desired mutants. Therefore, reported genotypic differences in sensitivity to the mutagens. Ashri (1982) reported that some cultivars recorded good germination in M_1 population after treatments with 0.4% and 0.5% EMS. Mutations recorded low germination and M_1 plants were sterile and stunted. Further, demonstrated genotypic differences to gamma-rays. Venezuelan cultivars were tested for the gamma rays and even for the sensitive cultivars, the LD 50 was 630 Grey (Gy.) and for the resistant it was 800 Gy (Ashri, 1998; Bedigian, 2010). Also noticed differences in cultivar tolerance to seed irradiation, M13 was more tolerant to gamma-rays than M12, although both were tolerant. Kamala and Sasikala (1985) found widely different sensitivity levels between cultivars. The three selection procedures following gamma irradiation, indicated that single plant selection from M_2 rows was best. The M_2 plants in bulk growing of cultivars is a good alternative (Ashri, 1998; Bedigian, 2010).

Pioneering investigations on induced mutations were conducted by Kobayashi (1965) who reported both morphological and developmental mutants. A wide range of mutants was found (Murthy, 1994) as in other crops. Some of the induced mutations had agronomic value as markers in genetic and molecular studies. The nonshattering trait was obtained through mutation, since it was absent in germplasm, Cagirgan (1996, 1997) in Turkey induced three such mutants with breeding affinity to the *idid* allele. In Thailand, Wongyai *et al.* (1997) reported a delayed shattering mutant. Further, developed semi shattering mutants in sesame (Ashri, 1998; Bedigian, 2010).

A monogenic recessive, determinate mutant with a unique plant architecture and clustered capsule was induced by Ashri with gamma rays (500 Gy) in the Israeli cultivar No. 45 (Ashri, 1988, 1995). Typically, five to seven capsules are arranged at the tip of the main stem and the branches and the internodes are small with reduced plant height. The mutant termed dt. 45 has larger seed than the source cultivar (Ashri, 1988; Brigham and Khan, 1989) which contains the same amount of oil and protein as the original cultivar (Brigham *et al.*, 1990; Khan *et al.*, 1991) and was bred into diverse genetic backgrounds. Pungsan was released in South Korea in 1996, resulted from incorporation of dt. 45 into a locally adapted cultivar (Kang et al., 1993; Kang 1997). The Sesaco programme, with crosses involving dt 45, produced several promising lines, with desired branching pattern and disease resistance (Ashri, 1998; Bedigian, 2010). Brigham attempted crosses with dt. 45 in Texas and selected promising lines. A similar mutant was induced in Turkey. Short flowering period mutations leading to uniform maturation were induced with EMS and gamma-rays in Thailand (Wongyai *et al.*, 1997).

The genetic male sterility mutants have been reported. A naturally occurring male sterile mutant found in Venezuela was used in breeding. Using gamma-rays (300-600 Gy.), four male sterile mutations were induced in India (Murthy, 1997) but some were also female sterile. Six male sterile mutations were induced in China (Li, 1997) and three were used in Turkey (Cagirgan, 1997). Male sterile mutations were induced by Rangaswamy and Rathinam (1982) and by Ramanatham *et al.* (1992) with lower gamma ray doses.

A polypetalous mutant, with the split corolla tube (known also as the star flower), reduces the opportunity for self-pollination was discovered by Langham (1947b) in Venezuala. It was also induced with gamma-rays by Murthy and Oropeza (1989) in Venezuela and with fast neutrons by Murthy and Bhatia (1990) in India. Induced disease resistance mutants have been reported in several regions. Lee *et al.* (1984) induced a mutation that resulted in moderate resistance to *Fusarium* and *Rhizoctonia* and resistance to *Corynespora* and *Phytophthora*. This mutant line was released as Ahnsan. In Sri Lanka, mutations were induced for resistance to *Phytophthora* and one of them was released as the cultivar ANK-82 (Bedigian, 2010). Variation for fatty acid content was induced by gamma-rays (Lee *et al.*, 1984) and by sodium azide (Kang, 1997) in South Korea. These efforts culminated with the release of Seodun, which has higher oleic content with better tolerance to *Phytophthora*. Heterosis was observed in hybrids between mutants originating from the same cultivar (Murthy, 1979).

Varieties developed through mutation breeding

The varieties have been developed through the use of induced mutations in some countries (Table 6), of which 13 varieties have been developed through the direct use of mutations and two through hybridization (Ashri, 1998). Ahnsan variety, released in South Korea with improved disease resistance was a major cultivar, grown in 1996 on 30% of the sesame area. Uma, Prachi, Nirmala and Usha are important in India, while the other cultivars cover small areas in the countries of their origin.

Table 6 Sesame varieties developed from induced mutations

Country	Variety	Year	Mutagen	Main character
Egypt	Cairo white 8	1992	Gamma rays	Non-branching
	Sinari white 48	1992	Gamma rays	Seed colour
India	Kalika	1980	EMS	Short
	Uma	1990	Chemical mutagen	Uniform maturity
	Usha	1990	Chemical mugaten	Higher yield
	Nirmala	2002		Diseases resistance
	Prachi	2002		Diseases resistance
Iraq	Babil	1992	Gamma rays	Earliness
	Rafiden	1992	Gamma rays	Earliness
	Eshtar	1992	Gamma rays	Capsule size
South Korea	Ahnsan	1985	X-rays	Disease resistance
	Suweon	1991	Cross with mutant	Lodging and diseases resistance
	Yaung back	1995	Sodium azide	Higher oil content
	Pangsan	1996	Cross with mutant	Determinate habit, seed retention
	Seedun	1997	Sodium azide	Higher oleic acid, *Phytophthora* tolerance
Sri Lanka	ANK-2	1995	Gamma rays	Disease resistance.

Breeding for quality attributes

Sesame oil plays an important role in Ayurvedic medicine. It is rubbed into the skin during abhyanga, to remove the impurities from the body. Sesame oil also has a reputation as a sedative in medicine. In Chinese system of medicine, dry flowers are used in curing frostbite and constipation. It is also used to cure common wart and clusters of warts, which are usually found in folk of China and showed a good result. Sesame seed contains unique substances, sesamin and sesamolin. These substances belong to a group of beneficial fibers called lignans. Sesame seeds are a good source of copper and calcium, also high, phosphorous, zinc, iron and magnesium. The seeds also have a good amount of vitamin B1, tryptophan and dietary fibers in different genotypes.

Oil content and fatty acid composition are the important components for quality breeding (Were *et al.*, 2006b). Oil content generally ranges from 35 to 58%, with oil in most of the commercial cultivars hovering around 50%. Sesame oil primarily comprises oleic acid, linoleic acid, palmatic acid and steric acid. Genotypic variation was observed for the proportion of fatty acids, but in general oleic acid and linoleic acids account for a predominant proportion (Lee *et al.*, 1984; Ashri, 1998; Bedigian, 2010). Oleic acid in Indian germplasm generally ranged from 39 to 48% while for linoleic acid the genotypic variation was from 30 to 45%. Higher level of palmatic acid (9.4-14.6%) is a matter of concern and its reduction appears a tangible breeding goal. Genotypic variation for protein content was noticed with a range of 19 to 30%. Sesame oil is unique in possessing lignans antioxidants as well as tocopherols. Cultivated types generally contain four lignans. These include sesamin, sesamolin, 2- episesalatin and sesangolin. These lignans prevent oxidation of sesame oil, impart stability and help increasing the shelf life. Sesame components serve as viable natural sources of antioxidants for food and non food applications. To breed high quality types, the total phenolic content, trolox equivalent antioxidant capacity assay, free radical scavenging capacity, inhibition of low density lipoprotein cholesterol and metal chelating capacity of extracts of whole black and whole white sesame seeds and their hull fractions in aqueous ethanol were investigated. Results demonstrated considerable antioxidant activity of sesame products tested specially black sesame hulls. A good free radical scavenging capacity of antioxidants from sesame cake extracts has also been indicated. Therefore, consumption of sesame rich in lignans results in physiological activity to alter lipid metabolism in a beneficial manner. With the growing health consciousness, the international demand and export of sesame are continuously increasing (Ashri, 1998; Bedigian, 2010). The pesticide residues was the major problem in the promotion of sesame export.

For breeding superior quality types, evaluated the genetic stocks in sesame (Ranganatha *et al.*, 2012). The genotypes are evaluated over the years and at different locations for quality attributes. During 2009, the lowest of FFA 0.80% was recorded in Tarun, followed by HT-1 (0.83%), T-13 (0.96%), TKG-21 and AKT-64 (0.97%). The oxalic acid content ranged from 0.49% in RT-103 to 1.87% in Prachi. Thirty varieties recorded less than 1% oxalic acid content. The oil content ranged up to 53.7% in Purva-1. The other entries exhibiting higher oil content included Tarun (50.8%), RT-346 (50.4%), JTS-8 (50.3 %) and TC-289 (50.0%). During 2010, the lowest FFA of 0.65 to 0.69% was recorded in AKT-64, Swetha Til and Shekhar. Oxalic acid ranged to the lowest of 0.49% in Swetha Til and 0.50 in AKT-101. Thirty three varieties recorded less than 1.0% oxalic acid. The entries with high oil included TKG-22, AKT-64 and Phule Til-1. During 2011, the lowest value of 1.07% FFA was recorded in DS-1, followed by T-13 (1.15%) and Rama (1.37%) and also other 26 varieties recorded less than 2.0% FFA. The oxalic acid ranged to the lowest of 0.66% in DS-1 and 0.70 in RT-127. Fifteen varieties recorded less than 1.0% oxalic acid. Based on the mean over locations and years, AKT-64, TC-289, TKG-55, RT-127, RT-346, Swetha Til. AKT-101 and TKG-21 were identified as desirable varieties for quality attributes.

Evaluation of Vietnamese and Combodian collections revealed oil content of 47.2 to 55.6% and mean oleic acid of 37.65% linoleic acid of 45.67% in the germplasm (Pham, 2011). Were *et al.* (2006 B) reported oleic acid of 31.6 to 41.9% and linoleic acid 42.9 to 53.9% in the genetic stocks. Uzun and Cagirgan (2009) identified molecular markers linked to determinate growth habit in sesame. Genotypic variation for fatty acid composition and oil content was noticed in the determinate and indeterminate types of sesame (Uzun *et al.*, 2009). Further, indicated indeterminate types accumulated higher oil content than determinate types.

Biotechnological approaches for sesame improvement

Tissue culture technology has been employed for crop improvement. However, little information is available on sesame. Sesame is found to be recalcitrant in nature. The first study on tissue culture in sesame was that of Lee *et al.* (1985b). George *et al.* (1987) have established tissue cultures from different parts. Kim *et al.* (1987) studied the effect of explants and hormone combination on callus induction. Chae and Park (1987) have established herbicide tolerant cell lines without achieving the plant regeneration. Lee *et al.* (1988) and Kim and Byeon (1991) investigated the effect of growth regulators on callus induction and organogenesis from different explants. Micropropagation has been achieved from shoot tip (Rao and Vaidyanath, 1997), nodal (Gangopadhyay *et al.*, 1998) and leaf (Sharma and Pareek, 1998) cultures. Somatic embryos have been obtained from zygotic embryos (Ram *et al.*, 1990) and seedling derived callus (Mary and Jayabalan, 1997; Xu *et al.*, 1997) with low frequencies in callus cultures. Indirect adventitious shoot regeneration from hypocotyl and/or cotyledon explants has been reported but at low frequencies (Rao and Vaidyanath, 1997b; Takin and Turgut, 1997; Younghee, 2001). Bhasker and Jayabalan (2006) reported reproducible micropropagation, callus induction protocol and morphogenesis. Were *et al.* (2006a) reported influence of nutrients, plant growth hormones and genotypes on adventitious shoot regeneration from cotyledon explants. Seo *et al.* (2007) reported the high frequency plant regeneration through direct adventitious shoot formation from deembryonated cotyledon segments. Chattopadhyaya *et al.* (2010) obtained an efficient protocol for shoot regeneration from internodes using the transverse thin cell layer culture method. Abdellatef (2010) evaluated the in vitro regeneration capacity of sesame cultivar exposure to culture media containing ethylene inhibitors such as cobalt chloride and silver nitrate and found growth promotive effect due to reduction in ethylene concentration or inhibition of ethylene action.

Embryo culture procedures were developed for rescuing interspecific F_1 hybrids. Qu *et al.* (1994) have described a successful embryo culture. The embryos of *S. schinzianum* x *S. indicum* were cultured 9 to 13 days after pollination. The embryos that germinated were transferred to MS medium supplemented with 0.2 mg BA/L for two weeks and then to MS medium supplemented with 0.5 mg NAA/L. Initial studies on anther culture in order to obtain haploid plants was reported by Kang (1994). However, haploid plants could not be produced. Vikas Kulkarni *et al.* (2011) have used embryo rescue method in interspecific hybridization between *Sesamum indicum* with *S. mulayanum* to develop male sterile lines. It is reported that a limited success has been achieved. Protoplast isolation and fusion protocol for sesame was investigated by Bapat *et al.* (1989).

The sesame yield potential is lower when compared with major oilseed crops due to early senescence and susceptibility to biotic and abiotic stress factors, including photosensitivity (Rao *et al.*, 2002). Wild species of sesame possess genes for resistance to biotic and abiotic stresses (Brar and Ahuja 1979; Weiss 1983; Ashri 1998; Toan *et al.*, 2011). However, introgression of useful genes from wild species into cultivars via conventional breeding has not been successful due to post fertilization barriers. The option is to transfer genes from other sources through genetic transformation. However, the obstacle to genetic transformation is the recalcitrant nature of sesame to in vitro regeneration. Hairy root cultures using Agrobacterium rhizogenes have been established (Ogasawara *et al.*, 1993; Jin *et al.*, 2005). Sesame has been shown to be susceptible to *A. tumefaciens*, but no transformed shoot/plant was recovered (Taskin *et al.*, 1999). Yadav *et al.* (2010) reported conditions for establishing an *A. tumefaciens* mediated transformation protocol for generation of fertile transgenic *Sesamum indicum* plants. This was achieved through the development of an efficient method of plant regeneration through direct multiple shoot organogenesis from cotyledon explants and the establishment of an optimal selection system. Using hypocotyl and cotyledon of sesame seedlings, Chun *et al.* (2009) established hairy root cultures and cDNA coding for a peroxidase was cloned from the roots. The frequency of hairy root formation was higher in hypocotyl than cotyledon. The sesame peroxidase gene was differentially expressed in different tissues.

DNA markers provide a tool for the marker assisted breeding and specially for cultivar identification. Among the different types of molecular markers, RAPD markers are useful for the assessment of genetic diversity. RAPD markers have been used in several crops. Abdellatef *et al.* (2008) used RAPD markers to characterize germplasm collections from Sudan. Diversity estimates provide a rationale for conservation and support the selection of material for breeding. Laurentin (2008) assessed metabolic diversity by non targeted metabolic profiling and elucidate the relationship between metabolic and genome diversity and observed different patterns of diversity at the genomic and metabolic levels indicating that selection plays a significant role in the metabolic diversity. Laurentin and Karlovsky (2007) and Ali *et al.* (2007) successfully used AFLP to distinguish cultivars to elucidate the genetic relationships among genotypes.

Suh *et al.* (2003) obtained 3328 ESTs from a cDNA library of 5-25 day old immature sesame seed. To compare gene expression profiles during development of green and nongreen seeds, a comparative analysis was carried out between developing sesame and Arabidopsis seed ESTs. Analysis of these two seed EST sets helped to identify similar and different gene expression profiles during seed development and to identify a large number of sesame seeds specific genes. They identified EST candidates for genes possibly involved in the biosynthesis of lignans, sesamin and sesamolin and also suggested a possible metabolic pathway for the generation of cofactors required for synthesis of storage lipid in nongreen oilseeds. Seed specific expression of several candidate genes was confirmed by northern blot analysis.

Sesame oil contains a high percent of linoleic and oleic fatty acids that is mostly used as food. The successful foreign gene transfer to a plant using genetically manipulated strains of *Agrobacterium tumefaciens* was reported. *In vitro* regeneration (Taskin and Turgut, 1997), *in vitro* propagation (George *et al.*, 1987), shoot tips culture (George *et al.*, 1987), protoplast culture (Bapat *et al.*, 1989) and naphthaquinone production (Ogasawara *et al.*, 1993) has been reported (Ashri, 1998; Bedigian, 2010). Taskin *et al.*, (1999) reported the susceptibility of a cultivar to *Agrobacterium tumefaciens*. Screening studies on susceptibility to infection by *Agrobacterium* by using cotyledon explants showed that tumers induced by the succinamopine strain A281 were extensive than by the octapine strain A136 NC, resulting in stable T-DNA transfer at a low frequency. However, no shoot regeneration was obtained. This was attributed to the low regeneration ability of sesame. The determination of genetic differences among genotypes has become the primary need to grant patent and the protection of PBR. Sharma *et al.* (2009) employed RAPD and ISSR markers for the characterization of sesame genotypes and suggested that putative variety specific RAPD and ISSR markers could be converted to Codominant SCAR/STS markers to develop robust variety specific markers.

Future perspective

- For sesame to be competitive, it should produce higher yield more reliably. Hence, it is essential to enhance the position of sesame in relation to other crops. Breeding high productive cultivars will assure continued production in the traditional growing areas, maintaining present crop options. Furthermore, for cultivation in better situations to provide new areas (Rabi- summer irrigated). Breeding programmes aimed at transgressive segregants for higher yield should be the priority.
- India will remain the leading country for sesame production and it will remain an important oilseed crop in the world, particularly in Asia. Efforts should be intensified to enhance germplasm resources, including filling the gaps with detailed investigations on wild species. Future collection and evaluation efforts should be closely coordinated. There should be enhanced networking and better exchange for rapid gains from genetic resources. The significant issue is the scarce

representation of the secondary and tertiary genepool in the PGR.

- The areas so far unexplored for plant genetic resources and diversity in landraces concentrated need to be considered. Wild species are rich source for resistance to stress. Only few species are represented with an insufficient number of samples. The situation warrant collection through specific explorations. The germplasm of wild species of African origin need to be assembled either through collaborative explorations or through mutual exchange.
- Biosystematic studies and the genome analysis of sesamum species is required. Documentation of all the germplasm is imperative to facilitate better utilization. Registration of candidate germplasm with distinct characters needs to be attended on priority to avoid IPR conflicts.
- The wild species have been reported to possess desirable genes like resistance to *Antigastra,* powdery mildew, wilt, bacterial blight, drought resistance, tolerance to heavy rainfall, erect branching, long capsules, fleshy roots and more seeds per capsule. The desirable characters are high yield potential coupled with harvest index, seed retention, uniform maturation through determinate habit. Future efforts for acquisition should focus on obtaining donors for the desirable traits.
- Special efforts are needed to establish and refinement of core collection and investigations on interspecific relationships for gene transfer.
- The important characters for breeding are high oil, protein, high sesamin, sesmolin, reduced anti nutritional factors, large seed size, well filled, shape, colour, seed coat rough and easily removable.
- The seedling characters are fast vigorous germination and emergence with strong hypocotyl elongation, rapid growth in early stage, ability to germinate and withstand lower temperatures.
- The rapid roots' growth, deep tap root penetration with the well distributed secondary root system. The leaves medium to broad at base, narrow lanceolate towards apex, short petiole and higher photosynthetic efficiency. Capsules with full seed set, short internodes, height varying with conditions and seasons.
- Determinate growth habit with a uniform and short capsule ripening period. Non shattering suitable for machine or traditional harvest.
- An improved harvest index should be stressed, thus reducing unproductive biomass. In sesame, harvest index varies from 15 to 20% and possibilities exist to double with improved plant types.
- Resistance to waterlogging, drought, salinity, non-lodging under high fertility and uniform maturity.
- The heterosis breeding should receive highest priority with emphasis on development of stable cytoplasmic genetic male sterility system or linked markers. The cytoplasmic male sterility is likely to be developed through inter specific crosses. In countries where the land holdings are small, farmer produced hybrids may be explored, preferably with hand emasculation and pollination. Development of suitable CGMS hybrid with diversification of lines for stability and resistance to stress may be undertaken using alien germplasm.
- Genetically superior divergent materials should be used in breeding. The backcross and induced mutation approaches should be employed for specific goals. It is very essential to consider the factors responsible for the lower seed yield under specific situations.
- Genotypes or hybrids with the potential to respond to added inputs should be developed. The efforts to discover with good seed retention should be continued. Attention should be paid for resistance to all abiotic stresses including salt resistance.
- Commonly cultivated varieties in sesame lack defensive traits against major diseases and insect pests leading to significant loss and instability in production. The rich source of resistant germplasm and wild species has not been effectively utilized in developing agronamically acceptable resistant varieties. Wherever damage is severe and the resistance is too low or absent, it should be augmented with transgenic sources. Modern tools like molecular markers should be employed for enhancing the efficiency of resistance breeding to make oilseed production more sustainable.
- Majority of sesame varieties are sensitive to photo and thermo periods, hence limits cultivation across seasons and regions. Therefore, breeding for wider adaptation is important.
- Breeding of special types for various export markets is very important. Hence, white, bold, high lignans and low free fatty acid, oxalic acid and phytic acid types are required.
- Sesame is used very widely for medicinal purposes and meeting the growing demands is essential, through better focus on germplasm utilization and combining conventional and non conventional approaches of sesame improvement.
- Studies to develop reproducible screening techniques for the diseases and insect-pests are required. Some of the major diseases to be addressed are *Macrophomina,* phyllody, *Alternaria, Cercospora,* powdery mildew,

through various breeding approaches. A breakthrough for resistance to phyllody will have a significant effect on sesame yield specially in Southeast Asia.

- Biotechnology for sesame improvement will play an important role for the development of transgenics resistant to biotic and abiotic stresses. Sesame has the comparative advantage in quality aspects, which so far could get little attention. There is scope for value addition and nutritional improvement. Breeding efforts need to be intensified in order to facilitate marker assisted selection. A combination of in vitro studies, DNA manipulations and improved conventional breeding is required for sesame improvement.

REFERENCES

Abdellatef E, Ahmed M M M, Daffalla H M and Khalafalla M M 2010. Enhancement of adventitious shoot regeneration in sesame (*Sesamum indicum* L.) cultivar promo KY using ethylene inhibitors. *Journal of Phytology*, **2**(1): 61-67.

Abdellatef E, Sirelkhatem R, Ahmed M M M, Radwan K H and Khalafalla M M 2008. Study of genetic diversity in Sudanese sesame (*Sesamum indicum* L.) germplasm using random amplified polymorphic DNA (RAPD) markers. *African Journal of Biotechnology*, 7(24): 4423-4427.

Abraham A 1945. Cytogenetical studies on Sesamum. *Proceedings of Indian Science Congress, Abstract*, 46, p. 80.

Ali G M, Yasumoto S and SekiKatsuka M 2007. Assessment of genetic diversity in sesame (*Sesamum indicum* L.) detected by amplified fragment length polymorphism markers. *Electronic Journal of Biotechnology*, **10**(1):12-23.

Annapurna K M S 2003. Studies on karyoptype, genome size and genome relations in some species of *Sesamum* L. (Pedaliaceae). Ph.D. thesis, Karnataka University, Dharwar, India.

Annapurna K M S M S and Hiremath S C 2008. Cytological analysis of interspecific hybrid between *Sesamum indicum* L. X S.orientale L. var. malabaricum. *Karnataka Journal of Agricultural Science*, **21**(4):498-502.

Anonymous 2010. *FAO Production Year Book*, Food and Agriculture Organisation Rome.

Ashri A (Ed.) 1981. *Sesame status and improvement*. FAO Plant Production and Protection, Paper 29. Rome.

Ashri A (Ed.) 1985. *Sesame and safflower: Status and potentials*. FAO Plant Production and Protection, Paper 66, Rome.

Ashri A 1982. Status of breeding and prospects for mutation breeding in peanuts, sesame and castor bean. In: *Improvement of oilseed and industrial crops by induced mutations*. pp. 65-80.

Ashri A 1987. Breeding improved sesame cultivars. *Report on expert consultation*. IAEA, Vienna, p.14.

Ashri A 1988. Sesame breeding-objectives and approaches. In: *Oil Crops-Sunflower, Linseed and Sesame*. Proceedings of Workshop IDRC, Ottawa, pp. 152-164.

Ashri A 1990. Sesame genetic resources: collection, evaluation and conservation. In: *Oil crops: Sesame and Safflower Subnetwork*. Proceedings of Workshop, IDRC, Ottawa. pp. 2-9.

Ashri A 1994. Genetic resources of sesame, present and future perpestive. In : R.K. Arora and K.W. Riley (eds.). *Sesame biodiversity in Asia, conservation, evaluation and improvement*. IPGRI, New Delhi, pp. 25-39.

Ashri A 1995. Sesame research overview: current status, perspective and priorities. In: M.R. Bennet and I.M. Wood (eds.), *Proceedings of the First Australian Sesame Workshop*, Darwin and Katherine, Northern Territory.

Ashri A 1998. *Sesame Breeding*. Plant Breeding Reviews, 16: 179-228.

Ashri A and Ladizinski G 1964. Anatomical effects of the capsule dehiscence allele in sesame. *Crop Science*, **4**: 136-138.

Ashri A J, Lee I and Kang C W 1991. Evaluation of genetic resources in sesame oil and protein content in Israel and Korea. In: *Proceedings of Sesame Workshop. Oilcrops Network for East Africa and South Asia*. IDRC, Ottawa, pp. 40-48.

Azeez M A and Morakinyo J A 2011. Genetic diversity of the seed physical dimensions in cultivated and wild relatives of Sesame. (*Genera Sesamum* and *ceratotheca*). *International Journal of Plant Breeding and Genetics*, **5**(4):369-378.

Bapat V A, George L and Rao P S 1989. Isolation, culture and callus formation of sesame (*S. indicum* L.) protoplasts. *Indian Journal of Experimental Biology*. **27**(2): 182-184.

Baskaran P and Jayabalan N 2006. *In vitro* mass propagation and diverse callus orientation on *Sesamum indicum* L. an important oil plant. *Journal of Agriculture Technology*, **2**(2): 259-269.

Baydar H 2005. Breeding for the ideal plant type of sesame. *Plant Breeding*, **124**: 263-267.

Bedigian D and Harlan J R 1986. Evidence for the cultivation of sesame in the ancient world. *Economic Botany*, **40**:137-154.

Bedigian D 1981. Origin, diversity, exploration and collection of sesame. In: *Sesame: Status and Improvement. FAO Plant Production and Protection*, **29**: 164-169.

Bedigian D 1984. *Sesamum indicum* L: crop origin, diversity, chemistry and ethnobotany. Ph. D Dissertation, University of Illinois, Champaign, Urbana. Dissertation abstracts international 1985, 45: 3410-B.

Bedigian D 1988. Sesamum indicum L. (Pedaliaceae): Ethanobotany in Sudan, crop diversity, lignans, origin, and related taxa. In: Goldblatt P, Lowry PP (eds) *Modern systematic studies in African Botany*. AETFAT Monographs in Systematic Botany, 25. Missouri Botanical Garden, St. Louis, pp 315-321.

Bedigian D 1991. Genetic diversity of traditional sesame cultivars and cultural diversity in Sudan. In: Old field ML, Alcorn JB (eds), *Biodiversity: culture, conservation and eco-development*. Westview Press, Boulder, pp. 25-36.

Bedigian D 2003a. Evolution of sesame revisited: domestication, diversity and prospects. *Genetic Resources and Crop Evolution*, **50**: 779-787.

Bedigian D 2003b. Sesame in Africa: origin and dispersals. In: Neumann K, Butler A, Kahlheber S (eds), *Food, Fuel and Fields - Progress in African Archaeobotany*. Africa Prehistorica, Heinrich Barth Institute, Cologne, pp, 17-36.

Bedigian D 2006. Assessment of sesame and its wild relatives in Africa. In: Ghazanfar SA and Beentje HJ (eds), *Taxonomy and* *ecology of African plants, their conservation and sustainable use. Royal Botanic Gardens,* Kew, pp. 481-491.

Bedigian D 2010. *Sesame: the genus Sesamum. Medicinal and Aromatic Plants - Industrial Profiles series,* Chapter 2. CRC Press, Taylor and Francis Group, Boca Raton.

Bedigian D and Harlan J R 1983. Nuba agriculture and ethanobotany, with particular reference to sesame and sorghum. *Economic Botany,* **37**:384-395.

Bedigian D, Seigler D S and Harlan J R 1985. Sesamin, sesamolin and the origin of sesame. *Biochemical Systematics and Ecology,* **13**:133-139.

Bedigian D, Smyth C A and Harlan J R 1986. Patterns of morphological variation in sesame. *Economic Botany,* **40**:353-365.

Bhat K V, Babrekar P P and Lakhanpaul S 1999. Study of genetic diversity in Indian and exotic sesame (*Sesamum indicum* L.) germplasm using random amplified polymorphic DNA (RAPD) markers. *Euphytica,* **110**:21-33.

Bhuyan J and Sharma M K 2003. Identification of heterotic crosses involving cytoplasmic genetic male sterile lines in sesame (*S.indicum* L.). *Sesame and Safflower newsletter,* **18**: 7-11.

Bisht I S, Bhat K V, Lakhanpaul S, Biswas B K, Pandiyan M and Hanchinal R R 2004. Broadening the genetic base of sesame (*Sesamum indicum* L.) through germplasm enhancement. *Plant Genetic Resources,* **2**:143-151.

Bisht I S, Mahajan R K, Loknathan T R and Agrawal R C 1998. Diversity in Indian sesame collection and stratification of germplasm accessions in different diversity groups. *Genetic Resources and Crop Evolution,* **45**: 325-335.

Brar G S and Ahuja K L 1979. Sesame, its culture, genetics, breeding and biochemistry. *Annual Review of Plant Science,* **1**: 245-313.

Brigham R D and Khan S R 1989. Genetic variability of seed constituents in selected lines of sesame (*Sesamum indicum* L.). *Agronomy Abstracts,* pp. 75.

Brigham R D, Khan S R and Young J K 1990. Fatty acid development in seeds of seven breeding lines of sesame (*Sesamum indicum*). *Agronomy Abstracts,* pp. 81-82.

Cagirgan M I 1996. A preliminary report on the first induced indehiscent capsule mutants in sesame. *Proceedings of EUCARPIA.* Tropical Plants, Montpellier. France. p. 248.

Cagirgan M I 1997. Mutation breeding of sesame for intensive management. In: *Proceedings of Induced mutations for sesame improvement IAEA.* Veinna, pp. 85-95.

Cagirgan M I 2006. Selection and morphological characterization of induced determinate mutants in sesame. *Field Crops Research,* **96**: 19-24.

Chae Y A, Park S K and Anand I J 1987. Selection in vitro for herbicide tolerant cell lines of *Sesamum indicum* 2: Selection of herbicide tolerant calli and plant regeneration. *Korean Journal of Plant Breeding,* **19**: 75-80.

Chattopadhyaya B, Banerjee J, Basu A, Sen S K and Maiti M K 2010. Shoot induction and regeneration using internodal transverse thin cell layer culture in *Sesamum indicum* L. *Plant Biotechnology Reporter,* **4**: 173-178.

Chun J A, Lee J W, Yi Y B, Park G Y and Chung C H 2009. Induction of hairy roots and characterization of peroxidase expression as a potential root growth marker in sesame. *Biochemistry and Biotechnology,* **39(4)**: 345-359.

Culp T W 1960 Inheritance of papershell capsules, capsule number and plant color. *Journal of Heredity,* **51**: 146-148.

Dharmalingam V and Ramanathan T 1993. Combining ability for yield and its components in sesame. *Oleaginex,* **48**: 421-424.

Duhoon S S 2001. Heterosis breeding in sesame. *Manual,* International Training Course on Sesame Genetics and Breeding, AICRP (Sesame and Niger) JNKVV Jabalpur, pp. 98-111.

Duhoon S S, Koppar M N and Srivastava U C 2000. Sesamum Biodiversity conservation in Indian Sub continent. *National Journal of Plant Improvement,* **2**:32-39.

Duhoon S S, Sharma S M, Lakhanpaul S and Bhat K V 2004. Sesame. In : *Plant Genetic Resources: Oilseed and Cash Crops.* (eds) B.S. Dhillon, R.K. Tyagi, S. Saxena and A. Agrawal. Narosa Publishing House, New Delhi, pp. 118-135.

Durga K K, Raghunatham G, Ranganatha A R G and Sharma P S 1997. Genetic variability for physiological attributes in sesame (*Sesamum indicum* L.). *Crop Research Hisar,* 13(2): 349-359.

Durga K K, Raghunatham G, Ranganatha A R G. and Sharma P S 1994. Studies on the combining ability for morpho physiological, reproductive and yield attributes in sesame. *International Journal of Tropical Agriculture,* **12**(3-4): 248-254.

Gangoadhyay G, Poddar R and Gupta S 1998. Micropropagation of sesame (*Sesamum indicum* L.) by *in vitro* multiple shoot production from nodal explants. *Phytomorphology,* **48**: 83-90.

Gao H, Lin J and Tu L C 1992. Cytological studies on the mechanism of the abortion of microsporogenesis in nucleic male sterile sesame (*Sesamum indicum* L.). In: Chinese. (English Abstract.). *Acta Agronomica Sinica,* **18**: 425-430.

George L, Bapat V A and Rao P S 1987. *In vitro* multiplication of sesame (*Sesamum indicum*) through tissue culture. *Annals of Botany,* **60**:17-21.

Harlan J R 1970. Evolution of cultivated plants. In: Frankel OH, Bennett E (eds) *Genetic resources in plants, their exploration and conservation.* Aldine, Chicago, IL, pp 19-32.

Harlan J R 1975. Geographic patterns of variation in some cultivated plants. *Journal of Heredity,* **66**:182-191.

Harlan J R 1992. *Crops and man.* Agronomy Society of America, Madison, WI.

Hiremath S C and Patil C G 1999. Genome homology and the putative progenitor of sesame. *Journal of Cytology and Genetics,* **34**:69-74.

Ibrahim A F, El-Kadi D A and Ragab A I 1983. Studies in diallel crosses of sesame (*Sesamum indicum* L.). I. Heterosis and inbreeding effects. Proceedings of Agronomy Society Crop Science Cairo, pp. 567-576.

Ihlenfeldt H D and Grabow Seidensticker U 1979. The genus *Sesamum* L. and the origin of the cultivated sesame. In: Kunkel G (ed.), *Taxonomic aspects of African economic botany,* Proceedings of Plenary Meeting of AETFAT. Excmo, Las Palmas de Gran Canari, pp 53-60

Inrie B C 1995. The potential contribution of breeding to development of a sesame industry in Australia. In: M.R.

Bennett and I.M. Wood (Eds.). *Proceedings of Australian Sesame Workshop*. NT. Department of Primary Industry and Fisheries. Darwin. pp. 71-82.

Jin U H, Chun J A, Han M O, Lee J W, Yi Y B, Lee S W and Chung C H 2005. Sesame hairy root cultures for extra cellular production of a recombinant fungal phytase. *Progressive Biochemistry*. **40**: 3754-3762.

Joshi A B 1961. *Sesame-A Monograph*. Indian Central Oilseeds Committee, Hyderabad, India, p. 267.

Kamala T and Sasikala S 1985. Gamma ray and colchicine induced mutants in TMV 5 and IS 103 Sesamum. *Indian Journal of Agriculture Science*, **5**: 151-155.

Kang C W 1994. Sesame breeding and agronomy in Korea. Arora and K.C. Riley(eds.). *Sesame biodiversity in Asia: conservation, evaluation and improvement*. IPGRI, New Delhi, pp. 65-90.

Kang C W 1997. Breeding for diseases and shatter resistant high yielding varieties using induced mutations in sesame. In: *Proceedings of Induced mutations for sesame improvement* IAEA Vienna, pp. 48-57.

Kang C W, Lee J I, Park R K and Choi B H 1993. Mutation breeding for determinate disease, lodging resistance and high yield in sesame (in Korean, English Abstract). *Korean Journal of Breeding*, **25**: 235-247.

Kawase M 2000. Genetic relationships of the ruderal weed type and the associated weed type of *Sesamum mulayanum* Nair distributed in the Indian subcontinent to cultivated sesame, *Sesamum indicum* L. *Japan Journal of Tropical Agriculture*, **44**:115-122.

Khan S R, Brigham R D and Young J K 1991. Expression of heterosis and reciprocal effects in crosses with indeterminate lines of sesame (*Sesamum indicum* L.). *Agronomy Abstracts*, p.101.

Khidir M O 1972. Natural cross fertilization in sesame under Sudan conditions. *Experimental Agriculture*, **8** (1): 55-59.

Kim H Y and Byeon G H 1991. Effect of growth regulators on organ cultures of sesame. *Sub Tropical Agriculture*, **8**: 93-103.

Kim K C and Lee J I 1981. Yielding ability and characteristics of collections of local sesame (*Sesamum indicum* L.) In: Korean. (English Abstract) *Korean Journal of Crop Science*, **26**: 263-268.

Kim M K, Park S K and Chae Y A 1987. Selection *in vitro* for herbicide tolerant cell lines of *Sesamum indicum*: Effects of explants and hormone combinations on callus induction. *Korean Journal of Plant Breeding*, **19**: 70-94.

Kobayashi T 1965. Radiation induced beneficial mutants. In: *The use of induced mutations in plant breeding*. Penguin Press. Oxford, pp. 399-403.

Kobayashi T 1981. The wild and cultivated species in the genus Sesamum. In: *Sesame and Safflower : Status and Improvement* (A. Ashri, Ed.). FAO plant Production and Protection Paper 29, Rome.

Langham D C 1945a. Genetics of sesame. *Journal of Heredity*, **36**: 135-142.

Langham D G 1945b. Genetics of sesame. II. Inheritance of seed, pod number, aphid resistance, yellow leaf and wrinkled leaves. *Journal of Heredity*, **36**: 245-254.

Langham D G 1946. Genetics of sesame. III. Open sesame and mottled leaf. *Journal of Heredity*, **37**: 149-152.

Langham D G 1947a. Genetics of sesame. IV. Some genetic variations in the color of the sesame flower. *Journal of Heredity*, **38**: 221-224.

Langham D G 1947b. Genetics of sesame. V. Some morphological differences of the sesame flower. *Journal of Heredity*, **38**: 347-352.

Laurentin H E and Karlovsky P 2006. Genetic relationship and diversity in a sesame (*Sesamum indicum* L.) germplasm collection using amplified fragment length polymorphism. *BMC Genetics*, **7**: 10:537-471.

Laurentin H and Karlovsky P 2007. AFLP fingerprinting of sesame (*Sesamum indicum* L.) cultivars: identification, genetic relationships and comparison of AFLP informative parameters. *Genetic Resources and Crop Evolution*, **54**: 1437 to 1446.

Laurentin H, Ratzinger A and Karlovsky P 2008. Relationship between metabolic and genomic diversity in sesame (*Sesamum indicum* L.). *BMC Genomics*, **9**: 250-260.

Lee C H and Chang K Y 1986. Genetic studies on quantitative characters for sesame breeding (in Korean, English Abstract). *Koraen Journal of Breeding*, **18**: 242-248.

Lee J I, Kang C W and Lee ST 1984. Breeding of sesame (*Sesamum indicum* L.) for oil quality improvement. III. Variation of fatty acid composition in gamma ray irradiated M_2 population. (In: Korean. English Abstract). *Research Report on Rural Development*, Suweon, **26**: 134-143.

Lee J I, Lee S T, Kang C W, Oh S K, Seong N S and Ham Y S 1985a. A new disease resistant and high yielding sesame variety Ansangae. (in Korean, English. Abstract). *Research Report*, RDA Crops, **27**: 199 -202.

Lee J I, Park Y H, Park Y S and Kim B G 1985b. Propagation of sesame (*S. indicum* L.) through shoot tip culture. *Korean Journal of Breeding*, **17**: 367-372.

Lee S Y, Kim H S, Lee Y T and Park C H 1988. Effect of growth regulators, cold pretreatment and genotype in anther culture of sesame (*Sesamum indicum* L.). *Research Report Rural Development*. Administration Biotechnology, **30**: 74-79.

Li Y 1997. The induced mutations of sesame male sterility and heterosis breeding. In: *Proceedings Induced mutations for sesame improvement*. IAEA, Vienna, pp. 18-23.

Manivannan N and Ganesan J 1993. Standardization of hand made commercial hybrid seed production in sesame. Sympoisum on. Heterosis Breeding in crop plants - Theory and application, Punjab Agricultural University, Ludhiana, p. 103.

Manivannan N and Ganesan J 2001. Stability for seed yield in F_1 hybrids of sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **18**(1): 108-109.

Mary R J and Jayabalan N 1997. Influence of growth regulators on somatic embryogenesis in sesame. *Plant Cell Tissue and Organ Culture*, **49**:67-70.

Mazzani B 1985. Sesame growing in Venezuela. In: A Ashri (ed.) *Sesame and Safflower : Status and Potentials*. FAO Plant Production and Protection Paper 66.Rome, p. 86-89.

Mazzani B D, Montilla N, Rivas and Allievi G 1981. Breeding and evaluation of F_1 hybrid cultivars of sesame in Venezuela. In: A. Ashri (ed.). *Sesame status and improvement*. FAO Plant Production and Protection Paper 29. Rome, pp. 136-137.

Mitra A K and Biswas A K 1983. New record of *Sesamum mulayanum* Nair in West Bengal. *Science and Culture*,

49:407-408.

Murthy B R and Oropeza F 1989. Diversity pattern in Sesame mutants selected for a semi arid cropping system. *Theoretical and Applied Genetics*, *77: 275-286*.

Murthy D S 1975. Heterosis, combining ability and reciprocal effects for agronomic and chemical characters in sesame. *Theoretical and Applied Genetics*, **45**: 294-299.

Murthy G S S 1994. Induced mutants for hybrid sesame. In: *Hybrid sesame*. Directorate of Oilseeds Research, Hyderabad. India, pp. 42-49.

Murthy G S S 1997. Induced mutant for the improvement of sesame and hybrid seed Production. In: *Proceedings of Induced mutanions for sesame improvement*. IAEA, Vienna. pp, 31-38.

Murthy G S S and Bhatia C R 1990. Inheritance of polypetalous corralea mutation in sesame. *Indian Academy of Plant Science*, **100**:7-10.

Nafie A N 1980. The genetic control of indehiscence and the yielding ability of indehiscent gentoypes of sesame (*Sesamum indicum* L.). *Ph.D.* Dissertation University of California, Riverside.

Nanthakumar G, Singh KN and Vaidyanathan P 2000. Relationships between cultivated Sesame (*Sesamum* sp.) and the wild relatives based on morphological characters, isozymes and RAPD markers. *Journal of Genetic and Breeding*, **54**:5-12.

Nayar N M and Mehra K L 1968 Sesame; its uses, botany, cytogenetics and origin. *Economic Botany*, **24**:20.

Nohara S 1933. Genetical studies on *Sesamum indicum* L. *Journal College of Agriculture*, Tokyo Imp University, **12**:227-386.

Ogasawara T, Chiba K and Tada M 1993. Production and high yield of napthoquinone by a hairy root culture of *Sesamum indicum*. *Phytochemistry*, **33**:1095-1098.

Osman H E 1985. Studies in sesame. I. Hybridization and related techniques, In: A. Ashri (ed.). *Sesame and safflower status and potential*. FAO Plant Production and Protection Paper 66. Rome, pp. 145-156.

Osman H E 1989. Heterosis and path coefficient analysis in sesame (*Sesamum indicum* L.). *Acta Agronomica Hungarica*, **38**: *105-112*.

Osman H E and Yermanos D M 1982. Genetic male sterility in sesame: reproductive characteristics and possible use in hybrid seed production. *Crop Science*, **22**: 492-498.

Parani M, Singh K N, Rangasamy S R S and Ramalingam R S 1996. A study on mechanism of phyllody disease resistance in *Sesamum alatum* Thonn. *Current Science*, **70** (1): 86-89.

Pathirana R 1995. Comparison of selection procedures in breeding for seed yield in segregating sesame populations. *Euphytica*, **82**: 73-78.

Pham D T, Bui, M T, Werlemark G, Bui C T, Merker A and Carlsson S A 2009. A study of genetic diversity of sesame (*Sesamum indicum* L.) in Vietnam and Cambodia estimated by RAPD markers. *Genetic Resources and Crop Evolution*, **56**: 679-690.

Pham D T 2011. Analyses of genetic diversity and desirable traits in sesame : Implications for breeding and conservation. Ph.D. Thesis. Swedish University of Agricultural Sciences, Alnarp.

Prabhakaran A J 1996. Genetic diversity of wild sesame from southern India. *Plant Genetic Resources Newsletter*, **106**:44-46.

Qu Z X, Wu Y and Xia F J 1994. Embryo rescue and plant regeneration in interspecific hybridization between *Sesamum indicum* and *S. schinzianum*. (In. Chinese, English Abstract). *Oil Crops of China*, **16**: 33-35.

Quijada P and Layrisse A 1995. Heterosis and combining ability in hybrids among 12 commercial varieties of sesame (*Sesamum indicum* L.). *Plant Breeding*, **114**:239-242.

Rajan S S 1981. Sesame breeding material and methods. In : A Ashri (eds) *Sesame: Status and Improvement*. FAO Plant Production and Protection Paper, **29** : 97 -*102*. Rome.

Ram R, Catlin D, Romero J and Cowley C 1990. Sesame: new approaches for crop improvement. In: Janick J, Simon JE (eds) *Advances in new crops*. Timber Press, Portland, pp 225-228.

Ramanathan T, Durairaj M S and Prabakaran A J 1992. Induced male sterils in *Sesamum indicum* L. *Sesame and Safflower Newsletter*, **7**: 34-36.

Ramanujam S 1944. The cytogenetics of amphidiploids, *S. orientale* x *S. prostratum*. *Current Science*, **13**: 40-41.

Ramanujam S and Joshi A B 1951. The use of wild species in breeding improved varieties of cultivated til (*Sesamum orientale* L.) and some considerations on the origin and distribution of *S. orientale*. *Indian Journal of Genetics and Plant Breeding*, **11**:100-104.

Ramalingam R S, Rangaswamy S R S and Narayanan A 1994. Identification of Cytoplasmic-Genic Male Sterile (CMS) Sources in Sesame through Reciprocal Crosses. In: *Hybrid Sesame*, DOR, Hyderabad, pp. 23-26.

Ranganatha A R G and Virupakshappa K 1993. Evaluation of early generation yield testing, SSD and bulk breeding procedures in sesame. *SABRAO Journal*, **25** (2): 115-122.

Ranganatha A R G, Srinivas T, Virupakshappa K, Mahishi D M and Shivashankar G 1994a. Influence of segregating generations on character association in sesame. *Indian Journal of Genetics and Plant Breeding*, **54** (2): 192-196.

Ranganatha A R G, Virupakshappa K, Srinivas T and Shivashankar G 1994b. Effectiveness of early generation yield testing in sesame. *Oleagineux-Paris*, **49** *(2): 55-58*.

Ranganatha A R G, Anjay Tripathi, Seema Paroha, Aasfa Tabassum and Anuj Nema 2012. Evaluation of genetic stocks for development of superior export types in Sesmae. National Seminar on Plant Genetic Research for eastern and north eastern India, *Abstract*, ISGPB, IARI, New Delhi, p.57.

Rangaswamy M and Rathinam M 1982. Mutagen induced male sterile lines in sesame. *Indian Journal of Genetics and Plant Breeding*, **42**: 142-143.

Rao K R and Vaidyanath K 1997. Induction of multiple shoots from seedling shoot tips of different varieties of Sesamum. *Indian Journal of Plant Physiology*, **2**:257-261.

Rao K R, Kishor P B K and Vaidyanath K 2002. Biotechnology of sesame-An oilseed crop. *Plant Cell Biotechnology and Molecular Biology*, **3**: 101-110.

Ray S D and Sen S 1992. Heterosis in relation to combining ability in sesame. *Indian Journal of Genetics and Plant Breeding*, **53**: 21-27.

Rheenen H A van 1981a. The desirability of three versus one flowers and capsules per leaf axil in sesame (*Sesamum indicum* L.). In: A. Ashri (eds.). *Sesame status and improvement*. FAO

Plant Production and Protection Paper 29. Rome, pp. 97-102.

Rheenen H A van 1981b. The desirability of long versus short capsules in sesame (*Sesamum indicum* L.). In: A. Ashri (eds.). *Sesame: status and improvement FAO Plant Production and Protection Paper 29.* Rome, pp. 103-107.

Rheenen H A van 1981c. The desirability of multi versus four locular capsules in sesame. In: A. Ashri (ed.). *Sesame status and improvement.* FAO Plant Production and Protection Paper 29. Rome, pp. 108-112.

Seo H Y, Kim Y J, Park T I, Kim H S, Yun S J, Park K H, Oh M K, Choi M Y, Paik C H, Lee Y S and Choi Y E 2007. High frequency plant regeneration via adventitious shoot formation from deembryonated cotyledon explants of *Sesamum indicum* L. *In Vitro Cell Development and Biology*, **43**: 209- 214.

Sharma M and Pareek L K 1998. Direct shoot bud differentiation from different explants of in vitro regenerated shoots in sesame. *Journal of Phytology Research*, **11**: 161-163.

Sharma S M 1994. Sesame research and its progress in India. In: A Omran (ed.). *Oil crops-sesame and safflower*, IDRC Ottawa, pp. 11-27.

Sharma S N, Kumar V and Mathur S 2009. Comparative analysis of RAPD and ISSR markers for characterization of sesame (*Sesamum indicum* L) Genotypes. *Journal of Plant Biochemistry and Biotechnology*, **18** (1): 266-71.

Sodani S N and Bhatnagar S N 1990. Heterosis and inbreeding depression in sesame. *Indian Journal of Genetics and Plant Breeding*, **50**: 87-88.

Solanki Z S and Gupta Deepak 2000 Heterosis in sesame (*Sesamum indicum* L.). *Indian Journal of Genetics and Plant Breeding*, **60**: 403.

Srinivas T, Raghunatham G and Ranganatha A R G 1992. Evaluation of bulk and single capsule descent breeding procedures in sesame (*Sesame indicum* L.). *Oleaginex*, **47**: 645-648.

Sudhir Kumar and A. Surendra Reddy 2005. Effect of gametocides in sesame (*S.indicum* L.). *Journal of Oilseeds Research*, **22**:381-83.

Suh M C, Kim M J, Hur C G, Bae J M, Park Y I, Chung C H, Kang C W and Ohlrogge J B 2003. Comparative analysis of expressed sequence tags from *Sesamum indicum* and *Arabidopsis thaliana* developing seeds. *Plant Molecular Biology*, **52**: 1107-1123.

Sumathi P and Muralidharn V 2009. Genetic analysis of the hybrids involving monostem/shy branching genotypes in sesame (*Sesamum indicum* L.). *Electronic Journal of Plant Breeding*, **1**:65-69.

Taskin K M and Turgut K 1997. In vitro regeneration of sesame (Sesamum indicum L.). *Turkish Journal of Botany*, **21**: 15-18.

Taskin K M, Ercan A G and Turgut K 1999. *Agrobacterium* tumefaciens - mediated transformation of sesame (*Sesamum indicum* L.). *Turkish Journal of Botany*, **23**: 291-295.

