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Special Article

Oil palm cultivation in India: past, present and future scenario

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ABSTRACT

Cultivation of oil palm, *Elaeis guineensis* Jacq. by giving irrigation is a unique practice in the world and is being followed only in India. The palms that were brought for ornamental purpose later paved the way to utilize them as source of vegetable oil. The wide gap between demand and supply in vegetable oil production using the nine annual oilseed crops, the population explosion, the increased consumption of vegetable oil due to increased GDP forced to grow the crop under Indian conditions to obtain more yield. The role played by various organizations in the development of oil palm industry is worth mentioning without which it would not have been successful. The role played by AICRP on Palms (ICAR) in raising the demonstration plots to find the feasibility of the crop in different areas of the country, DAC by appointing three committees to identify the potential areas for cultivation, DBT for taking up of large scale demonstrations and initiation of mutation breeding using gamma rays irradiation of seed sprouts, UNDP by sanctioning two mega projects on training and seed production and finally the TMOP taking the overall control of the project and maintain it successfully to achieve the best results are worth mentioning. The Government policies, are however, need to be reviewed at frequent intervals as these are responsible for the setback that were observed in different periods. If these are taken care off, the oil palm industry will be a successful venture in the country.

Keywords: Oil palm, Plantation development, Research priorities, Scope, Status

Vegetable oil is the main source of fat for human consumption. It is critical for the nutritional security of the people. However it is one of the major areas of deficit, both for edible and industrial purposes. India occupies a prominent place in global oilseeds scenario with 12-15% of area, 6-7% of vegetable oil production, and 9-10% of the total edible oil consumption and 13.6% of vegetable oil imports. The country has rich diversity of annual oilseed crops on account of diverse agro-ecological conditions. Nine annual oilseeds, which include seven edible oilseeds, *viz*., groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger and two non-edible crops, *viz*., castor and linseed are grown in the country. Despite having the largest area under oilseeds in the world (26.77 million ha), India currently imports about 56% of total oil requirement at a huge cost which was 3% in 1970-71. Low and unstable yields of most oilseed crops, and uncertainty in returns to investment, which result from the continuing cultivation of oilseeds in rainfed, high risk production environments, are the factors leading to this situation of wide demand-supply gap. Palm oil, which accounted for 80% of the total import basket will continue to be the major vegetable oil consumed. This golden crop is best positioned in all ways, such as pricing, logistics, nutritional values, versatile usage and being user friendly, to take care of the needs of the Indian consumer.

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General importance of oil palm

In the year 1824 the importance of the palm was identified by extracting the oil from its fruits by crude ways. During 1911 the palm was introduced into Malaysia by the then British rulers for commercial cultivation, which later changed the economy of that country in a surprising manner. This was mainly due to the existence of congenial climatic conditions like high rainfall and sunlight, which are the two basic things, required for the palm. Seeing the potentiality of the palm which yields 4-6 tonnes of oil per ha, many countries made an attempt to introduce its cultivation. So far 43 countries in the world are cultivating oil palm.

The introduction of oil palm into India was accidental or for ornamental purpose during 1848 in the National Botanical Gardens, Calcutta. Further introduction of Duras from Nigeria was made by Maharashtra Association for Cultivation of Sciences (MACS), Pune during 1948 to 1954 and planted in forest land, irrigation and canal bunds and in many places. Organized commercial cultivation of oil palm was started during 1972 to 1984 at two locations *viz*., Kerala and the Little Andaman. However during 1986 a shift was made in the development of oil palm in the country. The concept of irrigated oil palm was developed after identification of about 0.79 million ha in 11 states as potential for this crop. Three demonstration units of 1,000 ha. each were laid out during 1990 and subsequently massive Oil Palm Development Project (OPDP) was implemented by the Technology Mission on Oilseeds and Pulses, Ministry of Agriculture, Government of India.

The idea of using oil palm for vegetable oil purpose was first proposed by the State Department of Agriculture, Kerala, accordingly a team was deputed to Nigeria which suggested for introduction of the crop into Kerala which is having similar climatic conditions to that of its native country. Accordingly some seedlings were imported from Nigeria by Government of Kerala and planted in 40 ha area at Thodupuzha near Kottayam in 1960. This was considered as the first attempt of systematic cultivation of oil palm in the country and paved way for the foundation for Indian oil palm industry. These introduced palms are identified as of Dura types and used them as mother palms, later effectively used for large scale multiplication of seed sprouts. In 1968, one more consignment of oil palm plants were introduced into Sullia block of Dakshina Kannada district of Karnataka by the then Asst. Commissioner of Forest Mr. M. Chengappa. This time it was mainly to finalize the most remunerative crop among oil palm and rubber to take up large scale plantation in forest areas. A total of 1119 palms inside the forest and 79 palms at the road side on the way to Bangalore were planted using 9 m spacing. Except in Botanical gardens, Kolkata, all the other palms in the remaining places are still available and are yielding. Even the fruit bunches were harvested from the Sullia plantations and oil was extracted though in crude method by the forest officials till some time. Later on these are abandoned as the rubber was found economically remunerative compared to oil palm. The interesting thing observed in these gardens was even at 46 years age, these palms are yielding without any fertilizer application.