Thangavelu S 1994a. Diversity in wild and cultivated species of Sesamum and its use, In: R.K. Arora and K.W. Riley (Eds.). *Sesame Biodiversity in Asia. Conservation. Evaluation and Improvement.* IPGRI, New Delhi, pp. 13- 23.

Thangavelu S 1994b. Problems and prospects in production of hybrids in sesame. In: *Hybrid sesame: Proceedings of the Group Discussion*, Directorate of Oilseeds Research, Hyderabad, pp. 20-22.

Toan D P, Mulatu G, Tri M B, Tuyen C B, Arnulf M and Anders S C 2011. Comparative analysis of genetic diversity of Sesame from Vietnam and Cambodia using agro-morphological and molecular markers. *Heriditas*, **148**(1):28-35.

Tu I C 1993. Studies on sesame heterosis and its practical use in production. *Sesame and Safflower Newsletter*, **8**: 9-16.

Tu I C, Liang X Y, Wang W Q, Zheng Y Z and Liu J R 1995. Studies on the genetic male sterile in sesame (in Chinese, English Abstract). *Acta Agriculture Boreali Sinica*, **10**: 34-39.

Tu I C, Wang W Q and Liu J R 1991. Study of heterosis, combining ability and reciprocal effects in sesame (in Chinese, English Abstract). *Acta Agriculture Boreali Sinica*, **6**: 48-53.

Uzun B, Ulger S and cagirgan. M.I. 2002, Comparison of determinate and indeterminate types of sesame for oil content and fatty acid composition. *Turkish Journal of Agriculture and Forestry*, **26**(5): 269-274.

Uzun B and cagirgan M.I. 2009 Identification of molecular markers linked to determinate growth habit in sesame. *Euphytica*, **166** (3): 379-384.

Vikas Kulkarni, Sridevi O and Salimath PM 2011. Wild cytoplasm and cultivated nuclear genome interaction in sterile interspecific crosses of sesame. *Proceedings of National Seminar on Contemporary Approaches to Crop Improvement.* Abstracts UAS, Bangaloare, pp. 10-11.

Wang W Q, Zheng Y Z, Liu J R, Tu L C and Liang X Y 1995. A study of the effectiveness of hybrid seed production by utilizing genic male sterility in sesame (*Sesamum indicum* L.). *Oil Crops of China*. **17**: (1): 12-15.

Wang W Q, Zheng Z Y, Liang X Y, Liu J R and Tu I C 1993. Studies on heterosis and utilization of genetic male sterile lines in sesame. (in Chinese, English Abstract). *Acta Agriculture University Pekinensis*, **19** (Supp.): 108 112.

Weiss E A 1971. *Castor, Sesame and Safflower.* leonard Hill. London, pp. 311-525.

Weiss, E A 1983. *Oilseed Crops.* Longman, Essex, U.K. pp 282 340.

Were B A, Gudu S, Onkware A O, Carlsson A S and Welander M 2006a. *In vitro* regeneration of sesame (*Sesamum indicum* L.) from seedling cotyledon and hypocotyl explants. *Plant Cell Tissue and Organ Culture*, **85**: 235-239.

Were B A, Onkware A O, Gudu S, Welander M and Carlsson A S 2006b. Seed oil content and fatty acid composition in East African sesame (*Sesamum indicum* L.) accessions evaluated over 3 years. *Field Crops Research*, **97**: 254-260.

Wongyai W W, Sengkaewsook and Verawudh J 1997. Sesame mutation breeding- improvement of non shattering capsule by using gamm rays and EMS. In: *Proceedings of Induced Mutations for Sesame Improvement.* IAEA,Vienna, pp. 76-84.

Xu Z Q, Jia J F and Hu Z D 1997. Somatic embryogenesis in *Sesamum indicum* L. cv. nigrum. *Journal of Plant Physiology*, **150**: 755-758.

Yadav M, Chaudhary D, Sainger M and Jaiwal PK 2010. *Agrobacterium* tumefaciens mediated genetic transformation of sesame (*Sesamum indicum* L.). *Plant Cell Tissue and Organ Culture*, **61**: 543-551.

Yermanos D M 1980. Sesame. In: W.R. Fehr and H.H. Hadley

(Eds.) Hybridization of Crop Plants. *American Society of Agronomy*, Madison, Wisconsin, USA.

Yermanos D M 1984. Development of male sterile inbred lines and hybrid cultivars of indehiscent sesame. In: K.W. Riley (eds). *Oil crops*. IDRC Ottawa., pp. 137-142.

Yermanos D M and Osman H E 1981. Genetic male sterility in sesame: inheritance. *American Oil Chemistry Society*, **9**: 69-78.

Younghee K 2001. Effects of BA, NAA, 2, 4-D and AgNO3 treatments on callus induction and shoot regeneration from hypocotyl and cotyledon of sesame (*Sesamum indicum* L.). *Journal of Korean Society of Horticulture Science*, **42**: 70-74.

Yukawa, Y F Takaiwa, Shoji K, Masuda K and Yamada K 1996. Structure and expression of two seed specific cDNA clones encoding stearoyl acyl carrier protein desaturase from sesame, *Sesamum indicum*. *Journal of Plant Cell Physiology*, **37**: 201-205.

Zhan Y X, Zhou X C, Liu SK and Li Y R 1990. Studies on heterosis in sesame and its utilization: heterosis and genotypic correlation of characteristics. (in Chinese. English Abstract). *Scientia Agronomica Sinica*, **23**:27 36.

Zhang X R, ZhaoY Z, Cheng Y, Feng X Y, Guo Q, Zhou M D and Hodgkin T 2000. Establishment of sesame germplasm core collection in China. *Genetic Resources and Crop Evolution*, **47**:273-279.

Zhao Y Z 1994. Sesame and varietal improvement in China. In: R.K. Arora and K.W. Riley (eds.). *Sesame Biodiversity in Asia. Conservation, Evaluation and Improvement*. IPGRI. New Delhi, pp. 57-64.

Induction of promising mutants in groundnut (*Arachis hypogaea* L.) cultivar TPG-41

D M KALE AND N P PATEL

Western Agri Seeds Ltd., Plot No. 802/11, Western House, GIDC (Engg.) Estate, Sector-28, Gandhinagar-382 028, Gujarat

(Received: December, 2011; Revised: February, 2012; Accepted: March, 2012)

ABSTRACT

In a mutation experiment, popular high yielding groundnut (*Arachis hypogaea* L.) variety TPG-41 was used as an initial material. Well developed dry seeds were treated with 250 to 450 Gy of Gamma rays. In the M2 mutagenesis population, several variants were observed which bred true in M_3 and M_4 generations. They were designated as Western Research Groundnut Mutants (WRGM). Among them, WRGM-19-1 with short pod and attractive seed colour, WRGM-76 and WRGM-11-1 both with small pod were isolated. All mutants had higher oil content and reduced maturity period compared to the parent. In the yield evaluation for four seasons with parent variety WRGM-76 and WRGM-11-1 were found superior for pod and kernel yield. The performance of WRGM-19-1 which was renamed as 'Western Varadan' was comparable for both pod and kernel yield. In the Random Amplified Polymorphic DNA (RAPD) analysis 'Western Varadan' showed differentiating banding pattern compared to the parent.

Keywords: Groundnut, Mutation, Yield

In India, farmers prefer to grow early maturing varieties suited well in varied agro-climatic conditions both in rainy and winter/summer seasons. Mutation breeding technique has been successfully utilized to bring about desirable changes leading to the development of 2,252 mutant varieties in all crops across the world (Maluszynski *et al.*, 2000). Mutation work done in groundnut (*Arachis hypogaea* L.) in India was reviewed (Chandra Mouli *et al.*, 1989; Kale *et al.*, 2000). Out of 130 groundnut varieties belongs to different plant habit groups released so far in India (Ratankumar *et al.*, 2010), Spanish type groundnut occupies more than 50% of the groundnut area. A Spanish type variety TPG-41 released for cultivation (Kale *et al.*, 2004) has large pod and medium-late maturity period. Farmers have been exploiting the genetic potential of this variety by producing pod yield up to 7,200 kg/ha (Murty *et al.*, 2007). In view of its high yield potential and wider adaptability, it was used in the mutation experiment with an objective to improve further productivity and agronomic traits. In the present communication, the isolation of mutants, their agronomical traits and yield performance are reported.

MATERIALS AND METHODS

Earlier 250-350 Gy doses of gamma rays were found effective to induce beneficial mutants (Chandra Mouli *et al.*, 1989). In this experiment, well developed dry seeds of TPG-41 were irradiated at Bhabha Atomic Research Centre (BARC), Trombay, Mumbai with 250 to 450 Gy gamma rays from a Co^{60} source. Pedigree method was followed in the experiment. The M_1 and subsequent generations were grown in both rainy (July to October) and winter/summer (February to May) seasons at the research farm, Western Agri Seeds Ltd. (WASL), Gandhinagar, Gujarat. The variants observed in M_2 generation were harvested individually and advanced to M_3 and M_4 generations to study the breeding behaviour of the variants.

The procedure of recording plant height, leaflet size, pod characteristics and agronomical traits were recorded as reported earlier (Patil 1966). Mutation for pod size was confirmed on the basis of measuring length and breadth of each 10 pods and seeds. In addition, 100 kernel weight (HKW) was recorded and compared with the parent variety. True breeding mutants were designated as Western research groundnut mutants (WRGM) and yield tested along with parent variety by using randomized block design with three replications having unit plot size of 10 m^2 and 15 m^2 and spacing 30 cm x 10 cm and 40 cm x 10 cm in three winter/summer and one rainy seasons, respectively. The uniform size seed sample was used for oil and fatty acid analysis. The seed oil and oil fatty acid estimation was done at Gujarat Laboratory, Ahmedabad by following IS: 3579-1966 solvent extraction and AOAC 999.06 methods, respectively. The RAPD fingerprint screening was done at the SGS Pvt. Ltd., Ahmedabad by using ten types of primers for the generation of stable RAPD profile (i.e. RPI 1 to 10, procured from Banglore genei, Pvt. Ltd. India, cat No. 116688) as a primary primer.

RESULTS AND DISCUSSION

Decreased survival of plants and increased sterile plants with increased dose in M_1 generation was observed (Table 1). In 450 Gy treatment there was no survival of plant indicating that it could be a lethal dose for TPG-41. In M_2 population, among 103 and 46 plant progenies in 250 and 350 Gy treatments, respectively, 25 variants were observed for plant height, leaflet size, pod size and type, seed colour, etc. Of these, 21 variants bred true for their mutated characteristics in subsequent generations. Among the true breeding mutants, 'Western Varadan' and WRGM-11-1 from 250 and 350 Gy treatments, respectively bred true in M_4 and WRGM-76 from 250 Gy in M_3 generations.

In morphological studies (Table 2) 'Western Varadan' had dwarf growth habit (Fig. 1), smaller leaflet size, higher harvest index, short pod type, attractive grayish red seed coat colour, roundish seed shape and large hilum size. WRGM-76 and WRGM-11-1 had reduced plant height, smaller leaflet and pod size. All mutants matured in 105 to 110 days in rainy and 110 to 115 days in winter/summer seasons thus, maturing 5 to 10 days earlier compared to the parent.

The data on economical traits (Table 3) shows that Western Varadan had short pod type resulting in smaller seed size (Fig. 2), improved shelling percentage and higher oil content in both rainy and winter/summer seasons. WRGM-76 and WRGM-11-1 both had smaller seed size (Fig. 2) and higher oil content in both rainy and winter/summer seasons.

In the yield evaluation (Table 4), WRGM-76 showed significantly higher pod and kernel yield in 2010-11 winter/summer season and WRGM-11-1 in 2008-09 and 2010-11 winter/summer seasons. The performance for pod and kernel yield of all the mutants was comparable with parent in rainy season. In pooled mean for 4 seasons, WRGM-76 and WRGM-11-1 both gave each 9 % and 10 % more pod and kernel yield, respectively over the parent. 'Western Varadan' was comparable with the parent for pod and kernel (>2%) yield.

In molecular studies for RAPD finger print between 'Western Varadan' and TPG-41, out of ten types of primers (i.e. RPI 1 to 10), one primer i.e. RPI No. 4 (AM 773769) showed good banding pattern and differentiating result with single band. It was considered for final analysis. After completion of RAPD Polymorphic Chain Reaction (PCR) amplified products on 4% agarose gel along with 100bp ladder; a 90bp band was missing in the variety TPG-41 while the same band was clearly visible in the 'Western Varadan' (Fig. 2). This 90bp band distinguishes both mutant and parent variety.

Table 1 Effect of gamma rays on plat population of TPG-41

Generation	M_1		M_2			M_3 and M_4
Dose	Seeds sown	Survival at harvest	Progenies grown	Seeds sown	Variants identified	Mutants isolated
Control	150	130+0*	-	100	--	--
250 Gy	150	103+1	103	3108	23	20
350 Gy	150	46+19	46	869	2	1
450 Gy	150	--	--	--	--	--

* Figures indicate sterile plants

Table 2 Comparative data on morphological characteristics of WRGM

Characteristic			TPG-41	Western Varadan	WRGM-76	WRGM-11-1
Plant	Height (cm)		61.9	38.3	52.4	47.8
	Harvest Index (%)		52.0	59.0	52.7	52.8
Leaflet	Size (cm)		6.8 x 3.0	5.6 x 2.4	6.0 x 2.7	6.3 x 2.8
Flowering	On stem		Present	Present	Present	Present
	On branches		Sequential	Sequential	Sequential	Sequential
Pod	Constriction		Medium	Medium	Medium	Medium
	Reticulation		Medium	Medium	Medium	Medium
	Size cm 10 pods	Length	35.7	33.9	32.0	32.8
		Breadth	14.2	14.7	13.0	13.1
Kernel	Colour		Tan	Grayish red	Tan	Tan
	Shape		Spheroid	Roundish	Spheroid	Spheroid
	Size cm	Length	17.8	16.2	15.0	15.7
	10 seeds	Breadth	10.6	10.4	09.5	10.0
	Hilum size mm	Length	3.2	4.7	--	--
		Breadth	1.5	2.0	--	--
	Dormancy (Days)		30	30	25	30
Oil	Oleic Acid %		64.0	62.0	58.3	58.9
	Linoleic Acid %		19.8	22.2	25.4	27.0
Maturity (Days)	Rainy		115-120	105-110	105-110	105-110
	Winter/summer		120 -125	110-115	110-115	110-115

Table 3 Comparative data on economical traits of WRGM

Season		TPG-41	Western Varadan	WRGM-76	WRGM-11-1
		Shelling %			
Rainy	2009	70.9	70.0	72.2	68.8
	2010	71.0	73.8	73.0	72.9
Mean		71.0	72.4	72.6	70.9
Winter/summer	2008-09	73.0	74.7	69.9	72.6
	2009-10	73.1	73.1	72.4	70.3
	2010-11	72.0	74.1	72.0	73.7
Mean		72.7	74.0	71.4	72.2
		HKW (g)			
Rainy	2008	78	70	54	58
	2009	76	68	52	64
	2010	76	64	54	64
Mean		76.7	67.3	53.3	62.0
Winter/summer	2008-09	74	60	60	64
	2009-10	64	59	46	53
	2010-11	84	72	62	68
Mean		74.0	63.7	56.0	61.7
		Oil %			
Rainy	2010	52.4	54.2	53.9	53.2
	2011	52.8	55.2	53.6	53.2
Mean		52.6	54.7	53.8	53.2
Winter/summer	2009-10	54.2	55.9	55.9	54.9
	2010-11	53.4	55.2	54.1	55.0
Mean		53.8	55.6	55.0	55.0

Table 4 Comparative yield performance of WRGM

Season	TPG-41	Western Varadan	WRGM-76	WRGM-11-1	CD (P=0.05)
			Pod yield (kg/ha)		
2008-09 winter/summer	4760	4520	5370	5520 *	637
2009-10 winter/summer	4868	5095	5215	4998	666
2010-11 winter/summer	4567	4565	5302 *	5199*	401
Mean	4732	4727	5296	5239	----
2010 Rainy	4565	4595	4625	4750	322
Pooled mean	4690	4694	5128	5117	----
% increase over parent	----	----	9	9	----
			Kernel yield (kg/ha)		
2008-09 winter/summer	3474	3376	3754	3940 *	450
2009-10 winter/summer	3489	3658	3774	3513	458
2010-11 winter/summer	3215	3310	3818*	3831*	291
Mean	3393	3448	3782	3761	----
2010 Rainy	3245	3391	3377	3462	232
Pooled mean	3356	3434	3681	3686	----
% increase over parent	-----	2	10	10	----

* indicate significant superiority over the parent

Thus, it is possible to generate useful variability by nproving further economical traits in an established variety. ased on the trials conducted so far WRGM-76 and VRGM-11-1 showed higher yield potential compared to the arent variety in winter/summer and comparable in rainy easons. In addition, due to higher oil content in the mutants, oil yield/ha is expected to be more. Early maturity by 5 to 10 is an advantage. 'Western Varadan' has attractive seed colour and shape and also showed differentiating banding pattern compared to the parent. Further evaluation of all WRGM will be done in multi-location trials in near future.

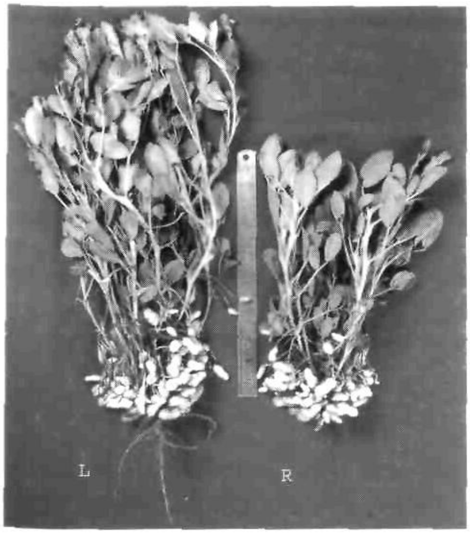


Fig. 1. Parent variety (TPG-41) (Left) & Mutant (Western Vardana) (Right)

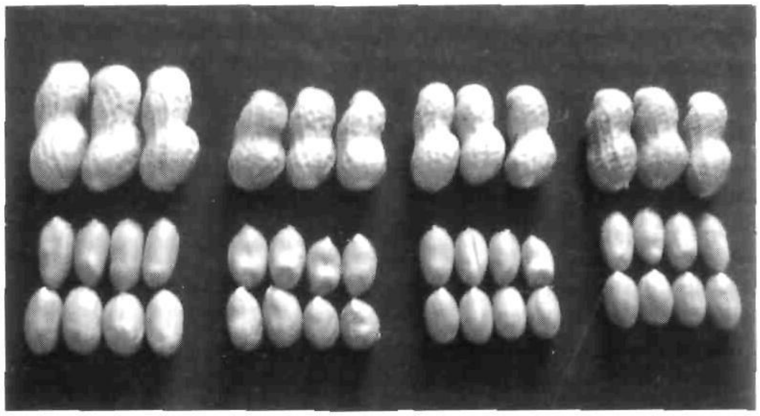


Fig. 2. (L to R) : (1) Parent Variety (TPG-41); (2) Western Vardana (3) WRGM-76 and (4) WRGM-11-1

ACKNOWLEDGEMENTS

We are thankful to Head, Nuclear Agriculture & Biotechnology Division, BARC, Mumbai for providing the seed of TPG-41 and gamma irradiation. Thanks are due to Dr. G.S.S. Murty, Scientific Officer 'H' (Retd.), BARC, Mumbai for suggestion on improvement of manuscript and Mr. Mangalbhai Patel for help in field management at WASL research farm.

REFERENCES

Chandra Mouli, Kale D M and Patil S H 1989. Mutation Research on Groundnut in India. Recent Advances in Genetics and Cytogenetics. Eds. S. A. Farook & I. A. Khan, pp.141:153.

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

Kale D M, Murty G S S and Baddigannvar A M 2004. TPG-41 A new large seeded groundnut variety released in India. *International Arachis Newsletter*, **24**: 19-20.

Maluszynski K K, Nichterlein L, Van Zanten and Ahloowalia 2000. Officially released mutant varieties - the FAO/IAEA. Data base Mutant varieties. *Breeding Reviews*, **12** : 1-84.

Murty G S S, Baddigannavar A M and Kale D M 2007. Impact of New Trombay Groundnut Varieties. Nuclear India, **41**/No.03-04 Oct. 2007.

Patil S H 1966. Mutations induced in groundnut by X-rays. *Journal of Genetics*, **26**(A): 334-348.

Ratankumar AL, Hariprasanna K and Lalwani H B 2010. Genetic improvement in Spanish type groundnut, *Arachis hypogaea* L. varieties in India over the years. *Journal of Oilseeds Research*, **27** (1):1-7.

Genetic variability, correlation and path analysis in niger, *Guizotia abyssinica* Cass.

S K THAKUR AND R K REDDY

ZARS, Chandangaon, Chhindwara, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004, Madhya Pradesh

(Received: November, 2010; Revised: January, 2012; Accepted: February, 2012)

ABSTRACT

Nature and magnitude of association among eight quantitative traits and their contribution towards seed yield was carried out in nine pre-release high yielding genotypes of niger (*Guizotia abyssinica* Cass.). The results revealed that days to maturity, plant height, number of seeds/capitulum and 1000 seed weight had significant positive association with seed yield. However, the negative relationship of seed yield with number of productive branches/plant and number of productive capitula/plant was also observed. Among the yield components, significant positive association was observed for days to maturity with plant height, number of productive branches/plant and number of productive capitula/plant, plant height with 1000 seed weight; number of productive branches with number of productive capitula/plant and seeds/capitulum and number of productive capitula/plant with seeds/capitulum. Path analysis revealed that 1000 seed weight has been an important trait to influence seed yield directly.

Keywords: Coefficient, Correlation, Niger, Variability, Path analysis

Niger (*Guizotia abyssinica* Cass.) is widely grown due to its increased demand and lower cost of cultivation. It has great elasticity of adaptation under various stresses and considerable potential for domestic and industrial uses. Seed yield is a complex character influenced by other traits hence, it cannot be improved by direct selection. Knowledge of heritability and correlation among components of productivity are valuable in selection hence, information on variability for seed yield and its attributing traits is very essential. Path analysis of yield components brings out the relative importance of their direct and indirect influence and helps in understanding their association with seed yield. In niger, such type of studies on yield and yield components are meagre therefore, the present study was undertaken to analyze the variability and correlations of components of productivity in niger crop.

MATERIALS AND METHODS

Field experiments were conducted utilizing of nine pre-release high yielding genotypes of niger at Research Farm of the JNKVV, Zonal Agricultural Research Station, Chandangaon, Chhindwara, M.P., in randomized block design with two replications in two successive rainy seasons of 2008-09 and 2009-10 with full package of practices. Observations were recorded, on plot basis for days to 50% flowering, days to maturity and seed yield (kg/ha) whereas, plant height (cm), number of productive branches/plant; number of productive capitula/plant, number of seeds/capitulum and 1000 seed weight were recorded on five randomly selected plants from each genotype/replication. The data was subjected to statistical analysis for genetic parameters. The character association was estimated from variance and covariance components as given by Fisher (1954) and Al-Jibouri *et al.* (1958) and the direct and indirect effects on seed yield were measured by path analysis, as per Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance revealed highly significant differences among treatment for all the characters except days to maturity and number of productive branches/plant. Estimation of genotypic coefficient of variation indicates the presence of higher amount of genetic variability among the cultivars. The highest magnitude of genotypic coefficient of variation was obtained for seed yield followed by number of capitula/plant and number of productive branches/plant which indicated the presence of high amount of genetic variability in these traits. Low values of genetic coefficient of variation was estimated for days to maturity and plant height indicating the presence of lower genetic variability for these traits. Moderate genetic variability was obtained for days to 50% flowering, number of seeds/capitulum and 1000 seed weight. The results are in agreements with the findings of Sahu and Patnaik (1981).

Days to 50% flowering had highest heritability followed by 1000 seed weight (80.4) whereas it was lowest for plant height (13.8). High variability for flowering was reported by Borole and Patil (1997). The highest genetic advance was observed for seed yield (82.0) followed by capitula/plant (5.89) and days to 50% flowering. High heritability coupled with high genetic advance was observed for days to 50% flowering and number of capitula/plant indicating the predominance of additive gene action for these two characters. For 1000 seed weight high heritability coupled with low genetic advance revealed predominance of non additive gene action. Moderate heritability with low genetic advance was observed for number of productive branches/plant suggesting that environment played major role in character expression (Borole and Patil, 1997).

Seed yield/plant exhibited significant and higher genotypic correlations in the positive direction with days to maturity, plant height, number of seeds/capitulum and 1000 seed weight. However, it was negatively correlated with days to 50% flowering, number of productive branches/plant and number of productive capitula/plant.

In general, genotypic correlations were higher in magnitude than their respective phenotypic correlations, indicating that selection for the correlated characters could give a better yield response than would be expected on the basis of phenotypic correlations. The present results were in agreement with Goyal and Kumar (1993).

Days to 50% flowering had significant positive correlation with days to maturity, plant height, number of *productive branches/plant and number of productive* capitula/ plant. Days to maturity had significant positive correlation with plant height, number of productive branches/plant and number of productive capitual/plant. Plant height had negative association with number of productive branches/plant and number of seeds/capitulum. Negative associations of number of seeds/capitulum were also observed with days to 50% flowering and days to maturity.

Table 1 Genetic parameters for seed yield and its components in niger

Character	Mean SEm±	Range Max.	Range Min.	GCV %	PCV %	H_{BS} %	GA*
Days to 50% flowering	53.5 0.5	55.2	48.7	3.4	3.6	91.7	3.6
Days to maturity	77.6 0.7	78.7	76.2	0.6	1.1	26.9	0.5
Plant height (cm)	118.6 5.1	125.5	113.5	1.7	4.8	13.8	1.6
No of productive branch/plant	12.4 1.1	14.5	11.5	5.3	9.6	30.9	0.7
No of productive capitulum/plant	42.5 5.5	53.7	31.5	10.6	16.9	39.7	5.8
No. of seeds/capitulum	31.7 2.2	35.0	30.0	3.6	8.0	20.6	1.1
1000 seed weight (g)	4.7 0.2	4.9	4.5	3.3	3.7	80.4	0.2
Seed yield	451.1 0.7	517.5	305.0	11.8	15.9	55.2	82.0

GCV = Genotypic coefficients of variance; PCV = Phenotypic coefficients of variance; HBS = Heritability in broad sense; GA = Genetic advance;
* = The selection differential (K) used was 2.6 at 5% selection intensity

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

Character	Correlation coefficient	Days to 50% flowering	Days to maturity	Plant height	No. of productive branches/plant	No. of productive capitula/plant	No. of seeds/capitula	1000 seed weight	Seed yield
Days to 50% flowering	P	1.000	0.665	0.277	0.405	0.076	-0.193	-0.567	-0.082
	G	1.000	1.039**	0.987**	0.805**	0.089	-0.347	0.692**	-0.093
Days to maturity	P		1.000	0.371	0.225	0.185	0.043	-0.311	0.049
	G		1.000	0.931**	0.844**	0.324*	-1.009**	-0.629**	0.452*
Plant height (cm)	P			1.000	0.253	0.006	0.380	-0.022	0.442
	G			1.000	-0.456*	0.111	-1.772*	0.335*	1.961**
No of productive branches/plant	P				1.000	0.523	0.336	-0.564	-0.067
	G				1.000	1.298**	0.750*	-1.093**	-1.035**
No of productive capitula/plant	P					1.000	0.128	-0.449	-0.044
	G					1.000	1.163**	-0.751**	-0.655*
No. of seeds/capitula	P						1.000	-0.015	-0.014
	G						1.000	-0.021	0.812**
1000 seed weight (g)	P							1.000	0.450*
	G							1.000	0.755*

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

Table 3 Direct and indirect effect of different characters on seed yield in niger

Character	Days to 50% flowering	Days to maturity	Plant height	No of productive branches/plant	No. of productive capitula/plant	No. of seeds/capitula	1000 seed weight	Seed yield
Days to 50% flowering	0.35	0.11	0.21	0.19	0.02	0.08	-1.08	-0.09
Days to maturity	0.36	0.11	0.20	0.19	0.10	0.23	-0.98	0.45
Plant height (cm)	0.35	0.10	0.22	-0.10	0.03	0.41	0.52	1.96
No of productive branches/plant	0.28	0.09	-0.10	0.23	0.40	-0.17	-1.71	-1.03
No of productive capitula/plant	0.03	0.02	0.00	-0.11	0.27	-0.04	-0.30	-0.66
No. of seeds/capitula	-0.12	0.00	0.21	-0.07	0.03	-0.39	-0.01	0.81
1000 seed weight (g)	-0.05	-0.03	-0.01	0.12	-0.12	0.01	0.67	0.76

Residual=0.212

Number of productive capitula/plant and number of seeds/capitulum were positively associated with each other, and both the characters had significant positive correlation with number of productive branches/plant. Thousand seed weight showed significant positive association with plant height only however, the associations were negative with all other characters. A comparison of direct and indirect effects of different traits on seed yield revealed that the change in nature and degree of association among the yield components were accompanied by the change in their direct and indirect effects.

Path coefficient analysis revealed that days to maturity, plant height and 1000 seed weight had positive direct effect coupled with positive correlation with seed yield (Table 3). Positive direct effect of number of productive capitula/ plant and its negative correlation with seed yield suggested that restrictions like simultaneous selection model must be imposed to nullify undesirable indirect effects (Channarayappa, 1987). Genotypic correlation coefficient of 1000 seed weight with seed yield and its direct effect, both in direction and magnitude indicated true relationship and direct selection for this trait will be more effective while making the selection for high yielding genotypes for breeding purposes.

REFERENCES

Al-Jibouri H A, Miller R A and Robinson H P 1958. Genotypic and environmental variance and co-variances in an upland cotton cross of inter-specific-origin. *Agronomy Journal*, **50** : 633-663.

Borole R D and Patil H S 1997. Genetic variability, correlation and path analysis in niger (*Guizotia abyssinica* Cass.). *Journal of Oilseeds Research*, **14** (1): 40-43.

Channarayappa 1987. Response to selection, correlation and path analysis in niger (*Guizotia abyssinica* Cass.). *Mysore Journal of Agricultural Sciences*, **21**: 92-93.

Dewey D R and Lu K H 1959. A correlation and path coefficient analysis of components of crested wheat gross and production. *Agronomy Journal*, **51** : 515-518.

Fisher R A 1954. *Statistical methods for research workers*. Oliver and Boyd. Ltd. London.

Goyal S N and Kumar S 1993. Correlation and regression studies in niger. *Gujarat Agricultural University Research Journal*, **18** : 6-8.

Sahu D P and Patnaik M C 1981. Variability, correlation and path analysis in niger. *Indian Journal of Agricultural Sciences*, **51** : 287-291.

Phenotypic stability for seed yield and yield contributing traits in niger, *Guizotia abyssinica* Cass.

S K THAKUR, R K REDDY AND A N TIKLE

ZARS, Chandangaon, Chhindwara, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004, Madhya Pradesh

(Received: November, 2011; Revised: January, 2012; Accepted: March, 2012)

ABSTRACT

The phenotypic stability for nine pre-release high yielding genotypes of niger (*Guizotia abyssinica* Cass.) grown over three successive rainy seasons, was studied for seed yield and seven yield contributing traits. Both linear and non-linear components of GxE interaction were found important for stability for seed yield and its components. Genotype JNS-28 was found to be stable for number of productive branches/plant and number of productive capitula/plant. Genotype JNS-107 showed stability for number of productive capitula/plant. Genotypes JNS-203 and JNS-204 were found to be stable for 1000 seed weight. Genotypes JNS-28 and JNS-107 exhibited below average stability and were identified for higher seed yield in favourable environments. Only genotype JNS-119 was found to be stable for seed yield.

Keywords: Environments, GxE interaction, Regression coefficients, Stability

Niger (*Guizotia abyssinica* Cass.) is grown in India in an area of 3.9 lakh ha with a production of 1.2 lakh t and productivity of 298 kg/ha (2008-09). The crop has been known for its adaptability to rainfed conditions on marginal and sub marginal lands in tribal, hilltop and sloppy areas. It is mainly grown in Madhya Pradesh, Chhattisgarh, Odisha and Maharashtra where as, to a little extent it is being cultivated is Karnataka, Bihar and Andhra Pradesh also. In general, genotypes interact with the environment, hence stability studies help in the identification of genotypes suitable for wider adaptation or for specific environments. Significant genotype x environment interaction in niger has been reported by Kumar *et al.* (1994), Hegde *et al.* (1999) and Patil *et al.* (2000).

The information available on stability analysis is meagre in niger, hence the present study was undertaken to estimate the stability parameters for seed yield and its components traits in niger.

MATERIALS AND METHODS

Field experiments were conducted at Research farm of the JNKVV Zonal Agricultural Research Station, Chandangaon, Chhindwara, M.P., during three successive rainy seasons of 2007-08, 2008-09 and 2009-10. The experiment comprised of nine pre-release high yielding genotypes, identified from station varietal trials of the Research Station. The experimental material was grown in randomized block design with two replications providing recommended cultural practices. Each entry was accommodated in plots containing eight rows of 4m length, R-R and P-P spacing were 30cm x 10-15 cm, respectively. Observations for plant height (cm), number productive branches/plant, number of productive capitula/plant, number of seeds/capitulum and 1000 seed weight (g) were recorded on five randomly selected plants from each genotypes where as, observation on days to 50% flowering, days to maturity and seed yield (kg/ha) were taken on plot basis. Considering each year as a separate environment, the data was subjected to statistical analysis for stability parameters as per the model proposed by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

The mean squares due to genotypes were significant for all characters (Table 1) except days to 50% flowering, number of seeds/capitulum and 1000 seed weight whereas, mean squares due to environments were significant for all character except number of productive branches/plant, number of capitula/plant and number of seeds/capitulum, suggesting presence of variability in the genotypes as well as in the environments for these characters. The mean squares due to E + (GxE) were significant for all characters except number of productive branches/plant and 1000 seed weight. The significant portion of these interaction were due to the linear components. Significant mean squares of environment (linear) due to all characters except number of productive branches/plant indicated differences between environments and their considerable influence on these characters. However, the mean squares due to GxE (linear) were significant for days to 50% flowering, days to maturity and plant height only indicating that variation in the performance of genotypes over environments could be predicted. These results are in accordance with the findings of Patil *et al.*

(2000). Significant variances due to pooled deviations for all characters except plant height and number of productive branches/plant indicated that genotypes differed with respect to their stability suggesting that performances of varieties were predictable. These results are in conformity with the results of Hegde *et al.* (1999).

Table 1 Analysis of variance for seed yield and yield contributing traits in niger

Source of variation	d.f.	*Mean squares*							
		Days to 50% flowering	Days to maturity	Plant height	No of productive branches/plant	No of productive capitula/plant	No. of seeds/capitula	1000 seed weight ( )	Seed yield
Varieties (V)	8	2.1	8.37**	71.81*	15.83**	5223*	8.87	0.04	7787.04*
Env. (E)	2	4.06*	125.03**	477.22**	0.75	65.12	18.69	0.33*	42948.16**
Gx E	16	8.74*	15.57**	87.27**	2.15	62.08*	34.08**	0.09	6027.05
Env. + GxE	18	8.22*	23.73**	130.57**	2.00	62.42*	32.37*	0.12	10129.40**
Env. Linear	1	8.13*	250.05**	954.46**	1.50	130.24	37.39*	0.66*	85.696.30**
GxE linear	8	3.02*	24.19**	135.08**	2.75	17.30	13.75	0.05	3837.29
Pooled deviation	9	12.85**	6.18*	35.02	1.39	94.99*	48.37**	0.12**	7303.84*
Pooled error	24	1.21	1.01	38.01	1.63	26.67	12.16	0.05	3624.66

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

Table 2 Stability parameters for seed yield and yield contributing traits in niger

Genotypes	*Standard parameters*	Days to 50% *flowering*	Days to *maturity*	Plant *height*	No of productive *branches/plant*	No of productive *capitula/plant*	No. of *seeds/capitula*	1000 seed *weight*	Seed yield
JNS-26	x	52.33	78.00	122.00	13.00	44.83	32.33	4.52	421.67
	bi	0.63	0.39	0.07	4.50	0.17	-2.72	0.75	0.90
	S^2di	16.61	1.78	65.96	6.13	224.24	26.40	0.01	19461.43
JNS-28	x	52.33	78.00	117.00	13.00	39.50	27.83	4.83	469.17
	bi	3.12	-0.17	-0.54	1.00	0.99	-0.82	-0.05	1.41
	S^2di	1.40	13.20	35.11	0.50	32.25	52.40	0.01	56.99
JNS-30	x	52.33	79.00	115.50	11.33	39.50	29.17	4.58	403.33
	bi	0.93	0.38	0.82	5.50	0.28	1.75	1.82	0.88
	S^2di	7.38	7.53	42.17	0.13	68.35	24.42	0.28	3558.85
JNS-107	x	52.83	78.50	119.33	11.67	33.67	29.33	4.60	454.17
	bi	0.23	0.05	0.67	5.00	1.05	1.26	1.35	1.22
	S^2di	8.62	3.43	4.96	0.00	1.17	6.53	0.18	8688.22
JNS-116	x	52.83	79.17	119.17	13.17	43.17	29.33	4.42	320.83
	bi	0.32	0.59	-0.20	5.0	2.92	0.70	1.88	1.59
	S^2di	30.08	1.40	12.28	0.50	112.87	26.16	0.03	2158.28
JNS-119	x	50.17	81.17	122.33	12.00	40.50	29.17	4.68	358.33
	bi	2.90	1.71	1.51	0.50	0.56	3.32	1.64	1.08
	S^2di	7.56	11.67	3.55	0.12	94.92	54.47	0.01	8469.28
JNS-203	x	51.83	81.83	130.00	11.17	38.33	28.00	4.53	430.00
	bi	1.92	1.70	2.09	0.12	0.79	2.21	1.07	1.12
	S^2di	21.85	.3.19	72.43	0.50	107.56	57.77	0.24	14204.11
NS-204	x	52.83	82.00	128.67	11.33	32.33	25.83	4.58	425.00
	bi	1.61	2.11	2.83	0.50	-0.37	2.33	0.98	1.37
	S^2di	21.85	6.21	41.67	0.12	81.17	28.54	0.31	4699.58
NS-251	x	52.67	81.33	122.83	11.50	35.33	29.00	4.55	344.17
	bi	3.16	2.24	1.75	0.12	2.7	0.97	-0.45	-0.57
	S^2di	10.83	8.19	37.08	4.50	132.37	101.59	0.02	4437.80
. mean		52.24	79.89	121.87	11.89	38.54	28.89	4.59	402.96
SEbi±		3.77	0.47	0.57	2.89	2.56	3.41	1.29	0.87
SEm±		2.53	1.75	4.18	0.83	6.89	4.91	0.25	60.43

Table 3 Stability of niger genotypes for seed yield and its different traits

Character	Genotype identified for		
	Stability	Poor environments	Rich environments
Days to 50% flowering	-	JNS-30	JNS-204
Days to maturity	JNS-11	JNS-116	JNS-203
Plant height	-	JNS-30 JNS-107	JNS-119
Number of productive branches/plant	JNS-28	-	-
Number of productive capitula/plant	JNS-28 JNS-107	JNS-230	-
Number of seeds/capitulum	JNS-251	JNS-116	JNS-107
1000 seed weight	JNS-203 JNS-204	JNS-26	JNS-30 JNS-107
Seed yield	JNS-119	JNS-26 JNS-30	JNS-28 JNS-107 JNS-203

For the characters days to 50% flowering, days to maturity and plant height, none of the genotypes found to be stable. Genotypes JNS-204 (1.61) JNS-203 (1.70) and JNS-119 (1.51) were found below average stable where as JNS-30 (0.93), JNS-116 (0.59) and JNS-107 (0.67) were found average stable for these characters. Genotype JNS-28 (1.00) had stable performance for number of productive branches/plant and number of productive capitulum/plant, as possessed unit regression coefficients and deviation values not much deviated form zero. Only JNS-107 was found to be stable for number of productive capitula/plant.

For number of seeds/capitulum genotype JNS-251 (0.97) had stable performance. Genotypes JNS-116 (0.70) and JNS-107 (1.26) exhibited below and above average stability, respectively indicated better performance in poor and rich environments, respectively. For 1000 seed weight genotypes JNS-203 (1.07) and JNS-204 (0.98) had unit regression coefficient and non significant deviation, had stability for this characters. Whereas, genotype JNS-26 (0.75) showed above average stability and suitable even for less favourable environments. Genotypes JNS-30 (1.82) and JNS-107 (1.35) which exhibited below average stability had high seed weight in favourable environments only.

For seed yield, higher yielding genotypes JNS-107 and JNS-203 had regression coefficients 1.22 and 1.12, respectively their higher values of deviation from regression indicated sensitivity to fluctuating environments; small changes in the environments register large changes in seed yield, where as regression coefficient 1.41 and less deviation from regression of high yielding genotype JNS-28 suggested its suitability for rich environments only. Only genotype JNS-119 had unit (1.08) regression coefficient and less deviation from regression and was hence, found to be stable for seed yield. Other two high yielding genotypes JNS-26 (0.90) and JNS-30 (0.88) had regression coefficients just below the unity with high deviation values indicating that these genotypes would perform better even in less favourable environments. The results are in agreement with the findings of Kumar *et al.* (1994).

REFERENCES

Eberhart S A and Russell W A 1966. Stability parameters for comparing varieties. *Crop Science*, **6** : 36-40.

Hegde D M, Patil H S, Singh B R and Goswami O 1999. Genotype x Environment interaction in niger composites. *Journal of Maharashtra Agricultural Universities*, **24** (3) : 246-248.

Kumar S, Singh P K and Trivedi H B P 1994. Stability of yield and its components in niger (*Guizotia abyssinica* Cass.). *Journal of Research, Birsa Agricultural University*, **6** (1) : 1-5.

Patil H S, Borole R D and Purkar J K 2000. Analysis of stability for seed yield and yield attributes in niger (*Guizotia abyssinica* Cass.). *Indian Journal of Agriculture Research*, **34**(1) : 66-66.

Cropping system diversification, its production potential and economics under Saurashtra region of Gujarat

B M DABHI, R M SOLANKI AND B K SAGARKA

Cropping System Research Centre, Dept. of Agronomy, Junagadh Agricultural University, Junagadh-362 001, Gujarat

(Received: November, 2011; Revised: March, 2012; Accepted: April, 2012)

ABSTRACT

A field experiment with 10 crop sequences was conducted during 2001-2005 at Cropping System Research Centre, Junagadh Agricultural University, Junagadh (Gujarat). All these cropping sequences were evaluated for their production potential, calorific value, production efficiency, land use efficiency and economics. Groundnut pod equivalent yield (9993 kg/ha), calorific value (38483 K cal), gross (₹ 173535/ha) and net realization (₹ 66544/ha) were recorded maximum through groundnut-onion-green gram crop sequence, while highest groundnut haulm equivalent yield (10256 kg/ha) was produced under groundnut-pearlmillet-cowpea crop sequence. Higher production efficiency (₹269.8/ha/day) and B:C ratio (1.11) were observed under groundnut-wheat-fallow crop sequence. Numerically higher land use efficiency of 87.7% was measured in soybean-fenugreek-groundnut crop sequence.

Keywords: Crop sequence, Production efficiency, Production potential

Intensive agriculture in the last few decades resulted in the depletion of natural resources especially, land, water and nutrients. On the other hand for meeting the food requirements of ever increasing population, the available land has to be intensively cultivated for augmenting agricultural production. Diversification of cropping system is necessary to get higher yield and return, to maintain soil health, preserve environment and meet daily requirements of human and animals. Thus, not only the number of crops but the types of crops included in the cropping sequence are also important. For this, exhaustive cereals crops need to shifted to other crops like oilseeds, pulses, vegetable and fodder crops. A study was therefore conducted to assess the possibility of increasing the cropping intensity by introducing short duration pulses, vegetables and oilseeds in the cropping systems and to increase the productivity and income of the farmers of the Saurashtra region through suitable cropping systems.

MATERIALS AND METHODS

A field experiment with 10 types of crop sequences was initiated during 2001 in randomized block design with three replications. The experiment was conducted for 5 consecutive years at the Cropping System Research Centre, Junagadh Agricultural University, Junagadh (Gujarat). Initially soil had organic carbon 0.28%, pH 7.8, EC 0.31 dS/m, available nitrogen 191.0 kg/ha, available P_2O_5 33.0 kg/ha and available K_2O 173.0 kg/ha. Details of different crop sequences, their varieties, spacing, sowing time, seed rate and recommended dose of fertilizers were furnished in table 1. Crops were grown with recommended package of practices. Pre-sowing irrigation was applied to ensure good germination of winter and summer crops. The total rainfall received during the years 2001, 2002, 2003, 2004 and 2005 was 853, 537, 1275, 971 and 1197 mm with 51, 22, 42, 43 and 41 rainy days, respectively. To compare crop sequences, the yield of all crops were converted into groundnut pod equivalent on price basis and data of different seasons and years were pooled and analyzed statistically. Land use efficiency was obtained by taking total duration of crop in individual crop rotation divided by 365 days. The production efficiency values in terms of ₹/ha/day were calculated by net returns of the rotation divided by total duration of the crop in that rotation (Tomar and Tiwari, 1990). The crop energy (K cal/100g) was calculated as follows: Groundnut (567), pearlmillet (361), soybean (432), onion (50), wheat (346), garlic (145), fenugreek (333), coriander (288), greengram (334), blackgram (347) and cowpea (323) based on data of IASRI, New Delhi.

RESULTS AND DISCUSSION

Main product: Different crop sequences exerted their significant influence on groundnut pod equivalent yield during all the seasons and on pooled data basis except, during summer season (Table 2). During the rainy season groundnut-wheat-fallow crop sequence (T_1) recorded significantly higher pod equivalent yield of 3592 kg/ha, followed by groundnut-onion-greengram crop sequence (T_3), groundnut-wheat-blackgram (T_5), groundnut-garlic-fallow (T_{10}) and groundnut-pearlmillet-cowpea crop sequence (T_9). The lowest groundnut pod equivalent of 448 kg/ha was realized in pearlmillet-wheat-fallow crop sequence (T_2). Whereas in winter season, soybean-onion-groundnut crop sequence (T_4) registered significantly the highest groundnut pod equivalent yield of 5506 kg/ha which remained at par with groundnut-onion-greengram crop sequence (T_3). The groundnut pod equivalent yield of fenugreek when raised after soybean (T_7) was the least (621 kg/ha). Narwal and Malik (1987) reported beneficial effects of legumes or green manuring on succeeding crop. Onion grown after soybean recorded higher groundnut pod equivalent yield as compared with that after groundnut. Jamwal (2000) reported that wheat crop give higher yield in greengram-wheat crop sequence than other crop sequences.

When data were pooled over years and seasons, the highest groundnut pod equivalent yield of 9993 kg/ha was recorded under groundnut-onion-greengram crop sequence (T_3), followed by soybean-onion-greengram crop sequence (T_4). The lowest groundnut pod equivalent was produced in soybean-fenugreek-groundnut crop sequence (T_7). The highest groundnut pod equivalent under groundnut-onion-greengram crop sequence might be due to higher yield of onion. Samui *et al.* (2004) reported the highest rice equivalent yield under rice-potato-groundnut crop sequence.

By-product: Groundnut-haulm equivalent yield was significantly influenced by different crop sequences during all the seasons and in pooled results (Table 2). During rainy season, groundnut-coriander-groundnut crop sequence (T_6) recorded significantly higher groundnut haulm yield of 5441 kg/ha and found comparable with rest of the crop sequences except, soybean-onion-groundnut crop sequence (T_4), soybean-fenugreek-groundnut crop sequence (T_7). Whereas in winter season, groundnut-pearlmillet-cowpea crop sequence (T_9) registered significantly the highest groundnut haulm equivalent yield of 4705 kg/ha. During summer season, pearlmillet-coriander-groundnut sequence (T_6) recorded significantly higher groundnut haulm equivalent yield of 3412 kg/ha, followed by soybean-onion-groundnut crop sequence (T_4).

Table 1 Experimental treatment details

Tr. No.	Season	Crop	Variety	Row spacing (cm)	Seed rate (kg/ha)	Fertilizer (kg/ha)		
						N	P	K
T_1	Rainy	Groundnut	GG-20	60	100	12.5	25	00
	Winter	Wheat	GW-496	22.5	120	12	60	00
	Summer	Fallow	-	-	-	-	-	-
T_2	Rainy	Pearl millet	GHB-558	60	4.5	80	40	00
	Winter	Wheat	GW-496	22.5	120	12	60	00
	Summer	Fallow	-	-	-	-	-	-
T_3	Rainy	Groundnut	GG-20	60	100	12.5	25	00
	Winter	Onion	Ag.F.Red	10x15	10	75	60	50
	Summer	Green gram	GG-2	45	25	20	40	00
T_4	Rainy	Soybean	Guj.-1	60	60	30	60	00
	Winter	Onion	Ag.F.Red	10x15	10	75	60	50
	Summer	Groundnut	GG-2	45	100	25	50	00
T_5	Rainy	Groundnut	GG-20	60	100	12.5	25	00
	Winter	Wheat	GW-496	22.5	120	12	60	00
	Summer	Black gram	T-9	45	25	20	40	00
T_6	Rainy	Pearl millet	GHB-558	60	4.5	80	40	00
	Winter	Coriander	Guj.-2	45	20	20	10	00
	Summer	Groundnut	GG-2	45	100	25	50	00
T_7	Rainy	Soybean	Guj.-1	60	60	30	60	00
	Winter	Fenugreek	Guj.-1	45	20	40	25	00
	Summer	Groundnut	GG-2	45	100	25	50	00
T_8	Rainy	Pearl millet	GHB-558	60	4.5	80	40	00
	Winter	Garlic	Guj.-3	10x15	700	50	50	50
	Summer	Fallow	-	-	-	-	-	-
T_9	Rainy	Groundnut	GG-20	60	100	12.5	25	00
	Winter	Pearl millet	GHB-558	60	4.5	80	40	00
	Summer	Cowpea	GC-4	45	25	20	40	00
T_{10}	Rainy	Groundnut	GG-20	60	100	12.5	25	00
	Winter	Garlic	Guj.-3	10x15	700	50	50	50
	Summer	Fallow	-	-	-	-	-	-

Table 2 Influence of cropping sequences on main and by-product of various crops (Mean of 5 years)

Treatment	Yield (kg/ha)							
	Groundnut pod equivalent				Groundnut haulm equivalent			
	Main product				By-product			
	Rainy	Winter	Summer	Total	Rainy	Winter	Summer	Total
T_1: G'nut - W- Fallow	3592	2478	0	6070	5039	2453	0	8392
T_2 : PM - W- F	448	2446	0	2894	5075	2519	0	7714
T_3 : G'nut -O- GG	3333	5120	1540	9993	4572	0	906	5478
T_4 : S-O- G'nut	1431	5506	940	7877	1317	0	3233	4550
T_5 : G'nut - W-BG	3282	2364	836	6481	4672	2338	743	7753
T_6 : PM - Cor- G'nut	499	1880	998	3378	5441	1332	3412	10085
T_7 : S-FG- G'nut	1287	621	734	2644	1285	1229	2445	4959
T_8 : PM - G- F	492	2965	0	3457	5141	0	0	5141
T_9 : G'nut - PM -C	3089	1404	1112	5605	4289	4705	1262	10256
T_{10} : G'nut - G-F	3144	2953	0	6097	4194	0	0	4194
CD (P=0.05)	929	1811	NS	1923	1749	1034	741	2080

Statistical analysis of summer season and by product of winter season was calculated with six treatments. G'nut=Groundnut, PM=Pearlmillet, GG=Greengram, BG=Blackgram, C=Cowpea, Cor.=Coriander, FG=Fenugreek, W=Wheat, G=Garlic, O=Onion, S=Soybean, F=Fallow

Table 3 Influence of different crop sequences on land use efficiency, production efficiency, total calories and economics (Five year mean)

Treatment	Duration (Days)	Land use efficiency (%)	Production efficiency (₹/ha/day)	Economics (₹/ha)			Total calories (K cal)	B:C ratio
				Gross	Cost	Net		
T1 : G'nut - W- Fallow	215	58.9	269.8	110131	52129	58002	31226	1.11
T2 : PM - W- F	190	52.1	90.6	60445	43231	17214	22063	0.40
T3 : G'nut -O- GG	280	76.7	237.7	173535	106991	66544	38483	0.62
T4 : S-O- G'nut	310	84.9	121.8	146001	108234	37767	34644	0.35
T5 : G'nut - W-BG	300	82.2	130.6	116597	77406	39191	32038	0.51
T6 : PM - Cor- G'nut	285	78.1	-17.4	71105	76073	-4968	14820	-0.07
T7 : S-FG- G'nut	320	87.7	-94.6	50164	80433	-30269	13368	-0.38
T8 : PM - G- F	245	67.1	-48.6	57765	69464	-11899	12022	-0.17
T9 : G'nut - PM -C	300	82.2	95.2	109315	80746	28569	29599	0.35
T10 : G'nut - G-F	265	72.6	82.1	100790	79045	21745	18613	0.28
CD (P=0.05)							5681	

G'nut=Groundnut, PM=Pearlmillet, GG=Greengram, BG=Blackgram, C=Cowpea, Cor.=Coriander, FG=Fenugreek, W=Wheat, G=Garlic, O=Onion, S=Soybean, F=Fallow

In terms of total groundnut haulm equivalent yield over season, groundnut-pearlmillet-cowpea crop sequence (T_9) obtained significantly maximum groundnut haulm equivalent yield of 10256 kg/ha which was comparable with pearlmillet-coriander-groundnut sequence (T_6) and groundnut-wheat-fallow sequence (T_1).