In the Botanical gardens of Kolkata the first generation palms are no more seen as they were dead. The second generation palms which are the off springs of the first generation are however seen yielding. Likewise a few palms are seen in the Kumarkripa guest house in Bangalore which are more than 40 years old whose details of planting is not known. Based on the experience gained from the Thodupuzha plantations, systematic large scale commercial cultivation of oil palm was started in Kerala in 1971. This is the first commercial scale plantation in India that was raised under government sector as joint venture. Both the State Government of Kerala and Union Government jointly developed these gardens under the umbrella of Oil Palm India Limited, Kottayam. The gardens were developed in Kulathpuzha, Bharatipuram and Chithara areas of Kollam district extending in an area of nearly 3705 ha. In similar lines, the Plantation Corporation of Kerala Limited (a Government of Kerala undertaking) has also started growing oil palm in Athirapally near Thrissur in a large scale. The Company has 705 ha of oil palm plantation in its Kalady Group of Estates lying all along the banks of Chalakudy river. Major part of the plantations is installed with drip irrigation system.

The Government of India in the wake of acceptance of the recommendations of National Commission on Agriculture in 1972 sanctioned the establishment of Andaman and Nicobar Islands Forest and Plantation Development Corporation Ltd. at Port Blair. The main objective of forming the Corporation was to develop and manage the inaccessible forests in Little and North Andaman on the principle of sustained annual yield and to undertake cultivation of agricultural and horticultural crops including red oil palm.

The Corporation started oil palm cultivation in an extent of 1593 ha out of the proposed 2400 ha in Little Andaman Islands during 1979-1981 by importing oil palm seed sprouts from different sources like Malaysia, IRHO and PNG. Only in these plantations, the branching of oil palm (with two and three branches) is seen which is unique in the entire world. In all the above mentioned areas oil palm is cultivated as rainfed crop without supplementing any irrigation. To process the fruits produced in these plantations, a fruit processing mill with a capacity of 1.5 tonnes of Fresh Fruit Bunches (FFB) per hour was established in the year 1985. Although it was envisaged to extend the plantation area in 5000 ha to make the project viable, in view of the adverse ecological impact perceived due to monoculture cultivation of red oil palm, Govt of India imposed the ban on further extension in 1985-86. During 1987-88 a few interested farmers in West Godavari district of Andhra Pradesh started oil palm cultivation in large areas under DRDA project. The first planting was done in Sitaramapuram village of Pedavegi mandal by the then Chief Minister of Andhra Pradesh which is the foundation for the modern oil palm industry of India using underground irrigation.

Realizing that commercial production of oil palm would help in achieving self-sufficiency in edible oils, the Department of Biotechnology (DBT) was entrusted with the oil palm cultivation by initiating Oil Palm Demonstration Project (OPDP) during 1988-89 in three states *viz*., Andhra Pradesh, Karnataka and Maharashtra. The objective was to demonstrate the possibility of oil palm cultivation under irrigated conditions. This was launched in East and West Godavari and Krishna districts in Andhra Pradesh, Shimoga district in Karnataka and Sindhudurg in Maharashtra.

While the earlier attempts of oil palm production were made on Government lands in Kerala and Andaman and Nicobar Islands, under this project it was introduced in farmers' lands. The DBT in collaboration with the Regional Departments of Horticulture had chosen the farmers in both Karnataka and Andhra Pradesh, while in Maharashtra, the project was implemented through the Department of Industries by the Development Corporation of Konkan Ltd. (DCKL). The DCKL had taken the land on lease from farmers of Asaldi and nearby villages in Sindhudurg district, Maharashtra and raised the plantations which are in abandoned condition now. In the recent years, these are

leased out to third parties. In one of the blocks that are under lease by M/s Sun Fruits Limited, Pune, *Stevia rebaudiana* (sweet Tulasi) is being cultivated in the inter rows by removing one entire row of oil palms.

Total land covered in all the three states was 3164 ha with 1050 ha in Andhra Pradesh, 1114 ha in Karnataka and 1000 ha in Maharashtra. In this project imported elite seeds called Tenera hybrid seeds and indigenous seeds were planted in the ratio of 80:20 respectively. The seedlings were reared in 10 nurseries for 15-20 months before giving to farmers. The project was unique because, the farmers were provided 100% subsidy and intercrops were allowed to grow here which were not grown anywhere else. This was to ensure source of income for the farmer till the economic viability of the crop was realized. Since the crop was not native to the country and its management practices were totally new, technical expertise from Costa Rica was utilized to evolve new management practices for the cultivation.