Land use and production efficiency: Land use efficiency of all 10 sequences revealed that highest land utilization efficiency of 87.7% was observed in soybean-fenugreek-groundnut crop sequence (T_7), followed by soybean-onion-groundnut crop sequence (T_4), because these sequences occupied the field for longer duration (320 days). It was least (52.1%) in T_2 i.e., pearlmillet-wheat-fallow sequence (190 days). Tomar and Tiwari (1990) and Jamwal (2000) also reported higher land use efficiency under pigeonpea-wheat and clusterbean crop sequences and groundnut-*toria*-wheat sequence, respectively which occupied the field for longer duration.

Highest production efficiency of ₹269.8/ha/day (Table 3) was obtained through groundnut-wheat-fallow sequence (T_1), followed by groundnut-onion-greengram sequence (T_3). The results confirms the findings of Yadav *et al.* (2005) and they reported that rice-what crop sequence having highest production efficiency in terms of ₹/ha/day.

Energy value: Significantly maximum calorific values of 38483 K cal (Table 3) was obtained in groundnut-onion-greengram crop sequence (T_3) this indicates that groundnut-onion-greengram crop sequence have higher value, high quality produce with highest biological efficient crop sequence, followed by soybean-onion-groundnut sequence (T_4). Yadav *et al.* (2005) also observed highest energetic values in maize-potato-sunflower crop sequence.

Economic analysis: Among all 10 crop sequences, the highest gross realization (₹ 173535/ha) and net return (₹ 66544/ha) were recorded with groundnut-onion-greengram crop sequence (T_3), It was owing to higher total sequence productivity among the rest of the crop sequences (Table 3), followed by soybean-onion-groundnut crop sequence (T_4)

and groundnut-wheat-blackgram sequence (T_5). Whereas, groundnut-wheat-fallow crop sequence stand in second position with realizing net return of ₹ 58002/ha. The benefit cost ratio was more in groundnut-wheat-fallow sequence (T_1), followed by groundnut-onion-greengram (T_3). It showed that groundnut-onion-greengram or soybean-onion-groundnut (T_4) rotation is input responsive crop rotations resulted with higher gross return/ha.

Thus, groundnut-onion-greengram or soybean-onion-groundnut sequence is more biologically efficient crop sequences having more calorific values and cash ensuing crops. However, the farmers still prefer groundnut-wheat or groundnut-wheat-blackgram crop sequences because of better stability and assured government procurement policy with greater remunerative profit margins than groundnut-onion-greengram sequence which is most risky, price fluctuation is more and less assured crop sequences in Saurashtra region of Gujarat.

REFERENCES

Jamwal J S 2000. Production potential and economics of different crop sequences in rainfed areas of Jammu. *Indian Journal of Agronomy*. **45**(2): 269-273.

Narwal S S and Malik D S1987. Effect of previous crops on the yield and nitrogen requirement of wheat. Paper presented at the Symposium on "Alternate Farming System" Indian Soc. Agron. At IARI, New Delhi, February 21-23, 1987.

Samui R C, Kundu A L, Majumder D, Mani P K and Sahu P K 2004. Diversification of rice (*Oryza sativa*)-based cropping system in new alluvial zone of West Bengal. *Indian Journal of Agronomy*, **49**(2): 71-73.

Tomar S S and Tiwari A S 1990. Production potential and economics of different crop sequences. *Indian Journal of Agronomy*, **35**(1&2): 30-35.

Yadav M P, Rai J, Kushwaha S P and Singh G K 2005. Production potential and economic analysis of various cropping systems for Central Plains Zone of Uttar Pradesh. *Indian Journal of Agronomy*, **50**(2): 83-85.

Effect of integrated nutrient management on system productivity of soybean-wheat cropping system in Vindhyan plateau of Madhya Pradesh

M D VYAS AND RUPENDRA KHANDWE

Rafi Ahamad Kidwai, College of Agriculture, RVS Krishi Vishwa Vidyalaya, Sehore-466 001, Madhya Pradesh

(Received: January, 2012; Revised: March, 2012; Accepted: May, 2012)

ABSTRACT

A field experiment was conducted with soybean [*Glycine max* (L.) Merrill] - wheat [*Triticum aestivum* L. emend. Fiori and Paol.] cropping system during 2006-07 to 2008-09 in Vertisol of Sehore, Madhya Pradesh with the objective to maximize the productivity of system and physicochemical properties of soil. The treatment consisted of combination of four organic sources in main plots were applied to soybean in rainy season and three fertility levels in subplot to soybean and wheat both. Application of soybean residues (SR) 5 t/ha + farm yard manure (FYM) 5 t/ha + Zn 5 kg/ha to soybean increased the yield attributes and grain yields of both the crops and soybean equivalent yield (SEY). The SEY was enhanced by this treatment 23.3%, 13.6% and 3.5% over control (no residues), FYM 5 t/ha and SR 5 t/ha alone, respectively, besides build-up in organic carbon and N content in soil. Application of recommended dose of fertilizer (RDF) to both crops components without deterioration of soil properties increased the yield parameters and grain yield of soybean and wheat and significantly increased the SEY by 46 % and 31.97 % over control (no fertilizer) and 50 % RDF. The energy use efficiency and energy productivity was higher in alone application of FYM 5 t/ha. The net returns, B:C ratio, uptake of NPK and protein content were also higher with 5 t/ha each of soybean residues and FYM along with Zn 5 kg/ha among organic nutrient sources and RDF among fertility levels in cropping system.

Keywords: Farm yard manure, Recommended fertilizer dose, Soybean residues, Soybean-wheat system

Significant efforts have been made to economise the use of fertilizers in field crops through application of biofertilizers and organic matter. Long term fertilizer experiment shows that application of fertilizer alone has a deleterious effect on soil health and crop productivity (Behera *et al.*, 2007). Integration of various sources of organic and inorganic fertilizers is more suitable because this reduces the application of chemical fertilizers and cost of cultivation, besides being an environmental friendly approach (Ram and Mir, 2006). The beneficial effect of organics with chemical fertilizers was also reported by Gupta *et al.* (2006) and Sharma *et al.* (2007). Combined use of organic and inorganic sources of fertilizers increases the production and profitability of field crops and helps in maintaining the fertility status of the soil. Organic manure and biofertilizers along with inorganic fertilizers are better for yield and good soil health (Singh *et al.*, 2007). The present investigation was taken up to study the effect of integrated nutrient management on system productivity of soybean-wheat cropping system since limited information is available.

MATERIALS AND METHODS

The field experiment was carried with soybean-wheat system during 2006-07 to 2008-09 at Sehore, Madhya Pradesh on typic chromusterts The soil had pH 7.5, organic carbon 0.35% and available N, P, K and Zn content 208, 15.8, 308 kg/ha and 0.5 mg/kg, respectively. Four treatments of organic manures *viz.*, soybean residues (SR) 5 t/ha, farm yard manure (FYM) 5 t/ha, SR 5 t/ha + FYM 5 t/ha + Zn 5 kg/ha and the control (no organic manure) were applied to soybean in rainy season as main plots and three fertilizer levels i.e., recommended dose of fertilizer (RDF), 50% of RDF and the control (no fertilizer) were given in sub plot to soybean and wheat both. The experiment was conducted in a fixed plot for three years. All the treatments were replicated thrice in a split plot design. The recommended dose of fertilizer for soybean and wheat was 20, 26.6, and 16.6 and 100, 26.6 and 33.2 kg N, P and K/ha, respectively. The half of N to wheat was applied as basal and the remaining at the time of first irrigation. Soybean crop was sown as rainfed and wheat crop was grown with two irrigation at crown root initiation and tillering stage. Urea, single super phosphate and muriate of potash were used as sources of N, P and K, respectively.

Soybean cv. 'JS 335' was sown at 45 cm row spacing on 28, 30 and 28[th] June and harvested on 10, 14 and 12[th] October of 2006, 2007 and 2008, respectively. Whereas, wheat cv. 'Sujata' was sown on 28, 30 and 27[th] October of 2006, 2007 and 2008 and harvested on 6, 8 and 5[th] March 2007, 2008 and 2009, respectively keeping row distance 22.5 cm. The NPK contents of SR and FYM were 1.8, 0.2, 1.2 and 0.72, 0.4, 0.52%, respectively. The energy budget of treatments was calculated by using the conversion factors for inputs, outputs and cultural activities (Panesar and Bhatnagar, 1994).

RESULTS AND DISCUSSION

Growth and yield: Based on the mean data of three years, the pods/plant and test weight of soybean and grain/spike and test weight of wheat were recorded significant differences, while plant height gave non-significant differences in both the crops (Table 1). Incorporation of organic sources improved the yield of soybean and that of wheat over the control (no organic manure). Application of SR 5 t/ha+FYM 5 t/ha+Zn 5 kg/ha proved superior in enhancing the yields of both the crops in the system. However, differences in wheat and soybean yield and soybean equivalent yield due to incorporation of SR 5 t/ha + FYM 5 t/ha+Zn 5 kg/ha and FYM 5 t/ha remained at par. The lowest yield was recorded in the control (no organic manure). The maximum yield in SR 5 t/ha+FYM 5 t/ha+Zn 5 kg/ha might be due to the beneficial effects of FYM and SR by way of regulated liberalization and balanced supply of nutrients, tilting microbial dynamics in favour of crop growth and creation of salutary soil environmental condition for crop growth. These results are in agreement with those of Billore *et al.* (2006). The yield enhancement in soybean yield due to incorporation of FYM along with fertilizers and Zn was also reported by Jain *et al.* (2005).

The RDF recorded significantly higher yield of soybean, wheat and soybean equivalent yield than 50 % of RDF and control (no fertilizer). Similar results were reported by Billore *et al.* (2006). Interaction effect of organic sources and fertility levels was recorded non significant.

Energy budget: The highest energy input was recorded in SR 5 t/ha+FYM 5 t/ha+Zn 5 kg/ha treatment followed by SR, FYM and control in that order (Table 2). The highest gross energy out put was also associated with SR 5 t/ha+FYM 5 t/ha+Zn 5 kg/ha. However, maximum net energy out put was recorded in the sole application of FYM 5 t/ha, the difference in net energy produced by SR 5 t/ha+FYM 5 t/ha+Zn 5 kg/ha and control (no organic manure) was found to be non-significant. The highest energy use efficiency and energy productivity were recorded with FYM 5 t/ha, while sole application of SR 5 t/ha was found to be most energy intensive. These differences may be due to differences in energy input and out put. In general, higher energy input resulted in lower energy use efficiency and productivity. Vyas *et al.* (2006) reported the similar results.

In case of application of fertilizers, the total energy output and gross output were observed with RDF followed by 50% of RDF. However, fertility level of 50% RDF recorded higher energy use efficiency (1.36) and energy productivity (92.66 g/MJ).

Nutrient uptake: Organic sources were significantly influenced the NPK uptake in soybean and wheat (Table 3). The higher uptake of NPK 90.26, 8.08 and 50.20 kg/ha by soybean and 42.7, 8.0 and 63.1 kg/ha by wheat, respectively, were recorded by application of SR 5 t/ha+FYM 5 t/ha+Zn 5 kg/ha. Application of RDF recorded significantly higher NPK uptake in both the crops than 50% RDF and control. Similar results were also reported Jain *et al.* (2005) and Ramesh *et al.* (2009).

Table 1 Effect of integrated nutrient management on growth, yield attributes, grain yield of soybean and wheat and soybean equivalent yield (pooled data of 3 years)

Treatment	Soybean				Wheat				Soybean equivalent yield (kg/ha)
	Plant height (cm)	Pods/ plant	Test weight (g)	Grain yield (kg/ha)	Plant height (cm)	Grains/ spike	Test weight (g)	Grain yield (kg/ha)	
Organic source									
SR @ 5 t/ha	52.8	20.2	81.3	1136	78.1	34.7	42.1	1874	2542
FYM @ 5 t/ha	55.3	22.1	86.5	1317	78.7	35.0	42.2	1966	2792
SR @ 5 t/ha + FYM @ 5 t/ha + Zn 5 kg/ha	56.3	24.7	89.1	1465	79.2	35.8	42.5	2077	3023
Control (no organic manure)	56.5	18.6	79.3	1098	75.4	32.2	41.8	1812	2457
SEm +	0.9	0.6	1.5	37	1.1	1.1	0.4	51	108
CD (P=0.05)	NS	2.1	5.3	116	NS	3.1	1.3	154	322
Fertility level									
RDF	57.1	23.6	90.1	1464	82.2	35.6	45.7	2237	3142
50 % of RDF	53.8	22.3	85.9	1331	76.8	34.8	43.3	2012	2840
Control (no fertilizer)	49.4	18.3	76.2	994	73.1	32.5	42.8	1544	2152
SEm +	0.9	0.4	1.2	34	3.1	0.88	0.38	84	77
CD (P=0.05)	2.7	1.2	3.5	114	NS	2.70	1.20	254	235

SR = Soybean residues; FYM : Farm yard manure

Table 2 Effect of integrated nutrient management on energy use efficiency, productivity and intensiveness of soybean and economics of system (pooled data of 3 years)

Treatment	Energy (MJ/ha) Input output	Gross output	Net	Energy use efficiency	Energy productivity (g/MJ)	Energy intensiveness (MJ/₹)	Cost of cultivation (₹/ha)	Net Return (₹/ha)	B: C ratio
Organic source									
SR @ 5 t/ha	32126	37367	5241	1.16	79.12	0.64	16450	23652	2.43
FYM @ 5 t/ha	29623	41042	11419	1.38	94.25	0.53	16950	27514	2.62
SR @ 5 t/ha + FYM @ 5 t/ha + Zn 5 kg/ha	35126	44438	9312	1.26	86.06	0.59	17450	29900	2.71
Control (no organic manure)	27615	36118	8503	1.31	88.97	0.57	15950	20808	2.30
SEm±	707	1058	385	0.03	0.68	0.02	155	532	0.03
CD (P=0.05)	2114	3220	1140	0.11	2.10	0.07	470	1618	0.09
Fertility level									
RDF	36570	46187	9617	1.26	85.92	0.58	17050	32888	2.92
50 % of RDF	30650	41748	11098	1.36	92.66	0.54	16700	27392	2.64
Control (no fertilizer)	26036	31634	5598	1.21	82.65	0.60	16350	20018	2.22
SEm±	632	1013	317	0.02	0.53	0.01	106	572	0.04
CD (P=0.05)	1890	3020	956	0.08	1.60	0.04	324	1748	0.12

Table 3 Effect of integrated nutrient management on total NPK uptake and protein content of soybean and wheat (pooled data of 3 years)

Treatment	Total NPK uptake (kg/ ha)						Protein content (%)	
	Soybean			Wheat				
	N	P	K	N	P	K	Soybean	Wheat
Organic source								
SR @ 5 t/ha	80.2	7.1	46.6	38.1	6.8	53.2	36.7	10.2
FYM @ 5 t/ha	78.9	7.2	45.8	36.7	7.2	51.1	36.4	10.0
SR @ 5 t/ha + FYM @ 5 t/ha + Zn 5 kg/ha	90.2	8.0	50.2	42.6	7.9	63.1	37.9	10.8
Control (no organic manure)	61.5	5.4	38.1	27.4	4.6	43.5	34.5	9.9
SEm±	3.4	0.8	1.9	3.0	0.7	2.7	0.0	0.2
CD (P=0.05)	10.2	2.4	6.0	9.3	2.2	8.2	0.2	0.8
Fertility level								
RDF	110.2	9.8	60.5	58.1	8.1	75.6	38.4	11.6
50 % of RDF	85.1	7.7	47.1	40.7	6.3	59.2	35.9	10.2
Control (no fertilizer)	72.6	5.5	40.1	28.6	4.2	46.6	35.1	9.2
SEm±	3.2	0.8	2.0	3.4	0.6	2.5	0.1	0.3
CD (P=0.05)	9.5	2.6	6.3	10.4	1.9	7.8	0.2	0.9

Table 4 Change in physico-chemical properties of soil due to different treatments after 3 years experimentation under soybean-wheat cropping system

Treatment	Soil pH	Organic carbon (%)	Available N (kg/ha)		P (kg/ha)		K (kg/ha)		Zn (kg/ha)	
			Actual	Change	Actual	Change	Actual	Change	Actual	Change
Organic source										
SR @ 5 t/ha	7.50	0.37	218	10	15.8	0.0	311	03	0.510	0.010
FYM @ 5 t/ha	7.50	0.40	232	24	15.7	- 0.1	320	12	0.510	0.010
SR @ 5 t/ha + FYM @ 5 t/ha + Zn 5 kg/ha	7.50	0.42	236	28	15.8	0.0	322	14	0.560	0.060
Control (no organic manure)	7.50	0.35	208	00	14.6	- 1.2	305	- 03	0.460	- 0.040
Fertility level										
RDF	7.50	0.38	222	14	16.2	0.4	314	06	0.410	- 0.090
50 % of RDF	7.50	0.37	216	08	15.6	- 0.2	312	04	0.430	- 0.070
Control (no fertilizer)	7.40	0.35	207	- 01	14.8	- 1.0	306	- 02	0.450	- 0.050
Initial Status	7.50	0.35	208		15.8		308		0.500	

Protein content: The protein content of grain was higher under the SR 5 t/ha + FYM 5 t/ha + Zn 5 kg/ha than SR 5 t/ha and FYM 5 t/ha alone treatment in both the crop. Application of RDF recorded significantly higher protein content than 50% RDF and control (no fertilizer).

Physico-chemical properties: After completion of 3 cycles of continuous soybean-wheat cropping sequence, application of FYM 5 t/ha alone and SR 5 t/ha + FYM 5 t/ha + Zn 5 kg/ha improved organic carbon and N contents of soil over their initial status besides unchanged P, K and Zn status of the soil (Table 4). Similar beneficial effect of organic manure were reported by several workers in soybean-based cropping systems (Shivakumar and Ahlawat, 2008; Ramesh *et al.*, 2009). The chemical fertilizer did not influence the soil properties *viz.*, soil pH, organic carbon, N, P, K and Zn content from their initial status in soil but the values of N, P and K content in soil were correspondingly towards lower sides with lower fertilizer doses. These results are in close agreement with the findings of Patel *et al.* (1995).

Economics: The data on overall economics of soybean - wheat cropping system indicated that SR 5 t/ha + FYM 5 t/ha + Zn 5 kg/ha was the most profitable by recording net returns of ₹29900/ha and B:C ratio of 2.71 followed by FYM 5 t/ha (net returns ₹ 27514/ha and B:C ratio 2.62) and SR 5 t/ha (net returns ₹ 23652/ha and B:C ratio 2.43). Application of RDF gave the highest net returns (₹ 32888/ha) and B:C ratio (2.92). Shivakumar and Ahlawat (2008) also reported similar findings.

The results indicated that in Vertisol of Vindhyan plateau of Madhya Pradesh integrated nutrient application of soybean residues @ 5 t/ha+FYM 5 t/ha+Zn 5 kg/ha to soybean crop along with application of recommended fertilizer levels to both the crop in soybean- wheat cropping system found to be the most productive and remunerative.

REFERENCES

Behera U K, Sharma A R and Pandey H N 2007, Sustaining productivity of wheat-soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant and Soil*, **297**(½): 185-199.

Billore S D, Joshi O P, Ramesh A and Vyas A K 2006. Sustainable soybean-wheat cropping system through long-term fertilizer application. *Journal of Oilseeds Research*, **23**(1): 60-62.

Gupta V, Sharma R S and Vishwakarma H S 2006. Long-term effect of integrated nutrient management on sustainability and soil fertility of rice (*Oryza sativa*) - wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, **51**(3): 160-164.

Jain Vikas, Jain, Vinamrata, Vishwakarma S K and Sharma R S 2005. Maximization of productivity for soybean (*Glycine max*) - wheat (*Triticum aestivum*) system in Kymore plateau and Satpura hill zone of Madhya Pradesh. *Indian Journal of Agronomy*, **50**(1): 19-21.

Panesar B S and Bhatnagar A P 1994. Energy norms for inputs and outputs of agricultural sector. (In) *Energy Management and Conservation in Agricultural Production and Food Processing*, pp. 5-16. Verma S R, Mittal J P and Singh Surendra (Eds). USG Publishers & Distributors, Ludhiana.

Patel E N, Jawale S M and Mahajan M S 1995. Production potential and fertility status of soil as influenced by wheat based cropping systems. *Indian Journal of Agronomy*, **40**(4): 544-548.

Ram Tulasa and Mir M S 2006. Effect of integrated nutrient management on yield and yield attributing characters of wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, **51**(3): 189-192.

Ramesh P, Panwar Singh A B and Ramana S 2009. Production potential, nutrient uptake, soil fertility and economics of soybean (*Glycine max*) - based cropping systems under organic, chemical and integrated nutrient management practices. *Indian Journal of Agronomy*, **54**(3): 278-283.

Sharma, Abhijit Singh, Harbir and Nanwal R K 2007. Effect of integrated nutrient management on productivity of wheat (*Triticum aestivum*) under limited and adequate irrigation supplies. *Indian Journal of Agronomy*, **52** (2): 120-123.

Shivakumar B G and Ahlawat I P S 2008. Integrated nutrient management in soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy*, **53**(4): 273-278.

Singh R K, Singh Sandeep Kumar and Singh L B 2007. Integrated nitrogen management in wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, **52**(2): 124-126.

Vyas A K, Billore S D, Joshi O P and Pachlania N 2006. Productivity of soybean genotypes as influenced by nitrogen and sulphur nutrition. *Indian Journal of Agricultural Sciences*, **76**(4): 272-273.

Management techniques for groundnut (*Arachis hypogaea* L.) under delayed sowing in rainfed Alfisols

B SAHADEVA REDDY[1], A MALLISWARA REDDY, P RADHIKA AND B RAVINDRANATHA REDDY

Agricultural Research Station, Acharya NG Ranga Agricultural University, Anantapur-515 001, Andhra Pradesh

(Received: January, 2011; Revised: May, 2012; Accepted: June, 2012)

ABSTRACT

A field experiment was carried out to find the appropriate management techniques in delayed sown groundnut during rainy season of 2007-08 to 2009-10. The treatments consists of two main plots i.e., rainfed and supplemental irrigation and five sub plots i.e., no fertilizer (control), recommended dose of fertilizer application (RDF), leaf webber control (LWC), late leaf spot control (LLSC) and leaf webber + late leaf spot control (LWC + LLSC). Higher number of filled pods/plant were recorded with leaf webber + late leaf spot control treatment and comparable with leaf webber control alone. 100 kernel weight and shelling percentage were higher with leaf webber control, which was at par with leaf webber + late leaf spot control treatments and significantly superior than rest of the treatments. Higher pod and haulm yield was recorded with leaf webber control (quinolphos @ 2 ml/l of water) + late leaf spot control (hexaconazole @ 2 ml/l of water), which was significantly superior to other treatments. Higher net returns were realized with leaf webber control (₹2936), which was closely followed by leaf webber + late leaf spot control (₹2713). The highest B:C ratio was realized with leaf webber control (1.36), which was closely followed by leaf webber + late leaf spot control (1.31), while B:C ratio was lowest with control (0.97).

Keywords: Delayed sowing, Groundnut, Leaf webber, Late leaf spot

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops in India, occupying and contributing nearly 30% of the total area and production of oilseeds in the country. The productivity level of groundnut in Anantapur district (595 kg/ha) of south India is far below the India average of 1112 kg/ha mainly because it is predominantly grown as a rainfed crop (80% of the total acerage) under various biotic and abiotic constraints that limit crop yield. Low rainfall and prolonged dry spells during the crop growth period were reported to be main reasons for low average yields (Reddy *et al.*, 2003). Anantapur district has the largest groundnut area (8.5 lakh ha) among all the districts of Andhra Pradesh and receives the lowest quantum of rainfall (553 mm) and second lowest in the country after Jaisalmer in Rajasthan. Anantapur district is drought prone district where crop failure due to failure of monsoons, erratic and scanty rain fall is a phenomenon as the district is located in the scanty rain fall zone and is rain shadow district. Rainfall is the most significant climatic factor affecting groundnut production. Analysis of rainfall from 1876 to 2009 indicates that 23 years the onset of monsoon rainfall falls in the month of August. Past rainfall data reveals that 10-70% area was sown in the month of August resulting low yields. Besides abiotic stresses, biotic factors have been recognized as the major factors limiting groundnut production under delayed sowings. Among defoliators, groundnut leaf miner (*Aproaerema modicella*) and among foliar diseases, late leaf spot (*Phaeoisariopsis personata*) are the two important biotic stresses in late sown groundnut. The green leaf miner (GLM) reduces yields by feeding on leaves, there by reducing the photosynthetically active leaf area. Yield losses due to GLM were reported to be >50% in Tamil Nadu (Logiswaran and Mohanasundaram, 1985). In India, losses in yield due to the leaf spots have been estimated 15 to 59%. Based on this, an experiment was conducted to know the effect of management practices under delayed sowing.

MATERIALS AND METHODS

A field experiment was carried out under delayed sown groundnut for three years during rainy season from 2007 to 2009 at Agricultural Research Station, Anantapur in rainfed Alfisols. The soil texture was red sandy loam, near neutral in reaction (pH 6.8). The initial soil fertility was low in organic carbon (0.28%), low in available nitrogen (60 kg N/ha), high in available phosphorous (110 kg P_2O_5/ha) and low in available potassium (95 kg K_2O/ha). The treatments consists of two main plots i.e., rainfed and supplemental irrigation and five sub plots i.e., no fertilizer, recommended dose of fertilizer application (RDF), leaf webber control (LWC), late leaf spot control (LLSC) and leaf webber + late leaf spot control (LWC + LLSC) were tested in split plot design with

[1]E-mail: bsrk_ctr@yahoo.co.in; malliswarareddy@yahoo.co.in

four replications. 'K-6' variety of groundnut was sown with a spacing of 30 cm x 10 cm. Recommended dose of 20 N- 40 P_2O_5 -50 K_2O kg/ha was applied as per the treatment. Entire dose of fertilizer was applied as basal. Plant protection chemicals i.e., quinolphos @ 2 ml/l of water to control the leaf webber, hexaconazole @ 2 ml/l of water to control the late leaf spot. Two (2007) to three sprays (2008 and 2009) was given to groundnut at 30 to 70 DAS based on intensity. Two supplemental irrigations were given to crop whenever dryspell occurs more than 10 days. Groundnut crop experienced two dry spells in 2007 and three dry spells during crop growth period in years 2008 and 2009. Whereas, in the year 2008, crop experienced wet spell. Groundnut crop particulars and weather parameters during crop growing period were given in table 1.

RESULTS AND DISCUSSION

Yield attributes: Three years pooled data results revealed that, yield attributes of groundnut did not show any significant difference by giving supplementary irrigation to late sown groundnut. The yield attributing characters such as filled pods/plant, 100 kernel weight and shelling percentage were favourably influenced by taking appropriate plant protection measures against leaf webber and late leaf spot. Higher number of filled pods/plant were recorded with leaf webber + late leaf spot control treatment and comparable with leaf webber control alone, where as lowest with control and recommended dose of fertilizer (RDF) treatments. 100 kernel weight was higher with leaf webber control, which was at par with leaf webber + late leaf spot control treatments and significantly superior to rest of the treatments. Higher shelling percentage was recorded with leaf webber control, which was statistically comparable with leaf webber + late leaf spot control treatments (Table 2). This might be due to higher photosynthetic area of groundnut leaves leads to translocation of biosynthates from source to sink achieved by control of leaf webber and late leaf spot.

Pod and haulm yield: The normal crop of groundnut if sown after August 15th due to delayed onset of monsoon generally results in crop failure or low net returns. Groundnut pod yield varies largely from year to year in Anantapur district. Farmers grow groundnut even beyond August mainly for fodder (haulms) requirement for their livestock. Under normal sown conditions (June to July), district average groundnut pod yield was 1259, 88 and 225 kg/ha in the years 2007, 2008 and 2009, respectively (Hand Book of Statistics, 2009). Gadgil (2000) observed that the variation in groundnut yield of Anantapur district arises to a large extent from the variation in the total rainfall during the growing season. The pod yield was drastically reduced during the year 2008, due to wet spell occurs at 10 DAS leads to luxurious vegetative growth which in turn leads to sparse in first flush of flowering. Owing to lanky growth of the crop, second flush of flowers were turned out in to aerial pegs. During 2009, out of three dry spells, two supplemental irrigations were given. The third dry spell occurs at pod development stage and supplemental irrigation was not given mainly due to non available of water. Hence, pod and haulm yield was drastically reduced.

Table 1 Groundnut crop particulars and weather parameters during crop growth period

Particulars	2007-08	2008-09	2009-10
Date of sowing	30-8-07	31-8-08	24-8-09
Date of harvest	22-12-07	28-12-08	19-12-09
Rainfall during the crop period (mm)	392	267	250.8
Rainy days during the crop period	16	21	18
Relative humidity during crop growth period (%)	67	86	86
Mean maximum temperature during crop growth period (°C)	31.3	31.7	31.2
Mean minimum temperature during crop growth period (°C)	17.9	19.3	20.8
Mean sunshine hours during crop growth period	6.5	7.5	7.0
No. of supplemental irrigations	2	2	2
No. of sprays given for control of leaf webber	2	3	3
No. of sprays given for control of late leaf spot	2	3	3
Dry spells (> 10days)	2	3	3
Wet spell (Continuous 7 rainy days)	--	1	--

Groundnut crop sown under delayed conditions responded well to control of leaf webber and late leaf spot. Higher pod and haulm yield was recorded with leaf webber control (quinolphos @ 2ml/l of water) + late leaf spot control (hexaconazole @ 2ml/l of water), which was significantly superior to other treatments (Table 3). Quinolphos + hexaconazole treated plots gave 86% higher pod yield and 66% haulm yield over the control. Jadeja *et al.* (1999) stated that, hexaconazole treated plots gave 71% higher pod yield and 66% higher fodder yield compared to control with the highest net returns of ₹ 9793/ha. Higher pod yield attributed with increased photosynthetic area and reducing the lesion formation. It was observed that whenever relative humidity was high (>80%) late leaf spot incidence is severe and whenever dry spell (>14 days) occurs, then leaf miner incidence was high. Late leaf spot incidence was low during the year 2007 mainly due to low relative humidity (67%), whereas, severe incidence of leaf spot was observed whenever relative humidity was high (> 80%) during 2008 and 2009 (Table 1). In the Anantapur region, leaf miners emerge during drought periods with no rainy days for more than 21 days during 35-110 days of the cropping period (Narahari Rao *et al*., 2000). Ranga Rao *et al*. (1997) also observed it to be severe during moisture stress conditions. The conditions favourable for the leaf miner growth are long dry spells resulting in high temperature and low humidity. At Anantapur under late sown conditions, the groundnut leaf miner incidence was significantly and negatively correlated with rainfall and minimum temperature and positively with sunshine hours (AICRPAM, 2001).

Economics: Net returns and B:C ratio was higher with chemically treated plots rather than untreated plots (Table 4). Higher net returns were realized with leaf webber control (₹2936), which was closely followed by leaf webber + late leaf spot control (₹2713). Where as, negative net monetary returns were realized with control (-₹ 285). The highest B:C ratio was realized with leaf webber control (1.36), which was closely followed by leaf webber + late leaf spot control (1.31), while B:C ratio was lowest with control (0.97) (Table 4).

Rain water use efficiency: Higher rain water use efficiency was noticed with supplemental irrigation (1.03 kg/ha-mm) when compared to rainfed (0.80 kg/ha-mm). Where as, higher rain water use efficiency was recorded with leaf webber control + late leaf spot control (1.05 kg/ha-mm), which was closely followed by leaf webber control (1.00 kg/ha-mm), respectively. While minimum rain water use efficiency was observed in control (0.58 kg/ha-mm).

Thus, two to three sprays based on intensity at 30 to 70 DAS with quinolphos @ 2 ml/l + hexaconazole @ 2 ml/l of water effectively controls late leaf spot and leaf webber leads to get higher yield, maximum net returns and B:C ratio in late sown groundnut under rainfed Alfisols of Anantapur region.

Table 2 *Filled pods/plant, test weight (g) and shelling percentage as influenced by late sowing groundnut*

Treatment	Filled pods/plant				100 kernel wt. (g)				Shelling (%)			
	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled
Main plot												
M_1 : Rainfed	5.7	3.5	2.7	3.9	30.2	32.0	31.7	31.5	72.0	71.1	67.5	70.4
M_2 : Suppl. Irrigation	5.8	3.0	3.3	4.0	32.0	32.7	32.8	32.6	73.4	71.0	65.9	70.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	0.8	NS	NS	NS	NS
Sub plot												
T_1 : Control	4.8	2.4	2.1	3.1	31.8	31.8	32.4	31.5	73.5	68.9	67.4	69.3
T_2 : RDF	5.8	2.9	2.8	3.8	31.4	29.5	30.9	29.5	73.4	69.0	63.4	67.9
T_3 : LWC	5.5	3.7	3.9	4.3	28.5	34.6	33.9	34.3	69.8	73.2	69.4	72.6
T_4 : LLSC	6.5	3.5	3.2	4.4	30.6	31.7	31.4	31.4	72.9	71.4	64.8	69.2
T_5 : LWC + LLSC	6.4	3.8	3.0	4.4	33.5	34.2	32.6	33.7	73.7	72.7	68.5	72.1
CD (P = 0.05)	0.9	0.8	1.1	0.4	4.8	2.1	2.6	1.3	NS	2.7	4.0	1.4

RDF: Recommended dose of fertilizer, LWC: Leaf webber control; LLSC: Late leaf spot control

Table 3 Pod and haulm yield (kg/ha) as influenced by late sown groundnut

Treatment	Pod yield (kg/ha)				Haulm yield (kg/ha)			
	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009-10	Pooled
Main plot								
M_1 : Rainfed	322	164	132	206	645	328	333	431
M_2: Suppl. Irrigation	355	180	137	224	675	360	321	452
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot								
T_1 : Control	261	92	92	148	531	184	265	327
T_2 : RDF	279	127	146	184	667	254	343	422
T_3 : LWC	349	183	186	239	616	367	341	442
T_4 : LLSC	368	185	130	228	698	370	359	475
T_5 : LWC + LLSC	435	273	120	276	793	546	327	543
CD (P = 0.05)	75	44	28	29	90	89	57	45

RDF: Recommended dose of fertilizer, LWC: Leaf webber control; LLSC: Late leaf spot control

Table 4 Economics (₹/ha) and rain water use efficiency (RWUE) as influenced by late sown groundnut

Treatment	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	RWUE (kg/ha-mm)
Main plot				
M_1 : Rainfed	8686	-264	1.07	0.80
M_2 : Suppl. Irrigation	10942	2077	1.31	1.03
Sub plot				
T_1 : Control	7240	-285	0.97	0.58
T_2 : RDF	8534	409	1.05	0.76
T_3 : LWC	11261	2936	1.36	1.10
T_4 : LLSC	10697	2272	1.26	1.00
T_5 : LWC + LLSC	11338	2713	1.31	1.05

RDF : Recommended dose of fertilizer; LWC : Leaf webber control; LLSC : Late leaf spot control

REFERENCES

AICRPAM 2001 *Annual Report,* All India Coordinated Research Project on Agrometeorology, CRIDA,Hyderabad, India.

Gadgil S 2000. Farming strategies for a variable climate-An Indian case study, In: *Proceedings of the International forum on Climate Prediction, Agriculture and Development,* April 26-28,2000, International Research Institute for Climate Prediction, New York, USA, pp.27-37.

Hand Book of Statistics 2009. Anantapur District published by Chief Planning Officer.

Jadeja K B, Nandolia D M, Dhruj I U and Khandar R R 1999. Efficacy of four triazole fungicides in the control of leaf spots and rust of groundnut. *Indian Phytopathology*, **52**:421-422.

Logiswaran G and Mohansundaram M 1985. Effect of intercropping, spacing and mulching in the control of groundnut leaf miner, *Aproaerema modicella*, *Deventer. Madras Agricultural Journal*, **72**: 695-700.

Narahari Rao K, Gadgil S, Rao P R S and Savithri K 2000. Tailoring strategies to rainfall variability-The choice of sowing window. *Current Science*, **78** (10): 1216-1230.

Ranga Rao G V, Reddy D and Shanower T 1997. Status of groundnut leaf miner in Peninsular India: Management options, *Meeting Abstracts of Pest management Research Unit,* United States Department of Agriculture (USDA).

Reddy T Y, Reddy V R and Anbumozhi V 2003. Physiological responses of groundnut (*Arachis hypogaea* L.) to drought stress and its amelioration: A critical review. *Plant Growth Regulation*, **41**:75-88.

Direct and residual effect of fertility on mustard productivity in pearl millet (*Pennisetum glaucum*) + urdbean (*Phaseolus mungo*) - Indian mustard (*Brassica juncea*) crop sequence

O P PREMI, B K KANPAL, S S RATHORE AND KAPILA SEKHAWAT

Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur-321 303, Rajasthan

(Received: November, 2010; Revised: November, 2011; Accepted: January, 2012)

ABSTRACT

A field experiment was conducted in rainy and winter seasons during 2004-07, at Bharatpur, to evaluate the residual effect of fertility levels in pearl millet (*Pennisetum glaucum*) + urd bean (*Phaseolus mungo*) cropping system on succeeding crop of Indian mustard (*Brassica juncea*). Application of 100 kg N + 33.3 kg P/ha during rainy season significantly increased the grain yield of pearl millet and urd bean, but the effect on mustard productivity was at par with 75 kg N + 25 kg P/ha, which indicated a net saving in 25% of N and P during rainy season. The direct application of N, P and S to Indian mustard also enhanced the growth, yield attributes and seed yield. Application of 100 kg N + 27.8 kg P + 40 kg S/ha increased seed yield by 33.1% over 100 kg N + 27.8 kg P. This treatment also gave higher mustard seed equivalent yield (3240 kg/ha), total nutrient uptake (124.5 kg N, 22.0 kg P and 24.2 kg S/ha) and net return (₹ 35650/ha).

Keywords: Crop sequence, Fertility levels, Indian mustard, Net returns, Residual effect

Rajasthan is a leading state for the production of Indian mustard (*Brassica juncea*), which contributes 45.7% of total production in the country (Anonymous, 2010). The soils are, generally, light in texture, low in organic carbon, medium in phosphorus (P) and deficient in sulphur (S) due to either by adoption of mono-cropping or extensive use of S free fertilizers. The S requirement of rapeseed-mustard is the highest (1.6 kg S/q of seed) among crop plants (Singh and Sahu, 1986). Indian mustard is an integral part of cropping system and being grown after pearl millet, cluster bean and urd bean (Sinsinwar *et al.*, 2002 and Premi *et al.*, 2006). Further, the productivity of the pearl millet - mustard crop sequence increased by the inclusion of urd bean in paired rows (Sinsinwar *et al.*, 2005). Presently, fertilizer application is based on nutrient requirement of individual crop and the carry over effect of fertilizer applied to preceding crop is generally ignored. The information regarding residual effect of pearl millet + urd bean and chemical fertilizers on mustard is meagre. With this view, the present investigation was carried out to assess the effectiveness of residual and direct effect of fertilizers applied to mustard on its productivity and soil fertility.

MATERIALS AND METHODS

A field experiment was conducted at Directorate of Rapeseed - Mustard Research, Bharatpur, Rajasthan during 2004-05 to 2006-07. The soil was sandy loam, with pH 8.2, containing 0.24% organic carbon, 125 kg/ha available N, 5.7 kg/ha available P and 26.5 kg/ha available S. The treatment consisted of three main-plots in rainy season and six sub-plots in winter season. During rainy season pearl millet + urd bean was grown with three fertility levels, *viz.*, 100% recommended fertility: 100 kg N + 33.3 kg P/ha ($N_{100}P_{33.3}$), 75% recommended fertility:75 kg N + 25 kg P/ha ($N_{75}P_{25}$), 50% recommended fertility:50 kg N + 16.7 kg P/ha ($N_{50}P_{16.7}$) in main plots. During winter season, each main-plot was divided into six sub-plots and fertility levels, *viz.*, 100 kg N + 27.8 kg P/ha ($N_{100}P_{27.8}$), 75 kg N + 20.8 kg P/ha ($N_{75}P_{20.8}$), 50 kg N + 13.9 kg P/ha ($N_{50}P_{13.9}$), 100 kg N + 27.8 kg P + 40 kg S/ha ($N_{100}P_{27.8}S_{40}$), 75 kg N + 20.8 kg P + 40 kg S/ha ($N_{75}P_{20.8}S_{40}$), 50 kg N + 13.9 kg P + 40 kg S/ha ($N_{50}P_{13.9}S_{40}$) were allotted to mustard. The experiment was conducted in split- plot design, replicated four times. The S was applied through gypsum (250 kg/ha). The rainy season crop pearl millet cv 'HHB 92' and urd bean'T9' were planted at 40 cm x 15 cm in paired row (2:2) in first fortnight of July in all the three years. Only the pearl millet crop was fertilized with recommended fertility level (as per treatment). The rainy season crops were grown under irrigated conditions. In winter season, mustard cv 'Rohini' was sown in sub-plots on first week of October every year. Seeds were sown in rows 30 cm apart and plant-to-plant distance was maintained at 10 cm by thinning at 25 days after sowing. Half of the N and full dose of P and S (as per treatment) were applied as basal and remaining dose of nitrogen was top-dressed after first irrigation i.e., 35 days after sowing (DAS). The, N, P and S were applied through urea, di-ammonium phosphate and gypsum, respectively. Second irrigation was given to the crop at 65 DAS. The recommended package of practices for mustard was followed. The soil samples were collected at 0-15 cm depth at the time of sowing and crop harvest to estimate organic carbon, available N, P and S content. Economic analysis was made considering the prevailing market costs of inputs and prices of out-put. Growth and yield attributes were recorded on five randomly selected plants. The soil samples for different nutrients were analyzed by using standard procedure. Analysis of variance was performed to determine the residual and direct effects of fertility using WINDOSTAT version 8.0 (Hyderabad, India).

RESULTS AND DISCUSSION

Growth and yield attributes: Plant height, effective tillers/plant, ear length of pearl millet varied significantly with fertility levels (Table 1). Application of 100 kg N + 33.3 kg P/ha resulted into maximum mean plant height, effective tillers/ plant, ear length and grain yield followed by 75 kg N + 25 kg P/ha. The superiority of these treatments over 50 kg N + 16.7 kg P/ha might be due to higher availability of N and P. These results are in close conformity with those of Choudhary and Gautam (2007) and Guggari and Kalaghatagi (2005). The productivity of pearl millet was also higher in subsequent years, might be due to residual fertility effect of mustard.

Plant height, pods/plant, 1000 seed weight and seed yield of urd bean increased significantly with increasing fertility level in all the three years. The higher growth and maximum grain yield were observed with the application of 100 kg N + 33.3 kg P/ha, but at par with that of 75 kg N + 25 kg P/ha, indicating that direct and residual effect of P enhanced grain filling, as also observed by Nandal *et al.* (1987).

The residual effect of fertility levels was evident on growth and yield attributes and the seed yield of mustard. Application of 100 kg N + 33.3 kg P/ha to the preceding pearl millet crop significantly increased plant height, primary and secondary branches/plant, siliquae/plant and seed yield over that of 50 kg N + 16.7 kg P/ha. Pearl millet + urd bean cropping system might have improved nutrient availability in the soil, for the mustard crop (Table 3). Mishra and Giri (2004) also recorded the similar findings. However, higher fertility level (N_{100} $P_{33.3}$) in preceding crop, significantly reduced mustard oil content.

Direct application of N, P and S significantly increased plant height, primary and secondary braches, siliquae/plant, seeds/siliqua and 1000 seed weight (Table 2). An application of 100 kg N + 27.3 kg P/ha resulted in significantly taller plants with more branches and higher 1000 seed weight than 50 kg N + 13.9 kg P/ha. In addition to N and P levels, 40 kg S/ha produced still taller plants with more number of branches. Thus, application of 100 kg N + 27.3 kg P + 40 kg S/ha gave the highest plant height, branches, siliquae/plant, seeds/siliqua and 1000 seed weight.

The N and P application to Indian mustard significantly increased the seed yield as it is directly correlated with growth and yield attributes. The highest seed yield was recorded with 100 kg N + 27.8 kg P/ha during first year, but this treatment was at par with 75 kg N + 20.8 kg P/ha, which might be due to residual effect of rainy season crops. On an average this treatment recorded 8.6% and 20.9% higher seed yield over 75 kg N + 20.8 kg P/ha and 50 kg N + 13.9 kg P/ha, respectively. Addition of 40 kg S/ha to 100 kg N + 27.3 kg P/ha further increased seed yield by 33%. Oil content was significantly higher under 50 kg N + 13.9 kg P + 40 kg S/ha, but at par with other fertility levels along with S fertilization. Kumar *et al.* (2002) and Premi *et al.* (2004) also reported increase in oil content and seed yield of mustard due to S application.

Nutrient uptake: Fertilization of rainy season crops with 100 kg N + 33.3 kg P/ha significantly increased the N and P uptake but was at par with 75 kg N + 25 kg P/ha. The fertility levels to preceding crop significantly affected the N, P and S uptake by mustard (Table 3). Application of 100 kg N + 33.3 kg P/ha to the preceding pearl millet + urd bean removed higher N (21.1%), P (32.0%) and S (20.2%) compared to 50 kg N + 16.7 kg P/ha but was at par with 75 kg N + 25 kg P/ha. This could be due to differences in fertility levels. Direct application of different levels of N, P and S to Indian mustard also affected the nutrient uptake significantly. An increase in fertility level led to increase in N, P and S uptake by mustard. The highest uptake of N (98.1 kg), P (15.4 kg) and S (23.9 kg) uptake/ha was recorded with 100 kg N + 27.3 kg P + 40 kg S/ha over other fertility levels. Total N, P and S uptake by pearl millet + urd bean - mustard sequence was higher under recommended fertility level (N_{100} $P_{33.3}$) but was at par with 75% fertility level (N_{75} P_{25}). The mustard crop receiving 100 kg N + 33.3 kg P + 40 kg S/ha removed 124.5, 22.0 and 24.2 kg N, P and S/ha, respectively. This might be due to higher yields of crops.

Residual soil fertility: After three years, the residual effect of fertility levels significantly influenced the available N, P, S and organic carbon content of the soil. Available P status showed marked improvement with recommended fertility level. The improvement in available P by residual P from pearl millet + urd bean after mustard harvest was because the P applied to pearl millet was not fully utilized by both the crops in the system. On the contrary, a sharp decline in organic carbon content, available N and S over its initial status was observed with each increment in fertility level (Table 3).

The increasing fertility levels to mustard caused corresponding improvement in available N, P and S after three years of experimentation. The trend was reverse in case of organic carbon content, which was significantly higher at low fertility levels (N_{50} $P_{13.9}$ and N_{50} $P_{13.9}$ S_{40}). However, organic carbon content, available N and available S declined over its initial status. This may be due to more mineralization at higher fertility and higher uptake by the crop.

Table 1 Effect of fertility levels on growth, yield attributes and yield of pearl millet and urdbean (Pooled data of three years)

Treatment	Pearl millet						Urdbean				
	Yield attributes						Yield attributes				
Fertility level	Plant height (cm)	Effective tillers/plant	Ear length (cm)	Grain weight/ ear (g)	Straw yield (kg/ha)	Grain yield (kg/ha)	Plant height (cm)	Pods/ plant	Seeds/ pod	1000 seed weight (g)	Grain yield (kg/ha)
$N_{100} P_{33.3}$	202.5	2.31	23.0	22.1	4530	1953	31.4	24.2	4.8	30.7	150
$N_{75} P_{25}$	175.7	2.06	21.6	21.3	4317	1893	29.3	21.8	4.6	30.5	133
$N_{50} P_{16.7}$	163.2	1.95	20.4	19.8	4143	1850	26.5	18.6	4.2	30.2	103
SEm±	5.3	0.05	0.3	0.2	58	11.4	0.7	0.8	0.1	0.1	8.5
CD (P=0.05)	18.2	0.19	1.1	0.6	186	38	2.4	2.8	0.3	0.2	26

Table 2 Effect of fertility levels on yield attributes, yield and oil content of mustard in pearl millet + urdbean-mustard sequence (Pooled data of three years)

Treatment	Plant height (cm)	Primary branches/ plant	Sec. branches/ plant	Siliquae/ plant	Seeds/ siliqua	Siliqua length (cm)	1000 seed weight (g)	Oil content (%)	Protein content (%)	Seed yield (kg/ha)
Fertility level to pearl millet + urdbean (Rainy season)										
$N_{100} P_{33.3}$	173.4	5.5	4.5	155.3	13.6	4.9	4.8	41.1	20.2	1310
$N_{75} P_{25}$	172.3	5.3	4.0	154.6	13.8	4.9	4.6	42.4	19.9	1260
$N_{50} P_{16.7}$	166.9	5.0	3.7	149.4	13.7	4.8	4.6	43.8	19.8	1100
SEm±	1.4	0.1	0.1	1.2	0.2	0.1	0.2	0.5	0.1	30
CD (P = 0.05)	4.7	0.2	0.2	4.1	NS	NS	NS	1.8	0.2	100
Fertility level to mustard (Winter season)										
$N_{100} P_{27.8}$	170.3	5.6	4.6	151.2	13.7	4.9	4.8	41.3	19.9	1240
$N_{75} P_{20.8}$	172.3	5.2	4.0	150.8	13.6	4.9	4.7	41.8	19.8	1140
$N_{50} P_{13.9}$	167.1	5.0	3.8	145.7	13.5	4.6	4.6	41.9	19.7	1030
$N_{100} P_{27.8} S_{40}$	175.9	5.6	4.5	168.6	14.1	4.9	4.9	43.1	20.6	1650
$N_{75} P_{20.8} S_{40}$	170.0	5.3	3.9	151.9	13.7	4.9	4.6	43.4	20.2	1200
$N_{50} P_{13.9} S_{40}$	169.4	4.9	3.7	150.2	13.6	4.9	4.6	43.5	20.2	1090
SEm±	1.0	0.1	0.1	1.8	0.1	0.2	0.1	0.5	0.1	60
CD (P = 0.05)	2.9	0.3	0.3	5.2	0.2	NS	0.1	1.5	0.4	160

Table 3 Effect of fertility levels on nutrient uptake and availability in pearl millet + urdbean-mustard sequence (Pooled data of three years)

Treatment	Nutrient uptake by Pearl millet + urdbean (kg/ha)			Nutrient uptake by Mustard (kg/ha)			Total nutrient uptake (kg/ha)			Soil nutrient availability (kg/ha)			
	N	P	S	N	P	S	N	P	S	O.C (%)	N	P	S
Fertility level to pearl millet + urdbean (Rainy season)													
$N_{100} P_{33.3}$	24.4	6.2	0.4	82.0	12.8	19.0	106.4	19.0	19.4	0.22	102.4	8.6	21.1
$N_{75} P_{25}$	22.4	5.8	0.3	76.8	11.5	17.5	99.1	17.3	17.8	0.25	99.1	7.7	23.8
$N_{50} P_{16.7}$	20.7	5.5	0.2	67.7	9.7	15.8	88.4	15.2	16.1	0.26	92.8	7.5	24.5
SEm±	0.6	0.1	-	2.1	0.5	0.5	2.4	0.6	0.8	0.01	1.7	0.3	0.3
CD (P = 0.05)	2.1	0.5	NS	7.3	1.6	1.6	8.3	1.9	2.6	0.02	5.9	1.0	1.2
Fertility level to mustard (Winter season)													
$N_{100} P_{27.8}$	24.8	6.4	0.3	79.3	12.1	17.8	104.0	18.5	18.1	0.22	101.8	8.6	20.8
$N_{75} P_{20.8}$	21.9	5.7	0.3	69.3	10.3	15.3	91.2	16.0	15.6	0.23	99.5	7.9	21.3
$N_{50} P_{13.9}$	19.0	5.1	0.2	61.9	9.0	13.8	80.9	14.2	14.0	0.25	93.7	7.6	22.0
$N_{100} P_{27.8} S_{40}$	26.4	6.7	0.4	98.1	15.4	23.9	124.5	22.0	24.2	0.22	100.3	8.7	24.6
$N_{75} P_{20.8} S_{40}$	24.0	6.1	0.3	78.3	12.1	19.1	102.2	18.2	19.5	0.25	97.1	8.0	25.2
$N_{50} P_{13.9} S_{40}$	20.9	5.3	0.3	67.0	10.7	17.0	87.8	16.0	17.3	0.26	96.3	7.5	25.9
SEm±	0.8	0.2	-	4.4	0.9	1.3	3.9	0.8	1.7	0.01	1.7	0.3	0.4
CD (P = 0.05)	2.3	0.6	NS	12.4	2.5	3.8	11.2	2.3	4.9	0.02	4.8	0.9	1.1

N : Nitrogen; P : Phosphorus; S : Sulphur; OC : Organic carbon

Table 4 System productivity and economics of production (Pooled data of three years)

Treatment	Mustard seed equivalent yield (kg/ha)	Economics		
		Cost of cultivation (₹/ha)	Net return (₹/ha)	B:C ratio
Fertility level to pearl millet + urdbean (Rainy season)				
N_{100} $P_{33.3}$	2780	19,210	28,030	1.46
N_{75} P25	2640	16,710	28,260	1.69
N_{50} $P_{16.7}$	2420	14,230	26,950	1.89
SEm±	50	-	-	-
CD (P = 0.05)	170	-	-	-
Fertility level to mustard (Winter)				
N_{100} $P_{27.8}$	2,750	18,960	27,790	1.47
N_{75} $P_{20.8}$	2480	16,470	25,750	1.56
N_{50} $P_{13.9}$	2220	13980	23,730	1.70
N_{100} $P_{27.8}$ S_{40}	3240	19460	35,650	1.83
N_{75} $P_{20.8}$ S_{40}	2650	16940	28,140	1.66
N_{50} $P_{13.9}$ S_{40}	2260	14480	22,860	1.58
SEm±	70	-	-	-
CD (P = 0.05)	220	-	-	-

System productivity and net returns: The system productivity measured as mustard seed equivalent yield (MSEY) and net returns were influenced by direct and residual fertility levels (Table 4). The MSEY of fertility levels during rainy season showed the maximum productivity (2780 kg/ha) with 100 kg N + 33.3 kg P/ha but was at par with 75 kg N + 25 kg P/ha. The higher MSEY was due to higher yield of both crops. Application of 100 kg N + 27.8 kg P + 40 kg S/ha to mustard gave the highest MSEY (3240 kg/ha) which was 18% higher over same fertility level without S application. The economic analysis of different treatments showed that residual effect of application of 75 kg N + 25 kg P/ha to pearl millet + urd bean proved superior and recorded maximum net return (₹28260/ha). However, B:C ratio was higher with 50 kg N + 16.7 kg P/ha (Table 4). These higher values were obtained due to low input cost. Among direct fertility levels, maximum net return (₹35650/ha) and B:C ratio (1.83) were recorded with 100 kg N + 27.8 kg P + 40 kg S/ha, which may be due to higher seed yield.

It was concluded that application of 75 kg N + 25 kg P/ha to pearl millet followed by 100 kg N + 27.8 kg P + 40 kg S/ha to mustard proved highly productive and remunerative system under semi-arid region of Rajasthan, also resulted into a net saving of 25 kg N and 8.3 kg P/ha in pearl millet + urd bean-mustard cropping system.

REFERENCES

Anonymous 2010. Agricultural Statistics at a glance. Agricultural Statistics, Division Directorate of Economics & Statistics, Department of Agriculture & Cooperation Ministry of Agriculture, Government of India.

Choudhary R S and Gautam R C 2007. Effect of nutrient-management practices on growth and yield of pearl millet (*Pennisetum glaucum*). *Indian Journal of Agronomy*, **52**(1): 64-66.

Guggari A K and Kalaghatagi S B 2005. Effect of fertilizer and biofertilizer on pearl millet (*Pennisetum glaucum*) and pigeonpea (*Cajanus cajan*) intercropping system under rainfed conditions. *Indian Journal of Agronomy*, **50**(1):24-26.

Kumar R, Singh D and Singh H 2002. Growth and yield of Brassica species as influenced by sulphur application and sowing dates. *Indian Journal of Agronomy*, **47**(3):418-421.

Mishra B and Giri G 2004. Influence of preceding season practices and direct application of fertilizer on growth, yield, oil content and oil production of Indian mustard (*Brassica juncea*). *Indian Journal of Agronomy*, **49**(4):264-267.

Nandal D P, Malik D S and Singh K P 1987. Effect of phosphorus levels on dry matter accumulation of *kharif* pulses. *Legume Research*, **19** (1): 31-33.

Premi O P, Kumar A, Sinsinwar B S and Manoj Kumar 2004. Productivity and economics of Indian mustard, *Brassica juncea* L. Cren & Coss as influenced by foliar spray of agro-chemicals. *Journal of Oilseeds Research*, **21**(2):299-300.

Premi O P, Jha S K, Manoj Kumar, Fateh Singh, Singh Y P, Bhogal N S, Singh A K, Sharma A K and Kumar A 2006. Comparative performance of Indian mustard, *Brassica juncea* (L.) Czern & Coss based crop sequences in semi-arid Rajasthan: on farm studies. *Journal of Oilseeds Research*, **23**(2):2006.

Singh H G and Sahu M P 1986. Response of oilseeds to sulphur. *Fertilizer News*, **31**: 23-30.

Sinsinwar B S, Fateh Singh and Premi O P 2002. Performance of Indian mustard (*Brassica juncea*) in sequential cropping systems under irrigated conditions. *Indian Journal of Agronomy*, **47**(2):173-176.

Sinsinwar B S, Premi O P and Kumar A 2005. Productivity and economics of different Indian mustard, *Brassica juncea* (L.) Czern & Coss based cropping systems under irrigated conditions. *Journal of Oilseeds Research*, **22**(1):40-41.

Evaluation of pre-emergence herbicides for weed management in sesame (*Sesamum indicum* L.) under semi-arid subtropical conditions

PARVENDER SHEORAN[1], VIRENDER SARDANA, SHER SINGH, PUSHP SHARMA AND A K ATWAL

Punjab Agricultural University, Ludhiana-141 004, Punjab

(Received: August, 2011; Revised: April, 2012; Accepted: May, 2012)

ABSTRACT

To evaluate the selectivity and efficacy of pre-emergence herbicides on weeds and the productivity of sesame (*Sesamum indicum* L.), field experiments were conducted during rainy season of 2004 to 2006 at Punjab Agricultural University, Ludhiana, Punjab (India). All the weed control treatments significantly reduced the population and dry weight of weeds and increased the seed yield of sesame over weedy check. Season long weed competition reduced the seed yield by 38.9% in comparison to recommended practice of one hand weeding [3 weeks after sowing (WAS)]. Herbicidal based weed management (irrespective of herbicide) increased the seed yield of sesame by 41.8-59.8% in comparison to weedy check. Among herbicides, pre-emergence application of alachlor @ 1.5 kg/ha resulted in significantly higher seed yield (593 kg/ha) with 10.6 and 12.7% yield superiority over pre-emergence application of fluchloralin @ 1.0 kg/ha and trifluralin @ 1.0 kg/ha, respectively. Integration of hand weeding with herbicide application irrespective of dose though resulted in higher seed yield, but the net income and B:C ratio were lower when compared with sole application of herbicide. The highest net income (₹ 4.99 x 10^3/ha) and benefit: cost ratio (1.53) were recorded with pre-emergence application of alachlor @ 1.5 kg/ha and this treatment was found to be as effective as manual weeding. This study identifies cost effective herbicide based weed management through pre-emergence application of alachlor @ 1.5 kg/ha as an alternative option to manual weeding in sesame. The research results were further validated through farmers' participatory field demonstrations conducted during 2007 where alachlor (1.5 kg/ha) treated plots excelled by 43.5 and 3.0% in comparison to unweeded control and hand weeding 3 WAS, respectively.

Keywords: Growth, Herbicides, Seed yield, Sesame, Weed management, Yield components

Weed infestation is one of the major biological constraints in realizing potential production of sesame (*Sesamum indicum* L.) crop sown during rainy season. Prevalence of high temperature coupled with high relative humidity and frequent rainfall favours luxuriant weed growth which not only smothers crop by restricting its growth particularly during early growth stages but also offers severe weed competition for essential natural and man made resources during the entire crop season. Several annual grasses and broadleaf weeds invade this crop causing heavy yield losses (Grichar *et al.*, 2001). An initial period of 15-20 days is very critical (Venkatakrishnan and Gnanamurthy, 1998) and season long weed competition has been found to reduce sesame yield to the extent of 50-75% depending the type and intensity of weed flora (Dungarwal *et al.*, 2003). Farmers rely predominantly on manual weeding as a traditional method of weed control in oilseeds in general and sesame in particular. Though the conventional methods of weed control are very effective but these are expensive, labour intensive and time consuming and most often protracted rains do not allow or delay the weeding during the critical weeding season. This necessitates for an alternative cost-effective economically viable weed management practice that can serve as a substitute for manual weeding. Use of dinitroanilines herbicides have been found effective in controlling weeds and increasing the seed yield of sesame (Grichar *et al.*, 2001; Grichar and Dotray, 2007). However, information regarding chemical weed control in sesame under rainfed conditions is lacking. In view of the above rationale, an attempt has been made to work out an effective weed management strategy based on herbicides applied alone or in combination with hand weeding under semi arid sub tropical conditions of Punjab.

MATERIALS AND METHODS

Field experiments were conducted for three years during the rainy seasons of 2004, 2005 and 2006, to evaluate the efficacy of some pre-emergence herbicides for weed control in sesame at the Oilseeds Research Farm of Punjab Agricultural University, Ludhiana (India) located at 30°56' N latitude and 75°52' E longitude. The soil of the experimental site was characterized as loamy sand in texture with pH 7.3, total nitrogen 0.30 ± 0.03 g/kg, organic matter 0.28±0.03% and Olsen P 8.1±1.2 mg/kg. The experimental region represents semi-arid climate with an average annual

[1]Asst. Agronomist (E-mail: sheoran76@rediffmail.com)

rainfall of 400-700 mm (75-80% of which is received during July to September), minimum temperature of 0 to 4°C in January, maximum temperature of 41 to 45°C in June. The experiment consisted of different doses of herbicides *viz*., fluchloralin (basalin 45 EC) @ 1 kg/ha, alachlor (lasso 50 EC) @ 1.5 kg/ha and trifluralin (treflan 45 EC) @ 1.0 kg/ha applied alone or in combination with hand weeding (4 WAS), hand weeding once (3 WAS) and a weedy check making a total of eight treatment plots (Table 1) laid out in a randomized block design with three replications. All the herbicide treatments were applied in 450 L of water/ha using the conventional knapsack sprayer with flat fan nozzle. The field was well prepared by having two-three ploughings followed by planking. After seed bed preparation, sesame variety 'TC 289' was sown in the first fortnight of July by using 2.5 kg seed/ha at 30 cm row spacing. Basal fertilizer application of 35 kg N/ha in the form of urea was done as a common practice to all the treatment plots. Adequate plant protection measures were undertaken to keep the insects-pests under check. Each year, the gross plot size was kept to be 23.1 m^2 by accommodating 14 rows each of 5.5 m length, whereas the net plot size remained 16.5 m^2 by leaving 2 rows on either side. Weed density and dry weight was recorded with the help of a quadrant (0.5 m x 0.5 m) placed randomly at two spots at maturity of the crop. Weed seedlings within these quadrants were counted, and the efficacy of different weed control treatments was evaluated by comparing the density with the unweeded control. The data on weed populations were subjected to square root transformation prior to statistical analysis. Weeds were cut to the ground level, washed with tap water, sun dried, and then oven dried at 70°C for 48 h, and then weighed. The weed control efficiency (WCE) was calculated by using the following formula (Tawaha *et al*., 2002):

$$\text{WCE} = \frac{\text{Weeds drymatter in untreated plot - Weeds drymatter in treated plot}}{\text{Weeds drymatter in untreated plot}} \times 100$$

At harvesting, five plants were selected randomly from each plot for measuring agronomic parameters including number of capsules/plant, seeds/capsule and 1000 seed weight. Treatment wise net plot was harvested to determine the seed yield which was expressed in kg/ha. The data thus obtained were analyzed statistically using analysis of variance technique and significant means were separated using least significance difference test (LSD) at 5% significance level for comparing the treatment means. The monetary benefits in terms of gross returns, net returns and benefit: cost ratio were also worked out for different weed control treatments by using the prevailing market prices of the produce and the inputs used. To further validate the research results under farmers' management conditions, the farmers' participatory demonstrations were conducted during rainy season of 2007 at 17 locations in six sesame growing districts of Punjab state by taking recommended practice of one hand weeding (3 WAS), pre-emergence application of alachlor @ 1.5 kg/ha (best treatment) and unweeded check as the treatment plots along with research trial at PAU, Ludhiana.

RESULTS AND DISCUSSION

Effect on weeds: The dominant weed flora in the field was *Cynodon dactylon* and *Eleusine aegyptiacum* in grassy weeds, while *Commelina benghalnesis* and *Digera arvensis* were amongst the main broadleaf weeds. In sedges, *Cyperus rotundus* was the pre-dominant weed (Table 1). On an average, broadleaf weeds (43-51%) and sedges (41-46%) were observed to be the dominant weed species in different years of experimentation while grasses accounted only to the extent of 6-12% of the total weeds population. Irrespective of weed species, overall weed population was comparatively higher in the year 2006 as compared to 2004 and 2005. During all the years (2004-2006), different weed control treatments including herbicidal based weed management practices applied either alone or in combination with hand weeding significantly reduced the species wise (grassy/sedges/broadleaf) weed population compared to the weedy check (Table 1). In general, application of fluchloralin or trifluralin, irrespective of the dose provided better control than alachlor against grassy weeds during early stages of crop growth, however, reverse was the case for the effectiveness of these herbicides against sedges as well as broadleaf weeds where alachlor was found more effective. All the weed management practices significantly reduced the population and dry weight of weeds at harvest as compared to unweeded control in individual years as well as in pooled analysis (Table 2). Hand weeding (3 WAS) significantly reduced the weed density than weedy check and caused 78.3% reduction in mean dry weight of weeds in comparison to season long weed competition. Pre-emergence application of either of the herbicides (irrespective of dose) applied alone could not compete with the manual weeding (3 WAS) in respect of weed management and caused only 41.4 to 72.0% reduction in mean dry weight of weeds as against the 78.3% in case of later (Table 2). Pre-emergence application of all the herbicides irrespective of the dose proved to be significantly superior to weedy check. Among herbicides, sole application of alachlor @ 1.5 kg/ha was found significantly superior in terms of reduction in density and dry weight of weeds when compared with fluchloralin and trifluralin both applied @ 1.0 kg/ha. Integration of one hand weeding (4 WAS) with pre-emergence application of either of the herbicides resulted in significant improvement in reduction of weed density and their dry biomass when compared with respective sole application of herbicides. Improvement in weed control efficiency to the tune of 14.6 to 30.4% was recorded with the highest under alachlor and lowest in case of trifluralin when one hand weeding was integrated with respective sole application of herbicides. The lowest weed density and weeds dry weight and highest weed control efficiency was observed with integrated application of alachlor @ 1.5 kg/ha with one hand weeding (4 WAS).

Effect on crop: The data on growth (plant height, branches/plant), yield attributing characters (capsules/plant, seeds/capsule, 1000 seed weight) and oil content for the three years were combined together for pooled analysis as in each case there was no interaction effect of treatment and the year. There was a significant improvement in plant height, capsules/plant and seeds/capsule due to different weed management practices in comparison to weedy check (Table 3). However, branches/plant, 1000 seed weight and oil content were non-conspicuously influenced by these treatments. Application of alachlor @ 1.5 kg/ha in combination with one hand weeding (4 WAS) resulted in significantly taller plants (131.2 cm) and more number of capsules/plant (54.2); however, highest number of seeds/capsule (47.5) were found to be significantly higher under hand weeding (3 WAS) among different weed management practices. Unweeded control resulted in lowest values of all the growth and yield attributing characters.

Table 1 Effect of weed control treatments on the species-wise density of weeds at harvest

Treatment	Weed density (No./m^2) at harvest								
	2004			*2005*			*2006*		
	Grasses	Sedges	Broadleaf	Grasses	Sedges	Broadleaf	Grasses	Sedges	Broadleaf
Unweeded control	1.9 (5.2)	6.2 (37.8)	2.7 (41.3)	2.6 (5.9)	5.7 (31.8)	6.4 (39.6)	4.6 (20.0)	8.8 (77.3)	8.2 (72.0)
Hand weeding 3 WAS (HW)*	1.7 (4.1)	5.1 (25.3)	1.9 (18.9)	1.7 (2.1)	3.0 (8.1)	2.7 (6.5)	1.0 (0.0)	4.4 (19.0)	4.1 (15.7)
Fluchloralin 1 kg/ha	1.6 (2.5)	6.3 (38.2)	2.1 (17.6)	1.6 (1.6)	5.3 (26.9)	3.5 (11.5)	2.3 (5.3)	8.2 (66.7)	5.6 (32.0)
Fluchloralin 1 kg/ha + HW 4 WAS	1.6 (2.1)	4.3 (17.6)	2.2 (22.2)	1.7 (1.9)	3.1 (8.3)	3.8 (13.8)	1.0 (0.0)	2.1 (4.0)	3.1 (9.3)
Alachlor 1.5 kg/ha	1.6 (3.5)	5.3 (26.9)	2.0 (29.6)	1.6 (1.5)	3.0 (8.1)	2.8 (7.1)	2.7 (12.0)	3.1 (10.7)	3.3 (10.7)
Alachlor 1.5 kg/ha + HW 4 WAS	1.5 (1.6)	4.7 (21.4)	1.7 (16.2)	1.4 (0.8)	2.7 (6.1)	2.0 (3.0)	1.0 (0.0)	2.5 (6.7)	1.0 (0.0)
Trifluralin 1.0 kg/ha	1.8 (1.8)	5.2 (26.5)	2.9 (39.9)	2.1 (3.4)	5.5 (29.7)	5.4 (28.2)	2.2 (4.0)	5.4 (28.0)	7.1 (50.7)
Trifluralin 1.0 kg/ha + HW 4 WAS	1.6 (1.5)	4.4 (18.1)	2.3 (21.6)	1.6 (1.6)	4.5 (19.6)	4.4 (18.8)	1.0 (0.0)	3.6 (12.0)	3.7 (13.3)
LSD (P=0.05)	0.07	0.4	0.1	0.2	0.6	0.5	0.4	1.0	0.7

*Recommended practice; WAS- Weeks after sowing; PE-Pre-emergence; Figures in parentheses are the means of original values. Data subjected to square root transformation.

Table 2 Effect of weed control treatments on the total weeds density and dry weight of weeds at harvest

Treatment	Total weed density (No./m^2) at harvest				Weed dry weight (g/m^2)				Weed control efficiency (%)
	2004	*2005*	*2006*	Mean	*2004*	*2005*	*2006*	Mean	
Unweeded control	9.2 (84.3)	8.8 (77.3)	13.0 (169.3)	10.5 (110.3)	154.3	81.3	58.5	98.1	-
Hand weeding 3 WAS (HW)*	7.0 (48.3)	4.2 (16.7)	5.9 (34.7)	5.8 (33.2)	32.7	10.0	21.0	21.2	78.3
Fluchloralin 1 kg/ha	7.7 (58.3)	6.4 (40.0)	10.2 (104.0)	8.3 (67.4)	49.7	22.0	34.9	35.5	63.8
Fluchloralin 1 kg/ha + HW 4 WAS	6.5 (41.9)	5.0 (24.0)	3.8 (13.3)	5.3 (26.7)	31.3	10.3	6.9	16.2	83.4
Alachlor 1.5 kg/ha	7.8 (60.0)	4.2 (16.7)	5.7 (33.3)	6.1 (36.7)	57.7	11.0	13.9	27.5	72.0
Alachlor 1.5 kg/ha + HW 4 WAS	6.3 (39.2)	3.3 (10.0)	2.5 (6.7)	4.4 (18.6)	32.0	4.7	2.5	13.1	86.6
Trifluralin 1.0 kg/ha	8.3 (68.2)	7.9 (61.3)	9.1 (82.7)	9.2 (84.1)	77.3	58.3	36.6	57.4	41.4
Trifluralin 1.0 kg/ha + HW 4 WAS	6.5 (41.2)	6.4 (40.0)	5.1 (25.3)	6.0 (35.5)	39.3	35.7	8.2	27.7	71.8
LSD (P=0.05)	0.4	0.6	1.1	0.8	30.4	17.3	12.1	11.6	

*Recommended practice; WAS- Weeks after sowing; PE-Pre-emergence. Figures in parentheses are the means of original values. Data subjected to square root transformation.

Table 3. Yield and yield attributing characters of sesame in relation to different weed control treatments

Treatment	Seed yield (kg/ha)				Oil *content* (%)	Plant *height* (cm)	Primary *branches/* plant	Capsules/ plant	Seeds/ capsule	1000 *seed wt.* (g)	Cost (x 10^3 INR/ha)		
	2004	2005	2006	Mean							Gross returns	Net returns	B:C ratio
Unweeded control	417	414	282	371	46.5	125.1	3.4	42.9	38.9	2.64	9.0	1.17	1.04
*Hand weeding 3 WAS (HW)**	563	602	655	607	48.2	130.3	3.9	51.3	47.5	3.10	15.9	5.20	1.38
Fluchloralin 1 kg/ha	488	469	650	536	47.4	127.9	3.7	47.3	43.4	2.79	13.0	3.44	1.36
Fluchloralin 1 kg/ha + HW 4 WAS	593	514	719	609	47.9	127.7	3.8	48.5	46.2	2.84	14.8	3.14	1.27
Alachlor 1.5 kg/ha	588	508	683	593	48.3	125.1	3.7	48.6	45.1	3.07	14.4	4.99	1.53
Alachlor 1.5 kg/ha + HW 4 WAS	658	563	732	651	48.2	131.2	3.9	54.2	46.9	3.14	16.2	4.72	1.41
Trifluralin 1.0 kg/ha	548	483	546	526	47.1	121.4	3.5	48.3	43.3	3.08	12.7	3.30	1.35
Trifluralin 1.0 kg/ha + HW 4 WAS	638	515	623	592	48.3	126.4	4.0	50.7	44.2	3.04	14.4	2.63	1.24
LSD (P=0.05)	87	92	128	56	NS	3.8	NS	5.8	4.2	NS	-	-	-

*Recommended practice; WAS- Weeks after sowing; PE-Pre-emergence

Application of herbicides (irrespective of dose) have no phytotoxic effect on the crop. Season long weed competition reduced the mean seed yield of sesame by 38.9% in comparison to recommended practice of one hand weeding (3 WAS) (Table 3). Significant improvement in seed yield of sesame was observed with all the weed control practices when compared with unweeded control. Irrespective of herbicide and dose, herbicidal based weed management increased the seed yield of sesame by 41.8-59.8% in comparison to weedy check. This might be due to decreased crop-weed competition for sunlight, nutrients and space resulting in significant improvement in growth and yield attributing components which ultimately contributed to higher seed yield in sesame. Among herbicides, pre-emergence application of alachlor @ 1.5 kg/ha resulted in significantly higher mean seed yield (593 kg/ha) with 10.6 and 12.7% yield superiority over pre-emergence application of fluchloralin @ 1.0 kg/ha and trifluralin @ 1.0 kg/ha, respectively. This treatment was found to be at par with manual weeding (3 WAS). Application of both fluchloralin and trifluralin was statistically at par with each other in this respect. These results corroborate with the findings of Grichar et al. (2009) and Dungarwal *et al.* (2003). The data further revealed that integration of one hand weeding (4 WAS) with pre-emergence application of each of the herbicide significantly improved the seed yield of sesame when compared with their respective sole application. Yield enhancement to the tune of 9.8, 12.5 and 13.6% was recorded when one hand weeding (4 WAS) was integrated with pre-emergence application of alachlor @ 1.5 kg/ha, trifluralin @ 1.0 kg/ha and fluchloralin @ 1.0 kg/ha, respectively. This is because many weeds, especially sedges and broadleaf weeds though initially controlled to some extent by sole application of pre-emergence but might have germinated later during the crop growth period causing significant yield reduction. However, integration of hand weeding (4 WAS) along with pre-emergence application of herbicides might have provided better control of weeds for longer crop growth period resulting in better yield advantage compared to sole application of herbicides. Similar beneficial effect of integrated approach for better weed control and higher yield have also been reported by Dungarwal *et al.* (2003). Highest mean seed yield of 651 kg/ha was recorded with pre-emergence application of alachlor @ 1.5 kg/ha in combination with one hand weeding (4 WAS) and was statistically at par with pre-emergence application of fluchloralin @ 1.0 kg/ha in combination with one hand weeding done at 4 WAS (609 kg/ha) and one hand weeding done at 3 WAS (607 kg/ha) (Table 3). This treatment resulted in 7.2 and 75.5% higher seed yield as compared to hand weeding (3 WAS) and weedy check, respectively. The application of fluchloralin @ 1.0 kg/ha was found to be most inferior among all the weed control practices in terms of seed yield, which was due to poor control of weeds provided by this treatment. Seed yield of sesame was negatively correlated with the dry matter of weeds. The seed yield decreased exponentially as the weeds dry matter increased and the weeds accounted for 95% variation in seed yield of sesame.

Economics: Implication of any of the weed management practice resulted in better monetary returns when compared with weedy check. Unweeded control culminated in lowest gross returns (₹9.0 x 10^3/ha), net returns (₹1.77 x 10^3/ha) and benefit: cost ratio (1.04). Integration of one hand weeding (4 WAS) with any of the herbicides (irrespective of dose) significantly improved the seed yield of sesame for getting better gross returns from the crop, but the increased cost of production in lieu of higher wages of the labour might have contributed towards comparatively lower net returns and benefit: cost ratio when compared with their respective sole application of the herbicides. Herbicidal based weed management through sole application of alachlor @ 1.5 kg/ha resulted in highest net returns (₹4.99 x 10^3/ha) and benefit: cost (1.53) ratio among different weed control treatments (Table 3).

Table 4 Comparative performance of alachlor in on-farm trials during rainy season of 2007

Location	Seed yield (kg/ha)		
	Unweeded control	Hand weeding 3 WAS*	Alachlor 1.5 kg/ha
Gurdaspur (2)	195	380	385
Hoshiarpur (3)	279	503	487
Sangrur (3)	315	382	431
Nawanshahr (3)	417	439	465
Ropar (4)	315	437	415
Ferozepur (2)	337	487	550
Weighted mean (17)	315	439	452

*Recommended practice; Figures in parentheses are the number of locations

Validation: The research results were further validated through farmers' participatory approach by conducting on-farm trials under field conditions. The results revealed that pre-emergence application of alachlor @1.5 kg/ha gave 43.4 and 3.0% higher seed yield as compared to unweeded control and hand weeding (3 WAS), respectively (Table 4). Similarly, at research farm herbicide based weed management through alachlor @ 1.5 kg/ha (pre-emergence) was as good as the recommended practice of hand weeding (3 WAS) for effective weed control and achieving similar yield levels (Table 5). However, it gave 58.9% higher yield when compared with season long weed competition (weedy check). This treatment resulted in highest benefit: cost ratio of 1.57 as against the 1.41 for hand weeding (3 WAS) and 1.16 for unweeded control (Table 5). Overall, the results of 4 research trials conducted at PAU, Ludhiana and on-farm trials conducted over 17 locations elucidated that weeds can be effectively managed with pre-emergence application of alachlor @ 1.5 kg/ha. This treatment recorded similar yield levels as obtained under the recommended practice of hand weeding (3 WAS), however, it excelled by 43.7% when compared with unweeded control (Table 6).

Based on the results of research and adaptive trails, it can be concluded that herbicide based weed management through alachlor @ 1.5 kg/ha (pre-emergence) provided effective control of weeds and could be used as a cost effective economically viable alternative to the farmers in sesame as the manual weeding is un-economical as well as tedious, time and labour consuming practice.

Table 5 Comparative performance of alachlor in research trial conducted at PAU, Ludhiana during rainy season of 2007

Treatment	Weed density (No./m^2)	Weed dry weight (g/m^2)	Seed yield (kg/ha)	Net returns (x 10^3 ₹/ha)	B:C ratio
Unweeded control	103.8 (10.2)	73.4	414	1.32	1.16
Hand weeding 3 WAS*	21.6 (4.7)	15.8	678	5.58	1.41
Alachlor 1.5 kg/ha	34.8 (5.9)	18.2	653	6.28	1.57

*Recommended practice; WAS- Weeks after sowing; PE-Pre-emergence

Table 6 Comparative performance of alachlor 1.5 kg/ha in research and on-farm trials

Trial	No. of trials	Unweeded control	Hand weeding 3WAS*	Alachlor @ 1.5 kg/ha
Research trials	4	382	625	608
On-farm trials	17	315	439	452
Overall weighted mean	21	334	480	482
Per cent increase over unweeded control			+ 43.7	+ 44.3
Per cent increase over hand weeding			-	· 0.4

* Recommended practice

REFERENCES

Dungarwal H S, Chaplot P C and Nagda B L 2003 Integrated weed management in sesame. *Indian Journal of Weed Science*, **35**: 236-238.

Grichar W J and Dotray P A 2007 Weed control and sesame (*Sesamum indicum* L.) response to pre-plant incorporated herbicides and method of incorporation. *Crop Protection*, **26**(12): 186-1830.

Grichar W J, Dotray P A and Langham R D 2009 Sesame (*Sesamum indicum* L.) response to pre-emergence herbicides. *Crop Protection*, **28**: 928-933.

Grichar W J, Sestak D C, Brewer K D, Besler B, Stichler C R and Smith D T 2001 Sesame (*Sesamum indicum* L.) tolerance and weed control with soil applied herbicides. *Crop Protection*, **20**: 389-394.

Tawaha A M, Turk M A and Maghairh G A 2002 Response of barley to herbicide versus mechanical weed control under semi arid conditions. *Journal of Agronomy and Soil Science*, **188**: 106-112.

Venkatakrishan A S and Gnanamurthy P 1998 Influence of varying period of crop-weed competition in sesame. *Indian Journal of Weed Science*. **30**: 209-210.

Need of ITK based rainfall analysis for safflower (*Carthamus tinctorius* L.) sowing under climate change situation in Maharashtra

J D JADHAV, J R KADAM, S V KHADTARE AND V A SHINDE

Mahatma Phule Krishi Vidyapeeth, Zonal Agricultural Research Station, Solapur, Maharashtra

(Received: December, 2011; Revised: February, 2012; Accepted: March, 2012)

ABSTRACT

Rainfall data for last five decades of Solapur (1951-2005) were collected at Dry Farming Research Station, Solapur and used for rainfall analysis. Rainfall analysis of southern part representing Solapur revealed the highest probability (>50%) of rainfall >20 mm in 38 to 40 MW with less variability (CV. 86 to 110%) and winter season dominance. Sowing of rainy season crops are possible in 25 MW and 26 MW at Solapur. The variability of rainfall was less in these weeks (97 to 98%). The monthly rainfall variability showed that the pre-seasonal rains in the month of April and May increased with high instability in the amount. The rainfall in the month of June, September and October recorded less variability as compared to the remaining month. The nakshatrawise rainfall variability showed that the good amount of rainfall in *Mrugshira, Punarvasu* and *Uttara nakshtra* indicated that the sowing of rainy and winter crops can be under taken in *Mrugshira* and *Purva, Uttara.* By knowing this experiment on sowing date and varieties in winter season safflower (*Carthamus tinctorius* L.) was conducted during (2006-07 to 2008-09). The three years data were considered for analysis and from average values it was concluded that the safflower sown in first fortnight of September (MW 36) (i.e., *Uttara Nakshtra*) (S_1) produced significantly maximum grain yield (954 kg/ha), and total monetary returns (₹ 18568/ha) over rest of the sowing dates. However, variety 'Kusuma' produced more grain yield (649 kg/ha) and total monetary returns. (₹ 11994/ha).The positive association of rainfall at emergence indicated better germination, GDD and T min positive association at rosette showed with increase in temperature better development of rosette in safflower. At branching GDD is positively correlated indicating again maximum temperature favours the branching and bud initiation. Further, HTU at bud initiation indicating the maximum hours of BSS is favourable for budding of safflower. The aphids/plant in relation to minimum temperature during the growing period of safflower showed a polynomial relationship .The minimum temperature below 16°C was found to be optimum for higher attack of aphids/plant. Beyond this limit aphid's population/plant decreases.

Keywords: Agrometeorological indices, Nakshtrawise rainfall, Pest, Yield

Safflower (*Carthamus tinctorius* L) is a member of the *Compositae* or *Asteraceae* family , cultivated mainly for its seed which is source of oil and bird feed. In India, safflower production remained stagnant at about 554 thousand t. In India, Maharashtra is the highest producer of safflower (63%) from the largest growing area (67%) followed by Karnataka (32% in production and 27% in area). Nakshatrawise (ITK Method) rainfall pattern for the scarcity zone of Maharashtra was earlier reported by Jadhav *et al.* (1997). The available information on climatic parameters i.e., rainfall is essential to analyze the potential of particular parameter which affect the crop production and distribution. Suitability of a sowing date to a place is generally referred in context to the annual rainfall and its distribution during the crop growth or crop growing season is a far more important. Hence, the rainfall normal of the Solapur in the scarcity zone for annual, monthly, seasonal, weekly and *nakshatra* period (ITK method) are worked out and presented in this paper to decide the sowing window of safflower crop. Keeping this in view an experiment was conducted with following objectives to study (I) growth of safflower under different agro-climatic conditions, (ii) the incidence of pest under different agro-climatic conditions and (iii) to develop the relationship between weather parameters and incidence of pest.

MATERIALS AND METHODS

Field experiments were conducted at research farm of dryland, Maharashtra at Solapur from 2006-07 to 2008-09. It is situated at 17°41N latitude, 75°-45E longitude at an altitude of 476 meters above sea level. The treatments consist of

Date of sowing (4):

S_1 = MW 36 -37 (Sept 03-Sept16),	*Uttara nakshatra*
S_2 = MW 38-39 (Sept 17-Sept 30),	*Hasta nakshatra*
S_3= MW 40-41 (Oct. 01- Oct 14),	*Chitra nakshatra*
S_4= MW 42-43 (Oct.15- Nov.28),	*Swati nakshatra*

Sub-treatments : Two varieties (V_1 = *Bhima*, V_2 = Phule kusuma)

and Sub-sub treatment : Two
(T_1 = *Unprotected*, T_2=*Protected (Recommended insecticide)*

The treatments were replicated thrice in split plot design with dates of sowing in main plots genotypes of safflower in subplots and plant protection measures in sub-sub plots. Crop was grown using appropriate package of practices. Observations on different phenological stages such as emergence, rossete termination, branch initiation, bud initiation, flower initiation, 50% flowering, cessation of flowering and physiological maturity stages were recorded. With the help of this meteorological data following agro meteorological indices *viz.*, growing degree days (GDD), growing degree days accumulated for attaining different phonological events were calculated with base temperature as 8°C following Hundal *et al.* (2004). The incoming photo synthetically active radiation was then calculated by multiplying solar radiation by 0.45 (Rosenthal *et al.*, 1991). Thermal interception rate was calculated as per the procedure adopted by Ong and Squire (1984) and Radiation use efficiency (RUE, g/MJ) of safflower cultivars during different phonological stages was computed. Before this the rainfall data at Dry Farming Research Station, Solapur was used for the Nakshatrawise rainfall probability and variability analysis.

RESULTS AND DISCUSSION

Decadal analysis of Solapur: Annual average rainfall (731.8 mm) and its variability in Solapur district which comes under scarcity zone of Maharashtra. The available rainfall data of the center was further used for decadal analysis by considering the first year of a decade. Accordingly, the analysis of rainfall for Solapur centre was worked out as annual, monthly, seasonal, weekly and *nakshatras*. (ITK based). The initial wet (w) and conditional (w/w) probabilities of the weekly rainfall for getting >20 mm rains and nakshatrawise initial rainfall probabilities for getting >20 mm and 40 mm rains were worked out. The variability of annual rainfall and its deviation from the normal rainfall in various decades for Solapur center of scarcity zone is presented below.

The nakshatrawise rainfall variability showed that the good amount of rainfall in *Mrugshira, Punarvasu* and *Uttara nakshatra* indicated that the sowing of rainy and winter season crops can be under taken in *Mrugshira* and *Purva, Uttara*, respectively. Further, it also indicates that *Pushya nakshatra* having higher probability followed by *Purva* and *Chitra nakshatra*. From the result of the study following conclusions could be drawn for rainfall analysis. The monthly rainfall variability showed that the pre-seasonal rains in the month of April and May increased with high instability in the amount. The rainfall in the month of June, September and October recorded less variability as compared to the remaining month. In seasonal rainfall variability, the South-West monsoon showed the variation in the rainfall from 442.6 to 675.4 mm with less variability (CV 15 to 38). The contribution of rains from North-East monsoon was in the range of 11.6 to 20.6% of total with CV. range from 47 to 75%. The weekly rainfall variability for most of the decades showed the less variability in 25, 28, 30, 31 and 32, 36, 38 to 40 MW. The 30 and 31 MW can be considered for contingency crop planning. The rainfall in 36 MW indicated that, the early sowing of some winter crops (i.e., sunflower) can be under taken. The normal sowing of winter crops can be under taken in 38 to 40 MW. The weekly rainfall probability 30 and 31 MW had the higher initial probability (mid season) followed by higher conditional probability of wet followed by wet week indicted that the sowing of contingency crops can be undertaken during these weeks. The MW 38 to 40 in winter season had the highest probability for sowing of crop like sorghum, safflower and chickpea. The nakshatrawise rainfall variability showed that the good amount of rainfall in *Mrugshira, Punarvasu* and *Uttara nakshatra* indicated that the sowing of rainy and winter season crops can be under taken in *Mrugshira* and *Purva, Uttara* (Table 1).

The safflower sown in first fortnight of September (MW 36) (S_1) produced significantly maximum grain yield (954 kg/ha), and total monetary returns (₹ 18568/ha) over rest of the sowing dates. However, variety 'Kusuma' produced more grain yield (649 kg/ha) and total monetary returns (₹11994/ha) (Table 2).

The consumptive use of moisture (295.3 mm) and moisture use efficiency (4.05 kg/ha/mm) was higher in crop sown at MW 36. Among the variety 'Bhima' recorded highest values of CUM, MUE days to attain maturity, GDD over variety 'Kusuma' (Table 3 and 4). All the varieties took 7 to 14 more days to attain maturity in first season than in the second season. Possible reason for difference in crop duration in all the varieties and sowing dates in two crop seasons could be due to the prevalence of higher temperature during most time of crop growth in the second season as compared to first season. Moreover less rainfall and less number of rainy days in the second crop season enable the air temperature to raise more which ultimately contributed to reduction of crop growth duration. The duration of different phonological events was in good agreement with those reported by Dhingra *et al.* (1995). Further, crops sown on early dates accumulated higher GDD for attaining any phonological event as compared to late sown crop in both seasons. All the varieties consumed less amount of thermal units for attaining physiological maturity in the second crop season which might be attributed to shortening of the crop duration in this season due to prevailing high temperature and dry weather as compared to the first crop season. These results are in agreement with Debosthali *et al.* (2007) and Singh *et al.* (2007).

Table 1 Decadal nakshtrawise rainfall (mm) and rainfall variability (CV%) at Solapur

Nakshatra	1951-60		1961-70		1971-80		1981-90		1991-2000		2001-05	
	RF	CV	RF	CV	RF	CV	RF	CV	RF	CV	RF	CV
Krithika	26	95	16	144	10	238	27	122	12	176	29	152
Rohini	50	57	34	67	38	103	50	88	38	68	24	93
Mrugashira	47	80	47	60	47	71	56	98	48	75	28	66
Aridra	42	56	47	88	47	118	46	81	85	66	19	64
Punarvasu	47	50	50	87	30	59	80	92	38	70	35	75
Pushya	104	84	64	65	70	85	64	68	46	116	66	59
Aashlesha	54	138	40	68	58	86	102	86	48	177	59	76
Magha	77	105	59	60	77	83	51	155	51	96	68	96
Purva	100	61	59	90	30	94	67	67	71	101	77	72
Uttara	51	105	71	82	82	47	141	64	42	80	48	90
Hasta	116	64	59	117	94	92	83	55	83	101	53	126
Chitra	37	77	11	132	33	156	17	216	54	69	44	80
Swati	23	203	24	126	25	130	22	125	14	210	1	200
Vishakha	9	155	7	208	20	170	11	207	15	145	0	200
Anuradha	1	238	2	200	14	224	2.	205	2	200	0	0

Radiation use efficiency (RUE) from different treatments are presented in table 5. Initially the RUE values were low and it increases up to 70 DAS i.e., up to 50% flowering stage further it decreases in all most all the sowing dates and treatments. Sompal (1999) found that RUE alone explained 70% variability in wheat yield. Based on the above results, it was concluded that radiation and beat use efficiency were directly correlated with growth and yield parameters. Heat use efficiency explained the maximum variability in grain yield i.e., upto 95% variation in safflower crop under dryland situation of Maharashtra.

Correlation studies: The weather parameter influence their contribution and performance of winter season safflower crop sown at various sowing dates were assessed in tenure of phase wise correlation.

Bhima: Rainfall showed positive correlation at emergence stage, which was helpful for better germination. T min showed positive association at rosette stage RH-II showed positive association and BSS and E pan showed negative association at flower initiation stage. This indicate low BSS and E pan and high humidity is favourable for flower initiation. The positive association of HTU at 50% flowering indicates the increase in temperature is helpful for seed setting. However, the negative association of GDD and HTU means decrease in temperature at cessation of flowering is helpful. The negative association of T max and positive association of RH-I and RH-II at maturity indicate low temperature is required for maturity to increase yield of Bhima (Table 6).

Kusuma: Positive association of T min, RH-I, RH-II at emergence indicate more moisture was available in the atmosphere. At rosette stage GDD was positively correlated indicate high temperature was favourable for development of rosette. Positive association of T min and RH-II and negative association of BSS at flower initiation stage indicated the low BSS and high RH-II was helpful for initiation of flower. The negative association of RH-I at 50% flowering indicated with decrease in RH-I the yield decreases. The positive association of E pan indicated the maximum use of moisture at cessation of flowering stage of the crop. The negative relation of T max, T min and E pan showed decrease in temperature at maturity decreases the yield. However, the positive relation of RH-I indicated the more morning humidity was favourable for increase in yield of 'Kusuma' variety of safflower (Table 7).

The positive association of rainfall at emergence indicated better germination, GDD and T min positive association at rosette showed with increase in temperature better development of rosette in safflower. At branching GDD in positively correlated indicated again maximum temperature favour the branching and bud initiation. Similar results were found by Agrawal and Upadyay (2009), Singh *et al.* (2003) and Mallick *et al.* (2006).

Pest weather relationship: From the studies between aphid population and their natural enemies, the positive correlation was observed under both normal and late sowing. However, the negative correlation between aphid population and maximum and minimum temperature under normal sown condition could be worked out. The parasitization (1%) under normal sown (SSF-702) condition was obtained on 46^{th} to 1^{st} MW. The activity of predator i.e., 1 LBB/plant also recorded during the same period under normal sown conditions, whereas, both the natural enemies were found active on 47^{th} to 1^{st} MW under late sowing.

Table 2 Grain yield and total monetary returns by different treatments in safflower (2006-07 to 2008-09)

Particulars	Average grain yield (kg/ha)			Total monetary return (₹/ha)		
			A) Sowing dates x varieties			
	Bhima	*P. Kusuma*	Mean	Bhima	P. Kusuma	Mean
S_1	902	1006	954	17653	19483	18568
S_2	658	697	677	12004	13096	12550
S_3	479	507	493	8204	8867	8535
S_4	386	389	387	6340	6530	6435
Mean	606	649		11050	11994	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Sowing date	42.0	130.8		851	2750	
Variety	22.7	80.6		398	1520	
S.D.x Varieties	71	N.S.		1571	N.S.	
			B) Sowing date t Treatments			
	T_1	T_2	Mean	T_1	T_2	Mean
S_1	1029	876	952	20757	16378	18567
S_2	717	638	674	13780	11260	12520
S_3	552	434	493	8936	8135	8535
S_4	419	356	387	6749	6120	6534
Mean	674	576		12555	10473	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Sowing date	42.0	130.8		851	2750	
Treatment	45.7	130.0		420.3	13.75	
S.D.x Treatment						
			C) Variety x treatment			
	T_1	T_2	Mean	T_1	T_2	Mean
V_1	597	536	566	11146	9398	10272
V_2	735	644	689	13964	11548	12756
Mean	666	590		12555	10473	
	SEm±	CD (P=0.05)		SEm±	CD (P=0.05)	
Treatment	45.7	130.0		420.3	13.75	
Variety	22.7	80.6		398	1520	
Treatment x Variety	55.8	N.S.		645.0	N.S.	