Work on tissue culture propagation of oil palm was initiated in the case of elite types imported from abroad, at Bhabha Atomic Research Centre (BARC), Mumbai and the plantlets produced have been supplied to Oil Palm Demonstration Project nursery at Bhadra Reservoir Project, Shimoga District, Karnataka. The seeds that were received from ASD were exposed to gamma rays irradiation to get mutation variability. Though no variation in the FFB increase was observed but physical variation was seen in the male inflorescence which showed lot of abnormality compared to untreated ones.

Role of TMOP: The Technology Mission on Oilseeds and Pulses (TMOP) launched in 1986 was the first comprehensive intervention aiming self-sufficiency in edible oils production through the spread of technology and provision of market support. The Mission met with early success. However, increasing demand for edible oils necessitated the imports in large quantities leading to a substantial drain on foreign exchange. Edible oil imports increased from around 15% of total edible oils consumption in 1995-96 to nearly 53% in 2009-10. The need for addressing this deficit motivated a systematic study of the oilseeds economy in order to formulate appropriate strategies to bridge the demand supply gap.

Committee on identification of potential areas for oil palm cultivation

The first committee to study the feasibility for oil palm cultivation in the country was appointed by DAC during 1986 under the chairmanship of Dr. K. L. Chadha, the then Horticulture Commissioner, Government of India. The committee has surveyed the coastal areas of India to identify the potential areas for the cultivation of the palm by sufficing the irrigation needs with artificial manner i.e., by exploring the underground water. It has identified an area of 0.79 m ha. comprising in the 11 states being potential for its cultivation. It also visited various oil palm growing countries like Costa Rica, Papua New Guinea, Nigeria and Malaysia to negotiate the supply of seed sprouts. Accordingly Govt. of India accepted the report and initiated the work plan with the help of Technology Mission on Oilseeds and Pulses (TMOP). To know the performance of the crop, DBT, Ministry of Science, Govt. of India raised the crop as demonstration plots in the potential districts of Andhra Pradesh, Karnataka and Maharashtra with farmers' participation. After seeing the successful growth of the palms in the demonstration plots, TMOP under Ministry of Agriculture has started a project namely Oil Palm Development Programme (OPDP) in a big way by offering subsidy to the farmers on seedlings as well as cultivation practices for the juvenile period of first three years. An area of 80,000 ha was estimated to bring under oil palm cultivation by the end of eighth five-year plan. However, nearly 40,000 ha area was only brought under this palm in India by the end of that plan. This indicated that 50% success was only achieved in convincing the farmers though most of the areas were located in Andhra Pradesh followed by Karnataka. Although efforts were made to introduce this crop in a large acreage in Tamil Nadu not much response was obtained from the farmers, which may be due to many reasons.

In the year 2006, i.e., exactly after 20 years of first committee, Govt. of India appointed Dr. K.L. Chadha to review the progress and further identify the potential areas for oil palm cultivation which recommended an area of 1.036 m ha as suitable for oil palm cultivation. whereas in 2012, one more committee under the chairmanship of Dr. P. Rethinam identified nearly 2.0 m ha of area as suitable for oil palm cultivation in the country.

Establishment of processing facilities

Establishment of processing mills under the aegis of public sector undertaking of State Government of Andhra Pradesh at Pedavegi and also subsidy on the establishment of processing mills by private entrepreneurs in all the potential states was done under the supervision of TMOP. The first mill was constructed at Pedavegi, West Godavari district during 1993. This is the basis for the processing of oil palm fruits. Followed by this many companies have established with latest technologies and upgraded their old factories to suffice the demand. Godrej Agrovet, Ruchi Soya and APOILFED have gone for two mills each in Andhra Pradesh alone. Presently the processing capacity of these mills is more than 300 tonnes per hour. In Karnataka, FAO model mill with one tonne/ hour capacity was constructed at Kabini in Mysore district. In Gujarat, the processing mill was constructed under Cooperative Society Act in Navsari district which is unique.

However, the first oil palm processing mill in the country for research purpose was established in CPCRI Research Centre, Palode in collaboration with the Regional Research Laboratories, CSIR, Trivandrum. The capacity of the mill is 0.5 tonnes/hour. The technology was transferred to private company which later on established in many states in India including AP, Gujarat, Orissa, etc. In the recent years much more modifications have been made by many processing units in terms establishment of nut breaking unit, kernel oil extraction units, methane gas capturing, tilting and vertical sterilizers and conveyor belt system. All these things made the industry more profitable by reducing the oil loss at different places.