Table 3 CUM and MUE as influenced by different treatments in safflower (2006-07 to 2008-09)

Treatment	CUM (mm)	MUE (kg/ha/mm)	Treatment	CUM (mm)	MUE (kg/ha/mm)
$S_1V_1T_1$	307.1	3.95	$S_3V_1T_1$	290.1	3.26
$S_1V_1T_2$	307.1	4.94	$S_3V_1T_2$	290.1	3.81
$S_1V_2T_1$	283.5	3.25	$S_3V_2T_1$	269.8	3.53
$S_1V_2T_2$	283.5	4.09	$S_3V_2T_2$	269.8	4.02
$S_2V_1T_1$	294.1	3.59	$S_4V_1T_1$	270.5	3.52
$S_2V_1T_2$	294.1	4.31	$S_4V_1T_2$	270.5	3.77
$S_2V_2T_1$	276.3	3.53	$S_4V_2T_1$	259.3	3.47
$S_2V_2T_2$	276.3	4.14	$S_4V_2T_2$	259.3	3.66

Table 4 Growing degree days by different treatments in safflower (2006-07 to 2008-09)

Treatment	Phenological stages							
	Emergence stage	Rosette stage	Branch initiation	Bud initiation	Flower initiation	50 % flowering	Cessation of flowering	Physiological maturity
$S_1V_1T_1$& T_2	125	356	167	197	462	146	118	324
Cumulative	125	481	648	845	1307	1453	1571	1895
$S_1V_2T_1$& T_2	108	322	151	167	419	155	116	301
Cumulative	108	430	581	748	1167	1322	1438	1739
$S_2V_1T_1$& T_2	116	362	165	167	424	108	138	295
Cumulative	116	478	644	810	1234	1342	1480	1775
$S_2V_2T_1$& T_2	100	330	148	160	393	104	152	278
Cumulative	100	429	578	737	1131	1234	1386	1664
$S_3V_1T_1$& T_3	118	346	129	140	386	104	161	285
Cumulative	118	464	593	733	1119	1223	1384	1670
$S_3V_2T_1$& T_2	101	313	123	124	365	93	152	280
Cumulative	101	415	538	661	1026	1119	1271	1551
$S_4V_1T_1$& T_2	116	319	127	152	336	103	164	300
Cumulative	116	435	562	714	1050	1154	1317	1617
$S_4V_2T_1$& T_2	100	294	111	138	325	94	138	281
Cumulative	100	394	505	643	968	1062	1200	1480

Table 5 Periodical radiation use efficiency (RUE gm/mj) in safflower (2006-07 to 2008-09)

		S_1		S_2		S_3		S_4	
MW	Days after sowing	Bhima	Kusuma	Bhima	Kusuma	Bhima	Kusuma	Bhima	Kusuma
36	SO	SOW	SOW	-	-	-	-	-	-
38	14	0.33	0.27	SOW	SOW	-	-	-	-
40	28	0.68	0.53	0.29	0.22	SOW	SOW	-	-
42	42	1.56	1.42	0.64	0.49	0.24	0.21	SOW	SOW
44	56	1.98	1.87	1.52	1.38	0.59	0.39	0.21	0.19
46	70	3.15	2.78	1.89	1.79	1.47	1.32	0.55	0.33
48	84	3.05	2.71	3.09	2.68	1.83	1.69	1.38	1.27
50	98	2.85	2.67	2.98	2.59	3.02	2.56	1.77	1.55
52	112	2.73	2.42	2.79	2.54	2.88	2.45	2.85	2.43
2	126	2.65	-	2.67	2.38	2.71	2.39	2.77	2.37
4	140	-	-	2.55	-	2.54	2.23	2.65	2.24
6	154	-	-	-	-	2.48	-	2.47	-

Fig. 1 : Aphids V/s Tmin in Safflower

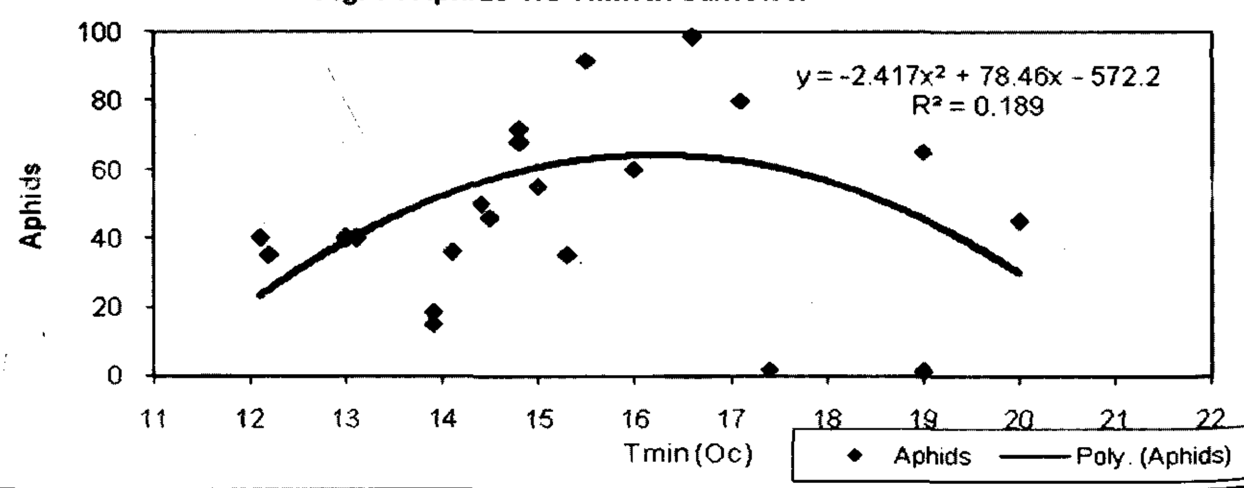


Table 6 Correlation coefficient between grain yield with weather parameters/agrometeorological indices and phenophases of safflower cv. Bhima and Kusuma (2006-07 to 2008-09)

Met. Indices		Phenophase							
		Emergence stage	Rosette stage	Branch initiation	Bud initiation	Flower initiation	50 % flowering	Cessation of flowering	Physiological maturity
T max	Bhima	-0.01	-0.72	0.76	0.80	0.12	0.92	0.25	-0.95*
	Kusuma	-0.62	-0.14	0.67	0.56	0.23	0.71	0.75	-0.99**
T min	Bhima	0.73	0.99**	0.90	0.50	0.94	0.86	-0.72	-0.92
	Kusuma	0.99**	0.72	0.80	-0.16	0.97*	0.47	0.16	-0.96*
RHI	Bhima	0.80	0.88	-0.05	-0.49	0.93	-0.29	0.57	0.95*
	Kusuma	0.98*	0.41	-0.17	0.39	0.68	-0.96*	0.64	0.97*
RHII	Bhima	0.64	0.93	-0.20	-0.27	0.99**	-0.70	-0.84	0.97*
	Kusuma	0.97*	0.42	0.21	-0.21	0.95*	-0.12	-0.70	0.80
WDS	Bhima	0.22	0.43	-0.23	0.87	0.33	0.21	-0.54	-0.70
	Kusuma	0.39	-0.01	0.06	0.81	-0.02	0.19	-0.73	-0.94
BSS	Bhima	-0.45	-0.94	0.51	0.35	-0.96*	0.24	0.59	0.80
	Kusuma	-0.75	-0.32	-0.32	0.41	-0.99**	-0.32	0.48	0.70
Rain	Bhima	0.99**	0.58	-0.42	0.10	0.89	0.00	0.00	0.00
	Kusuma	0.50	-0.18	0.22	0.09	0.75	0.00	0.00	0.00
E pan	Bhima	0.25	-0.81	0.46	0.64	-0.99**	0.47	0.34	-0.92
	Kusuma	-0.46	-0.25	0.32	0.52	-0.83	-0.02	0.96*	-0.98*
GDD	Bhima	0.87	0.69	0.88	0.95*	0.93	0.93	-0.99**	0.82
	Kusuma	0.36	0.98*	0.88	0.50	0.89	0.43	0.02	0.23
HTU	Bhima	-0.32	-0.84	0.80	0.80	0.06	0.98*	-0.96*	0.89
	Kusuma	-0.64	-0.18	0.30	0.59	0.29	0.55	0.13	0.48

The aphids/plant in relation to minimum temperature during the growing period of safflower showed a polynomial relationship as depicted in fig 1. The minimum temperature below 16°C was found to be optimum for higher attack of aphids/plant. Beyond this limit aphid's population/plant decreases (Anonymous, 2009).

Experiment on sowing date and safflower varieties in winter season was conducted during 2006-07 to 2008-09. The three years data were considered for analysis and from average values it was concluded that the safflower sown in first fortnight of September (MW 36) (i.e., *Uttara Nakshtra*) (S_1) produced significantly maximum grain yield (954 kg/ha) and total monetary returns (₹ 18568/ha) over rest of the sowing dates. However, variety 'Kusuma' produced more grain yield (649 kg/ha) and total monetary returns (₹11994/ha). The positive association of rainfall at emergence indicated better germination, GDD and T min positive association at rosette showed with increase in temperature better development of rosette in safflower. At branching GDD in positively correlated indicated again maximum temperature favour the branching and bud initiation. Further, HTU at bud initiation indicated that the maximum hours of BSS is favourable for budding of safflower. The aphids/plant in relation to minimum temperature during the growing period of safflower showed a polynomial relationship .The minimum temperature below 16°C was found to be optimum for higher attack of aphids/plant. Beyond this limit aphid's population/plant decreases.

REFERENCES

Agrawal K K and Upadhyay 2009. Thermal indices for suitable sowing time of Chickpea in Jabalpur region of Madhya Pradesh. *Journal of Agrometeorology*, **11** (1) : 89-91.

Anonymous 2009. A bi-annual report on AICRP on Agro-Meteorology, CRIDA, Hyderabad.

Debosthali V, Salunki C and Akmanchi A 2007. Relationship of LAI and biomass of Soybean with Agroclimatic indices. *Journal of Agrometeorology*, 7 (2) : 249-254.

Dhingra K K, Kaur H, Dhaliwal L K and Singh J 1995. Phenological behabiour and heat units requirement of soybean genotypes under different date of sowing, *Journal of Research Punjab Agricultural University*, **32**:129-135.

Hundal S S, Kaur P, Malikpuri S D S and Joy J 2004. Prediction of growth and yield of pearlmillet using agroclimatic indices. *Journal of Agrometeorology*, **6**:166-170.

Jadhav J D, Shewale M. R, Patil J D and Mokashi D D 1997. Nakshatrawise analysis of rainfall for crop planning- A Case Study of Solapur. Paper presented in state level seminar on "Efficient Crop Production under Rainfed Conditions for

Sustainable Agriculture" held at Konkan Krishi Vidyapeeth, Dapoli. (MS) on Feb 26-27, 1997 pp 403.

Mallick K, Sarkar C, Bhattacharya B K, Nigam R and Hundal S S 2006. Thermal indices for some wheat genotypes in Ludhiana region. *Journal of Agrometeorology*, **8** (1) 133-136.

Ong C K and Squire G R 1984. Response to temperature in a stand of pearlmillet (*Pennisetum typhoides* S & H). VII. Final number of spikelets and grains. *Journal of Experimental Botany*, **36** : 1233-40.

Rosenthal W D, Gerik T J and Wade L J 1991. Radiation use efficiency among grain sorghum cultivars and plant densities. *Agronomy Journal*, **85** : 703-05.

Singh I A, Rao U V M, Singh D and Singh R 2007. Study on agrometeorological indices for soybean crop under different growing environments. *Journal of Agrometeorology*, **9**(1) : 81-85.

Singh M, Niwas R, Bishnoi O P and Sharma K 2003. Phenology of wheat cultivars in relation to thermal indices under different management practices. *Haryana Agricultural University Journal of Research*, **33**:23-28.

Sompal 1999. Modeling growth and yield in wheat under different management practices using remote sensing techniques. Ph.D. Thesis, CCSHAU, Hisar, pp. 134.

Bio-Efficacy of newer insecticides on castor capsule borer, *Dichocrocis punctiferalis* Guenee.

M SUGANTHY

Department of Oilseeds, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu

(Received: May, 2008; Revised: April, 2010; Accepted: January, 2012)

ABSTRACT

Field experiments were conducted at Tapioca and Castor Research Station, Yethapur, during rainy season of 2004 and 2005, to assess the efficacy of newer insecticides on capsule borer. The castor (*Ricinus communis* L.) hybrid TMVCH 1 was sown in plots of 5.4 m x 6.0 m with the spacing of 90 cm x 60 cm. The experiments were conducted in a randomized block design with ten treatments and three replications. Treatments were imposed twice at 15 days intervals when the pest population crossed the economic threshold level. The results revealed that foliar application of profenophos 0.05% recorded the maximum reduction of defoliation after two foliar sprays. Regarding the capsule damage, spinosad 0.018% registered the lowest capsule damage. Foliar application of spinosad 0.018% was found to be on par with profenophos 0.05% in the management of both the defoliators and capsule borers. Since, spinosad 0.018% is a costly chemical; profenophos 0.05% can be effectively utilized in the management of castor defoliators and capsule borer. Percent reduction in parasitisation by the natural enemies namely, *Microplitis ophisuae* and *Cotesia* sp. was observed to be maximum in thiodicarb 0.075% spray. The maximum seed yield was recorded in profenophos 0.05% treatment.

Keywords: Bio-efficacy, Capsule borer, Castor, Newer insecticides

Castor (*Ricinus communis* Linn.) is an important non-edible oilseed crop cultivated throughout India. Intensive cultivation with castor hybrid has picked up both under irrigated and rainfed condition in Tamil Nadu. But the production and yield of the crop is affected by insect pest complex from early stage to maturity (Rai, 1976). Among them, the capsule borer, *Dichocrocis punctiferalis* Guenee is very serious pest, which attacks the inflorescence and mainly bores the capsules and causes direct seed yield loss which in-turn reduces the net returns to the farmers. The capsule damage was nearly 30 to 40% in castor growing areas at Salem and Namakkal districts of Tamil Nadu during the rainy season of 2004-2005. Only few chemicals are used for the management of castor pests which are less effective during the pest out break. There is a need for evaluating newer insecticides which may give better solution for the management of castor capsule borer. Hence, this study was conducted to find out the bio-efficacy of newer insecticides for the management of castor capsule borer.

MATERIALS AND METHODS

Field experiments were conducted at Tapioca and Castor Research Station, Yethapur during the rainy season of 2004 and 2005 to assess the efficacy of newer insecticides on capsule borer. The castor hybrid TMVCH 1 was sown in plots of 5.4 m x 6.0 m with the spacing of 90 cm x 60 cm. The experiments were conducted in a randomized block design with ten treatments and three replications. Treatments were imposed twice at 15 days intervals when the pest population crossed the economic threshold level. Observations were recorded on the total number of capsules and damaged capsules/spike before imposing the treatments and at the time of harvest and per cent damage was worked out. Seed yield was recorded and benefit : cost ratio was worked out. The data were subjected to statistical analysis (Panse and Sukhatme, 1978). The imposed treatment details are presented in table 1.

RESULTS AND DISCUSSION

The results of first year trial conducted during the rainy season of 2004 revealed that foliar application of spinosad 0.018% and profenophos 0.05% registered the lowest capsule damage of 1.8% and 2.7%, respectively, followed by indoxacarb 0.015% (3.2%) and thiodicarb 0.075% (3.4%), as against 17% in the untreated control. Application of acephate 0.075%, deltamethrin 0.003% and monocrotophos 0.05% were found to be on par with each other in the management of capsule borer. The maximum seed yield of 1081 kg/ha and the benefit: cost ratio of 2.30 was recorded in profenophos 0.05% treatment as against the minimum seed yield of 559 kg/ha and the benefit: cost ratio 1.49 in untreated control (Table 1).

Results of the second year (2005) revealed that spinosad 0.018% registered the lowest capsule damage of 6.9% as against 21.8% in the untreated control. Foliar application of spinosad 0.018% was found to be on par with profenophos 0.05% in the management of capsule borer. The maximum seed yield of 1138 kg/ha with the B:C ratio of 2.42 was recorded in profenophos 0.05% treatment as against the minimum seed yield of 712 kg/ha in untreated control (Table 1).

Table 1 Bio-efficacy of newer insecticides on capsule borer and seed yield of castor

Treatment	Capsule damage (%)				Seed yield (kg/ha)		B:C Ratio	
	Rainy season, 2004-05		Rainy season, 2005-06		Rainy season, 2004-05	Rainy season, 2005-06	Rainy season, 2004-05	Rainy season, 2005-06
	Before treatment	At harvest	Before treatment	At harvest				
Thiodicarb 0.075%	12.8	3.4	18.6	10.4	903	948	1.63	1.71
Spinosad 0.018%	13.6	1.8	21.4	6.9	957	1045	1.47	1.60
Indoxacarb 0.015%	11.7	3.2	20.8	8.7	940	992	1.40	1.48
Novaluron 0.01%	14.3	6.3	19.3	14.1	941	889	1.33	1.26
Profenophos 0.05%	15.1	2.7	24.5	7.5	1081	1138	2.30	2.42
Acephate 0.075%	11.8	4.9	22.4	11.3	1030	983	2.23	2.12
Deltamethrin 0.003%	16.4	3.9	18.7	10.9	1046	1075	2.15	2.21
Monocrotophos 0.05%	12.3	5.5	23.1	14.6	967	992	2.10	2.15
Bacillus thuringiensis var *kurstaki* + Boric acid + Neem oil 3%	13.7	9.1	19.8	16.4	923	897	1.92	1.92
T_{10} - Untreated control	18.0	18.2	20.7	21.8	559	712	1.49	1.87
CD (P=0.05)	7.32	1.61	4.34	3.12	247	124	-	-

DAT - *Days after treatment*

Patel *et al.* (1987) reported that application of monocrotophos 0.05% and endosulfan 0.07% were more effective and economical for the control of this pest. Studies on capsule borer management at Directorate of Oilseeds Research, Hyderabad also revealed that the treatments with decamethrin 0.003% resulted in the lowest capsule damage (12.2%) followed by acephate 0.075% (12.3%), monocrotophos 0.05% (14.0) and fenvalerate 0.02% (14.5%) as compared to 28.6% capsule damage in untreated control. Similarly, the results of the experiments conducted at Tapioca and Castor Research Station, Yethapur during 2001-02 also revealed that the insecticides *viz.*, decamethrin (0.003%), profenophos (0.05%) and monocrotophos (0.05%) were effective in controlling capsule borer (21.7 to 22.7%) when compared to botanicals (Anonymous, 2001-02). In both the trials, spinosad 0.018% and profenophos 0.05% performed better, which is in accordance with the earlier report (Anonymous, 2004-05 and 2005-06).

REFERENCES

Anonymous 2001-02. *Annual Progress Report-Castor.* Directorate of Oilseeds Research, Hyderabad.

Anonymous 2004-05. *Annual Progress Report-Castor.* Directorate of Oilseeds Research, Hyderabad.

Anonymous 2005-06. *Annual Progress Report-Castor.* Directorate of Oilseeds Research, Hyderabad.

Anonymous 2006. *Strategies for enhancing castor production in India.* Directorate of Oilseeds Research, Hyderabad.

Panse V G and Sukhatme P V 1978. *Statistical Methods for Agricultural Workers.* ICAR Publications, New Delhi.

Patel M M, Naik M M, Bapodara J G, Fatteh U G and Vyas H N 1987. Bio-efficacy of certain insecticides against *Dichocrocis punctiferalis* Guen. *Indian Journal of Plant Protection.* **15** (1). 27-30.

Rai B K 1976. *Pests of Oilseeds Crops in India and their Control.* Indian Council of Agricultural Research, New Delhi, pp.121.

Epidemiology of sunflower necrosis disease in Andhra Pradesh

BHARATI N BHAT, D RAJA RAM REDDY, S CHANDER RAO[1], M GANESH AND T V K SINGH

College of Agriculture, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030

(Received: November, 2011; Revised: March, 2012; Accepted: April, 2012)

ABSTRACT

Among 35 common weed species collected from surrounding areas of sunflower fields, natural infection of virus causing sunflower necrosis disease (SND) was detected in twelve weed species *viz*., *Digeria arvensis, Achyranthus aspera, Lagasca mollis, Parthenium hysterophorus, Acanthospermum hispidum, Ageratum conyzoides, Commelina bengalensis, Euphorbia geniculata, Phyllanthus niruri, Malvestrum coromandelianum, Abutilon indicum* and *Physalis minima* by back inoculation on assay host, cowpea cv. C-152 and further confirmed by DAC-ELISA. Under artificial inoculated conditions, *Ageratum conyzoides, Gomphrena globosa* and *Physalis minima minima* produced both local and systemic symptoms of the twelve weed species tested. Studies on the effect of different dates of sowing of sunflower cv. Morden on thrips population and SND incidence revealed that thrips infestation was high in June followed by July sown crops. The disease incidence was more in July and less in November and December sown crop. Thrips population was at peak level in the initial stages of crop growth and declined gradually at senescence stage. Maximum temperature had significant positive impact on thrips population, while significant negative correlations were found with relative humidity and rainfall. Incidence of SND was positively correlated with relative humidity and rainfall.

Keywords: Date of sowing, Sunflower necrosis disease, Thrips, Virus, Weather parameters, Weed species

Sunflower (*Helianthus annuus* L.) is an important edible oilseed crop in the country next to groundnut and soybean. In recent years, the crop is affected by sunflower necrosis disease (SND) which hampered its cultivation. The disease was observed for the first time in the country during 1997 at Bagepalli village of Kolar district of Karnataka, where, 80% disease incidence in seed production plots was reported (Singh *et al*., 1997) which later spread to the major sunflower growing regions of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu. The causal agent of SND was identified as Tobacco streak virus of *Ilar* virus group (Ravi *et al*., 2001). Initial studies on survival of sunflower necrosis virus revealed the presence of virus throughout the year on several weeds *viz*., *Parthenium hysterophorus, Tridax procumbens, Phyllanthus* spp., *Euphorbia geniculata* and *Digeria arvensis* (Anonymous, 2002). Information on sources of survival of causal virus including prevalence of thrips fauna and weed flora is inadequate with special reference to predominant sunflower growing regions of A.P. The incidence of thrips in relation to weather parameters, effect of different sowing dates on thrips incidence and disease occurrence was not studied in depth. Keeping these points in view, detailed investigation on epidemiology of sunflower necrosis disease was undertaken during 2009-10 and 2010-11.

MATERIALS AND METHODS

Natural host range: To identify sources of virus inoculum, various weed plants found in and around sunflower fields were tested for the presence of the virus by inoculating the sap obtained from the leaves of weed plants to the assay host cowpea cv. C-152 (Prasada Rao *et al*., 2003). The weed species were identified based on the key characters given by Kondap *et al*. (1985) and with the help of an Agronomist, Weed Control Scheme, ANGRAU. The plants were kept under observation for a period of 40 days for the development of disease symptoms under glass house conditions.

Experimental host range: To identify the weed species which serve as source of inoculum, weed plants grown from seeds were sap inoculated with freshly prepared standard extract of virus at fourth leaf stage. The plants were labeled and kept under observation for a period of 40 days for the development of disease symptoms.

The presence of the virus in the inoculated weed samples was tested by Direct antigen-coated enzyme linked immunosorbent assay (DAC-ELISA). The assay was performed in 96 well polystyrene microtitre plates. The extractions of infected leaf samples of weed species were made in carbonate buffer. The test samples @ 200 μl/well were dispensed into ELISA plates and incubated at 37°C for 1h. The plates were washed three times by allowing 3 minutes between each wash with phosphate buffer saline tween (PBST). Cross adsorption of antiserum with healthy leaf extract was done by grinding the healthy cowpea leaves in antibody buffer, which was prepared by adding 100 ml PBST, 2.0 g polyvinyl pyrrolidine and 0.2 g ovalbumin to give 1:20 dilution and then diluted to 1:1000 in antibody

[1] Senior Scientist, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

buffer. This was dispensed @ 200 µl/well into ELISA plates. The plates were incubated at 37°C for 1 h and washed three times with PBST. To each well, 200 µl of anti rabbit immunoglobulin conjugated with alkaline phosphatase, diluted to 1: 500 in antibody buffer was added and the plates were incubated at 37°C for 1 h. After washing the plates three times with PBST, 200 µl of P-nitrophenyl phosphate substrate was added to each well. The plates were then incubated at room temperature for 30-120 min. Development of yellow color indicates positive reaction and the absorbance values were recorded at 405 nm using ELISA reader. Healthy leaf samples of the same weed species served as control.

Further, seedlings of sunflower cv. Morden and cowpea cv. C-152 were back inoculated to confirm the presence of virus.

Effect of dates of sowing on thrips population and necrosis disease: To determine the effect of staggered sowings on the incidence of SND, sunflower cv. Morden was sown at monthly intervals during 2009-10 and 2010-11. The trial was carried out at College farm, Rajendranagar, Hyderabad in a randomized block design with 10 dates of sowing as treatments with three replications. At each date of sowing, seeds of sunflower cv. Morden were sown in 7 rows with spacing of 60 cm x 30 cm in 4.2 m x 3.0 m plots. Incidence of SND was recorded in all the treatments, plot wise at weekly intervals starting from 4 weeks after sowing up to 9 weeks after sowing. If disease severity is more than 10%, then plants are considered to be infected with necrosis disease. Similarly population of thrips was also recorded at weekly intervals, from 10 randomly tagged plants (terminals) in each treatment. Meteorological observations on temperature, relative humidity and rainfall were also recorded during the period of experimentation. The mean data of three replications was statistically analyzed. To establish the influence of weather parameters on thrips population and disease incidence, the data was subjected to simple correlation and multiple regression analysis (Rangaswamy, 2000).

RESULTS AND DISCUSSION

A total of 35 weed species were observed in surrounding areas of sunflower fields during the survey and around the experimental fields (Table 1). Among them, *Parthenium hysterophorus, Commelina bengalensis, Euphorbia geniculata, Achyranthus aspera, Digeria arvensis, Abutilon indicum and Trianthema portulacastrum* were predominant in the fields. When the sap from 35 weed species were inoculated to cowpea assay host (cv. C-152), only 12 species *viz., D. arvensis, A. aspera, Lagasca mollis, P. hysterophorus, A. hispidum, A. conyzoides, C. bengalensis, E. geniculata, P. niruri, Malvestrum coromandelianum, A. indicum* and *Physalis minima* found infected by the virus and produced necrotic local lesions on cowpea (cv. C-152). Three weed species *viz., P. hysterophorus, P. niruri* and *C. bengalensis* were symptomless carriers, which were further confirmed by DAC-ELISA using polyclonal antiserum of TSV.

Of the twelve weeds species tested for their reaction to SND by sap inoculation only *A. conyzoides, Gomphrena globosa* and *P. minima* revealed both local and systemic symptoms, whereas, *L. mollis, A. aspera, C. bengalensis, E. geniculata* and *A. indicum* showed only systemic infection. Four weed spp., *viz., Amaranthus viridis, Euphorbia hirta, P. hysterophorus* and *T. portulacastrum* did not express visible symptoms. Conspicuous local lesions surrounded by red border were noticed on *G. globosa* 8-10 days after inoculation followed by systemic veinal necrosis. Chlorotic lesions appeared on *P. minima* 8-10 days after sap inoculation followed by mottling after 20-25 days of inoculation. All the weed species, except *E. hirta* gave positive reaction in DAC-ELISA. Though *A. viridis, P. hysterophorus* and *T. portulacastrum* looked apparently healthy, they exhibited chlorotic lesions when indexed on cowpea cv. C-152 and also reacted positively for DAC-ELISA test, indicating them as symptomless carriers. The findings are in accordance with reports of Anonymous (2002), wherein, the survival of sunflower necrosis virus (SNV) was reported through out the year on several weeds *viz., P. hysterophorus, T. procumbens, Phyllanthus* spp., *E. geniculata* and *D. arvensis.* Prasada Rao *et al.* (2003) also confirmed natural infection of TSV in *D. arvensis, A. aspera, L. mollis, P. hysterophorus, A. conyzoides, C. bengalensis* and *E. geniculata* by DAC-ELISA test. Ajith Prasad and Nagaraju (2005a and 2005b) detected SNV in seven weeds and six crop plants by serological diagnosis.

Effect of dates of sowing on the incidence of sunflower necrosis disease: The disease appeared in all the treatments between 25-30 days after sowing i.e., 4th week after sowing. In general, the disease incidence increased with the age of the plants and recorded maximum incidence at 9 weeks after sowing (WAS). Necrosis disease incidence was maximum in the crop sown during July followed by June and minimum in December and March sown crop. The perusal of data revealed that there were significant differences among the different dates of sowing. Disease incidence recorded : July sown crop was significantly highest (16.0 %) compared to all other dates of sowing at 9 WAS during 2009-10 (Table 2). Lowest disease incidence (2.0%) was recorded in the crop sown during March which was on par with December sown crop. Incidence of SND in August (8.3 %), September (6.3%) and October (7.3%) sown crops was significantly higher than remaining treatments and on par with each other.

Table 1 Detection of virus causing SND in weed plants collected from surrounding sunflower field using assay host, cowpea cv. C-152

Vernacular Name	Family	Botanical name	Field symptoms	Transmission
Galijeru	Azioaceae	*Trianthema portulacastrum* L.	Nil	-
Pogantikoora	Amaranthaceae	*Alternanthera sessilis* L.	Nil	-
Thotakoora	,,	*Amaranthus spinosus* L	Nil	-
Chenchalikoora	,,	*Digeria arvensis* Forsk	VC	+
Uttareni	,,	*Achyranthes aspera* L.	M	+
Sickle leaf	Asteraceae	*Lagasca mollis* Cav.	St	+
Vayyaribhama	,,	*Parthenium hysterophorus* L.	SL	+
Hispid starburr	,,	*Acanthospermum hispidum* DC.	NL	+
Marulamathanji	,,	*Xanthium strumorium* L.	Nil	-
Goat weed	,,	*Ageratum conyzoides* L.	NL	+
Gaddi chamanthi	,,	*Tridax procumbens* L.	Nil	-
Guntakala-vasaka	,,	*Eclipta alba* Hassak.	Nil	-
Amruthakada	Commelina-ceae	*Commelina bengalensis* L.	Nil	+
Kukkavaminta	Capparaceae	*Cleome viscosa* L.	Nil	-
Errananabalu	Euphorbiaceae	*Euphorbia geniculata* L.	M	+
Nanabalu	,,	*Euphorbia hirta* L.	M	-
Nelausiri	,,	*Phyllanthus niruri* Auct	SL	+
Muripindaku	,,	*Acalypha indica* L.	Nil	-
Tantipa	Fabaceae	*Cassia serrata* L.	Cl	-
Neelajentana	,,	*Clitoria ternatea* L.	Nil	-
Vempali	,,	*Tephrosia purpurea* Pers.	Nil	-
Kukkathulasi	Labiatae	*Ocimum canum* Sims.	Nil	-
Tummi	,,	*Leucas aspera* Willd.	Nil	-
Vishaboddi	Malvaceae	*Sida acuta* L.	M	-
False mellow	,,	*Malvestrum coromandelianum* Garcke	VC	+
Adavibenda	,,	*Abutilon indcium* Sweet.	M	+
Peddapayala-kura	Portulacaeae	*Portulaca oleraceae* L.	Nil	-
Koopanti	Solanaceae	*Physalis minima* L.	Cl	+
Kamanchi-chettu	,,	*Solanum nigrum* L.	Mo	-
Prickly poppy	Papaveraceae	*Argemone mexicana* L.	Nil	-
Perintakoora	Tiliaceae	*Corchorus olitorius* L.	Nil	-
Nettle leaf	Verbenaceae	*Stachyterpeta indica* L.	M	-
Rylukampa	,,	*Lantana camera* L.	Nil	-
Garitakamma	Vernoniaceae	*Veronia cinerana* L.	Nil	-
Palleru	Zygo-phyllaceae	*Tribulus terrestris* L.	Nil	-

Symptoms : Cl- Chlorosis; — Mosaic; Mo- Mottling; NL- Necrotic lesions; SL- Symptomless infection; St- stunting; VC- Veinal chlorosis;
Transmission to assay host: (+) positive transmission, (-) negative transmission

The results indicated significant variation in the incidence of SND at different dates of sowing (Table 3) during 2010-11. Observations on per cent disease incidence revealed maximum disease incidence in July sown crop (19.0 %) at 9 WAS, followed by June (15.33 %), while 11.66 % disease incidence was recorded in August showing similar trend as in previous season. Low disease incidence was observed in November and October sown crops.

Effect of different dates of sowing on thrips incidence: The population of thrips in sunflower recorded at weekly intervals during 2009-10 (Table 3). The results revealed that there were significant differences among the treatments. Thrips infestation was highest in June sown crop with an average of 5.0 thrips/plant followed by July (3.40 thrips/plant). Significant difference in thrips infestation was clearly observed between different stages of the crop. The mean population was low at 4 WAS and increased progressively upto 7 WAS to reach the peak level coinciding with flowering of the crop.

During 2010-11 season also significant interaction was observed between dates of sowing and population of thrips (Table 4). Mean thrips infestation was highest in June sown crop (2.46 thrips/plant) followed by July sowing, which recorded an average of 1.65 thrips/plant. The mean population of thrips was low at 4 WAS and reached peak level at 7 WAS when the crop was at flowering. Thereafter, thrips population decreased gradually.

In the present study, increased SND incidence was observed when the crop was sown during July month compared to other dates of sowing. Similar findings of high incidence of SND were reported in July sown sunflower crop (Chander Rao *et al.*, 2003; Shirshikar, 2003). Further, it was reported that disease incidence was less in November-December sowings, which supports present findings. Increased thrips incidence in July sown crop may be attributed to an increased activity of thrips. This is in agreement with the findings of Harvir Singh (2005) who recorded maximum population of thrips on June and July sown crop, which may be due to flared incidence of thrips owing to dry weather and moderate temperature resulting in increased incidence of SND. Katti *et al.* (2009) reported that maximum population of thrips rested on June 9th to July 23rd sowings indicating higher population of thrips during rainy season.

Correlation and regression studies: The correlation analysis for thrips population with weather parameters indicated positive correlation of thrips with maximum temperature, minimum temperature and wind speed, while negative correlation was recorded with rainfall, morning and evening relative humidity during 2009-10. The correlation analysis indicated significant and positive correlation with maximum temperature (0.497*), minimum temperature (0.316*) and wind speed (0.465*). However, it was negatively correlated with morning relative humidity (-0.397*) and significant, whereas it was negatively correlated with evening relative humidity (-0.086) and rainfall (-0.069) and non significant. The correlation analysis for SND and weather parameters indicated positive correlation with maximum temperature, minimum temperature, morning and evening relative humidity, rainfall and wind speed. It was significant and positively correlated with minimum temperature (0.603**), evening relative humidity (0.510**), rainfall (0.572**) and wind speed (0.298**), whereas it was significant and negatively correlated with sunshine (-0.532**) during 2009-10.

Table 2 Effect of staggered sowings on incidence of SND in sunflower cv. Morden during 2009-10

Date of sowing**	Per cent disease incidence* at WAS											
	2009-10						2010-11					
	4	5	6	7	8	9	4	5	6	7	8	9
June	6.00 (14.15)	8.00 (16.41)	8.30 (16.74)	12.00 (20.26)	12.30 (20.54)	12.70 (20.88)	10.30 (18.72)	10.30 (18.72)	10.66 (19.06)	11.00 (19.37)	12.33 (20.54)	15.33 (23.04)
July	9.30 (17.75)	15.00 (22.78)	15.30 (23.03)	15.67 (23.31)	15.67 (23.31)	16.00 (23.58)	15.00 (22.79)	15.33 (23.04)	16.33 (23.80)	17.33 (24.57)	18.66 (25.58)	19.00 (25.83)
August	4.30 (11.97)	7.30 (15.67)	7.70 (16.11)	8.00 (16.43)	8.30 (16.74)	8.30 (16.74)	0.66 (5.18)	0.66 (5.18)	1.33 (6.54)	3.66 (10.96)	8.00 (16.35)	11.66 (19.90)
September	3.30 (10.34)	4.60 (12.42)	4.60 (12.42)	5.00 (12.75)	5.00 (12.75)	6.30 (14.51)	0.33 (4.62)	0.66 (5.18)	1.66 (7.33)	2.00 (8.13)	2.66 (9.36)	4.33 (12.00)
October	1.30 (6.54)	3.85 (11.28)	6.00 (14.05)	6.70 (4.85)	7.00 (15.34)	7.33 (15.57)	0.33 (4.62)	0.33 (4.62)	0.66 (5.18)	1.00 (5.97)	1.66 (7.33)	1.66 (7.33)
November	2.30 (8.74)	2.30 (8.74)	3.33 (10.49)	3.67 (10.96)	3.67 (10.96)	3.67 (10.96)	0.33 (4.62)	0.33 (4.62)	0.33 (4.62)	0.66 (5.18)	0.66 (5.18)	0.66 (5.18)
December	1.33 (6.54)	1.33 (6.54)	1.66 (7.33)	2.00 (7.95)	2.00 (7.95)	2.33 (8.56)	0.66 (5.18)	0.66 (5.18)	1.00 (5.74)	1.33 (6.54)	1.66 (7.33)	2.00 (8.13)
January	2.33 (8.74)	2.33 (8.74)	2.66 (9.36)	3.00 (9.97)	3.33 (10.49)	3.33 (10.49)	1.33 (6.54)	1.66 (7.33)	2.33 (8.74)	4.33 (12.0)	4.66 (12.46)	4.66 (12.46)
February	2.00 (7.94)	2.33 (8.74)	3.00 (9.88)	3.33 (9.27)	4.00 (11.48)	5.00 (12.75)	1.66 (7.33)	2.33 (8.74)	3.33 (10.49)	5.00 (12.88)	5.33 (13.34)	5.33 (13.34)
March	1.33 (6.54)	1.33 (6.54)	1.66 (7.33)	1.66 (7.33)	2.00' (8.13)	2.00 (8.13)	1.00 (5.74)	1.33 (6.54)	1.66 (7.33)	2.00 (8.13)	2.33 (8.74)	2.66 (9.36)
SEm+	0.890	0.821	0.775	0.903	0.878	0.743	0.620	0.690	0.658	0.890	0.689	0.587
CD (P=0.05)	2.646	2.440	2.303	2.685	2.608	2.209	1.843	2.051	1.955	2.645	2.049	1.746

Figures in parentheses are angular transformed values; WAS: Weeks after sowing; *Mean of three replications; ** Date of sowing (1st day of second fortnight of each month)

Table 3 Effect of staggered sowings on thrips population in sunflower cv. Morden during 2009-10

Date of sowing **	No. of thrips/plant* at WAS						Mean
	4	5	6	7	8	9	
June	2.00 (1.58)	7.66 (2.86)	8.43 (2.99)	9.00 (3.08)	1.50 (1.41)	1.36 (1.37)	5.00 (2.21)
July	2.13 (1.62)	1.67 (1.47)	2.30 (1.67)	4.45 (2.22)	5.70 (2.48)	4.20 (2.16)	3.40 (1.97)
August	3.50 (1.99)	1.96 (1.57)	1.26 (1.33)	1.54 (1.41)	2.00 (1.59)	1.30 (1.34)	1.90 (1.54)
September	1.20 (1.30)	1.23 (1.31)	0.80 (1.14)	1.46 (1.40)	0.83 (1.15	1.03 (1.24)	1.09 (1.26)
October	0.13 (0.79)	1.26 (1.33)	1.29 (1.34)	1.43 (1.38)	0.83 (1.15)	0.46 (0.98)	0.90 (1.16)
November	0.43 (0.96)	0.26 (0.87)	0.36 (0.93)	0.36 (0.93)	0.27 (0.87)	0.36 (0.93)	0.34 (0.92)
December	0.03 (0.73)	0.03 (0.73)	0.06 (0.75)	0.13 (0.79)	0.17 (0.82)	0.23 (0.86)	0.11 (0.78)
January	0.23 (0.85)	0.27 (0.87)	0.36 (0.93)	0.43 (0.96)	0.46 (0.98)	0.40 (0.95)	0.36 (0.93)
February	0.27 (0.87)	0.33 (0.91)	0.36 (0.93)	0.73 (1.11)	0.56 (1.03)	0.46 (0.98)	0.45 (0.97)
March	0.13 (0.79)	0.13 (0.79)	0.20 (0.83)	0.20 (0.83)	0.23 (0.86)	0.27 (0.87)	0.19 (0.83)
Interaction			SEm+	CD (P=0.05)			
Month			0.0150	0.042			
WAS			0.0116	0.032			
Month x WAS			0.0367	0.103			

Figures in parentheses are square root transformed values; WAS: Weeks after sowing; *Mean of three replications; ** Date of sowing (1st day of second fortnight of each month)

Table 4 Effect of staggered sowings on thrips population in sunflower cv. Morden during 2010-11

Date of sowing **	No. of thrips/plant* at WAS						
	4	5	6	7	8	9	Mean
June	0.86 (1.17)	2.26 (1.66)	3.90 (2.10)	3.16 (1.19)	2.93 (1.91)	1.66 (1.47)	2.46 (1.70)
July	2.40 (1.70)	1.56 (1.41)	1.50 (1.41)	1.56 (1.44)	1.47 (1.40)	1.40 (1.38)	1.65 (1.46)
August	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	1.56 (1.44)	1.06 (1.25)	0.30 (0.89)	0.49 (0.95)
September	0.00 (0.71)	0.00 (0.71)	1.13 (0.80)	0.63 (1.06)	0.26 (0.87)	0.13 (1.06)	0.21 (0.84)
October	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.06 (0.75)	0.16 (0.82)	0.06 (0.75)	0.05 (0.74)
November	0.03 (0.73)	0.30 90.73)	0.00 (0.71)	0.06 (0.75)	0.03 (0.73)	0.03 (0.73)	0.03 (0.73)
December	0.00 (0.71)	0.00 (0.71)	0.03 (0.73)	0.03 (0.73)	0.06 (0.75)	0.13 (0.80)	0.04 (0.74)
January	0.06 (0.75)	0.13 (0.80)	0.20 (0.84)	0.36 (0.93)	0.23 (0.86)	0.10 (0.77)	0.18 (0.82)
February	0.16 (0.82)	0.23 (0.86)	0.33 (0.91)	0.46 (0.98)	0.23 (0.86)	0.06 (0.75)	0.24 (0.86)
March	0.13 (0.80)	0.16 (0.82)	0.36 (0.93)	0.50 (0.99)	0.10 (0.77)	0.06 (0.75)	0.22 (0.84)
Source of variation			SEm+	CD (P=0.05)			
Month			0.123	0.0345			
WAS			0.009	0.0267			
Month x WAS			0.003	0.0847			

Figures in parentheses are square root transformed values; WAS: Weeks after sowing; *Mean of three replications; ** Date of sowing (1st day of second fortnight of each month)

Regression analysis of thrips population and weather parameters indicated that maximum temperature and wind speed could explain 46% of total variation in thrips infestation. The multiple linear regression equation after step down elimination was $Y = -33.85 + 1.19 X_1 + 0.51 X_7$ indicating an increase in one unit maximum temperature increased thrips by 1.19 units and one unit increase in wind speed increased thrips population by 0.51 units keeping other parameters constant. Regression analysis of SND and weather parameters revealed that 48% variation in SND incidence has been explained by a linear function involving maximum temperature, rainfall and sunshine. Among the parameters studied, maximum temperature and rainfall had positive impact, whereas sunshine had significant negative impact. The multiple linear regression equation after step down elimination was $Y = -16.66 + 0.965 X_1 + 0.064 X_5 - 1.091 X_6$ indicating an increase of one unit of maximum temperature increased SND by 0.965 units and one unit increase in rainfall increased the disease by 0.064 units. On the other hand, one unit increase in sunshine decreased SND by 1.09 units.

There was positive correlation of thrips population with maximum temperature, minimum temperature, wind speed and negative correlation with rainfall, RH I and sunshine. Of these weather parameters, significant positive correlation existed between thrips population and minimum temperature (0.428*) during 2010-11. The correlation analysis for sunflower necrosis disease incidence and weather parameters indicated positive correlation with maximum temperature, minimum temperature, morning and evening relative humidity, rainfall and wind speed. While, negative correlation existed between SND and sunshine. The analysis also revealed significant and positive correlation with minimum temperature (0.676**), evening relative humidity (0.617**) and rainfall (0.626**). However, it was significant and negatively correlated with sunshine (-0.716**) during 2010-11.

Regression analysis of thrips population and weather parameters indicated that minimum temperature, evening relative humidity and rainfall explained 54% of total variation in thrips infestation. The multiple linear regression equation after step down elimination was $Y = -9.370 + 0.5480 X_2 + 0.06832 X_4 - 0.08713 X_5$ indicating an increase of one unit minimum temperature and evening relative humidity increased thrips population by 0.548 units and 0.0683 units, respectively. While, one unit increase in rainfall decreased thrips population by 0.087 units. Regression analysis of SND and weather parameters revealed that maximum temperature, evening relative humidity and sunshine explained 63% of variation. Among these parameters, maximum temperature and evening relative humidity had significant positive impact, while sunshine exerted significant negative impact. The multiple linear regression equation after step down elimination was $Y = -20.9616 + 0.909 X_1 + 0.123 X_4 - 0.929 X_6$ indicating an increase of one unit minimum temperature and evening relative humidity increased SND by 0.909 units and 0.123 units, respectively. While, one unit increase in sunshine decreased SND by 0.929 units. The multiple linear and correlation analysis on thrips population studies with growth stage and weather parameters indicated that the crop growth stage and weather parameters affect thrips population.

In the present study, significant positive correlation existed between thrips population and minimum and maximum temperature. The overall results revealed that the weather parameters like maximum temperature favour build up of thrips population and their activity resulting in spread of SND during initial stages of crop growth under field conditions. On the other hand, rainfall and relative humidity affect the thrips activity resulting in reduced incidence of SND under field conditions. The studies indicated the involvement of various weather parameters in thrips fluctuation during different growing seasons. A similar study by Shivasharanayya and Nagaraju (2003) explained successful correlation between thrips population, SND incidence and weather factors. Further, positive correlation between thrips population and maximum temperature and negative correlation with rainfall and relative humidity were also reported by Halakeri (2006). Upendhar *et al.* (2006) reported that relative humidity, temperature and rainfall affect thrips and the vector ability in the field, resulting in SND incidence under natural conditions.

Thus, several weed species were found to act as reservoir of sunflower necrosis virus which may help in perpetuation and further spread of SND under field conditions. A positive correlation of SND with maximum and minimum temperature, relative humidity and rainfall existed showing the involvement of these parameters in fluctuation in the disease incidence.

REFERENCES

Ajith Prasad H N and Nagaraju 2005a. Serological diagnosis of sunflower necrosis virus in crop plants grown around sunflower and the thrips vector prevailing on them. *Environment and Ecology*, **23**:814 -816.

Ajith Prasad H N and Nagaraju 2005b. Serological diagnosis of sunflower necrosis virus in weeds grown around sunflower and the thrips vector prevailing on them. *Environment and Ecology*, **23**:759-76.

Anonymous 2002. *Annual Progress Report of AICRP on Oilseeds-Sunflower, 2002-03*, Directorate of Oilseed Research, Hyderabad. 234 pp.

Chander Rao S, Basappa H and Vijaya Bhaskar A 2003. Epidemiology and yield loss projections of sunflower necrosis disease. ISOR National Seminar: Stress Management in Oilseeds, 28-30 January, pp.88 -89.

Halakeri A V 2006. Studies on serodiagnosis, epidemiology and management of sunflower necrosis viral disease in Northern

Karnataka. Ph.D. Thesis. UAS, Dharwad.

Harvir Singh 2005. Thrips incidence and necrosis disease in sunflower, *Helianthus annuus* L. *Journal of Oilseeds Research*, **22**(1): 90-92.

Katti Pramod, Naganagoud A and Chandranath H T 2009. Influence of dates of sowing on the incidence of thrips of sunflower. *Journal of Oilseeds Research*, **26** (special issue): 483-484.

Kondap S M, Venkat Reddy N, Chandrashekar Rao P and Narsimha Reddy 1985. Weed Management in crops. A Practical Mannual. Pp.93.

Prasada Rao R D V J, Reddy D V R, Nigam S N, Reddy A S, Waliyar F, Yellamanda Reddy T, Subramanyam K, John Sudheer M, Naik K S S, Bandopadhyay A, Desai S, Ghewande M P, Basu M S and Somasekhar 2003. Peanut stem necrosis: A new disease of groundnut in India. *Information Bulletin no. 67*. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, pp.16.

Rangaswamy R 2000. *A text book of Agricultural Statistics*. New Age International (P) Hyderabad Publishers New Delhi. Pp.496.

Ravi K S, Buttgereitt A, Kitkaru A S, Deshmukh S, Lesemann D E and Winter S 2001. Sunflower necrosis disease from India is caused by an *Ilar* virus related to tobacco streak virus. *New Disease Reports*, **3** : 1-2.

Shirshikar S P 2003. Influence of different sowing dates on the incidence of sunflower necrosis disease. *Helia*. **26**: 109-116.

Shivasharanayya and Nagaraju 2003. Relationship among weather parameters, thrips population and incidence of sunflower necrosis virus disease. *Plant Disease Research*, **18**: 4-47.

Singh S J, Nagaraju, Krishna Reddy K M, Muniyappa V and Virupakshappa K 1997. *Symposium on Economically important diseases of crop plants*. 18-20 December. Bangalore.

Upendhar S, Singh T V K and Prasad Rao R D V J 2006. Relationship between thrips population, sunflower necrosis disease incidence and weather parameters. *Journal of Oilseeds Research*, **23**(2): 267-269.

Inheritance of *Alternaria* blight resistance in linseed (*Linum usitatissimum* L.)[1]

RAM JEET, P K SINGH[2], JYOTI SINGH[2] AND R L SRIVASTAVA

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

(Received: June, 2011; Revised: February, 2012; Accepted: March, 2012)

ABSTRACT

The inheritance of resistance to *Alternaria* blight in linseed (*Linum usitatissimum* L.) was studied in the fourteen crosses involving seven resistance donors (BAU 610A, EC 384154, JRF 3, JRF4, Polf 34, H 22, H 25) and four susceptible varieties (Padmini, Parvati, Shubhra and LCK 3003). The F_1, F_2 and back cross generations were grown during winter season 2005-06 and screened under high humidity field condition along with infector rows and infector hedge of susceptible check 'Chambal'. Observation on disease incidence was recorded on leaves and on buds. Resistance was recessive in all the crosses as evident from F_1 reactions and appeared to be governed by single recessive gene in twelve crosses and by two independent non-allelic genes exhibiting complementary epistasis for susceptibility with F_2 digenic ratio of 9:7 in the remaining two crosses i.e., BAU 610 A x Parvati and BAU 610 A x Shubhra.

Keywords: *Alternaria* blight, Inheritance, Linseed, Resistance

Alternaria blight is the most challenging disease of linseed and known to occur in almost all the major linseed growing areas of India. Dey (1933) first time reported *Alternaria* leaf spot disease of linseed caused by *Alternaria lini* from Kanpur in Uttar Pradesh. *Alternaria lini* Dey perpetuates through the contaminated seeds and infected plant debris and found predominantly in Indian sub-continent.

The disease is characterized by aerial infection of plant parts i.e., leaves as well as buds. This disease is recurring every season with different degrees of intensity which leads to wide fluctuation in the production and productivity of the crop every year. Although, some chemical control measures in the form of seed treatment and foliar spray has been recommended yet, it would be effective only when chemical sprayed at appropriate time. However, host resistance would be the most effective and an economic alternative to manage this disease. Identification of different sources of resistance is an important pre-requisite which has been achieved through multi-location field screening trials. Therefore, the present investigation was undertaken to elucidate the inheritance pattern of *Alternaria* blight resistance in linseed.

MATERIALS AND METHODS

The experimental materials comprised seven resistant donors of linseed identified on the basis of multi-location disease screening trial conducted over years under AICRP (Linseed) and four agronomic bases showing susceptibility to *Alternaria* blight. Seven selected *Alternaria* blight resistant and four susceptible lines were crossed in line x tester fashion during winter season 2003-04. Sufficient F_1 seeds were produced in each cross. Parts of the F_1s were used for generation advancement and back crossing and the rest part was retained for screening. Floral traits and plant types of the parents were used as markers to check the trueness of F_1 plants. Back crossing of F_1s with their respective susceptible parents and advancement of F_1 generation were carried out simultaneously during winter season 2004-05. The parents F_1, F_2 and back cross populations (F_1 x susceptible parent) of 14 selected crosses were grown during winter season 2005-06 in single 3m row length with 30 cm x 5 cm crop geometry following infector rows and infector hedge of susceptible check 'Chambal'. Each of the parents and F_1s were sown in a single row while F_2 and back cross populations were sown in five and three rows, respectively. Frequent irrigations were applied and furrows made all around the plot to create humidity for proper disease development. Disease reactions on leaves were recorded in 0-5 scale (Anonymous, 2010) whereas, area of leaves/bud infection was recorded in per cent. (0= no disease HR; 1= 0 to 10% R; 2=10.1 to 25% MR; 3=25.1 to 50% MS; 4=50.1 to 75% S; 5=above 75% HS). The goodness of fit to mendelian segregation of resistant/susceptible plants was tested by Chi square test, whose significance was tested against the table value with (n-1) degrees of freedom where n is the total number of segregating classes (Stansfield, 1986).

RESULTS AND DISCUSSION

Inheritance of *Alternaria* blight reaction was studied in all the fourteen crosses under natural condition and the results presented in table 1 revealed that all the 14 F_1s were susceptible indicating the susceptibility to be dominant over resistance. Similar observations on the susceptibility to

[1]Part of Ph.D. Thesis submitted to C.S. Azad University of Agriculture and Technology, Kanpur in 2009

[2]Project Coordinating Unit (Linseed), C.S. Azad University of Agriculture and Technology, Kanpur-208 002, Uttar Pradesh

Alternaria blight being under the influence of dominant genes have been reported in studies involving crosses of resistant x susceptible linseed genotypes by Kalia *et al.* (1965). The F_2 segregation pattern of the resistant x susceptible crosses revealed digenic ratios of 9 susceptible : 7 resistant for two crosses involving resistant parent BAU 610A with susceptible parents Parvati and Shubhra. In contrast, a monogenic segregation ratio of 3 susceptible : 1 resistant was obtained in remaining 12 crosses involving resistant parents EC 384154, JRF3, JRF 4, Polf 34, H 25 and H22 with susceptible parents Shubhra, LCK 3003, Padmini and Parvati. The back cross progenies segregated in to 1R: 1S with acceptable chi square value confirming the F_2 hypothesis that resistance is governed by a single recessive gene. The resistant parent BAU 610A thus, appear to differ from the susceptible parents Parvati and Shubhra in respect of two gene pairs while the resistant parents EC 384154, JRF 3, JRF 4, Polf 34, H 25 and H 22 differed from susceptible parents Shubhra, LCK 3003, Padmini and Parvati in respect of a single gene pair. Nagaraj *et al.* (2004) also reported a variation among different crosses in the number of genes governing resistant to sterility mosaic disease in pigeonpea.

Table 1 Segregation of field reaction to *Alternaria* blight in F_1, F_2 and back cross populations of linseed

Cross	Generation	No. of observed plants	Segregation		Expected ratio Susceptible : Resistant	Chi square	'p' range
			No. of susceptible plants	No. of resistant plants			
BAU-610A x Parvati	F_1	37	37	-	-	-	-
	F_2	297	161	136	9 : 7	0.50	0.80-0.70
	BC_2	182	182	0	-	-	-
BAU-610A x Shubhra	F_1	41	41	-	-	-	-
	F_2	314	174	140	9 : 7	0.089	0.95-0.90
	BC_2	176	176	0	-	-	-
EC-384154 x Shubhra	F_1	43	43	-	-	-	-
	F_2	318	232	86	3 : 1	0.585	0.80-0.70
	BC_2	179	179	0	-	-	-
EC-384154 x LCK-3003	F_1	40	40	-	-	-	-
	F_2	290	210	80	3 : 1	0.843	0.70-0.50
	BC_2	184	184	0	-	-	-
JRF-3 x Shubhra	F_1	38	38	-	-	-	-
	F_2	299	221	78	3 : 1	0.169	0.95-0.90
	BC_2	169	169	0	-	-	-
JRF-3 x LCK-3003	F_1	39	39	-	-	-	-
	F_2	283	217	66	3 : 1	0.240	0.90-0.80
	BC_2	173	173	0	-	-	-
JRF-4 x Padmini	F_1	44	44	-	-	-	-
	F_2	287	219	68	3 : 1	0.26	0.95-0.90
	BC_2	175	175	0	-	-	-
JRF-4 x Shubhra	F_1	40	40	-	-	-	-
	F_2	286	212	74	3 : 1	0.116	0.95-0.90
	BC_2	178	178	0	-	-	-
Polf-34 x Shubhra	F_1	39	39	-	-	-	-
	F_2	295	225	70	3 : 1	0.164	0.95-0.90
	BC_2	169	169	0	-	-	-
Polf-34 x LCK-3003	F_1	42	42	-	-	-	-
	F_2	284	217	67	3 : 1	0.30	0.90-0.80
	BC_2	176	176	0	-	-	-
H-25 x Padmini	F_1	36	36	-	-	-	-
	F_2	279	204	75	3 : 1	0.526	0.80-0.70
	BC_2	177	177	0	-	-	-
H-25x Shubhra	F_1	48	48		-		-
	F_2	307	235	72	3 : 1	0.390	0.90-0.80
	BC_2	182	182	0	-	-	-
H-22 x Parvati	F_1	42	42	-	-	-	-
	F_2	302	222	80	3 : 1	0.408	0.90-0.80
	BC_2	178	178	0	-	-	-
H-22 x LCK-3003	F_1	39	39	-	-	-	-
	F_2	299	220	79	3 : 1	0.321	0.90-0.80
	BC_2	175	175	0	-	-	-

Knowledge about the number, nature and diversity of genes controlling resistance is very much needed for the exploitation of resistant cultivars in the breeding programme. The crosses involving resistant parents EC 384154, JRF 3, JRF 4, Polf 34, H 25 and H 22 segregated for one of the genes and a monogenic ratio of 3 susceptible : 1 resistant was obtained. However, when parent like BAU 610A differ by two genes, a digenic ratio of 9 susceptible : 7 resistant were obtained indicating the complementary nature of two dominant genes for susceptibility. Similar results have been reported by Sinha *et al.* (2006) in durum wheat. It is therefore, postulated that resistance against *Alternaria* blight in the parent BAU 610A is under the control of two independent loci exhibiting complementary gene action. When locus 1 or 2 or both occur in homozygous recessive state, resistant reaction occurs while dominant alleles at both loci would be necessary to result in disease susceptibility.

The presence of different resistant gene(s) in the two categories of resistance sources will be very useful in breeding for durable resistance by the diversification of resistance sources and gene pyramiding. However, more detailed studies including F_3 generation would have to be conducted to analyses the virulence spectra and diversity in the pathogen population through controlled experiments with each of these genes.

REFERENCES

Anonymous 2010. AICRP on Linseed 2010. *Annual Report, 2010-11.* Project Coordinating Unit(Linseed), CSAUA&T, Kanpur, pp:146

Dey P K 1933. An *Alternaria* blight of linseed plant. *Indian Journal of Agricultural Sciences*, **3** : 881-96.

Kalia H R, Chand J N and Ghai B S 1965. Inheritance of resistance to *Alternaria* blight of linseed. *Journal of Research*, **2** : 104-5.

Nagaraj K M, Chickkadevaiah and Kulkarni R S 2004. Inheritance of resistance of sterility mosaic virus in pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Indian Journal of Genetics and Plant Breeding*, **64** : 118-20.

Sinha A K, Kumari Renu and Singh A K 2006. Inheritance of *Alternaria* leaf blight resistance in durum wheat (*Triticum durum* Desf.). *Indian Journal of Genetics and Plant Breeding*, **66**: 200-02.

Stansfield W D 1986. *Theory and Problem of Genetics.* McGraw-Hill Inc., pp : 452.

A strategic communication technique for transfer of castor and sunflower production technologies

R VENKATTAKUMAR AND M PADMAIAH[1]

National Academy of Agricultural Research Management, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

(Received: April, 2011; Revised: April, 2012; Accepted: May, 2012)

ABSTRACT

Farmers approach different sources and channels for acquiring information pertaining to improved agricultural practices. Therefore it is necessary to identify the different sources and channels of communication pertaining to improved production technologies as preferred by the farming community. A study was conducted to assess the communication behaviour of castor (60) and sunflower (60) frontline demonstrations (FLD) farmers in Mahabubnagar district of Andhra Pradesh. FLD farmers, contact farmers (Adarsha Rythu) and input dealers were the para professional sources that provide scope for extending technology transfer support for castor and sunflower production technologies, while Doordarshan (DD), private television channels and news papers were the major impersonal cosmopolite sources. It was found that only informal/casual method of information evaluation and storage methods were followed by the sunflower as well as the castor FLD farmers. The use of FLD farmers as resource persons to share their experiences in field days/ campaigns/exhibitions/group meetings/training programmes are to be promoted, since the effect of group contact methods will be better compared to that of mass methods. Efforts are needed by the radio and television channels to use FLD farmers as resource persons in various agricultural programmes with effective modes to encourage farmers further to utilize farm programmes as information sources. Based on the communication behaviour of castor and sunflower FLD growers, a strategic communication technique was suggested for effective transfer of improved production technologies of sunflower and castor with multiprogned strategy at various levels.

Keywords: Castor, Communication behaviour, Communication model, FLD farmers, Sunflower

An important pre-requisite for the adoption and diffusion of an innovation within the social system is the effective communication of information pertaining to the innovation involved. Farmers have their own information networks, through which they get information about agricultural practices and solutions to their problems. However, in many farming populations, the access to information is often variable, due to differences among circumstances, ability to adopt technological options and availability of extension communication infrastructure. Hence, a farmer may rely on a few information sources and reject many others. To be of benefit, information must be communicated to and internalized effectively by its intended beneficiaries (FAO, 2003). Therefore it is necessary to identify the different sources and channels of information pertaining to improved production technologies as preferred by the farming community.

Many studies were conducted to assess the communication behaviour of farmers. Babykumari *et al.* (1999) opined that opinion leaders could be an effective source of information pertaining to improved agricultural practices for farmers and farm women. The study conducted by Escalada and Heong, (2004) concluded that mass media could effectively transfer some elements of knowledge-intensive pest management practices. Mass media played a meager role in provision of information needed by livestock growers in Iran in order to tackle the problems of low access to and use of printed media (Fami *et al.*, 2006). The beneficiary farmers of watershed development scheme in Central India had better access to information sources than the non-beneficiaries (Krishna *et al.*, 2007). Localite sources like neighbours, friends, progressive farmers and opinion leaders were playing important role as personal localite sources of information pertaining improved rapeseed-mustard production technologies. Scientists and agricultural officers were considered as credible information sources but less accessible to rapeseed-mustard growers (Sharma *et al.* (2008). Sendilkumar, (2010) found that there were distinct pattern of information sources utilized by soybean growers with respect to personal cosmopolite, personal localite and impersonal cosmopolite sources. These results confirm the diversity of communication behaviour of farmers.

Among the various oilseeds grown in Andhra Pradesh, castor and sunflower are important as the valuable components of cropping sequences and systems of the State. Sunflower has been grown in an area of 4.19 lakh ha with 3.26 lakh t. production and 778 kg/ha productivity, while castor has been cultivated in 1.59 lakh ha area with 0.81 lakh t. production and 509 kg/ha productivity (Venkattakumar and Hegde, 2010). Directorate of Oilseeds Research (DOR), Hyderabad, which has sunflower and castor as its mandate

[1]Principal Scientist, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

crops apart from safflower, intended to develop and disseminate improved sunflower and castor production technologies for the needy oilseed growers including those from Andhra Pradesh. DOR, Hyderabad employs many transfer of technology strategies to disseminate the improved sunflower and castor production technologies including that of frontline demonstrations (FLDs). Such FLDs are being laid out in Mahabubnagar district of Andhra Pradesh (strategic jurisdiction) with the help of interested farmers. These FLD farmers are supposed to act as the information sources for fellow farmers. Hence, it was decided to assess the communication behaviour of castor and sunflower FLD farmers, with the following objectives:

- To assess the information seeking, evaluating, storage and dissemination behaviour of castor and sunflower FLD farmers
- To suggest a strategic communication technique to effectively disseminate improved sunflower and castor production technologies

MATERIALS AND METHODS

To assess the communication behaviour of castor and sunflower FLD farmers, a survey was conducted during May-August, 2010 at Mahabubnagar district of Andhra Pradesh, wherein the improved sunflower and castor production technologies were demonstrated through FLDs by farmers' participatory mode. The farmers involved in demonstration of technologies during the period between 2005 and 2009 were contacted so that a total of each 60 castor and sunflower FLD farmers would be the sample of the study. The data was collected through a structured interview schedule through personal interview method. The information pertaining to information seeking behaviour was collected in a four point continuum representing the frequency of contact of information sources (Always-20; Frequently-15; Rarely-10; Never-5), whereas that of information evaluation, storage and dissemination behaviour were collected in a two point continuum representing their agreement (yes-1/no-0). The information seeking behaviour/source utilization behaviour was collected in four different parts like personal cosmopolite (professional, para-professional), personal localite (professional, para-professional). impersonal cosomopolite and non-professional sources. The professional personal cosmopolite part had 13 sources, whereas para-professional personal cosmopolite, personal professional localite, personal para-professional localite and non-professional parts had 6, 3, 5 and 4 sources, respectively against which the castor and sunflower FLD farmers had to give their opinion based on their experience. The information evaluation and information storage parts had each five methods against which the farmers had to reply. Interpersonal, group and mass contact methods of information dissemination behaviour had 7, 3 and 4 methods, respectively against which the FLD farmers had to respond. The collected data were coded, tabulated and analysed using percentage analysis, simple correlation and multiple regression measures. The results of the analysis are being discussed hereunder.

RESULTS AND DISCUSSION

Communication behaviour of sunflower FLD farmers: Researchers, scientists of State Agricultural Universities (SAUs) and Indian Council of Agricultural Research (ICAR) institutes, agricultural fairs and exhibitions, field days/ campaigns/ meetings and extension officers of the banks were the major professional and personal cosmopolite sources from where the sunflower FLD farmers sought information pertaining to sunflower production technologies (Table 1). These results are in conformity with that of Sharma *et al.* (2008) and Sendilkumar (2010). Input dealers, previous FLD farmers and contact farmers of neighbouring villages were the para-professional personal cosmopolite sources for sunflower FLD farmers, while field days, campaigns and meetings organized in the own villages were the personal localite sources to seek information pertaining to sunflower production technologies. Family members, neighbours and friends were the non-professional sources of information, while private television channels, DD and newspapers were the impersonal cosmopolite sources utilized by the sunflower FLD farmers. These results were contradictory to that of Fami *et al.* (2006).

Discussing the usefulness of the acquired information with family members, weighing the merit of information based on the past experience and discussing the information with extension professionals were the major methods of information evaluation behavior utilized by sunflower FLD farmers (Table 2). Memorizing the information, communicating the information to family members and asking them to remember and relating the new information to old one for easy remembrance were the major information storage methods used by sunflower FLD farmers. The results pertaining to information evaluation and storage methods used by sunflower FLD farmers were contradictory to that of Babykumari (1999). The sunflower FLD farmers disseminated the information pertaining to improved sunflower production technology known to them throu[gh] personal contact methods like discussing with fellow farmer[s] friends, relatives, neighbours, by replying through phon[e] calls, and through informal chats during social function[s] Their use of mass contact methods to disseminate th[e] information pertaining to sunflower production technologie[s] was observed low.

The relationship between communication behaviour [o]f sunflower FLD farmers and their socio-economic profile ar[e] given in table 3 (correlation analysis) and 4 (regressio[n] analysis). Educational status of the sunflower FLD farmers had direct and significant relationship with overall communication behaviour as well as all the individual components. Gross cropped area, gross irrigated area, monthly income, membership in social or credit/marketing organizations, approximate monthly expenditure on mobile recharge and number of visits to nearby village/mandal/ town/city were the factors that had direct and significant relationship with overall communication behaviour of sunflower FLD farmers. Educational status of the sunflower FLD farmers contributed their information seeking behaviour, while experience in agriculture, nature of agricultural participation, gross cropped area, approximate monthly expenditure towards bus/share taxi charges contributed towards information evaluation behaviour. No factors contributed towards, information storage and output behaviour of sunflower FLD farmers. Educational status of them contributed towards their overall communication behaviour pertaining to improved sunflower production technologies. The above results conclude that there is a need to train the sunflower FLD farmers towards effective information storage and evaluation methods and using mass contact methods for disseminating information. Sunflower growers with higher educational status may be selected as the FLD farmers for demonstrating improved sunflower production technologies.

Communication behaviour of castor growers: Officials of non-governmental organizations (NGOs), researchers/ scientists of research institutes or SAUs and agricultural fairs/ exhibitions were the major personal cosmopolite sources from where castor FLD farmers sought information pertaining to improved castor production technologies, whereas input dealers, demonstration farmers and progressive farmers were the para-professional sources. These results are in conformity with that of Sharma *et al.* (2008) and Sendilkumar (2010). The castor FLD farmers had similar personal localite professional sources as that of sunflower FLD farmers, but with different order of preference. FLD farmers, contact farmers and input dealers were the para-professional personal localite sources. Private television channels, DD and newspapers were the major impersonal cosmopolite sources utilized by castor FLD farmers. They evaluated the. information pertaining to improved castor production technologies acquired through various resources by weighing the merit of the information on the light of past experience, discussing the usefulness of the information with family members and para-professional extension personnel. The results pertaining to information evaluation and storage methods utilized by castor FLD farmers were contradictory to that of Babykumari, (1999).They had similar information storage method as that of sunflower FLD farmers. They disseminated the acquired information through interpersonal channels like friends/ relatives/neighbours, fellow farmers and discussing with professional or para-professionals. Their group as well as mass contact channels for dissemination of improved castor production technologies was similar that of sunflower FLD farmers.

The relationship between communication behaviour of castor FLD farmers and their socio-economic profile are given in table 3 (correlation analysis) and 4 (regression analysis). Educational status of the castor FLD farmers had direct and significant relationship with overall communication behaviour as well as all the individual components. Gross cropped area, monthly income, approximate monthly expenditure on mobile recharge, approximate monthly expenditure on petrol/diesel for vehicles and number of visits to nearby village/mandal/ town/city were the factors that had direct and significant relationship with overall communication behaviour of castor FLD farmers. Experience in agriculture and monthly expenditure on mobile recharge contributed towards information seeking behaviour of castor FLD farmers. Age, educational status, experience in agriculture, monthly income and membership in organizations contributed towards their information evaluation behaviour. Experience in agriculture, gross cropped area and approximate expenditure on transport charges contributed towards information storage behaviour, whereas age, educational status, experience in agriculture and monthly income contributed towards information dissemination behaviour of the castor FLD farmers. Educational status, experience in agriculture and approximate expenditure on transport charges contributed towards overall communication behaviour of the castor FLD farmers. The results indicate that there is a need to train the castor FLD farmers towards effective information storage and evaluation methods and using mass contact methods for disseminating information. Castor growers with higher educational status and experience in castor cultivation may be selected as the FLD farmers for demonstrating improved castor production technologies.

FLD farmers, contact farmers (Adarsha Rythu) and input dealers were the para professional sources that provide scope for extending support in transfer of castor and sunflower production technologies. Capacity building and effective as well as planned utilization of such sources definitely will add strength to the transfer of technology activities (Table 5). As far as planning for impersonal cosmopolite sources is concerned. the target group has to be categorized based on their literacy rate, educational and socio-economic status, so that pragmative approach can be followed in effectively utilizing print and television media (Fami *et al.*, 2006). The castor and sunflower growers must be trained on judging the information based on environmental conditions, social and techno-economic feasibility and available resources. In addition, they must be reinforced about the importance of recording/ documenting the information pertaining to improved production technologies in permanent note books or diaries so that they can refer back whenever need arises (Babykumari *et al.*, 1999). Special programmes/projects targeting FLD farmers to use mobile phones for transfer of improved production technology on free of cost may be organized by the development departments. The research institutes may take-up pilot/ full fledged research projects to assess the effectiveness and impact of mobile communication for transfer of improved production technology. The use of FLD farmers as resource persons to share their experiences in group contact methods like field days/campaigns/ exhibitions/group meetings/training programmes are to be promoted, since the effect of group contact methods will be better compared to that of mass methods (Table 5) (Babykumari *et al.*, 1999). Efforts are needed by the radio and television channels to use FLD farmers as resource persons in various agricultural programmes with effective modes to encourage the farmers to utilize farm programmes as information sources (Babykumari, 1999, Escalada and Heong, 2004, Fami *et al.*, 2006).

Table 1 Information seeking/input behaviour (N=120)

	Sunflower (n=60)		Castor (n=60)	
	Total Score	Rank	Total Score	Rank
A. Personal cosmopolite				
a. Professional sources				
Assistant Agricultural Officer	370	7	410	5.5
Agricultural Officer	395	5	410	5.5
Assistant Director of Agriculture	260	11	270	11
Agriculture Extension Officers of banks	400	3.5	390	7
Researchers/Scientists	520	1	520	2
KVK professionals	250	13	265	13
Officials of NGOs	255	12	685	1
Representatives of private input companies	325	9	270	11
Media personnel	270	10	270	11
Field trips/tours	380	6	360	8.5
Field days/campaigns/meetings	400	3.5	430	4
Agricultural fairs/exhibitions	420	2	460	3
Training programmes	350	8	360	8.5
b. Para-professional sources				
Demonstration farmers of nearby villages	375	2	355	2
Contact farmers (Adarsha Rythu) of nearby villages	340	3	305	4
Panchayat leaders/well known progressive farmers	300	5	330	3
Office-bears of farmers' organizations	305	4	300	5
Self-help groups and members	265	6	265	6
Input dealers	430	1	510	1
B. Personal localite				
a. Professional sources				
Field days/ campaigns/ meetings in own village	360	1	400	1
Agricultural fairs/ exhibitions in own village	345	2	310	3
Training programmes in own village	330	3	320	2
b. Para-professional sources				
FLD farmers of own village	560	1	545	1
Contact farmers (Adarsha Rythu) of own village	435	2	405	2
Input dealers of own village	300	4	340	3
Local leaders	335	3	315	4
SHGs of own village	270	5	270	5
c. Non-professional sources				
Neighbours	440	2	580	2
Friends	405	3.5	515	3
Family members	545	1	720	1
Relatives	405	3.5	470	4
C. Impersonal cosmopolite				
Radio	265	10	255	10.5
Television (DD)	495	2	620	2
Private television channels	625	1	670	1
Agricultural magazines	360	4	390	4
News paper	385	3	405	3
Leaflets/folders/notices	310	7	345	5.5
Booklets/bulletins	295	8	330	7.5
Wall painting/advertisements	335	6	345	5.5
Display boards/hoardings	340	5	330	7.5
Film shows	250	11	255	10.5
Getting regular mobile advisory services	290	9	295	9

Table 2 Information processing (evaluation and storage) and dissemination methods

(N=120)

	Sunflower (N=60)		Castor (N=60)	
	%	Rank	%	Rank
I. Evaluation method				
Weighing the merit of information on the light of past experience	92	2	98	1
Discussing *the usefulness of information with family members*	96	1	96	2
Discussing the usefulness *of information with professional extension personnel*	78	3	80	4
Discussing the information with para-professional extension personnel	74	4	86	3
Judging the information based on environmental conditions, socio-economic and technical feasibility and available resources	62	5	65	5
Accepting the information as such	8	6	0	6
II. Storage method				
Memorizing the information as such	98	1	100	1
Relating the new with old idea for easy recalling	88	3	92	2.5
Conveying the information to family members asking them to remember	94	2	92	2.5
Maintaining the note books/ diary to record the information	20	4	6	4.5
Preserving the printed literature and referring whenever needed	14	5	6	4.5
III. Dissemination method				
a. Interpersonal contact				
Informing to friends/ relatives/ neighbours	94	2	96	1.5
Discussing with fellow farmers at farm premises	96	1	96	1.5
Replying phone calls	62	3	47	4
Replying/ communicating through letters	4	7	0	7
Exchanging/ supplying literature	14	5	6	5
Discussing with either professionals or para-professionals	46	4	82	3
Giving information through mobile SMS	6	6	2	6
b. Group contact				
Sharing experience in field days/ campaigns/ exhibitions	12	3	20	2.5
Sharing experience in group meetings/ training programmes	14	2	20	2.5
Through informal chats during social functions	66	1	84	1
c. Mass contact				
Giving talks/ participation in radio programmes	6	2	10	1
Giving talks/ participation in programmes of DD/ private channels	10	1	10	2
Writing for magazines	2	3.5	0	3.5
Writing for news papers	2	3.5	0	3.5

Table 3 Relationship between communication behaviour of sunflower FLD farmers and their personal characteristics

(N=120)

Behaviour category	*Personal Characteristics*												
	AGE	ES	EA	NAP	GCA	GIA	MI	MSO	FL	AMR	APV	ABC	NMM
							Sunflower (n=60)						
ISB	-0.183NS	0.618**	-0.147NS	0.151NS	0.481**	0.421**	0.542**	0.350*	-0.193NS	0.612**	0.394**	0.163NS	0.399**
IEB	-0.146NS	0.431**	-0.329NS	0.137NS	0.089NS	0.187NS	0.203NS	0.144NS	0.011NS	0.277NS	0.209NS	0.230NS	0.152NS
ISM	-0.116NS	0.524**	-0.104NS	0.048NS	0.484**	0.308*	0.423**	0.338*	-0.220NS	0.462**	0.308*	0.157NS	0.286*
IOB	-0.065NS	0.438**	-0.009NS	0.082NS	0.341*	0.421**	0.425**	0.228NS	-0.112NS	0.603**	0.524**	0.044NS	0.413**
CB	-0.181NS	0.654**	-0.181NS	0.147NS	0.478**	0.434**	0.540**	0.357*	-0.185NS	0.633**	0.435**	0.188NS	0.408**
							Castor (n 60)						
ISB	-0.164NS	0.561**	-0.148NS	0.038NS	0.330*	0.258NS	0.366**	0.172NS	-0.085NS	0.524**	0,343*	0.058NS	0.357*
IEB	-0.023NS	0.370**	0.096NS	0.021NS	0.155NS	0.015NS	0.111NS	-0.115NS	-0.018NS	0.223NS	0.221NS	0.062NS	0.209NS
ISM	0.116NS	0.448**	0.022NS	0.012NS	0.301*	0.080NS	0.161NS	0.090NS	0.058NS	0.175NS	-0.071NS	0.270NS	0.188NS
IOB	-0.065NS	0.483**	0.038NS	0.050NS	0.372**	0.425**	0.536**	0.195NS	-0.056NS	0.589**	0.465**	0.092NS	0.382**
CB	-0.116NS	0.585**	-0.077NS	0.039NS	0.346*	0.247NS	0.367**	0.130NS	-0.065NS	0.511**	0.340*	0.095NS	0.366**

Table 4 Factor contributing communication behaviour of FLD farmers

(N=120)

Personal characteristic	Behaviour category									
	Sunflower (n=60)					Castor (n=60)				
	ISB	IEB	ISM	IOB	CB	ISB	IEB	ISM	IOB	CB
Intercept	0.300NS	0.596NS	0.913NS	0.921NS	0.371NS	0.071NS	0.378NS	0.452NS	0.686NS	0.090NS
Age	0.438NS	0.059NS	0.948NS	0.530NS	0.821NS	0.124NS	0.020*	0.867NS	0.045*	0.052NS
Educational status	0.034*	0.017*	0.130NS	0.125NS	0.009**	0.013*	0.002**	0.011*	0.047*	0.002**
Experience in agriculture	0.504NS	0.043*	0.938NS	0.262NS	0.840NS	0.159NS	0.001**	0.732NS	0.004**	0.025*
Nature of agriculture participation	0.361NS	0.978NS	0.629NS	0.740NS	0.411NS	0.900NS	0.988NS	0.930NS	0.820NS	0.941NS
Gross cropped area	0.658NS	0.037*	0.298NS	0.144NS	0.425NS	0.083NS	0.317NS	0.012*	0.953NS	0.070NS
Gross irrigated area	0.428NS	0.839NS	0.735NS	0.199NS	0.458NS	0.528NS	0.469NS	0.151NS	0.538NS	0.464NS
Monthly income	0.594NS	0.672NS	0.788NS	0.698NS	0.636NS	0.644NS	0.011*	0.783NS	0.737NS	0.311NS
Membership in social/ credit/ marketing organizations	0.267NS	0.666NS	0.394NS	0.665NS	0.335NS	0.209NS	0.009**	0.418NS	0.176NS	0.073NS
Family labours (No)	0.212NS	0.900NS	0.269NS	0.506NS	0.199NS	0.616NS	0.434NS	0.177NS	0.569NS	0.435NS
Approximate monthly expenditure on mobile recharge	0.100NS	0.462NS	0.441NS	0.331NS	0.095NS	0.039*	0.226NS	0.105NS	0.031*	0.024*
Approximate monthly expenditure on petrol/ diesel vehicles	0.787NS	0.273NS	0.945NS	0.196NS	0.788NS	0.116NS	0.231NS	0.004**	0.398NS	0.244NS
Approximate monthly expenditure on bus/ share-taxi charges	0.645NS	0.009**	0.697NS	0.836NS	0.284NS	0.146NS	0.427NS	0.079NS	0.311NS	0.314NS
Number of visits to nearby village/ mandal/ town/ city	0.891NS	0.438NS	0.844NS	0.756NS	0.862NS	0.156NS	0.895NS	0.063NS	0.736NS	0.201NS

ES=Educational status; EA=Experience in agriculture; NAP=Nature of agriculture participation; GCA=Gross cropped area; GIA=Gross irrigated area; MI=Monthly income; MSO=Membership in social/ credit/ marketing organizations; FL=Family labour AMR=Approximate monthly expenditure on mobile recharge; APV=Approximate monthly expenditure on petrol/ diesel for vehicles; ABC= Approximate monthly expenditure on bus/ share-taxi charges; NMM=Number of visits to nearby village/ mandal/ town/ city; ISB=Information seeking behaviour; IEB=Information evaluation behaviour; ISM=Information storage methods; IOB=Information output behaviour; CB=Communication behaviour; *=Significant at 5% level of probability; **=Significant at 1% level of probability; NS=Non-significant

Table 5 Strategic communication model to transfer sunflower/castor production technologies

Stakeholders involved/strategies	District	Mandal	Village
Organizers	ATMA, KVK, NGOs	KVKs, NGOs	NGOs, contact farmers, input dealers, AAOs
Facilitators	SAUs, Research institutes	SMS of KVKs, NGOs and AOs	SMS from NGOs, AAOs, FLD farmers input dealers, progressive farmers
Beneficiaries	FLD farmers, contact farmers, progressive farmers, SMS of KVKs and NGOs, AOs/AAOs/input dealers	FLD farmers, contact farmers, progressive farmers, /input dealers	Castor/ sunflower growers
Strategies	Training programmes	Fairs/ exhibitions/ training programmes	Campaigns, training programmes, FLDs field days
Overall strategy	Financial empowerment; adequate administrative approval on priority basis; coordination of efforts; convergence with government programmes and schemes with effective strategies for mass media publicity		

Based on the communication behaviour of castor and sunflower FLD growers, it has been suggested that the effective transfer of oilseed production technologies with special reference to sunflower and castor needs a multiprogned strategy at various levels (Table 5). At the district level, Agricultural Technology Management Agency (ATMA), Krishi Vigyan Kendra (KVKs) and NGOs may take initiatives to collaborate with SAUs and research institutes to organize training programmes on improved castor and sunflower production technologies targeting subject matter specialists (SMS) of KVKs and NGOs, FLD farmers, contact farmers, progressive farmers, agricultural and assistant agricultural officers (AOs/AAOs) of agricultural department, input dealers, so that they can serve as the sources of information at mandal and village levels. KVKs and NGOs their respective SMS, and AOs may facilitate fairs/exhibitions/training programmes on improved castor and sunflower production technologies for FLD farmers, contact farmers, progressive farmers, /input dealers, so that they can serve as the sources of information at village levels. Similarly, NGOs, contact farmers, input dealers, AAOs at village level may organize campaigns, training programmes, FLDs and respective field days through SMS from NGOs, AAOs, input dealers, progressive farmers as resource persons for the benefit of castor/sunflower growers. For all these programmes to become field-level reality there is a need for financial empowerment; adequate administrative approval on priority basis; coordination of efforts; convergence with government programmes and schemes with effective strategies for mass media publicity.

REFERENCES

Babykumari K, Nanjaiyan K, Chandrakandan K and Netaji Seetharaman R 1999. Communication behaviour of opinion leaders. *Journal of Extension Education*, **10** (3): 2462-2465.

Escalada MM and Heong K L 2004. The case of using mass media: Communication and behaviour change in resource management. *Proceedings of the 4th International Crop Science Congress*. 26 Sep-1 Oct 2004. Brisbane, Australia. P (1-11).

Fami N Shabanali, Kalantari Kh and Asadi A 2006. Information sources used by livestock farmers in Iran. *MANAGE Extension Research Review*, **7** (1): 9-22).

Sai Krishna N, Shaik N Meera and Muthuraman P 2007. Dynamics of adoption of recommended rice production technologies among migrant farmers. *MANAGE Extension Research Review*, **8** (1): 65-70.

Sendilkumar R 2010. Knowledge and information source utilization pattern of soybean growers. *Indian Research Journal of Extension Education*, **10** (3): 71-74.

Sharma A K, Jha S K, Vinod Kumar, Sachan R C and Arvind Kumar 2008. Critical analysis of information sources and channels preferred by rapeseed-mustard farmers. *Indian Research Journal of Extension Education*, **8** (2&3): 42-45.

Venkattakumar R and Hegde D M 2010. *Frontline Demonstrations in Oilseeds: Annual Report (2009-10)*. Directorate of Oilseeds Research. Hyderabad. p.160.

Castor (*Ricinus communis* L.) frontline demonstrations in Jodhpur district of Rajasthan : An impact study

M PADMAIAH, R VENKATTAKUMAR[1], ISHWAR SINGH[2], S S SOLANKI[2] AND C SARADA

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

(Received: April, 2011; Revised: April, 2012; Accepted: May, 2012)

ABSTRACT

Jodhpur is one of the major castor growing districts in Rajasthan. One hundred and sixty nine frontline demonstrations (FLDs) were conducted by Regional Agricultural Research Station (RARS), Mandor in Jodhpur district of Rajasthan from 1997-98 to 2006-07 to demonstrate the improved castor production technologies suitable for eco-system. An attempt was made to analyze the impact of the demonstrations in vertical and lateral spread of the technologies and the resultant improvement in yield and income of the castor growers. Twenty-five FLD and the corresponding non-FLD castor growers were selected through proportionate random sampling procedure. There was no significant difference between the FLD and non-FLD farmers in their knowledge, adoption and yield levels. This shows the impact of FLDs in lateral spread of the improved technologies of castor crop. The castor area of the district has increased by about five times and production by about six times during the period 2002-03 to 2006-07. The FLDs had an overall expost-facto impact of 26% increase in yield and ₹12620/ha in net returns. The B:C ratio was 3.5 with improved technology is higher as compared to farmers practice which was 2.8. There is a vast scope available for increasing the yield levels of castor in the district and the reservoir was projected. Non-availability of quality seeds is the major constraint for the castor growers of the study area. There is a need for intensive extension efforts by department of agriculture, through constructive collaboration with Agricultural Research Station, Mandor, Krishi Vigyan Kendras and local Non-Governmental Organizations to improve the yield and the production levels of castor in Jodhpur district.

Keywords: Castor, Frontline demonstrations, Impact study

In India, castor (*Ricinnus communis* L) crop is grown in an area of 8.7 lakh ha, with a production of 11.7 lakh t and productivity of 1352 kg/ha (Damodaram and Hegde, 2010). Gujarat, Andhra Pradesh and Rajasthan are the major castor producing states. Castor in Rajasthan is mainly grown as sole irrigated crop, in some pockets as rainfed crop and sporadically as border crop/ intercrop in the fields of chilly as a shade crop. The districts namely Jalore, Sirohi, Barmer, Jodhpur and Pali are important in their contribution to the increase in area and production of castor in Rajasthan. Development/identification of superior castor hybrids, generation of production technology and dissemination of improved technology through FLDs resulted in enhancement of castor area, production and productivity in the last five years (Anonymous, 2008). However, area, production and productivity of castor in Rajasthan are fluctuating widely, which could be understood from table 1.

One hundred and sixty nine FLDs were conducted in Jodhpur district of Rajasthan from 1997-98 to 2006-07 to demonstrate the improved castor production technologies that are suitable for that particular eco-system. The concurrent impact of such demonstrations is given in table 2. An attempt was made to analyze the impact of the demonstrations in vertical and lateral spread of the technologies and the resultant improvement in yield and income of the castor growers, with the following objectives: (a) to document the profile characteristics of castor growers; (b) to assess the knowledge and adoption level of castor growers in Jodhpur district of Rajasthan as an impact of FLDs; © ro assess the impact of frontline demonstrations on yield and income obtained by the oilseed growers; (d) to delineate the constraints encountered by the castor growers in Jodhpur district of Rajasthan and (e) to suggest strategies to improve the castor cultivation scenario in Rajasthan.

MATERIALS AND METHODS

Locale of the study: Jodhpur district of Rajasthan was selected as the locale of the study area and Regional Agricultural Research Station (RARS), Mandor, conducted the FLDs on castor. Geographically, Jodhpur is situated in between 26 15'N to 26 45'N latitude and 73°E to 77°29'E longitude in the west. Average annual rainfall ranges from 100 mm in the western part to about 300 mm in the eastern part. Maximum temperature in the month of June remains around 40°C and minimum temperature in the month of

[1]Principal Scientist, NAARM, Rajendranagar, Hyderabad-500 030, Andhra Pradesh
[2]Agricultural Research Station, Mandor, Rajasthan.

January is around 8°C. In general soil types are alkaline loamy but free from hazards of salinity. The fertility status of the soil is poor for nitrogen (0.15 to 0.3 % organic carbon), medium in phosphorous and high in potash availability.

Sampling design: The study villages were namely, Sambadia, Khariamitapur and Umaidnagar where FLDs were conducted during 2003-04 to 2005-06 and the corresponding non-FLD castor growers were selected through proportionate random sampling procedure. The final sample of the study included 25 each FLD and non-FLD castor growers.

Data collection and statistical tools: A well-structured interview schedule was utilized to collect the data from the selected respondents with the help of the key informants of the respective villages and the scientific team from RARS, Mandor. The collected data were analyzed using standard statistical tools *viz*., mean standard deviation, percentage and t-test analyses, to have meaningful interpretation of the data.

RESULTS AND DISCUSSION

Profile characteristics of the respondents: Majority of the FLD and non-FLD castor growers were middle aged (35 to 55 years). Majority the FLD castor growers were illiterate to middle school level educated, whereas non-FLD castor growers were illiterate (Table3.). The farming experience of the FLD farmers was low to medium, whereas that of the other category was medium. Both the FLD and non-FLD castor growers had medium level of castor cultivation experience. Majority of the FLD farmers were possessing semi-medium to medium size of farm holdings, whereas majority the other category farmers had semi-medium size of farm holdings. As far as the area under castor cultivation is concerned, the FLD and non-FLD farmers were small and marginal to small in nature.

Factors responsible for castor cultivation: Suitability of the crop to the prevailing environment of the study area is the foremost factor that contributed for the initiation and spread of castor cultivation. There are other crops like mustard, vegetables, bajra, etc., are grown in the study area and this crop according to the respondents has less cost involved, which is the second important factor that contributed for castor cultivation. Also, the damage due to pests and diseases is comparatively lower and that forms third important factor that contributed for castor cultivation. Local availability of market and processing facilities for the castor seeds are the further important contributing factors that enhance the further growth of castor cultivation in the study area. Availability of credit facilities for borrowing loans for incurring the cultivation cost and possibility of having castor based cropping systems also the factors that contributed to the castor cultivation in the study area.

Concurrent impact of the frontline demonstrations: A total of 169 FLDs were conducted by the RARS, Mandor during the period of 1997-98 to 2006-07 on whole package technology, improved hybrids, recommended dose of fertilizers and plant protection measures. The impact of whole package technology on the seed yield increase was 22 and 26% under rainfed and irrigated situations, respectively, with corresponding additional net returns of ₹ 8746 and ₹ 7436/ha. Similarly, the seed yield increase was 26, 16 and 33% for improved hybrids (GCH-4 and RHC-1), recommended dose of fertilizers and plant protection measures, with corresponding additional returns of ₹ 4861, 5104, 5720/ha, respectively (Table 2).

Expost-facto adoption behaviour of the respondents (lateral spread of the technologies): Majority of the FLD and non-FLD castor growers were medium in knowledge and adoption level of recommended castor cultivation practices and the resultant yield level of their castor crop. FLD farmers and non-FLD farmers were compared with respect to the adoption, knowledge and yield levels by employing t-test. The results indicated that there was no significant difference between the FLD and non-FLD farmers in their knowledge, adoption and yield levels. This shows the impact of FLDs in lateral spread of the improved technologies of castor crop (Table 4). The overall such impact is mainly due to the faster spread of the technologies in Khariamitapur and Umaidnagar villages (Table 5).

Vertical growth of the crop: The vertical spread of castor in Jodhpur district of Rajasthan could be visible very well from Table 1. The castor area of the district increased by about five and production by about six times (Table 1) during the period 2002-03 to 2006-07. However, the overall productivity of the district is a matter of concern and there is a vast scope for further improvement of the same (Table 1).

Expost-facto impact of FLDs in yield and economics: It could be understood from Table 5 that the seed yield increase, as an impact of FLDs obtained by FLD farmers in Khariamitapur was 25% more than that of the non-FLD farmers and the additional net returns obtained by the former was ₹ 12214/ ha. The B:C ratio was 3.5 and 2.8 for FLD and non-FLD farmers, respectively. In Sambadia village also, the seed yield increase obtained by the FLD farmers was to the tune of 85%, with an additional net returns of ₹ 25280/ha. Here, the B:C ratio was 3.1 and 1.7 for FLD and non-FLD farmers, respectively. Contrastingly, in Umaidnagar village, the seed yield increase obtained was less than 1%, with meager additional net returns of ₹ 365/ha. The B:C ratio was 3.9 for both FLD and non-FLD farmers showing that the lateral spread of the technology was better in Umaidnagar, followed by Khariamitpur. This may be because reason that the Umaidnagar and Khartiamitapur villages are located on the main road and have easy approach for the development personnel and researchers to visit there frequently and impart the improved castor cultivation practices.

Constraints in castor cultivation: Non-availability of good quality seeds, inadequate electricity supply for irrigation are the major constraints for the castor growers. Higher cost of the labour and their unavailability, frost injury during the mid-December to mid-January period and occurrence of more male flowers in the genotypes grown are some of the constraints that follow the major constraints as felt by the respondents. Erratic rainfall pattern, fluctuation in the market price, high cost of inputs and the poor quality of the irrigation water are the next important constraints. Damage due to sucking pests, termites and wild animals are the biotic stresses that affect castor cultivation in the study area. Wilt damage was also a concern in the study area apart from extension constraints like unawareness towards improved production technology, lack of sufficient subsidy programmes and wider extension personnel, farmers ratio are to be overcome to improve the castor cultivation in the study area.

Suggestions to improve the castor cultivation:

- The existing castor seed production and supply system in the study area was not meeting the demands of castor growers and farmers have to depend on the outside seed supplying agencies. The hybrid RHC-1 developed at Mandor need to be included in the seed supply chain. There is wide scope for production of hybrid RHC-1 in collaboration with the DOA, National seeds corporation(NSC) and Rajasthan State Seeds Development Corporation (RSSDC) which ensures the timely supply of quality seed to the castor growers of the area.

- Intensive training progrrammes need to be organized for the farmers particularly on efficient water management, castor production technology and hybrid seed production by the scientists of RARS, Mandor in co-ordination with DOA will greatly improve the knowledge level and skills of the farmers there by increase in castor cultivation area and productivity.

- DOA should also take advantage of the expertise of KVKs and other voluntary organizations for disseminating the improved castor production technologies like integrated package for management of insect pests and diseases, integrated nutrient management and frost injury that affect castor crop. So that the collaborative efforts will reduce the extension gap between the farmers and extension personnel and better dissemination of technologies.

Table 1 Castor area, production and productivity in Rajasthan and Jodhpur

	Area		*Production*		*Productivity*	
	Rajasthan	Jodhpur	Rajasthan	Jodhpur	Rajasthan	Jodhpur
2002-03	26173	1792	21911	1018	837	568
2003-04	63633	4835	89846	3799	1412	786
2004-05	109717	9079	103782	7234	946	797
2005-06	127941	16187	101409	9045	793	559
2006-07	78514	11892	104426	6812	1330	573

Table 2 Concurrent impact of frontline demonstrations on castor in Jodhpur district of Rajasthan (1997-98 to 2006-07)

Technology	Situation	No. of demos.	Mean seed yield (kg/ha)		% increase in yield	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Addl.net returns (₹/ha)	B:C ratio	
			IT	FP		IT	FP	IT	FP		IT	FP
Whole package	Irrigated	118	3239	2562	26	10974	9799	48903	38928	8746	4.5	4.0
	Rainfed	15	3000	2453	22	17464	15607	51000	41707	7436	2.9	2.7
Hybrids	Irrigated	27	2033	1609	26	8764	8022	28312	22709	4861	3.2	2.8
Fertilizer	Irrigated	7	2759	2374	16	11254	9685	38818	32145	5104	3.4	3.3
Plant protection	Irrigated	2	2601	1952	33	10519	9171	28331	21263	5720	2.7	2.3

Table 3 Distribution of respondents according to their socio-personal characteristics

Category	FLD farmers (%)	Non-FLD farmers (%)
Age (years)		
Young (<35)	12.00	16.00
Middle (35 to 55)	84.00	80.00
Old (>55)	4.00	4.00
Educational status		
Illiterate	32.00	56.00
Primary level (up to 5th STD)	12.00	24.00
Middle level (6-8th STD)	8.00	0.00
High level (9-10TH STD)	28.00	16.00
Secondary level (11-12th STD)	12.00	0.00
College level	8.00	4.00
Farming experience (years)		
Low	36.00	20.00
Medium	48.00	60.00
High	16.00	20.00
Mean	19.34	
SD	8.15	
Castor cultivation experience (years)		
Low	4.00	8.00
Medium	52.00	68.00
High	44.00	24.00
Mean	6.82	
SD	2.50	
Farm size		
Marginal (< 1 ha)	0.00	0.00
Small (1-2 ha)	16.00	8.00
Semi-medium (2.01-5 ha)	36.00	60.00
Medium (5.01- 10 ha)	48.00	24.00
Large (> 10 ha)	0.00	8.00
Area under castor		
Marginal (< 1 ha)	20.00	16.00
Small (1-2 ha)	52.00	44.00
Semi-medium (2.01-5 ha)	28.00	40.00
Medium (5.01- 10 ha)	0.00	0.00
Large (> 10 ha)	0.00	0.00

Table 4 Distribution of respondents according to their adoption behaviour and yield

Category	FLD farmers (%)	Non-FLD farmers (%)
Knowledge level		
Low	8.00	20.00
Medium	76.00	64.00
High	16.00	16.00
Mean	17.44	
SD	3.44	
't' value	0.0079 NS	
Adoption level		
Low	8.00	36.00
Medium	72.00	40.00
High	20.00	24.00
Mean	31.56	
SD	3.00	
't' value	0.2290 NS	
Yield level		
Low	0.00	40.00
Medium	76.00	60.00
High	24.00	0.00
Mean	28.56	
SD	8.99	
't' value	6.4272 E-11 NS	

Table 5 Impact of frontline demonstrations in Jodhpur district

Village	Mean seed yield (kg/ha)		% increase in yield	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Additional net returns (₹/ha)	B:C Ratio	
	FLD	NFLD		FLD	NFLD	FLD	NFLD		FLD	NFLD
Khariyamitapur	3389	2708	25	17393	17350	61007	48750	12214	3.5	2.8
Sambadia	3060	1655	85	17617	17591	55088	29782	25280	3.1	1.7
Umaidnagar	3846	3819	0.7	17950	17828	69225	68738	365	3.9	3.9
Overall	3432	2727	26	17653	17590	61773	49090	12620	3.5	2.8

REFERENCES

Anonymous 2008. *Research Review Report (2002-03 to 2006-07).* AICRP on Castor. Agricultural Research Station. Mandor, Jodhpur. Rajasthan.

Damodaram T and Hegde D M 2010. *Oilseeds Situation-A Statistical Compendium.* Directorate of Oilseeds Research, Hyderabad-500 030.

Development of an efficient plant regeneration system in groundnut (*Arachis hypogaea* L.)

S M BHOSALE, R L CHAVHAN[1], M K VERMA AND V R HINGE

Dept. of Plant Biotechnology, College of Agriculture, Marathwada Krishi Vidyapeeth, Parbhani-431 402, Maharashtra

(Received: October, 2011; Revised: March, 2012; Accepted: April, 2012)

ABSTRACT

A simple, efficient and reproducible regeneration protocol was developed for groundnut (*Arachis hypogaea* L.) cv. LGN1 which become mandatory for genetic transformation studies. The explant embryonic axis was used for *in vitro* regeneration of groundnut. The highest number of shoot regeneration (90%) was observed on MS basal media fortified with 1.0 mg/l BAP. The combination of 1.0 mg/l GA_3, 0.1 mg/l BAP and 0.1 mg/l NAA showed good response for shoot elongation. Rooting was observed in elongated shoots in half MS basal medium supplemented with 0.7 mg/l NAA and 0.5 mg/l kinetin with the highest frequency of root induction (70%). The well grown rooted shoots were successfully hardened in plastic pot containing cocopit and subsequently transferred to earthen pot containing sand, soil and FYM in 1:1:1 proportion in a green house.

Key words: Embryonic axis, Groundnut, Plant regeneration, Transformation

The major breeding objective of the groundnut (*Arachis hypogaea* L.) programme is to develop high yielding varieties with distinguished features including earliness, resistance to major pests, diseases, drought, salt and cold as well as high protein and oil content. Conventional methods were found inadequate for achieving these objectives and improvement of this crop (Murthy and Reddy, 1993). Genetic improvement of groundnut through transgenic development would able to sort out these shortcomings. The most essential requirement for the production of transgenic groundnut is the availability of simplest reproducible regeneration protocol. The *in vitro* culture in groundnut have been carried out by several researchers, especially María and Alberto (2000), Palanivel and Jayabalan (2000), Matand and Prakash (2007), Shan *et al.* (2009) and Alam and Khaleque 2010). However these studies provide limited success rates of *in vitro* regeneration (37-91.5%) and varied from genotype to genotypes.

Hence, present study was initiated to develop simple, efficient protocol of groundnut regeneration via direct organogenesis which is a prerequisite for transformation studies.

Seeds of groundnut (*Arachis hypogaea* L.) cv. LGN1 were obtained from Oilseed Research Station, Latur, Marathwada Krishi Vidyapeeth, Parbhani, India. Seeds were initially rinsed in a solution of Tween 20 for 5 min followed by three times rinsing with sterile distilled water; further removed the traces of detergent. Seeds were subjected to surface sterilization by 70% ethanol (v/v) for 5 min, followed by 0.01-0.1% mercuric chloride treatment for 5 min. Subsequently the seeds were rinsed three times in sterile distilled water. The seeds were inoculated in a tube containing half MS basal medium, kept in dark condition for 2-3 days for germination. The germinated seedlings of 2-3cm height were used for explant preparation. The embryo was aseptically extracted by removing shoot apex and root pole carefully. It has been referred as mature embryonic axes and used as explant for regeneration of groundnut. The mature embryonic axes was cultured on full strength MS medium (Murashige and Skoog, 1962) supplemented with growth regulator BAP (0.5-3.0 mg/l) alone or in combination with IAA (0.5 mg/l) and 3% sucrose, gelled with 0.8 % agar agar for standardization of regeneration medium (SIM1-SIM10) for shoot initiation (Table 1). The control set was maintained with devoid of any plant growth regulator. The pH of media was adjusted to 5.8 and autoclaved at 121°C for 20 min. The cultures were incubated at 25 ± 2°C for a 16 hr photoperiod of 80 $\mu E/m^2/s^1$ light intensity. Each treatment of 10 explants were used for initiation of shoot and repeated twice, to maintain the accuracy of experiment. Data of regenerated shoot were exploited to calculate regeneration percentage of cultures for each treatment.

The regenerated shoots were then transferred on shoot elongation medium. The various concentration of GA_3 (0.5-2.0 mg/l), BAP (0.1-0.5 mg/l) and NAA (0.1-0.5 mg/l) with MS basal medium were tested to standardize the best combination for shoot elongation medium (SEM).

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

The elongated shoots were transferred on to root induction medium (RIM) containing half strength basal MS medium supplemented with various concentrations of IAA or NAA (0.5-1.0 mgl/l) and kinetin (0.5 mgl/l) (Table 2).

The rooted plantlets were transferred on primary hardening medium comprising sterile Cocopit treated with Bavistin (0.1%) for acclimatization and survival of completely developed plantlets. These well established plantlets were subsequently transferred to the secondary hardening medium comprising sand, soil, and FYM in proportion of 1:1:1 at greenhouse.

The present study reveals a simple protocol for *in vitro* regeneration of groundnut cv. LGN 1.

Shoot initiation and elongation: Shoot initiation was observed on MS basal medium supplemented with varying levels of BAP alone or in combination with IAA. Maximum shoot initiation from mature embryonic axes was observed in SIM2 medium comprising 1.0 mg/l BAP alone or in combination with 0.5 mg/l IAA (Table 1) within 3 weeks of inoculation (Fig.1).

The medium SIM2 gave 90% regeneration response from embryonic axes of groundnut while medium SIM7 comprising 0.5 mg/l IAA gave 80% regeneration response. These results were found in contrast with the earlier reports stating that NAA (0-2.69 µM) is needed for shoot initiation by using various explants (Shan *et al.*, 2009; Alam and Khaleque, 2010). Maria and Alberto (2000) reported that shoot bud induction was observed on MS medium supplemented with BAP (5.0 mg/l) in peanut whereas (Alam and Khaleque, 2010) reported that among different growth hormone BAP (2.0-2.5 mg/l) was found more suitable for regeneration compare to 2,4-D and NAA. This indicates that the effect of growth regulators depend not only on applied concentrations but also on their interaction and it is varied from genotype to genotype. Also the higher concentration of BAP was found inhibitory for shoot elongation (Verma *et al.*, 2009). The present investigation described low levels of BAP (1.0 mgl/l) found suitable for induction of shoot bud in *groundnut* cv. LGN1.

Table 1 Comparative study of effect of various concentrations of BAP alone and in combination with 0.5 mg/l IAA on shoot initiation of genotype LGN1

Medium	Growth regulator mg/l		No. of explants cultured	No. of explants respond to shoot induction	Explants forming shoots (%)	Days of shoot induction
	BAP	IAA				
SIM 1	0.5	--	10	6	60	9-10
SIM 2	1.0	--	10	9	90	9-10
SIM 3	1.5	--	10	5	50	11-12
SIM 4	2.0	--	10	5	50	11-12
SIM 5	2.5	--	10	3	30	11-13
SIM 6	3.0	--	10	2	20	13-15
SIM 7	1.0	0.5	10	8	80	12-13
SIM 8	1.5	0.5	10	6	60	12-15
SIM9	2.0	0.5	10	4	40	12-15
SIM10	2.5	0.5	10	2	20	12-15

Table 2 Percentage of root induction from regenerated groundnut shoots on MS media supplemented with different concentrations of IBA and NAA in combination with 0.5 mg/l KIN

Medium	Growth regulator		No. of explants respond to root induction	Explants forming roots (%)	Days of rooting
	NAA	KIN			
RIM 1	0.5	0.5	5	50	15-20
RIM 2	0.7	0.5	7	70	10-15
RIM 3	1.0	0.5	4	40	20-25
	IBA	KIN			
RIM 4	0.5	0.5	5	50	15 [illegible]
RIM 5	1.0	0.5	3	30	16-22

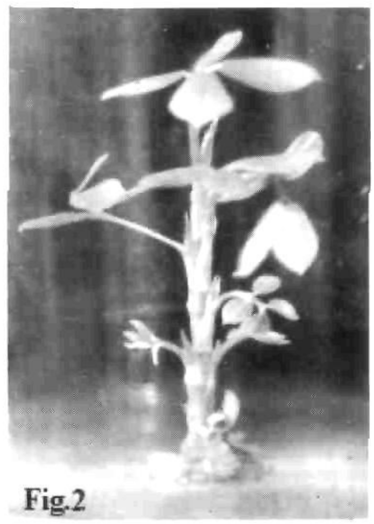
Shoot elongations of regenerated groundnut plants were observed on MS medium fortified with combination of growth regulators GA_3 (2.0 mg/l), BAP (0.1 mg/l), NAA (0.1 mg/l). Many researchers have utilized GA_3 for elongation of shoot buds (Shan *et al.*, 2009; Elavazhagan *et al.*, 2009). Elongation of shoots was observed on shoot elongation medium within three weeks of subculture (Fig.2)

Root induction: *The root induction medium-RIM* 2 comprising half MS medium supplemented with NAA (0.7 mg/l) and kinetin (0.5 mg/l) has shown quick and good response for root induction. Roots were emerged from the cut ends of the shoots in all cultures within 15-20 days (Fig

3). The highest rooting efficiency of 70% was found on RIM 2 medium (Table 2). Comparative study of treatment combination of growth regulator, NAA and kinetin revealed superiority over treatment combination of IBA and kinetin in respect of rooting efficiency. Several researchers *viz*., Shan *et al.* (2009), Palanivel and Jayabalan (2000) were also reported root induction on half strength MS with NAA (2.69 μM) or IBA (9.0 μM). Thus, present study could reveal the genotype LGN1 showed maximum rooting efficiency at less concentration of growth regulator NAA and Kinetin.

Hardening: The *in vitro* regenerated plantlets were transferred to the plastic cups and later successfully grown in the green house (Fig. 4). The 75% of transplanted plant survived and resumed growth, matured, flowered normally and set seeds. No morphological variants were obtained in the regenerated plants.

Thus, in present investigation a successful attempt has been made in development of simple *in vitro* regeneration protocol from mature embryonic axes of groundnut. Mature embryonic axes of groundnut showed high potential for *in vitro* regeneration and would be used for genetic transformation of groundnut cv. LGN 1.



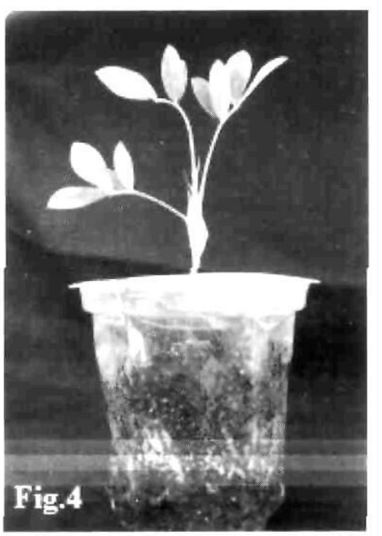


Fig.1a & b : Shoot regeneration from embryonic axes explants containing 1.0 mg/l BAP and 0.5 mg/l NAA.

Fig.2 : Elongation of shoot on shoot elongation medium (SEM) containing 2.0 mg/l GA_3, 0.1 mg/l BAP and 0.1 mg/l NAA.

Fig.3 : Induction of root on root induction medium (RIM) comprising half strength of MS medium containing 0.7 mg/l NAA and 0.5 mg/l KIN.

Fig.4 : Primary hardening of regenerated plantlets in plastic cups.

Fig.5 : Secondary hardening of regenerated plantlets in pot containing sand, soil and FYM in 1:1:1 proportion.

REFERENCES

Alam A K M M and Khaleque M A 2010. *In vitro* Response of Different Explants on Callus Development and Plant Regeneration in Groundnut (*Arachis Hypogeae* L.). *International Journal of Experimental Agriculture,* **1**(1):1-4.

Elavazhagan T, Jayakumar S, Chitravadivu C and Balakrishnan V 2009. *In vitro* culture and cytological studies on *Helianthus annuus* L. *Botany Research International,* **2**(4): 258-262.

María F C and Alberto D R J 2000. Protocol for regeneration *in vitro* of *Arachis hypogaea* L. *Electronic Journal of Biotechnology,* **3**(2): 1-4.

Matand K and Prakash C S 2007. Evaluation of peanut genotypes for *in vitro* plant regeneration using thidiazuron. *Journal Biotechnology,* **130**(2):202-7.

Murashige T and Skoog F 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Plant Physiology,* **15**: 473-497.

Murthy T G K and Reddy P S 1993. *Cytogenetics and genetics of groundnut.* Oxford and IBH Publication Company Pvt. Ltd. New Delhi.

Palanivel S and Jayabalan N 2000. Correlative Effect of Adenine Sulphate and Benzylaminapurine on the Regeneration Potentiality in Cotyledonary Explants of Groundnut (*Arachis hypogaea* L.). *Journal of Biotechnology,* **2**(1) 12-24.

Shan L, Tang G, Xu P, Liu Z and Yuping B 2009. High efficiency *in vitro* plant regeneration from epicotyl explants of Chinese peanut cultivars. *In Vitro Cellular & Developmental Biology - Plant,* **45**(5)525-531.

Verma A, Malik C P, Gupta V K and Sinsinwar Y K 2009. Response of groundnut varieties to plant growth regulator (BAP) to induce direct organogenesis. *World Journal of Agricultural Sciences,* **5**(3): 313-317.

Genetic divergence in sunflower (*Helianthus annuus* L.)

G VINAY KUMAR, J SURESH, S SUDHEER KUMAR, A GEETHA AND P SAIDAIAH

Dept. of Genetics and Plant Breeding, College of Agriculture, Acharya N.G. Ranga Agril. University, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

(Received: March, 2011; Revised: January, 2012; Accepted: March, 2012)

ABSTRACT

Genetic divergence using Mahalanobis D^2 statistic was worked out in 63 sunflower (*Helianthus annuus* L.) inbreds including three hybrids. The 63 genotypes were grouped into eight clusters using Touchers method. Cluster III had a large number of 16 genotypes. While ten genotypes were included in cluster VII, whereas V Cluster included nine genotypes, cluster VIII with eight genotypes, cluster I and IV with six genotypes each and cluster VI with five genotypes (RHA-340, RHA-348, RHA-17, R-12 and R-17). Cluster II comprised only three genotypes, three checks, *viz.*, KBSH-44, KBSH-1 and DRSF-108. Characters like oil content, days to 50% flowering, number of filled seeds/head, test weight and number of unfilled seeds/head had contributed more to the total divergence. The pattern of distribution of genotypes into various clusters revealed that there was no relationship between geographical distribution and genetic diversity. Greater genetic divergence was found between II and VII clusters and II and VI clusters, thus suggesting that the genotypes of these clusters may be exploited to explore the fullest range of variability for the character(s) and to realize good recombinant lines.

Key words: Clustering pattern, D^2 analysis, Genetic divergence, Sunflower

Several measures of genetic distance have been proposed so far, of which Mahalanobis generalized distance is most widely used. Hence, an attempt was made to study the genetic divergence in 63 sunflower genotypes obtained from Directorate of Oilseeds Research, Hyderabad.

A field experiment consists of 63 inbred lines including three hybrids were sown in randomized block design with two replications during the winter season of 2007 at College Farm, College of Agriculture, ANGRAU, Hyderabad. Each genotype was sown in three rows of 4.5 m length adopting a spacing of 60 cm x 30 cm. Two to three seeds were sown per hill to facilitate better emergence and to maintain uniform stand. Thinning was done at second week to retain one seedling/hill. Recommended agronomic practices were followed to grow a healthy crop. Observations were recorded on five randomly selected plants for each genotype in each replication. The characters studied were, days to 50% flowering, head diameter, number of leaves/plant, plant height, days to maturity, number of unfilled seeds/head, number of filled seeds/head, 100 seed weight, oil content and seed yield/plant. The mean values over replications were subjected to analysis of variance and then to Mahalanobis D^2 statistic to measure genetic divergence as suggested by Rao (1952). The genotypes were grouped into various clusters following Toucher's method described by Rao(1952).

The analysis of variance revealed significant differences (Table 1) among the 63 genotypes for all the 10 traits, indicating the existence of genetic variability. On the basis of relative magnitude of D^2 statistics, the 63 genotypes were grouped into eight clusters (Table 2). using Toucher's method (Singh and Chaudhary, 1977). Cluster III had a large number of 16 genotypes. Ten genotypes were included in cluster VII, whereas V cluster nine genotypes, cluster VIII with eight genotypes, cluster I and IV with six genotypes each and cluster VI with five genotypes (RHA-340, RHA-348, RHA-17, R-12 and R-17). All the three checks, KBSH-44, KBSH-1 and DRSF-108 were fallen in Cluster II. Thus, the pattern of distribution of genotypes from different geographical regions into different clusters was random, indicating that there is no correlation between clustering pattern and eco-geographical distribution of genotypes.

Tendency of genotypes occurring in clusters across the geographical boundaries demonstrates that the geographical isolation is not the only factor causing genetic diversity in sunflower. Similarly, the forces other than geographical origin such as genetic drift, natural and artificial selection, exchange of breeding material might have played an important role in the fixation of diversity among the genotypes. Variation in the environment could also be responsible for this diversity. The success and usefulness of Mahalonobis's analysis in qualifying the genetic divergence has been followed in sunflower (Thirumala Rao, 2002 and Srinivas, 2006).

The average intra and inter cluster D^2 and D values among eight clusters were presented in table 3. Most of the intra clusters are closely related and intracluster average cluster D^2 values ranged from 23.244 (Cluster I) to 76-769 (Cluster VI), while the maximum D^2 value was found between the cluster II and cluster VII (376.234) indicating the more genetic diversity between these two groups, while *the minimum intercluster* D^2 *value was observed between* cluster III and IV (79.275), suggesting close genetic relationship and similarity for most of the traits between *genotypes of these two groups*. The greater distance between the clusters indicates the wider genetic diversity between the genotypes. Variation in environment was also responsible for this diversity. Similar conclusions were also drawn by other researchers (Komuraiah, 2002; Reddy and Devasenamma, 2004 and Mohan and Seetharam, 2005).

Table 1 ANOVA for seed yield and yield attributes in sunflower

Character	*Mean sum of squares*		
	Replications	Treatments	Error
Days to 50% flowering	1.34	13.52**	0.69
Head diameter (cm)	1.14	8.43**	1.18
Number of leaves/plant	22.12	23.72**	4.55
Plant height (cm)	1038.31**	582.36**	72.64
Days to maturity	1.20	9.94**	1.39
Number of unfilled seeds/ head	7.31	2645.72**	794.56
Number of filled seeds/ head	637.33	14055.41**	3005.93
Test weight (g)	0.13	1.33**	0.14
Seed yield/plant (g)	0.99	74.88**	8.84
Oil content (%)	29.92*	77.44**	1.33

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

Table 2 Distribution of 63 sunflower genotypes in different clusters

Cluster	No. of genotypes	Genotype
I	6	ARM-238, ARM-245, ARM-239, ARM-250, ARM-242, ARM-248.
II	3	KBSH-1, KBSH-44, DRSF-108.
III	16	GP-325-3, GP9-472-4-1, GP9-472-7-2, GP1-2086, GP2-1746, GP9-33E-4-2, GP-1334-3,GP-322-1,GP-322-2, GP2-2035, GP9-38-2-1, R.S.BOARDAGEN-2, GP1-69, GP9-846-4-4, GP9-279-7-4,GP9-290-5-3.
IV	6	GP-247-1, R.S.BOARDAGEN-1, GP2-1217, GP9-1191-1, GP-2158-4, GP9-472-5-5.
V	9	RHA-6D-1, 3373-R, R-272-I, RHA-23, RHA-334, RHA-296, RHA-587, RHA-272, P-81-R.
VI	5	RHA-340, RHA-348, RHA-17, R-12, R-17.
VII	10	NDR-7, R-586, RHA-274, HRHA-2, AK-1R, NDR-8, R-16, P-74-R, PK-104, BGR-25310.
VIII	8	NBR-3, P-72-R, NDR-6, PET-2-89-1B, RHA-298, R-649, R-69-R, ADV-110.

Table 3 Average intra and inter cluster distances (D^2 values)

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII
Cluster I	(4.821) C 23.244)	(11.452) C 131.1633	(9.004) C 81.079	(9.732) C 94.717	(9.332) C 87.092	(14.210) M 201.935	(12.704) C 161.416	10.413 C 108.432
Cluster II		(8.248) C 68.032	(12.098) C 146.362	(14.635) M 214.195	(14.888) M 221.668	(19.391) H 376.016)	(19.396) H 376.234	17.196 M 295.726
Cluster III			(6.977) C 48.682)	(8.903) C 79.275	(11.642) C 135.558	(18.191) H 330.922	(15.834) M 250.728)	15.079 M227.386
Cluster IV				(6.381) C 40.722	(9.377) C 87.945	(15.679) C 245.853	(11.907) C 141.780	13.835 C 191.417
Cluster V					(7.570) C 57.31	(11.262) C 126.844	(8.997) C 80.956	10.033 C 100.681
Cluster VI						(8.931) C 79.769	(10.007) C 100.151	11.077 C 122.706
Cluster VII							(6.918) C 47.872	10.746 C 115.486
Cluster VIII								8.279 C 68.558

Values in parenthesis are D values; H : Highly divergent (above 300); M : Moderately divergent (200-300); C : Closely related (below 200)

Table 4 Contribution of different characters towards genetic divergence (D^2) in 63 sunflower genotypes

	Times ranked first	Per cent contribution towards divergence
Days to 50% flowering	345	17.67
Head diameter (cm)	20	1.02
Number of leaves/plant	13	0.67
Plant height (cm)	16	0.82
Days to maturity	43	2.20
Number of unfilled seeds/head	74	3.79
Number of filled seeds/head	228	11.67
Test weight (g)	122	6.25
Seed yield/plant (gm)	54	2.77
Oil content (%)	1038	53.15

Table 5 Cluster means of genotypes for various characters in sunflower

Cluster	Days to 50 % flowering	Head diameter (cm)	Number of leaves/ plant	Plant height (cm)	Days to maturity	Number of unfilled seeds/head	Number of filled seeds/head	Test weight (g)	Seed yield/plant (g)	Oil content (%)
Cluster I	64.367	14.442	27.583	163.708	93.800	196.108	471.661	4.458	20.583	33.733
Cluster II	63.300	16.633	28.100	161.267	93.567	207.328	694.663	5.370	36.215	40.250
Cluster III	61.012	14.659	28.550	151.950	91.184	218.642	444.685	5.079	22.374	39.734
Cluster IV	58.517	14.625	28.467	155.100	90.483	200.664	425.219	5.017	20.889	34.433
Cluster V	60.633	12.433	24.100	129.733	90.822	182.052	424.811	4.727	19.876	30.639
Cluster VI	60.620	9.630	24.160	119.200	93.200	164.362	401.596	3.409	14.531	24.710
Cluster VII	59.610	12.805	21.640	126.970	90.830	181.663	403.881	4.062	15.970	24.990
Cluster VIII	64.575	11.644	24.663	136.038	95.100	203.269	429.309	4.881	20.334	27.375

The characters contributing maximum divergence needs greater emphasis for deciding on the clusters for the purpose of selection of parents in the respective cluster for hybridization. The number of times, each of the yield component character appeared in first rank and its respective per cent of contribution towards genetic divergence was presented in table 4. The results showed that oil content percent contributed highest towards genetic divergence (53.2%) by taking 1038 times ranking first, followed by days to 50% flowering (17.7%) by 345 times, number of filled seeds/head (11.7%) by 228 times, test weight (6.3%) by 122 times, seed yield/plant (2.8%) by 54 times, head diameter (1.0%) by 20 times.

Cluster means of genotypes for various characters in sunflower (Table 5) revealed that cluster I represented genotypes with highest means for plant height, days to maturity, whereas genotypes with high means for head diameter, number of filled seeds/head, test weight and seed yield/plant were included in cluster II. High genotypic means for number of leaves/plant and number of unfilled seeds/head were present in cluster III and cluster VIII had genotypes with high means for days to 50% flowering. These clusters can be preferred in selecting the genotypes for the respective traits as they recorded good means.

The genetic divergence analysis revealed presence of substantial amount of genetic variability among the genotypes. The pattern of distribution of genotypes into various clusters is random, showing that geographical diversity and genetic diversity are not related to each other. Greater genetic divergence was found between cluster II and VII, II and IV indicating that superior hybrids or recombinants can be realized by mating between the lines of these clusters in a definite fashion.

REFERENCES

Komuraiah K 2002. Genetic diversity analysis of superior inbred lines in sunflower (*Helianthus annuus* L.). M.Sc. (Ag.) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.

Mahalanobis P C 1936. On the generalized distance in statistics. *Proceedings of Natural Academy Science, India,* **2**: 49-55

Mohan G S and Seetharam A 2005. Genetic divergence in lines of sunflower derived from interspecific hybridization. *SABRAO Journal of Breeding and Genetics,* **37** (2): 77-84.

Rao C R 1952. *Advanced statistical methods in biometrical research.* John Wiley and sons Inc., New York, 1952, pp. 357-363.

Reddy AV and Devasenamma V 2004. Genetic divergence in sunflower, *Helianthus annuus.* L. *Journal of Oilseeds Research*, **21**(2): 257-259.

Singh R K and Chaudhary B D 1977. *Biometrical methods in quantitative genetic analysis.* Kalyani Publishers. New Delhi.

Srinivas B 2006. Genetic divergence studies in sunflower (*Helianthus annuus* L.) M.Sc. (Ag.) Thesis Acharya N.G. Ranga Agricultural University, Hyderabad.

Thirumala Rao V 2002. Evaluation of new inbred lines for autogamy, oil content, yield and yield attributes in sunflower (*Helianthus annuus* L.) M.Sc. (Ag.) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.

Autogamy in sunflower (*Helianthus annuus* L.) genotypes

G VINAY KUMAR, J SURESH, S SUDHEER KUMAR, A GEETHA AND P SAIDAIAH

Dept. of Genetics and Plant Breeding, College of Agriculture, Acharya N.G. Ranga Agril. University, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

(Received: March, 2011; Revised: January, 2012; Accepted: March, 2012)

ABSTRACT

Autogamy study conducted in sunflower (*Helianthus annuus* L.) using 60 inbreds and three check hybrids at College Farm, College of Agriculture, ANGRAU during the winter season of 2007 revealed that hybrids recorded higher autogamy (82.1%) and geitonogamy (90.6%) followed by inbreds (82.2, 80.6%) and hybrids (90.7%, 89.6%). The inbred lines PK-104 (94.0), NDR-8 (92.3%), RHA-274 (92.1%), R-17 (91.3%) and PET-2-89-1B (91.0%) showed high rate of autogamy. These lines can be used in breeding programme to improve the autogamy rate in the elite inbred lines.

Key words: Autogamy, Geitonogamy, Genotypes, Seed set %, Sunflower

Sunflower (*Helianthus annuus* L.) is a highly cross-pollinated oilseed crop, generally cross pollination takes place through insects, particularly bees. To over come the higher degree of self-incompatibility, adequate pollination by other means has to be taken up and to overcome the problem of poor seed set, there is a need to develop suitable varieties and hybrids with higher degree of self fertility. Realizing the importance of self-compatibility in sunflower, it is essential to have a comprehensive study to identify high autogamous lines with high seed oil and high yield (Ivanov, 1975). Keeping this in view, the present investigation was conducted to evaluate the newly developed inbreds of the Directorate of Oilseeds Research along with populations and hybrids.

Sixty sunflower genotypes including inbred lines, populations and hybrids were evaluated in randomized block design at College of Agriculture, Hyderabad during the winter season 2007. Each genotype was sown in three rows of 5 m length with a spacing of 60 cm x 30 cm and replicated thrice. Under each treatment and in each replication, 15 plants were randomly selected for three operations, out of which five plants were covered with cloth bag soon after the appearance of ray florets and were not disturbed till maturity to study autogamy percent, another five plants were covered with cloth bag and hand pollination was done by gently rubbing the heads with hand without removing bags to study the geitonogamy and the other five plants were left for open pollination. Seed set percentage; autogamy and geitonogamy were calculated as per George and Shein (1980). The data was recorded on number of filled seeds/head, number of unfilled seeds/head and seed yield in the heads covered with cloth bags, those covered with cloth bags and hand pollinated and open pollinated. Seed set per cent autogamy and self-compatibility were calculated as shown below:

$$\text{Seed set (\%)} = \frac{\text{Number of filled seeds under open pollination}}{\text{Total number of seeds under open pollination (Filled seeds + unfilled seeds)}} \times 100$$

Seed set under autogamous condition

$$= \frac{\text{Number of filled seeds under self pollination}}{\text{Total number of seeds under self pollination}} \times 100$$

Seed set under geitonogamous condition

$$= \frac{\text{Number of filled seeds under bagging with hand pollination}}{\text{Total number of seeds under bagging with hand pollination}} \times 100$$

$$\text{Autogamy (\%)} = \frac{\text{Seed set under self pollination (SP)}}{\text{Seed set under open pollination}} \times 100$$

$$\text{Geitonogamy (\%)} = \frac{\text{Seed set under bagging with hand pollination (HP)}}{\text{Seed set under open pollination}} \times 100$$

Table 1 Seed set per cent, autogamy and geitonogamy under different conditions

Genotype	Seed set per cent			Autogamy	Geitonogamy
	SP	HP	OP		
ARM-238	63.11	67.23	72.34	87.25	92.94
ARM-239	61.73	65.09	70.25	87.88	92.66
ARM-242	52.80	66.61	67.50	78.22	98.69
ARM-245	61.16	61.65	74.72	81.86	82.52
ARM-248	58.90	67.72	66.75	88.25	101.45
ARM-250	62.01	72.39	71.48	86.76	101.28
GP-325-3	*50.43*	*58.58*	*67.48*	*74.73*	*86.81*
GP-247-1	54.95	64.26	70.73	77.70	90.85
GP-1334-3	54.04	58.51	69.83	77.38	83.79
GP-2158-4	48.84	59.45	65.84	74.18	90.30
GPJ-69	50.12	59.99	66.55	75.31	90.14
GP1-2086	50.37	57.62	64.96	77.54	88.70
GP-322-1	54.84	64.56	69.91	78.44	92.36
GP-322-2	60.58	68.96	69.73	86.88	98.90
GP2-1217	49.96	69.67	67.88	73.59	102.63
GP2-1746	62.36	57.26	68.88	90.53	83.12
GP2-2035	50.64	58.03	70.78	71.54	81.99
GP9-33E-4-2	52.57	64.54	63.39	82.93	101.81
GP9-38-2-1	*49.23*	*55.14*	*71.63*	*68.73*	*76.98*
GP9-472-4-1	50.83	58.99	65.84	77.20	89.59
GP9-472-5-5	*48.96*	*52.02*	*61.88*	*79.12*	*84.06*
GP9-472-7-2	56.20	62.98	68.58	81.94	91.82
GP9-846-4-4	48.33	54.84	62.02	77.93	88.43
GP9-279-7-4	50.69	56.32	60.34	84.00	93.33
GP9-290-5-3	48.10	53.69	62.18	77.35	86.34
GP9-1191-1	57.64	62.08	65.94	87.40	94.14
RHA-6D-1	54.98	68.95	68.47	80.30	100.69
RHA-23	47.64	68.50	65.70	72.51	104.26
RHA-272	55.58	69.71	76.50	72.65	91.12
RHA-296	50.18	62.41	69.56	72.15	89.73
RHA-298	*56.63*	*67.02*	*66.53*	*85.12*	*100.74*
RHA-334	58.28	67.63	66.48	87.67	101.73
RHA-340	59.58	66.59	73.32	81.26	90.82
RHA-348	57.06	68.45	74.13	76.97	92.33
RHA-587	61.53	64.29	70.33	87.50	91.41
RHA-274	67.09	65.62	72.87	92.06	90.05
RHA-17	55.82	49.23	68.64	81.32	71.73
NBR-3	68.00	59.59	76.42	88.98	77.98
NDR-6	56.82	56.21	69.10	82.23	81.34
NDR-7	62.41	62.87	70.75	88.21	88.86
NDR-8	61.69	62.75	66.89	92.23	93.82
R.S.BOARDAGEN-1	*58.72*	*68.33*	*75.62*	*77.65*	*90.36*
R.S.BOARDAGEN-2	57.93	64.03	70.11	82.63	91.32
PET-2-89-1B	58.28	63.99	64.07	90.98	99.89
R-586	60.92	61.02	70.60	86.29	86.42
R-12	54.81	60.27	69.94	78.37	86.17
R-17	59.99	55.79	65.68	91.34	84.94
R-272-I	55.86	62.57	71.56	78.07	87.44
R-16	54.58	56.80	66.77	81.75	85.07
3373-R	*59.35*	*63.92*	*67.68*	*87.70*	*94.46*
R-649	58.19	64.28	67.92	85.67	94.64
R-69-R	59.59	65.77	66.00	90.29	99.65
P-81-R	55.92	64.99	75.07	74.49	86.56
P-72-R	53.39	62.80	67.28	79.36	93.33
P-74-R	56.47	57.22	69.03	81.82	82.89
ADV-110	59.67	62.06	66.84	89.28	92.86
HRHA-2	60.50	58.80	67.50	89.63	87.11
BGR-25310	54.59	61.99	65.14	83.81	95.17
AK-1R	57.43	58.13	70.70	81.23	82.22
PK-104	65.74	63.81	69.92	94.02	91.26
Mean of inbreds	56.41	62.24	68.68	82.17	90.73
Checks					
KBSH-1	60.63	69.62	75.33	80.48	92.42
KBSH-44	67.34	70.89	76.00	88.62	93.28
DRSF-108	58.34	66.51	80.20	72.75	82.94
Mean of checks	62.10	69.01	77.18	80.62	89.55
General mean	56.68	62.56	69.07	82.10	90.68

SP= Self pollination; HP Bagging with hand pollination; OP Open pollination

Perusal of results revealed that seed set (Table 1) was highest under open pollination followed by hand pollination and self-pollination. According to Seetharam (1982), seed set under open pollination recorded significant difference over other pollination methods and it is determined to a large extent by the population of pollinators in the vicinity of the crop. This might be due to pollen movement effected by insect pollinators. The lowest seed set under self-pollination was mainly due to lack of pollen transfer to the stigmatic surface and self-incompatibility nature. Considering the mean per cent of seed set across pollination methods and genotypes, revealed that hybrids registered relatively higher seed set followed by inbreds and populations. The mean per cent seed set was highest under open pollination (69.08%) followed by bagging with hand pollination (62.56%) and selfing (56.68%). This could be due to compatible alleles in the hybrid compared to inbreds. Genotypes, RHA-274, KBSH-1 and KBSH-44 under self pollination, RHA-272, KBSH-1 and KBSH-44 under hand pollination and open pollination, three inbreds RHA-272, DRSF-108 and KBSH-44 recorded higher seed set per cent.

Autogamy percent was higher in hybrids followed by inbred lines and populations. Similar results were reported by earlier workers (Sumangala and Giriraj, 2002). According to Miller and Fick (1997) the degree of self-incompatibility and self-fertility depends on three conditions *viz.*, genetic control, environment and morphology of floral structures. In the present study, genotypic differences influenced degree of autogamy ill the genotypes studied. Hybrid, KBSH-44, inbreds, NDR-8 followed by RHA-274 and R-17 recorded higher autogomy percentage. Therefore, it is necessary for development of self-fertile populations or hybrids to alleviate the dependency on bees for good seed set (Roath and Miller, 1982). Selection for self-fertility enables to accumulate self-compatible genes in germplasm lines (Sumangala and Giriraj, 2002). A genotype is considered as self-fertile if it sets seed under bagging, George (1982) pointed out that this procedure does not ensure potential self-pollination in some genotypes which, however, can be achieved by manual self-pollination, therefore, the latter method should be included in self-compatibility studies. Hence, they estimated self-compatibility as the ratio between seed set under manual self-pollination and open pollination. In the present study, estimates of self-compatibility of genotypes (Table 1) revealed some interesting facts. The genotypes with low autogamy recorded higher self-compatibility. Thus, autogamy does not reflect self-compatibility. George (1982) also obtained similar results. It is also evident that even an incompatible genotype can be exhibit higher self-compatibility under induced pollination. As reported earlier, self-pollinated in the covered heads was ensured in this study by hand pollination eight times uniformly during peak flowering to ensure that all the florets in the capitulum hand equal opportunity to receive pollen for fertilization. The possible reason might be high self-fertility coupled with timely supplemented pollen for more than 100% self compatibility recorded in some of the genotype. In these genotypes, the seed set was higher under bagging + hand pollination than under open-pollination. The seed set under open pollination is mainly determined by the activity of insect pollinators, particularly honey bees. The hybrids recorded higher self-compatibility followed by inbreds across the pollination methods. Similar results were earlier reported by Rathod *et al.* (2003). Between the two pollination methods, cloth bags with assisted pollination recorded higher self-compatibility compared to cloth bag suggesting higher compatibility reaction of pollen when assisted by manually.

Hence, in sunflower breeding programmes, greater emphasis should be laid on evaluating the genotypes for self-compatibility. For the development of inbreds highly self-compatible lines with uniform plant height and flowering, high seed yield and oil content should be utilized. This may further enable us to accumulate self-compatible genes in the inbred lines. In heterosis breeding also, it is desirable to evaluate the inbred lines for self-compatibility, as it ultimately influences self-compatibility in the hybrids as well.

REFERENCES

Geroge D L 1982. Self compatibility and autogamy of hybrids and their parents in sunflower (*Helianthus annuus* L.). *Disseration Abstracts International*, B. **43**: 2106.

George D L and Shein S 1980. Effect of pollination and compatibility on seed set. *The sunflower*, pp. 12-14.

Ivanov I G 1915. Study on compatibility and incompatibility display in crossing selfed sunflower lines. *Rastenievod. Nauk*, **12** : 30-35.

Miller J F and Fick G N 1997. *The Genetics of Sunflower Technology and Production.* (Ed. A.A., Schneiter), ASA, CSSA, SSSA, Madison, WI, USA, pp. 441-445.

Rathod T H, Patil B N, Mohod V K and Tripathi N S 2003. Autogamy study in sunflower (*Helianthus annuus* L.). *Annals of Plant Physiology*, **16**(2): 129-132.

Roath W W and Miller J F 1982. Environmental efforts on seed in oilseed sunflower (*Helianthus annuus* L.). *Canadian Journal of Plant Sciences*, **62**: 867-873.

Seetharam A 1982. Strategy for improving sunflower production in India. 20th All India convention of oilseeds and oil trade industry, ICAR New Delhi, pp. 53-59.

Sumangala S and Giriraj K 2002. Self-compatibility and autogamy in sunflower (*Helianthus annuus* L.). genotypes. *Journal of Oilseeds Research*, **19**(1): 6-10.

Identification of specific cross combination in sesame (*Sesamum indicum* L.)

S V S GANGADHARA RAO

Senior Scientist (G&PB) & Head, Agricultural Research Station, Peddapuram-5, East Godavari Dt., AP

(Received: December, 2011; Revised: February, 2012; Accepted: April, 2012)

ABSTRACT

Six sesame (*Sesamum indicum*) parents *viz*., G2, SI 3012, E-8, MT 101, Kayankulam-1 and Thilothama were crossed in a diallel fashion with out reciprocals. The resultant F_1s along with their parents were evaluated to identify specific cross combinations in Sesame during rainy season of 2008 at Agricultural Research Station, Yellamanchili, Visakhapatnam District, Andhra Pradesh. The best specific cross combinations for seed yield observed were E8 x MT 101, G2 x Kayankulam, SI 3102 x MT 101, G2 x Mt 101 and Kayamkulam-1 x Thilothama which recorded an *sca* of 3.887, 3.470, 2.970, 2.515 and 2.095, respectively. The *per se* performance is also high recording more than 20g for all the above combinations. The crosses E8 x MT 101 for plant height and number of branches/plant, G2 x Thilothama for number of capsules/plant, Kayankulam x Thilothama for days to maturity were found to be best cross combinations.

Key words: Combining ability, Diallel, *sca*, Sesame

The performance and adaptation of parents are not always a true indicator of superior combining ability as it depends upon complex interaction system among genes. Thus, the choice of parents is the crucial step in any breeding programme to develop better varieties. Therefore, the present investigation was carried out to identify the best general combiners and specific cross combinations for seed yield and its components in sesame (*Sesame indicum* L.).

Six parents *viz*., G2, Si-3012, E-8, MT-101, Kayamkulam-1 and Thilothama were crossed in a diallel fashion without reciprocals and the resultant fifteen F_1 were evaluated along with their parents during the rainy season of 2008, at Agricultural Research Station, Yellamanchili, Visakhapatnam District, Andhra Pradesh. The experiment was conducted in randomized block design with three replications adopting a spacing of 30cm between the rows and 15cm between the plants. The package of practices followed were as recommended by Acharya N.G. Ranga Agricultural University. The observations were recorded on five randomly selected plants in each cross for the characters plant height, number of branches/plant, number of capsules/plant, days to maturity and seed yield/plant in grams. Combining ability analysis was done as per Griffing (1956) approach method-2 and model-1.

ANOVA for combining ability revealed that the general combining ability (*gca*) and specific combining ability (*sca*) means were significant for the characters plants height, number of capsules/plant and seed yield/plant indicating the important of additive, non-additive gene action and maternal effects (Table 1).

In general, the variance due to *gca* was larger than those due to *sca* for the traits, number capsules/plant, days to maturity and seed yield indicating the significance of additive gene action in the inheritance. Hence, improvement of these traits may be possible through selection. Devasena *et al.* (2001) also reported higher *gca* variance for days to maturity and number capsules on main stem. Ramalingam *et al.* (1990) also observed higher *gca* variance than *sca* variance for seed yield. The variance due to *sca* was larger than *gca* in plant height and number of capsules/plant indicating non-additive gene action, hence these characters could be improved by bi-parental crossing followed by recurrent selection. Singh (2004), Ramalingam *et.al* (1990), Manivannan and Ganeshan (2001) observed high *sca* variance for number of primary branches.

Among the parents MT-101 was found to be the best general combiner for seed yield. Parents E-8 and MT-101 were found to be the best general combiners for plant height, while G-2 and MT-101 were observed as best general combiners for number of capsules/plant. The *per se* performance of the parents was a good indication of *gca* effects for seed yield/plant. Higher *gca* effects were related to additive or additive x additive gene effects which are the only fixable part.

The best specific cross combination for seed yield was E- 8 x MT-101 followed by G2 x Kayamkulam-1, similarly the best specific cross combination for other traits are presented in the table 2. The specific combinations (E-8 x MT-101, Si 3012 x MT-101 and G-2 x MT101) for seed yield involved parents having low and high *gca* effects indicating the presence of additive and dominance type gene interaction. The others specific combinations for seed yield (G-2 x Kayamkulam-1 and Kayamkulam-1 x Tilothama) were having low x low general combiners (Table 3). It is evident that parents with high *gca* effects will not necessarily generate best specific cross combinations as reported earlier by Fatteh *et al.* (1995). However few crosses between low x low general combinations produced high *sca* effects suggesting the presence of overdominance and epistatic gene action. The present investigation suggested that the crosses *viz.*, E -8 x MT-101, Si-3012 x MT-101 and G-2 x MT-101 may be selected for exploitation of heterosis and also to obtain transgressive segregants in later generations.

Table 1 Analysis of variance for combining ability for yield and its components

Source	D.F	Plant height	No. of branches/plant	No. of capsules/ plant	Days to maturity	Seed yield/plant (g)
gca	5	174.93**	0.93	1601.75**	1.28	10.56**
sca	15	229.62*	1.28	969.89**	0.99	5.56**
Error	40	7.48	1.19	7.47	0.78	1.07

* and ** = Significant at P=0.05 and P=0.01 level, respectively

Table 2 Best specific cross combinations for five characters

Character	Cross	*sca* effect	*gca* of parents	
			P_1	P_2
Plant height	E8 x MT101	25.50	4.60	4.30
No. of branches /plant	E8 x MT101	1.43	0.08	0.58
No. of capsules /plant	G2 x Thilothama	56.80	20.38	-9.75
Days to maturity	Kayamkulam x Thilothama	-12.68	0.667	-0.208
Seed yield	E8 x MT 101	3.89	-0.53	2.18

Table 3 Top ranking five specific cross combinations for seed yield in sesame

Cross	Mean seed yield/plant	*sca*	*gca* status of the parent	
			P_1	P_2
E8 x MT101	24.00	3.887	-0.528	2.181**
G2 x Kayamkulam	21.00	3.470	-0.153	-0.778**
Si 3012 x MT-101	23.00	2.970	-0.944**	2.181**
G2 x MT-101	23.00	2.515	-0.153	2.181**
Kayamkulam x Thilothama	20.00	2.095	-0.778**	0.222

**=Significant at P=0.01 level

REFERENCES

Devasena N, Muralidhara V and Punitha D 2001. Combining ability for yield related traits in sesame (*Sesame indicum* L.). *Journal of Oilseeds Research,* **18** (1):115-117.

Fatteh U G, Patel N A, Chaudhari F P, Dangaria C I and Patel P G 1995. Heterosis in relation to general and specific combining ability in sesame. *Journal of Oilseeds Research*, **12**:184-190.

Griffing B 1956. Concept of general and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Sciences*, **9**:463-494.

Manivannan N and Ganeshan J 2001. Combining ability in sesame through diallel analysis. *Journal of Oilseeds Research*, **17**:249-254.

Singh P K 2004. Identification of specific cross combinations in sesame, *Sesamum indicum* L. *Journal of Oilseeds Research,* **21** (2): 338-339.

Ramalingam A, Muralidharan V and Mohanmmad Shrief N 1990. Combining ability studies in sesame. *Journal of Oilseeds Research*, **7**:75-77.

Genetic variability, heritability and genetic advance for yield and yield components in castor (*Ricinus communis* L.) genotypes

M RAMESH[1], C LAVANYA, M V BRAHMESWARA RAO AND H P MEENA

Department of Genetics and Plant Breeding, College of Agriculture, Acharya N.G. Ranga Agricultural University, *Rajendranagar, Hyderabad-500 030, Andhra Pradesh*

(Received: March, 2012; Revised: April, 2012; Accepted: May, 2012)

ABSTRACT

The present investigation was carried out in 64 castor (*Ricinus communis* L.) genotypes. The material for investigation consisting of 14 advanced lines, six male lines, 38 germplasm accessions, two pistillate lines, two released varieties and two checks (Kiran and 48-1) were grown in a randomized block design in two replications at Directorate of Oilseeds Research, Hyderabad. Variability parameters were estimated for seed yield (g/plant) and yield component characters. Seed yield at 120 days after planting recorded highest phenotypic coefficient of variability (PCV) value (50.2%). Highest genotypic coefficient of variability (GCV) value was recorded for seed yield at 150 days after planting (49.5%). The highest heritability was recorded by seed yield at 180 days after planting (97.4%) followed by seed yield at 150 days after planting (97.2%). The genetic advance as per cent of mean was highest for seed yield at 150 days after harvesting (100.4%) followed by seed yield at 120 days after planting (96.6%), effective spike length (89.4%), seed yield at 180 days after planting (86.4%) and number of capsules/plant (72.7%). The character seed yield revealed high variability, heritability and genetic advance as per cent of mean.

Key words: Castor, Genetic advance, Heritability, Variability

Castor (*Ricinus communis* L.) with 2n=20, an important industrial non-edible oil seed crop belongs to the family *Euphorbiaceae*, indigenous to Eastern Africa. It is grown in arid and semi-arid regions. Castor seed oil and its by-products have wide genetic variability is the most important feature of any population and variability present in the population is the prerequisite in response to selection for any crop improvement programme. Selection of superior varieties or populations will be possible only when adequate variability exists in the gene pool. Hence, the insight into the magnitude of variability present in a gene pool of a crop species is of utmost importance to plant breeder for initiating a judicious plant breeding programme. The coefficient of variation expressed in phenotypic and genotypic levels are used to compare the variability observed among different characters. Hence, knowledge about the variability using parameters like genotypic coefficient of variation (*gcv*) and phenotypic coefficient of variation (*pcv*) is of paramount importance for an efficient breeding programme in crops like castor. It is not possible to identify a genotype with higher performance for all the characters implied that it is advisable to improve the individual trait in the order of economic importance and requirement. The heritability estimates aid in determining the relative amount of heritable portion in variation and thus helps the plant breeder in selecting the elite genotypes from a diverse population. Therefore, the present study was undertaken for assessing the extent of genetic variability, heritability and genetic advance in castor germplasm lines.

The present study was conducted during the rainy season of 2007 at the Directorate of Oilseeds Research (DOR), Rajendranagar, Hyderabad. The experimental site is located at an altitude of 542 m MSL, 17°15'16" N latitude and 78°18' 30" E longitude. The experimental material for the present study, comprised of six male lines, 14 advanced lines, 38 germplasm accessions, two pistillate lines, two released varieties, two checks available at Hyderabad. Each genotype was sown in two rows of 4.5 m length with a spacing of 90 cm x 45 cm and recommended package of practices were adopted to grow a healthy crop. Five plants in each plot and in each replication were selected at random and single plant observation was recorded for plant height upto primary raceme (cm), number of nodes upto primary raceme, total length of main spike (cm), effective length of main spike (cm), effective number of spikes/plant, number of capsules on main spike. 100 seed weight (g), seed yield (g/plant) at 120, 150 and 180 days after sowing and oil content (%). The phenotypic and genotypic coefficient of variation, heritability and genetic advance as per cent of mean were calculated following standard methods. The data were subjected to analysis of variance for the character estimated on the basis of mean values (Panse and Sukhatme, 1985). The estimates

[1] E-mail: rameshmalothu1@gmail.com

of PCV and GCV were classified as given by Sivasubramanian and Madhavamenon (1973). The phenotypic and genotypic co-efficient of variability were calculated as Burton and De Vane (1953). Heritability estimates in broad sense for yield components of castor genotypes was estimated and the heritability estimates were categorized as suggested by Robinson *et al.* (1949), while genetic advance was worked out as per Johnson *et al.* (1955).

The analysis of variance indicated high and significant variation for all characters under study (Table 1). The range of variation was maximum for seed yield at 180 days after planting (6.0-205g) followed by plant height up to primary raceme (25-130cm) and number of capsules/plant (10.0-76.0cm) (Table 2). The higher mean was associated with high range, indicating the scope of improvement through simple selection procedure. The PCV was greater than GCV for all the characters studied showing the environmental effect for all the characters (Table 2). It is evident that using coefficients of variation as a measure, the magnitude of PCV and GCV were highest for seed yield 150 days after planting, followed by 120 days after planting, effective spike length, number of nodes upto primary raceme (Table 2). While, medium GCV and PCV was revealed for total spike length, 100 seed weight and number of nodes up to primary raceme. Similar findings was reported by Ayalneh *et al.* (2012). Low variability was observed for oil content and number of nodes up to primary raceme.

Table 1 Analysis of variance for seed yield and yield attributes of castor

Character	Mean sum of squares		
	Replications	Treatment	Error
No. of nodes up to primary raceme	0.51	16.49**	0.83
Plant height up to primary raceme	464.74	1419.32**	49.63
Total spike length (cm)	36.01	215.24**	23.01
Effective spike length (cm)	155.76	339.46**	12.51
No. of capsules/plant	206.04	350.98**	26.39
No. of effective spikes/plant	17.40	18.90**	3.78
100 seed weight	2.42	83.61**	1.58
Seed yield (g)/plant			
120 days after sowing	1170.19	441.01**	15.67
150 days after sowing	1557.93	877.54**	12.67
180 days after sowing	2548.80	2189.98**	29.19
Oil content (%)	4.33	62.20**	1.27

Table 2 Magnitude of variability, heritability and genetic advance for seed yield and yield attributes of castor

Character	Minimum	Maximum	Coefficient of variation		Heritability in broad sense (%)	GA as per cent mean
			GCV (%)	PCV (%)		
No. of nodes up to primary raceme	6	21	21.23	20.18	90.4	39.5
Plant height up to primary raceme (cm)	25	130	36.02	34.8	93.2	69.1
Total spike length	13	62	27.6	24.8	80.7	45.9
Effective spike length	9	61	46.7	45.1	92.9	89.4
No. of capsules/plant	10	76	41.1	38.1	86.0	72.7
No. of effective spikes/plant	5.2	15.4	36.2	29.5	66.6	49.7
100 seed weight (g)	12.9	62.2	22.9	22.5	96.3	45.5
Seed yield g/plant						
120 days after sowing	7	69	50.2	48.5	93.4	96.6
150 days after sowing	3	145	50.2	49.5	97.2	100.4
180 days after sowing	6	205	43.1	42.5	97.4	86.4
Oil content (%)	30.4	53.7	12.9	12.6	96.0	25.5

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

However, high variance values alone are not the determining factors of the expected progress that could be made quantitative traits (Falconer, 1981). It was suggested that the GCV together with the high heritability (h^2) estimates would give a better picture of the extent of genetic gain to be expected under selection. In the present investigation, all the characters expressed high heritability estimates ranging from 66.6 to 97.4%. High heritability (broad sense) estimated were observed for all the traits indicated that the dependence of phenotypic expression reflect the genotypic ability to transmit the genes to their off spring. These results are in accordance with the results of Solanki and Gupta Deepak (2000). High genetic advance as per cent of mean was highest for seed yield at 150 and 120 days after planting followed by effective spike length and number of capsules/plant. While, the number of nodes up to primary raceme, total spike length, number of effective spikes/plant and 100 seed weight characters recorded medium genetic advance as per cent of mean. Only oil content (25.5%) observed low genetic advance as per cent of mean.

High heritability with high genetic advance as per cent of mean was observed for seed yield at 180, 150 and 120 days after planting followed by effective spike length and number of capsules/plant. Similar results also recorded by Kaushik *et al.* (2007) and Patel *et al.* (2010). It was observed that seed yield recorded high heritability coupled with high genetic advance as per cent of mean indicating the improvement of seed yield can be achieved by adopting simple selection procedures with which additive genes can be pyramided and will be gaining in the selection process. The expression of traits is unstable. Hence, breeder should not rely on the estimates of heritability.

REFERENCES

Ayalneh T, Habtamu Z and Amsalu A 2012. Genetic Variability, Heritability and Genetic Advance in Tef (Eragrostis tef (Zucc.) Trotter) lines at Sinana and Adaba. *International Journal of Plant Breeding and Genetics*, **6**(1): 40-46.

Burton G W and De Vane E W 1953. Estimating heritability in tall fescue (*Fescuta arudinaceae*) from replicated clonal material. *Agronomy Journal*, **45**: 478-481.

Falconer D S 1981. *Introduction to Quantitative Genetics*. 2nd Edn. ELBS. Longman. Pp. 14-169.

Johnson H W, Robinson H F and Comstock R E 1955. Estimates of genetic and environmental variability in soybeans. *Agronomy Journal*, **47**: 314-318.

Kaushik N, Kumar Krishnan, Kumar S and Roy S 2007. Genetic variability and divergence studies in seed traits and oil content of jatropha (*Jatropha carcus* L.) accessions. *Biomass and Bioenergy*, **31**(7):497-502.

Panse V G and Sukhatme P V 1985. *Statistical methods for Agricultural Workers*. Indian Council of Agricultural Research Publications, New Delhi pp. 87-89.

Patel J R, Saiyed, M P Patel C G, Bhatt R K and Bhatt J P 2010. Genetic variability and correlation studies in castor (*Ricinus communis* L.). *International Journal of Agricultural Sciences*, **6** (1): 129-131.

Robinson H F, Comstock R E and Harvey P H 1949. Estimation of heritability and degree of dominance in corn. *Agronomy Journal*, **41**: 353-359.

Sivasubramanian S and Madhavamenon P 1973. Genotypic and phenotypic variability in rice. *Madras Agricultural Journal*, **60**: 1093-1096.

Solanki Z J and Gupta Deepak 2000. Correlation and path analysis for oil yield in sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **17**: 51-53.

Productivity of soybean (*Glycine max*) in relation to cultivars and graded levels of nutrients

S G JADHAV, N K KALEGORE, D A CHAVAN, F G SHAIKH AND P R DADGALE

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

(Received: October, 2011; Revised: March, 2012; Accepted: April, 2012)

ABSTRACT

A field experiment was conducted at Agricultural College farm, Latur during the rainy season of 2008. Five soybean (*Glycine max* L.) Cultivars *viz.*, JS-335, MAUS-81, MAUS-71, JS-93-5 and MAUS-47 in main plots and three NPK fertilizer levels *viz.*, 15:30:15, 30:60:30 and 45:90:45/ha in sub-plots were tested using a split plot design. Soybean cultivar, MAUS-71 and NPK fertilizer level of 30:60:30 gave higher seed yield of 2210 kg/ha and 2065 kg/ha, respectively.

Key words: Nutrients, Soybean cultivars, Yield attributes

In Maharashtra, soybean crop was grown on an area of 30.63 lakh ha in 2008-09 with an annual production of 27.57 lakh metric t. and productivity of 900 kg/ha. Soybean is the crop of warm tropical zone thriving best in a wide range of pH and soil types. There must be good conditions for obtaining higher yield which can be achieved through balanced nutrition comprising nitrogen (N) and adequate supply of phosphorus (P) and potassium (K). Phosphorus plays an important role in growth, development and maturity. It helps in flowering and fruiting. Out of total uptake of P by soybean plant, 60% P moves into grain. Therefore, application of P is a must. Intensive cropping coupled with increased use of N and P fertilizer, lower use of organic manures and very low rates of application or practically no application of K is limiting soil productivity. Because of which low seed production and inferior quality of oil and protein content in of oilseed crops is observed. Keeping these in view, the present investigation was undertaken to evaluate the soybean cultivars response to graded doses of NPK fertilizers.

The field experiment was carried out at the Agriculture College farm, Latur during rainy season of 2008. The soil of the experimental field was clayey in texture, medium in available N (205 kg/ha), medium in available P (15.7 kg/ha), high in available K (479 kg/ha). The soil was slightly alkaline in reaction (8.05). The experiment was laid out in a split-plot design with three replications. The treatments consisted of five cultivars *viz.*, V_1-JS-335; V_2-MAUS-81; V_3-MAUS-71; V_4-JS-93-5; V_5-MAUS-47 in main plot and three graded levels of fertilizer *viz.*, F_1-15:30:15; F_2-30:60:30 and F_3-45:90:45 kg NPK/ha, respectively was tested in sub-plot. The precipitation received during the crop growth season was 398.9 mm distributed over 22 rainy days. Sowing of soybean was done on 26th July, 2008 by dibbling with 2 seeds/hill at a distance of 45 cm x 5 cm at 2.5 cm depth. The entire dose of NPK was drilled at sowing uniformly in the plots as per treatments.

The variety MAUS-71 recorded significantly higher plant height than rest of the soybean varieties which could be attributed to genetic makeup of variety. The plant height of individual genotype was directly proportional to the duration of the variety and fertilizer application. Similar results were observed by Khelkar *et al.* (1994). The leaf area/plant and number of root nodules/plant was significantly higher in variety MAUS-71 which was comparable with MAUS-81. Total drymatter accumulation was maximum in MAUS-71, due to larger leaf area and more plant height. Larger leaf area resulted in more photosynthetic activity and greater accumulation of carbohydrates and thereby increased drymatter production. Similar results were reported by Prasad *et al.* (1993).

Plant height increased linearly with increase in dose of fertilizer from 15:30:15 kg NPK/ha through 45:90:45 kg NPK/ha. The maximum plant height was recorded with 45:90:45 kg NPK/ha which was at par with 30:60:30 kg NPK/ha. Application of 30:60:30 kg NPK/ha resulted in maximum leaf area, number of root nodules/plant and drymatter accumulation/plant while in respect of leaf area all the levels of fertilizer were comparable with each other. Similar results were reported by Patel and Chandravanshi (1996).

Various cultivars differed significantly in seed yield. Maximum pod yield and grain yield/plant was obtained with variety MAUS-71, which was significantly superior to rest of the varieties but was at par with MAUS-81. Similarly, maximum test weight of seed was noticed in MAUS-71 variety. Seed yield of variety MAUS-71 was significantly superior to the rest of the varieties, but was at par with MAUS-81. The difference in the seed yield was mainly due to genetic character of the variety. However, the seed yield and pod yield/plant was affected mainly at maturity period due to genotypes and different fertilizer grades. Warad *et al.* (1992) and Durga Singh and Gopalswami (1991) found significant differences in test weight of different varieties.

Various fertilizer levels significantly affected yield attributes of soybean wherein maximum pod yield/plant, grain yield/plant, test weight and seed yield (kg/ha) were recorded with 30:60:30 kg NPK/ha. Better expression of yield attributes like plant height, number of functional leaves, leaf area, drymatter accumulation and number of pods/plant contributed to enhanced yield. The results are in line with Patel and Chandrawanshi (1996).

Table 1 Growth parameters of soybean in relation to different cultivars and fertilizers

Treatment	Plant height (cm)	Leaf area (cm^2)	No. of root nodules/ plant	Drymatter (g/plant)	Pod yield/plant (g)	Grain yield/plant (g)	Test weight (g)	Seed yield (kg/ha)	Oil yield (kg/ha)	Protein yield (kg/ha)
Cultivar										
JS-335	49.7	92.5	13.3	27.7	18.6	14.1	129.7	1992	427	787
MAUS-81	50.8	99.3	14.4	29.1	19.5	14.7	129.8	2130	461	828
MAUS-71	51.4	101.5	15.1	31.5	20.0	15.2	131.7	2210	466	883
JS-93-5	49.8	88.5	12.7	26.9	17.7	13.8	129.2	1812	385	753
MAUS-47	31.7	85.5	11.5	24.5	11.7	10.7	127.4	1540	310	618
SEm+	0.2	1.1	0.4	0.4	0.5	0.3	1.8	47	9.0	17
CD (P=0.05)	0.6	4.0	1.3	1.7	1.4	0.8	NS	139	28.0	53
Fertilizer (kg NPK/ha)										
15:30:15	50.1	75.9	12.1	26.0	16.6	12.8	129.7	1845	385	725
30:60:30	51.2	79.8	14.4	28.9	18.5	14.2	132.2	2065	436	834
45:90:45	52.2	77.6	13.2	27.3	17.3	13.7	131.1	1928	411	766
SEm±	0.6	1.6	0.5	0.6	0.4	0.4	0.9	47	6.0	11.3
CD (P=0.05)	1.9	4.9	1.6	1.6	1.1	1.1	2.8	139	20.0	33.9

REFERENCES

Durga Singh R and Gopalswami N 1991. Effect of plant geometry and level of nitrogen and phosphorus on productivity of soybean. *Indian Journal of Agronomy*, **36**(4) : 545-548.

Khelkar P M, Jadhav S L, Shinde V U and Malvi S D 1991. Response of soybean varieties to plant densities and fertilization. *Indian Journal of Agronomy*, **36**(3) : 414-415.

Patel S R and Chandrawanshi B R 1996. Nitrogen and phosphorus nutrition of soybean grown on Vertisol. *Indian Journal of Agronomy*, **41**(4) : 601-603.

Prasad J V, Ramaiah N V and Satyanarayanan V 1993. Response of soybean to varying levels of plant density and phosphorus. *Indian Journal of Agronomy*, **38**(3) : 494-495.

Warad L K, Solanke B U, Patil H N and Khot M A 1994. Effect of nitrogen on yield and protein content of soybean. *Journal of Soils and Crops*, **2**(1) : 26-28.

Studies on inter/mixed cropping systems of mustard [*Brassica juncea* (L.) Czern & Coss] + lucerne (*Madicago sativa*) under agro-climatic conditions of Northern Gujarat

JITENDRA SINGH, B S PATEL, G N PATEL AND SHAUKAT ALI

Dept. of Agronomy, C.P. College of Agriculture, Dantiwada Agricultural University, Sardarkrushinagar-385 506, Gujarat

(Received: June, 2011; Revised: January, 2012; Accepted: February, 2012)

ABSTRACT

An experiment was conducted during 2009-10 at Agronomy Instructional Farm, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar to study inter/mix cropping systems of mustard [*Brassica juncea* (L.) Czern & Coss] + lucerne (*Madicago sativa*) under northen Gujarat agro-climate conditions. The treatments consisted (10) sole mustard, mustard - pearlmillet, mustard + lucerne mixed seeds at 30 and 45 cm row spacing, Mustard at 30 and 45 cm row spacing + broadcasting of lucerne at 21 DAS (1st irrigation), mustard at 45 cm row spacing + line sowing of lucerne between two rows of mustard, mustard + lucerne mixed seeds at 45 cm row spacing + line sowing of lucerne between two rows of mustard, broadcasting mustard + lucerne mixed seeds and lucerne sole at 22.5 cm row spacing. The results reveled that significantly higher mustard equivalent yield (5,812 kg/ha), net return (₹ 143243/ha), LER (2.1) recorded under mustard + lucerne mixed seeds at 45 cm row spacing + line sowing of lucerne between two rows at the time of first irrigation. However, mustard + lucerne mixed seeds at 30 cm row spacing recorded the highest BCR value (3.95). This treatment also found second best treatment in respect to mustard equivalent yield and net return. The maximum water use efficiency (10.8 kg/ha/mm) was recorded under mustard + lucerne mixed seeds at 45 cm row spacing + line sowing of lucerne between two rows at the time of first irrigation.

Key words: LER, Lucerne, Mustard, Mustard equivalent yield, Pearlmillet, WUE

Mustard (*Brassica juncea* L. Czern & Coss) is an important edible oilseed crop of arid and semi-arid regions of North Gujarat. Mustard in winter followed by pearlmillet in summer is popular cropping system of the region. Summer pearlmillet has higher water (400-500 mm) and fertilizer requirement (120-60-0 NPK kg/ha). There is a need to find out an alternative crop of pearlmillet during summer season which has lesser water and fertilizer requirement. There appears a good scope of inter/mixed cropping of lucerne seed production with mustard which requires less irrigations (200-250 mm). This practice has more advantages over sole crop of mustard due to the maximum utilization of natural resources along with saving of irrigation water and improvement of soil fertility, (Patel *et al.*, 2007). Information on inter/mixed crop of lucerne for seed production with mustard is meager. Hence, this investigation was carried out.

A field experiment was conducted during 2009-10 at C.P. College of Agriculture, Sardarkrushinagar. The soil of the experimental site was loamy sand with low available nitrogen (165 kg/ha), medium in available phosphorus (43 kg/ha), high in available potassium (285 kg/ha) and low in sulphur (9.6 mg/kg). The experiment was laid out in randomized block design with four replications. The net plot size was 5 m x 1.8 m. The experiment comprises of 10 treatments as given in table 1. The mustard variety GM 3 was sown in the last week of October whereas lucerne variety Anand 2 was sown (except mustard + lucerne mixed in line sowing) in the first fortnight of November. The summer pearlmillet variety GHB 558 was sown in second fortnight of February. Seed rate of mustard, lucerne and summer pearlmillet were 3.50, 5.00 and 3.75 kg/ha, respectively. The mustard and pearlmillet were fertilized with 75:50:40 NPS and 120:60 NP kg/ha in the form of diammonium phosphate, urea and gypsum, respectively. The mustard crop was harvested in second fortnight of February, followed by cutting of lucerne. Thereafter, lucerne was left for seed production. The lucerne was fertilized with 20 kg N/ha in the form of urea along with irrigation after cutting. Mustard crop was given 6 irrigations (290 mm) in which one irrigation given for good germination and seedling establishment, remaining five irrigation 50 mm. Whereas, lucerne was irrigated 5 times (250 mm), the summer pearlmillet was supplied irrigation 8 times in which one irrigation given for good germination and seedling establishment, remaining seven irrigation 50 mm (390 mm). The lucerne seed and pearlmillet were harvested in the first fortnight of May. Seed yields of mustard, lucerne and summer pearlmillet and fodder yield of summer pearlmillet were recorded. Mustard equivalent yield was calculated on the basis of market rates. There was no damage of insect and pest in all the crops throughout crop pendency.

Mustard seed yield: The different treatments had significant effect on seed yield (Table 1). Mustard at 30 cm row spacing + broadcasting of lucerne at the time of first irrigation established its superiority by recording the highest seed yield of 2,007 kg/ha over existing practices treatments mustard - summer pearlmillet cropping system and mustard sole at 45 cm having the seed yield of 1840, 1838 kg/ha, respectively. Percent increase in seed yield of mustard under treatments mustard at 30 cm row spacing + broadcasting of lucerne at the time of first irrigation over mustard - summer pearlmillet cropping system and mustard sole at 45 cm row spacing were 8.3 and 8.4%, respectively. These treatments were found to be at par to each other and significantly superior over treatment T_4 and T_9. The seed yield of mustard was not reduced with inter/mixed cropping of lucerne, might be due to complimentary effect of lucerne as inter/mixed crop. Patel *et al.* (2007) reported 9% higher mustard yield under inter/mixed cropping systems of lucerne N fixing behaviour of lucerne crop. Likewise, in inter/mixed cropping systems of mustard and lucerne, mustard has more advantage as it was more exposed to sun because of taller nature. Whereas, lucerne growing under canopy and suffered more in present experiment at vegetative growth period.

Table 1 Effect of different inter/mixed cropping systems on mustard, lucerne and pearlmillet seed and fodder yield, mustard equivalent yield, land equivalent ratio and water productivity

Treatment	Mustard seed yield (kg/ha)	Lucerne/Pearlmillet yield (kg/ha)		Mustard equivalent yield (kg/ha)	Land equivalent ratio	Quantity of water applied (mm)	Water use efficiency kg/ha/mm
		Seed	Fodder				
T_1 : Mustard sole at 45 cm row spacing	1838	-	-	1931	1.0	290	6.7
T_2 : Mustard + lucerne mixed seeds at 30 cm row spacing	1926	521	2548	5607	2.0	540	10.4
T_3 : Mustard + lucerne mixed seeds at 45 cm row spacing	1903	509	2516	5496	1.9	540	10.2
T_4 : Mustard at 45 cm row spacing and line sowing of lucerne between two rows at the time of first irrigation at 21 DAS	1718	378	1872	4407	1.6	540	8.2
T_5 : Mustard at 30 cm row spacing + broadcasting of lucerne at the time of first irrigation	2007	376	1863	4700	1.8	540	8.7
T_6 : Mustard at 45 cm row spacing + broadcasting of lucerne at the time of first irrigation	1974	385	1905	4718	1.8	540	8.7
T_7 : Mustard + lucerne mixed seeds at 45 cm row spacing + line sowing of lucerne between two rows at the time of first irrigation	1954	572	2711	5812	2.1	540	10.8
T_8 : Lucerne sole at 22.5 cm row spacing and seed production after third cutting	-	581	2752	4563	1.0	840	5.4
T_9 : Broadcasting of mustard + lucerne mixed seeds	1572	472	2341	4905	1.7	540	9.1
T_{10} : Mustard - summer pearlmillet cropping system	1840	3674	9478	4810	2.0	680	7.1
SEm±	88	21	-	169	0.1	-	-
CD (P=0.05)	258	63	-	489	0.2	-	-
CV (%)	9.5	9.0	-	7.2	7.4	-	-

Sale price (₹/kg) : Mustard – ₹ 24/kg; Lucerne = ₹ 150/kg

Mustard equivalent yield: Different treatments had significant effect on mustard equivalent yield (Table 1). Significantly higher mustard equivalent yield was recorded in inter/mixed cropping treatment (5812 kg/ha) (mustard + lucerne mixed seeds at 45 cm row spacing + line sowing of lucerne between two rows at the time of first irrigation to mustard), but it remained at par with mustard + lucerne mixed seeds at 30 cm row spacing and mustard + lucerne mixed seeds at 45 cm row spacing. It might be due to additional advantage of lucerne and mustard complementary relationship. Nitrogen fixation by lucerne was the major factors responsible for higher production of mustard equivalent yield. Similar findings are reported by Sinsinwar *et al.* (2004).

Land equivalent ratio (LER): All inter/mixed cropping treatments recorded more than 1.00 LER value as compared to sole crops of mustard and lucerne which ultimately indicated greater biological efficiency of the systems. Significantly higher value of LER was registered in treatment T_7 (mustard + lucerne mixed seeds at 45 cm row spacing + line sowing of lucerne between two rows at the time of first irrigation to mustard) which was at par with treatments T_{10} (mustard-summer pearlmillet cropping system), T_2 (mustard + lucerne mixed seeds at 30 cm row spacing) and T_3 (mustard + lucerne mixed seeds at 45 cm row spacing) with respective values of LER as 2.0, 2.0 and 1.9. The lowest LER of 1.6 was recorded under treatment T_1 (mustard sole at 45 cm row spacing).

Water use efficiency: Mustard-summer pearlmillet (T_{10}) requires higher number of irrigations than mustard + lucerne mixed seeds at 45 cm row spacing + line sowing of lucerne between two rows at the time of first irrigation to mustard (T_7). This treatment gave higher water use efficiency (10.76 kg/ha/mm) compared to sole mustard, mustard-summer pearlmillet and other practices of mustard + lucerne. It might be due to higher equivalent yield recorded under mustard + lucerne mixed seeds at 45 cm row spacing + line sowing of lucerne between two rows at the time of first irrigation than other treatments and need of lesser amount of water as compared to mustard-summer pearlmillet. Similar results are reported by Patel *et al.* (2007).

REFERENCES

Patel G N, Patel M K, Patel R M, Patel K M and Pathak H C 2007. Economics of inter/mixed cropping of lucerne (*Madicago sativa*) in mustard *Brassica juncea* (L.) Czern & Coss in Northern Agro-Climatic zone of Gujarat. *Journal of Oilseeds Research*, **24** (2): 340-342.

Sinsinwar B S, Kumar A, Premi O P and Singh F 2004. Production potential and nitrogen requirement of Indian mustard *Brassica juncea* (L.) Czern & Coss. in different crop sequences under brackish water. *Journal of Oilseeds Research*, **21**(1): 175-177.

Genetics of root characteristics in sunflower (*Helianthus annuus* L.) under contrasting water regimes

A GEETHA[1], A SIVASANKAR, J SURESH, LAKSHMI PRAYAGA, P SAIDAIAH AND G ANURADHA

Department of Plant Physiology, College of Agriculture, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030, Andhra Pradesh

(Received: January, 2012; Revised: February, 2012; Accepted: May, 2012)

ABSTRACT

Root characters are important while breeding for drought tolerance. Therefore, an experiment was carried out during winter season 2008 at College of Agriculture, ANGRAU, Hyderabad to study root characters under two contrasting water regimes in twenty nine genotypes of sunflower (*Helianthus annuus* L.). The results indicated repressing effect of drought on root traits such as root volume and root dry weight, while root length showed higher values under drought. Whereas number of primary root has no impact due to drought but it is purely genotypic character. Based on results GP-812-5 followed by DSF-111 and DK-3849 are promising lines for drought tolerance which maintains higher root length.

Key words: Drought tolerance, Genotypes, Root biomass, Root length, Root volume, Sunflower

The root system of a plant is important when considering drought tolerance breeding (Rauf, 2008). Root characteristics such as root length, root biomass, and root volume would determine the efficiency of water extraction from soil. Sunflower (*Helianthus annuus* L.) genotypes having deep and extensive root system can extract water up to 270 cm depth (Rachidi *et al.*, 1993). Root growth depends upon several factors such as plant genotype, water availability, plant population and soils. Limited research literature is available on the intraspecific variations for the root system in sunflower (O'Toole and Bland, 1987), since determination of root characteristics in the field is very laborious and time consuming. Only few reports are available on characterized variation on sunflower root system (Rauf and Sadaqat, 2007). Angadi and Entz (2002) compared root system characteristics and water extraction patterns of dwarf hybrids with hybrids of standard height. An increase in root length in response to moisture stress along with the decrease in lateral root length as an adoptive measure for drought stress can be generalized from experiments conducted on sunflower (Rauf and Sadaqat, 2007). These studies indicated that higher root growth was linked with better drought tolerance. Hence, an experiment was designed to evaluate sunflower genotypes based on root characters.

The experiment was laid out in a factorial randomised block design with two factors and 29 genotypes replicated thrice during winter season of 2008 at College Farm, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad. The two factors i.e., control and water stress. Control plots were irrigated at 10 days intervals throughout the crop growth period whereas in stress plots irrigation withhold from 40 to 60 DAS i.e., at flower bud initiation stage. Each genotype was sown in two rows at 5 m length with spacing of 60 cm x 30 cm. Two to three seeds were sown/hill to achieve uniform stand. Thinning was done at two weeks after sowing to retain one seedling/hill. Recommended package of practices were followed to grow a healthy crop. The root characters were studied at peak flowering stage i.e., at 60 DAS. The irrigation was given in control and stress plots to make soil surrounding roots system loose and plant was pulled smoothly by digging soil. Care was taken so that no root structure was dismantled and soil adhering root system was washed carefully using a jet stream of water. The root part was separated from stem portion and observations were made on number of primary roots, root length of longest root, root volume and once all the parameter were recorded, roots were also kept for drying. Root length was measured by taking the root measurement from the collar to tip of the root using measuring scale. Similarly, root volume was measured following the water displacement method proposed by Archimedes. Root dry weights were also measured.

Root length was significantly higher in stress treatment (7.3%) compared to control (Table 1). Significant variation was observed among cultivars for root length. Genotype GP-978 followed by DSF-111, M-1029 and GP-812-5 showed higher root length compared to most of the other genotypes in control, whereas in stress GP-812-5 followed by DSF-111 and DK-3849 recorded maximum root length.

[1]E-mail: geethagri 100@yahoo.co.in

However, in combined effect of genotype with control and stress DSF-111 followed by GP-812-5, ASF-104, DK-384, GP-978 and GP_9-515-73 were at par and recorded significant superior root lengths and DSF-104 recorded lowest root length among cultivars. This confirmed the earlier results of Rauf and Sadqat (2007). Deeper root system would allow water extraction from lower soil profiles and thus, it is expected that the plant will perform better under moisture stress. Sunflower genotypes having deep and extensive root system can extract water up to depth of 270 cm (Rachidi *et al.*, 1993).

Increase in root length is an adaptive mechanism for drought tolerant genotypes. Therefore, higher value may be used for the discrimination between drought tolerant and susceptible genotypes. Increase in root length may be due to higher osmotic adjustment ability. Chun *et al.* (2005) also indicated that increase in root length occurred at expense of lateral roots.

Decrease in root biomass had been observed with the increase in soil depth and compaction under moisture stress conditions (Petcu and Petcu, 2006).

Table 1 Mean of root length (cm) and root volume (cm^3) of sunflower genotypes as influenced by moisture stress

Genotype	Root length (cm)				Root volume (cm^3)			
	Control	Stress	Mean	% decrease	Control	Stress	Mean	% decrease
RSF-101	8.00	13.17	10.58	-64.58	81.67	40.00	60.83	51.02
TSF-103	13.00	13.00	13.00	0.00	323.33	163.33	243.33	49.48
ASF-107	7.67	12.30	9.98	-60.43	91.67	31.67	61.67	65.45
DSF-114	12.00	12.00	12.00	0.00	220.00	105.00	162.50	52.27
SH-177	9.67	16.00	12.83	-65.52	130.00	80.00	105.00	38.46
DSF-104	7.00	10.33	8.67	-47.62	80.00	63.33	71.67	20.83
RSF-106	15.00	9.67	12.33	35.56	230.00	138.33	184.17	39.86
DSF-111	18.37	18.73	18.55	-2.00	230.00	141.67	185.83	38.41
RSF-107	11.17	12.00	11.58	-7.46	136.67	90.00	113.33	34.15
ASF-104	17.53	17.33	17.43	1.14	73.33	33.33	53.33	54.55
TSF-106	11.00	8.17	9.58	25.76	140.00	81.67	110.83	41.67
SH-491	14.17	14.17	14.17	0.00	93.33	76.67	85.00	17.86
M-1029	16.33	14.43	15.38	11.63	76.67	36.67	56.67	52.17
GP-812-5	16.27	20.10	18.18	-23.57	75.00	48.33	61.67	35.56
GP-247-4	7.33	14.33	10.83	-95.45	23.33	22.00	22.67	5.71
GP_4-2605	12.30	13.27	12.78	-7.86	26.67	16.67	21.67	37.50
GP-69	10.47	10.13	10.30	3.18	20.00	10.00	15.00	50.00
GP_4-2935	15.17	9.60	12.38	36.70	81.67	38.33	60.00	53.06
GP-978	18.90	14.47	16.68	23.46	56.67	33.33	45.00	41.18
DK-3849	15.57	18.10	16.83	-16.27	228.33	135.00	181.67	40.88
GP_9-515-7-3	14.97	17.03	16.00	-13.81	168.33	100.00	134.17	40.59
GP_4-2885	11.87	11.67	11.77	1.69	30.00	25.00	27.50	16.67
RHA-274	7.87	10.13	9.00	-28.81	46.67	13.33	30.00	71.43
GP_4-187	7.67	13.20	10.43	-72.17	46.67	16.67	31.67	64.29
GP-2793	11.83	11.67	11.75	1.41	56.67	43.33	50.00	23.53
GP_4-2704	15.40	15.73	15.57	-2.16	71.67	70.00	70.83	2.33
EC-512690	13.60	11.60	12.60	14.71	93.33	53.33	73.33	42.86
GP_6-846-4-4	12.00	15.33	13.67	-27.78	86.67	81.67	84.17	5.77
GP_9-38-C-2-1	11.20	12.23	11.72	-9.23	40.00	39.33	39.67	1.67
Mean	12.53	13.44	12.99	-7.32	105.46	63.03	84.25	40.23
CD (P=0.05) for treatments			0.69				3.90	
CD (P=0.05) for genotypes			2.64				14.80	
CD (P=0.05) for T x G			3.74				21.03	

Table 2 Mean of root dry weight (g) and number of primary roots of sunflower genotypes as influenced by moisture stress

Genotype	Root dry weight (g)				Number of primary roots			
	Control	Stress	Mean	% decrease	Control	Stress	Mean	% decrease
RSF-101	31.50	16.33	23.92	48.15	21.33	19.50	20.42	8.59
TSF-103	185.00	109.67	147.33	40.72	24.67	23.33	24.00	5.41
ASF-107	55.33	17.33	36.33	68.67	19.33	21.67	20.50	-12.07
DSF-114	125.00	51.33	88.17	58.93	20.00	17.43	18.72	12.83
SH-177	31.07	25.33	28.20	18.45	25.43	23.57	24.50	7.34
DSF-104	33.17	23.55	28.36	28.98	10.10	11.53	10.82	-14.19
RSF-106	183.67	98.33	141.00	46.46	24.87	17.07	20.97	31.37
DSF-111	144.33	75.67	110.00	47.58	23.90	21.90	22.90	8.37
RSF-107	150.00	80.87	115.43	46.09	22.57	20.23	21.40	10.34
ASF-104	31.00	18.67	24.83	39.78	15.90	21.23	18.57	-33.54
TSF-106	52.67	28.00	40.33	46.84	10.13	15.33	12.73	-51.32
SH-491	41.33	33.67	37.50	18.55	19.33	19.67	19.50	-1.72
M-1029	55.67	27.00	41.33	51.50	20.00	23.67	21.83	-18.33
GP-812-5	38.37	34.07	36.22	11.22	11.33	16.00	13.67	-41.18
GP-247-4	11.00	7.93	9.47	27.88	16.67	14.00	15.33	16.00
GP_4-2605	16.00	13.00	14.50	18.75	18.67	20.67	19.67	-10.71
GP-69	16.33	8.00	12.17	51.02	15.00	15.33	15.17	-2.22
GP_4-2935	46.67	29.33	38.00	37.14	21.67	25.00	23.33	-15.38
GP-978	24.73	14.00	19.37	43.40	13.67	13.33	13.50	2.44
DK-3849	126.67	66.43	96.55	47.55	20.00	18.67	19.33	6.67
GP_9-515-7-3	79.00	41.67	60.33	47.26	23.00	25.90	24.45	-12.61
GP_4-2885	20.00	13.33	16.67	33.33	16.23	21.00	18.62	-29.36
RHA-274	33.80	20.33	27.07	39.84	22.00	13.67	17.83	37.88
GP_4-187	34.33	20.33	27.33	40.78	17.00	10.00	13.50	41.18
GP-2793	21.10	19.13	20.12	9.32	20.00	22.67	21.33	-13.33
GP_4-2704	46.10	40.67	43.38	11.79	12.00	16.00	14.00	-33.33
EC-512690	80.18	20.67	50.42	74.22	19.00	16.00	17.50	15.79
GP_9-846-4-4	34.33	25.67	30.00	25.24	16.33	17.67	17.00	-8.16
GP_9-38-C-2-1	29.67	25.00	27.33	15.73	24.67	23.33	24.00	5.41
Mean	61.31	34.67	47.99	43.46	18.79	18.87	18.83	-0.44
CD (P=0.05) for treatments			1.85				NS	
CD (P=0.05) for genotypes			7.03				1.20	
CD (P=0.05) for T x G			9.95				1.70	

Root dry weight was reduced (43%) by stress in comparison with control (Table 2). Among genotypes, there was significant difference in root dry weight. TSF-103 followed by RSF-106 under control and only one genotype TSF-103 under stress exhibited significantly superior root dry weights over rest of the genotypes. In genotype x treatments effect, TSF-103 recorded significantly superior root dry weight among all the genotypes. Minimum root dry weight of was recorded by GP-247-4. The results are in accordance with results of Petcu and Petcu (2006), Rauf and Sadqat (2007). The decrease in root weight may due to depressing effect of drought on lateral roots, which have decreased overall root weight.

Root volume decreased significantly in stress compared to control by 40.2% (Table 1). TSF-103 recorded highest root volume, while GP-69 recorded lowest root volume under control, stress and interactions. The present investigation supports the findings of El Midaoui *et al.* (2003). El Midaoui *et al.* (2003) suggests a close relationship exist between root volume and root dry weight. Reduction of root volume under water stress originates not only from growth inhibition but also from a loss of turgidity as reported in wheat (Ali Dib and Monneveux, 1992).

Number of primary roots shows no significant difference between control and stress (Table 2). But among genotypes significant differences were found in number of primary roots. SH-177, RSF-106, TSF-103 and GP_9-38-C-2-1 under control and GP_9-515-7-3 and GP4-2935 under stress were at par, respectively and exhibited higher number of primary roots over other genotypes. Whereas in interaction, SH-177, GP_9-515-7-3, TSF-103, GP_9-38-C-2-1 and GP4-2935 were on par in number of primary roots and superior over other genotypes. Genotype DSF-104 exhibited lowest number of primary roots. Primary roots may not play any significant role in drought tolerance as the data was non-significant. However, this trait may be specific for particular genotype. Root characters are considered as important traits for studying drought tolerance physiology since genotypes capable of maintaining higher water levels in their tissue by producing deeper and extensive root system and thrives well under low water stress. Based on results GP-812-5 followed by DSF-111 and DK-3849 are promising lines for drought tolerance which maintains higher root length. The genotype TSF-103 maintains higher root dry weight and volume under stress condition. These lines can be used as potential parental lines in drought tolerance breeding programme.

REFERENCES

Ali Dib T and Monneveux P 1992. Adaptation á la sécheresse et notion d'idéotype chez le blé dur. I. Caractères morphologiques d'enracinement. *Agronomy Journal*, **12**: 371-379.

Angadi S V and Entz M H 2002. Root system and water use patterns of different height sunflower cultivars. *Agronomy Journal*, **94**:136-145.

Chun L, Guoho M I, Jiansheng P and Fusuo Z 2005. Genetic analysis of maize root characteristics in response to low nitrogen stress. *Plant and Soil*, **276**:369-382.

El Midaoui M, Serieys H, Griveau Y and Benbella M 2003. Effects of osmotic and water stresses on root and shoot morphology and seed yield in sunflower (*Helianthus annuus* L.) genotypes bred for morocco or issued from introgression with *H. argophyllus* T. and G. and *H. debilis* nutt. *Helia*, **26**(38): 1-16.

O'Toole J C and Bland W L 1987. Genotypic variation in crop plant root systems. *Advances in Agronomy*, **41**: 91-145.

Petcu G H and Petcu E 2006. Effect of cultural practices and fertilizers on sunflower yields in long term experiments. *Helia*, **29**(44):135-144.

Rachidi F, Kirkham M B, Stone L R and Kanemasu E T 1993. Soil water depletion by sunflower and sorghum under rainfed conditions. *Agricultural Water Management*, **24** (1): 49-62.

Rauf S 2008. Breeding sunflower (*Helianthus annuus* L.) for drought tolerance. *Communications Biometry. Crop Science*, **3** (1): 29-44.

Rauf S and Sadaqat H A 2007. Effects of varied water regimes on root length, drymatter partitioning and endogenous plant growth regulators in sunflower (*Helianthus annuus* L.). *Journal of Plant Interactions*, **2**:41-51.

Efficacy of botanicals in the management of mustard aphid, *Lipaphis erysimi* Kalt. and their impact on beneficial insects

S P SINGH[1], Y P SINGH, RAM SINGH AND RAJENDRA NAGAR

Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur-321 303, Rajasthan

(Received: July, 2011; Revised: March, 2012; Accepted: May, 2012)

ABSTRACT

Field experiments to evaluate the botanicals were conducted at Directorate of Rapeseed-Mustard Research farm during 2008-09 and 2009-10. Treatments were green chilly extract 5%, red chilly extract 5%, neem seed kernel extract (NSKE) 5%, neem oil 1%, neem oil 2%, azadirachtin 1500 mg/kg (0.1%), karanj oil 1%, detergent 0.1%, water spray and control both the years. Significantly low population of mustard aphid was observed under all the treatments in comparison with control during 2008-09 and 2009-10. Alone water spray did not play any significant role in controlling the mustard aphid. No phytotoxic symptoms were observed on the crop in any treatment. Significantly higher yield was recorded in all the treatments except in detergent 0.1% and water spray in comparison to control. Most favourable incremental cost-benefit ratio was obtained under the treatments i.e., azadirachtin 1500 mg/kg (0.1%) followed by green chilly extract 5% and NSKE 5%. All the treatments were also found safer to the natural enemies of mustard aphid and pollinators (honeybees).

Key words: Botanicals, Incremental cost-benefit ratio, Mustard aphid, *Lipaphis erysimi*, Natural enemies, Pollinators

Mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Homoptera: Aphididae) is the key pest of rapeseed-mustard crop in India responsible to cause yield losses ranging from 11.6 to 99% (Mishra and Agrawal, 1992) and oil reduction up to15% (Verma and Singh, 1987) and also responsible to transmit single-stranded RNA luteoviruses disease in the crop (Banerjee *et al.*, 2004). In the past, a number of chemical insecticides have been evaluated by many workers against this dreaded pest and some of them were reported effective (Singh *et al.*, 2007 and Singh and Singh, 2009). These chemical insecticides have been found more or less toxic to a number of parasitoids and predators i.e., *Diaeretialla rapae, Chrysoperla carnea,* coccinellids and *Syrphid* spp. and also to pollinators (Singh *et al.*, 2007).

Environmental pollution, hazards to human beings, development of resistance in insect-pests, increase in cost of production and build up of insecticide residue in oil and cake beyond the permissible limit are the other issues associated in the use of chemical pesticides. It was thought imperative to evaluate some eco and user friendly botanicals against mustard aphid to safeguard the crop as well as natural enemies and pollinators.

Field experiments were conducted in a simple randomized block design having three replications with mustard cultivar Pusa Jai Kisan (Bio-902) in the plot size of 4.2 m x 3m with row to row and plant to plant distances 30cm and 10cm, respectively. There were 10 treatments including water spray and control (Table 1). Teepol @ 0.1% was used as adjuvant in all the botanical treatments. Recommended agronomic practices were followed to grow the crop. Ten plants per plot were randomly selected and tagged for the observations on aphid at one day before and 3, 7 and 10 days after application of treatments. Adult and larvae of coccinellids, maggot of *Syrphid* spp, and honeybees population was recorded on these tagged plants to observe the toxic effect of botanicals. Phytotoxicity if any was observed on the basis of symptoms on leaf tips and leaf surface, wilting, vein clearing, necrosis, epinasty and hyponasty. The seed yield/net plot was converted to kg/ha. Incremental cost benefit ratio was calculated on the basis of market price of botanicals, cost of labour used and market price of mustard seed and analysed statistically.

Significantly low number of mustard aphid/plant at 3, 7 and 10 days after the spray was observed under all the treatments over the control during the year 2008-09. Water spray did not provide significant reduction in mustard aphid population over the control. The yield was significantly higher (2160-2540 kg/ha) under all the treatments except detergent 0.1% (1930 kg/ha) over the control (1630 kg/ha). No significant difference in seed yield was observed between water spray (1650 kg/ha) and control (1630 kg/ha) (Table 1). Similarly during 2009-10, significantly low number of mustard aphid was also observed under all the treatments over the control treatment at 3, 7 and 10 days after the spray. Significantly higher yield was recorded in the treatments i.e., karanj oil 1% (2240 kg/ha), azadirachtin 1500 mg/kg (0.1%)

[1]E-mail: drspsingh64@gmail.com

(2220 kg/ha), neem oil 2% (2210 kg/ha), NSKE 5% (2140 kg/ha), neem oil 1% (2090 kg/ha), green chilly extract 5% (2060 kg/ha) over the control (1630 kg/ha). Significant difference in seed yield was not observed among red chilly extract 5% (1820 kg/ha), detergent 0.1% (1790 kg/ha), water spray (1510 kg/ha) and control (1490 kg/ha) (Table 1). Phytotoxicity symptoms were not observed under any treatment. Singh and Lal (2009) found that neem formulations such as NSKE 5%, neem leaf extract 5% and neem oil 2% were effective in reducing the mustard aphid population.

Table 1 Efficacy of botanicals against mustard aphid during 2008-09 and 2009-10

Treatment	2008-09					2009-10					Incremental cost-benefit ratio
	No. of aphid on 10cm top twig/plant				Yield (kg/ha)	No. of aphid on 10cm top twig/plant				Yield (kg/ha)	
	Pre-treatment	3 DAS	7 DAS	10 DAS		Pre-treatment	3 DAS	7 DAS	10 DAS		
Green chilly extract 5%	95.3	16.2	14.4	12.0	2370	78.3	42.3	28.4	22.3	2060	1:17.3
Red chilly extract 5%	107.2	22.4	18.4	15.2	2160	72.7	48.3	32.4	26.5	1820	1:13.7
Neem seed kernel extract %	90.6	14.2	12.1	11.2	2480	68.4	40.2	28.1	17.6	2140	1:14.6
Neem oil 1%	101.5	17.8	14.2	11.8	2370	76.5	43.2	28.5	20.3	2090	1:7.6
Neem oil 2%	106.6	12.2	10.3	9.0	2540	72.9	38.8	26.2	14.8	2210	1:5.2
Azadirachtin 1500 mg/kg (0.1%)	92.3	14.8	12.3	9.5	2430	80.8	30.6	24.6	14.2	2220	1:23.1
Karanj oil 1%	96.7	12.6	11.1	8.7	2530	75.3	36.8	22.3	13.7	2240	1:1.5
Detergent 0.1%	100.5	60.2	51.6	44.0	1930	69.8	40.2	34.6	30.7	1790	1:10.0
Water spray	108.9	137.6	176.3	204.5	1650	72.4	96.3	105.5	160.8	1510	1:1.5
Control	103.8	134.2	180.4	212.2	1630	80.2	107.8	122.2	155.6	1490	-
CD (P=0.05)	-	34.2	33.4	36.2	410	-	12.4	10.6	11.9	420	-

DAS=Days after spray

Table 2 Effect of botanicals on natural enemies of mustard aphid and honeybees

Treatment	Population of natural enemies of mustard aphid (syrphid fly*, coccinelids**) and honeybees*** (number/10 plants)			
	Pre-treatment	3 DAS	7 DAS	10 DAS
Green chilly extract 5%	3.9*	3.5*	3.4*	2.6*
	3.2**	2.4**	2.4**	3.0**
	5.7***	4.6***	5.3***	5.4***
Red chilly extract 5%	4.1*	3.0*	3.5*	3.7*
	3.0**	2.3**	2.1**	2.7**
	5.1***	4.5***	4.8***	5.0***
Neem seed kernel extract 5%	3.5*	3.2*	3.2*	3.3*
	3.0**	2.5**	2.5**	2.8**
	5.2***	4.5***	4.8***	5.3***
Neem oil 1%	3.8*	3.2*	3.5*	3.7*
	3.1**	2.2**	2.5**	3.0**
	5.8***	4.7***	5.2***	5.4***
Neem oil 2%	4.2*	3.4*	3.9*	4.0*
	3.3**	2.2**	2.6*	3.0**
	6.3***	4.8***	5.0***	5.7***
Azadirachtin 1500 mg/kg (0.1%)	4.0*	3.1*	3.4*	3.5*
	2.8**	2.3**	2.2**	2.4**
	5.4***	4.5***	5.0***	5.3***
Karanj oil 1%	3.2*	2.8*	3.1*	3.7*
	3.4**	2.4**	2.8**	3.0**
	5.5***	3.7***	3.5***	4.6***
Detergent 0.1%	4.1*	3.2*	3.7*	4.0*
	4.0**	2.9**	2.6**	3.3**
	6.2***	4.9***	5.4***	5.8***
Water spray	8.3*	4.0*	3.5*	4.3*
	3.0**	3.2**	3.3**	3.6**
	5.9***	6.6***	6.8***	6.1***
Control	3.9*	3.9*	4.8*	4.0*
	3.2**	3.5**	3.3**	3.4**
	6.1***	6.6***	6.6***	6.3***
CD (P= 0.05)	-	1.5*	1.6*	1.5*
	-	1.5**	1.8**	1.7**
	-	2.0***	2.0***	2.2***

DAS=Days after spray

Maximum incremental cost-benefit ratio was obtained under the treatment azadirachtin 1500 mg/kg (0.1%) (1:23.1) followed by green chilly extract 5% (1:17.3), NSKE 5% (1:14.6), red chilly extract 5% (1:13.7), detergent 0.1% (1:10.0), neem oil 1% (1:7.6), neem oil 2% (1:5.2), karanj oil 1% (1:1.5) and water spray (1:1.5) (Table 1). Akhauri and Singh (2009) found that highest return (1:24.6) was obtained in NSKE 5% followed by dimethoate 30EC (22.7), imidacloprid 17.8% SL (19.4), beta-cyhalothrin (18.1), neem oil (15.9), endosulfan (14.4) and diflubenzuron (9.0). Significant reduction in the population of syrphid fly, coccinellids and honeybees was not observed under any treatments (Table 2) indicates that the use of these botanicals is safe to these beneficial insects in mustard crop.

REFERENCES

Akhauri R K and Singh N K 2009. Bio-efficacy of some insecticides and bio-products against mustard, *Lipaphis erysimi* (Kalt.) in yellow sarson. *Journal of Oilseed Research*, **26**: 456-457.

Banerjee S, Hess D, Majumdar P, Roy D and Das S 2004. The interactions of *Allium sativum* leaf agglutinin with a chaperonin group of unique receptor protein isolated from a bacterial endosymbiont of the mustard aphid. *Journal of Biological Chemistry*, **279**(22): 23782-23789.

Mishra S S and Agrawal H O 1992. A review on chemical control of mustard aphid, *Lipaphis erysimi*. *Plant Protection Bulletin*, **44**(1,2): 1-10.

Singh C P and Lal M N 2009. Bio-efficacy of plant extract against mustard aphid, *Lipaphis erysimi* (Kalt.) in *Brassica* oilseed crop. *Crop Research*, **37**(1/3): 203-206.

Singh S P and Singh Y P 2009. Bio-efficacy of pesticides against mustard aphid. *Annals of Plant Protection Sciences*, **17**(1): 240-242.

Singh T R, Singh M P, Singh K I, Devi Th B and Singh N G 2007. Comparative efficacy of certain neem products and conventional insecticides against *Lipaphis erysimi* (Kalt.) and their safety to its natural enemies in rapeseed. *Indian Journal of Entomology*, **69**(3): 269-264.

Verma S N and Singh O P 1987. Estimation of avoidable losses to mustard by aphid, *Lipaphis erysimi* in Madhya Pradesh. *Indian Journal of Plant Protection*, **15**(1): 87-89.

INDIAN SOCIETY OF OILSEEDS RESEARCH

DIRECTORATE OF OILSEEDS RESEARCH

Rajendranagar, Hyderabad-500 030

PROCEEDINGS OF THE 18th GENERAL BODY MEETING OF ISOR

The 18th Annual General Body meeting of the ISOR was held at GKVK Campus, Bengaluru on 29th April, 2012 at 10.00 AM.

The Meeting was chaired by Dr. S.S. Rajan, Former FAO consultant and former Project Coordinator (Oilseeds) and Dr. B.B. Singh, ADG (OP) and Dr. K.S. Varaprasad, Project Director DOR and Organizing Secretary of 8th International Safflower Conference were the Guests of Honour.

Dr. H. Basappa, Principal Scientist and General Secretary, ISOR welcomed the gathering and presented general overview of activities undertaken by Indian Society of Oilseeds Research during the period and thanked the past Executive and Editorial committee of ISOR for bringing out the Journal of Oilseeds Research timely printed and distributed to all the members of ISOR. He has also informed the House, the process has already been initiated to elect a new Executive of ISOR (2012-2013) by the Presiding Officer.

Dr. K.S. Varaprasad, Organizing Secretary of 8th International Safflower Conference elaborated on successful conduct of the 8th ISC which was provided a platform to review and debate the current achievements and constraints in safflower research workers and to refine future prospects and strategies that could address the challenges in improving safflower production and sustenance in the world. He has also informed the house about Follow-up action on the identified areas and formulation of a roadmap for achieving the action points initiated. He profusely thanked DG, DDG (CS) and ADG (OP) ICAR for their constant support and guidance for successfully organizing the Conference.

Dr. B.B. Singh, ADG (OP) lauded the efforts and useful activities being pursued through ISOR.

Dr. S.S. Rajan, Chairman of the meeting emphasized the need for increasing the visibility of ISOR by integrating "Developmental" aspects for promoting Oilseed Research and Development in the country.

As a regular feature of the Society two retiring life members of ISOR were felicitated during the Meeting for their significant contributions in the area of Oilseed Research and Development.

The following agenda items were discussed and following decisions were taken:

- The Audited financial annual report of the Society for the year 2011-12 and detailed statement of Expenditure and Receipts of the 8th International Safflower Conference presented by the General Secretary, ISOR was unanimously adopted by the house.
- The expenditure amount of felicitation to the Retired life members was increased from Rs.600/- to Rs.1,000/- in each case. The house suggested possibility of creating the 'corpus fund' may be explored for the purpose.
- It was suggested to explore the feasibility of publishing more volumes (>2) of Journal of Oilseeds Research per year

The Chairman, Dr. S.S. Rajan in his concluding remarks thanked the members for sustained support to the Society activities and contributing effectively for overall growth and development of the Society. The meeting concluded with a vote of thanks proposed by Dr. G. Suresh, Sr. Scientist, DOR and Treasurer, ISOR.

***

JOURNAL OF OILSEEDS RESEARCH

GUIDELINES TO AUTHORS

The Journal of Oilseeds Research is published half-yearly. The following types of material are considered for publication on meeting the style *and requirements of the journal (details in July, 2010 issue).*

1. **Articles on original research completed,** not exceeding 4000 words (up to 15 typed pages, including references, tables, figures, etc.) should be exclusive for the journal. They should present a connected picture of the investigation and should not be split into parts. Complete information of Ph.D thesis should preferably be given in one article.
2. **Short Communication**, *not more than 1300 words (total 5 typed pages), which deal with (I) research results that are complete but do not* warrant comprehensive treatment, (ii) descriptions of new material or improved techniques or equipment, with supporting data, and (iii) a part of thesis or study. Such notes require no headed sections.
3. **Critical Research Review Articles**, showing lacunae in research and suggesting possible lines of future work. These are mostly invited from *eminent scientists.*
4. The research article or note submitted for publication should have a direct bearing on agricultural production or open up new grounds for productive research. Articles on oilseeds research, economics, demonstrations, social sciences, extension, etc., are also considered. Basic type of articles and notes relating to investigation in a narrow specialized branch of a discipline may not form an appropriate material for this journal, nor do the articles of theoretical nature, or those of local importance, repetitive, based on old data, with no positive significance.
5. Author should note: (a) period (years) of conducting the experiment must be indicated, (b) article should preferably be submitted soon after completion of experiment, (c) articles on genetics and plant breeding and on plant crops should be based on data of minimum two years, (d) contribution involving a former or present student must clarify that it is not based/based on complete M.Sc. Thesis, or complete or a part of the Ph.D thesis, indicating its year of submission and (e) Article Certificate must be signed by all the authors and must contain subscription numbers of authors.
6. **Title** should be short, specific and information. It should be phrased to identify the content of the article and include the nature of the study and the technical approach, essential for key-word indexing and information retrieval.
7. **A Short Title** not exceeding 35 letters should also be provided for running headlines.
8. **By-line** should contain, in addition to the names and initials of the authors, the place (organization) where research was conducted. Change *of address should be given as a footnote, e-mail ID and correspondence address separately.*
9. **Abstract**, written in complete sentences, should not have more than 150 words. It should contain a very brief account of the materials, methods, results, discussion and conclusion, so that the reader need not refer to the article except for details. It should not have reference to literature, illustrations and tables.
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).
19. Articles should be **Typewritten** in MS Word format in Times New Roman font with 12 font size in double line spaced throughout (including byline, abstract, references and tables) on white, durable A-4 size paper with one inch margins on all sides. The hard copy of the Articles should be sent in triplicate after checking typographical errors. **It is mandatary to send soft copy of the article in neatly packed CD and/or by E-mail on: editorisor@gmail.com. Articles not sent by CD or E-mail will take longer time to consider for its publication.**
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.
21. **Proof Correction** - Author(s) should be prepared to make necessary corrections or modifications in their article in accordance with the remarks/suggestions of the referee of the article. The decision of the Referee and/or Indian Society of Oilseeds Research is final in this regard. No arguments or clarifications are entertained in any manner at any stage.
22. While submitting the article(s), please ensure that all the authors are life/annual members of the ISOR.

Printed & Published by General Secretary on behalf of The Indian Society of Oilseeds Research,
Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030, India,
Ph : (040) 24016141/24015345; Fax : (040) 24017969
Web site: http://www.isor.org.in; E-mail: oilseedsociety@gmail.com
Computer Typesetting : **Sasi Graphics**, Rajendranagar, Hyderabad Printed by **M/s Progressive Press Pvt. Ltd**, Hyderabad