Captive plantations

Commercial cultivation of oil palm in India was started as captive plantations in Kerala followed by Little Andaman by OPIL and ANIFPCL, respectively. In OPIL an area of 3000 ha was planted in three different estates namely Bharatipuram, Kulathpuzha and Chitara where as in Little Andaman, it is in Netaji Nagar, Krishna Nalla and Ramakrishna Puram areas covering 1593 ha. Later PCKL has also started its captive plantations in Athirapally area of Thrissur district in 750 ha. Apart from these it is not observed in any other states. All these are under rainfed cultivation like in Malaysia and Indonesia. However the concept of oil palm cultivation in the country has been changed later on. Since 1988 onwards, the cultivation is done with the supplement of irrigation

Factors for success of oil palm

Oil palm cultivation by giving irrigation is unique in the entire world as it is generally grown as rainfed crop in other South East Asian countries. Similarly raising plantations with the help of farmers' participation is also a unique feature though in Malaysia and Indonesia it is done at 70:30 ratio. Since 70% plantations are with the processors as captive plantations, these do not have the problem of short supply of FFB. Since the farming community is 100% involved in raising plantations and supply of FFB to the companies in the country, the latter had to depend on them for the sake of fruits. This is the main draw back in Indian oil palm industry, warranting complete care of the palms from planting to harvest and later supply off FFB for obtaining quality oil. However, many factors are found positive for the successful growing of oil palm in many states which include the following.

Climate: Climate is the important phenomena that should be taken in to consideration for growing oil palm. Although many congenial conditions except rainfall, throughout the year are prevailing in the country, the deficit factor is incorporated by way of giving irrigation during off-season. Having high underground irrigation potentiality and exploring them by using motor pump sets is a unique feature in oil palm cultivation in the world.

Progressiveness of the farmers: The success of oil palm cultivation in the country is mainly due to the farmers as they are by and large enthusiastic and progressive in nature. This led them to take-up oil palm cultivation as a challenge and many farmers got success in the process. Implementation of intensive cultivation practices made them successful in oil palm cultivation.

Low production cost: Cultivation cost of oil palm is comparatively cheaper to other plantation as well as oil producing crops. This is mainly because it harbours low pest problems and less labour intensive as compared to other oilseed crops like groundnut. As the palms are responding positively and yielding more than 25 tonnes of FFB per ha with fertilizers and irrigation this is the fetching factor for the oil palm success in India.

Industry support: During the inception of oil palm cultivation in commercial manner in Andhra Pradesh and Karnataka, no processing facilities were established. Similar conditions were existed in Andaman and Nicobar Islands where in the produce was harvested and thrown into the sea or used as mulch. However, in Andhra Pradesh the first processing factory was established in 1993 i.e., four years after the first commercial planting of oil palm was done at Pedavegi. This was followed by the establishment of many other factories that created confidence among the farmers and ultimately provoked them for oil palm cultivation.

Apart from it in the major three potential states namely Andhra Pradesh, Karnataka and Tamil Nadu the potential areas identified by the Chadha Committee has been divided in to different zones and allotted to different companies for creating development and processing facilities. The allotted companies developed the oil palm nursery in their regions by obtaining the sprouts from the major oil palm growing countries like Costa Rica, Papua New Guinea, France and also from Palode area of Kerala. After rising in the primary and secondary nurseries these seedlings have been distributed to the oil palm growers after ascertaining the suitability of land and water. In the process of development the companies have also been engaged themselves in the management practices of oil palm by passing the suggestions on cultivation practices. They have also established collection centres for the procurement of the harvested FFBs from farmers to send them to the processing factories within the stipulated time. These companies are also responsible to make the payment within the stipulated time as per the oil palm act being followed by all the State Governments. This

not only eradicated the middleman system but also ensures the farmer the correct price for their produce, which is not possible for any other crop.

Government support: As a matter of fact the role of Government is the most vital in the establishment and success of oil palm industry in India. Without its participation in the initial periods by way of appointing a separate district level officer for this crop, by giving seedling subsidy, cultivation subsidy for the first three years i.e., during the unproductive period (Juvenile period) and later on fixing the price for FFBs with the consultation of farmers and company officials in the form of oil palm price fixation committee wherein the officials representing the TMOP and the Director of the National Research Centre for Oil Palm are members.

Market Intervention Scheme: When the palm oil prices were crashed internationally, the Government has come into the rescue of the farmers as well as the processors to save the Indian oil palm industry. By adopting the Market Intervention Scheme (MIS), Government has purchased the FFBs from farmers at profitable prices to both farmers and processors. For this it had to pay higher prices, which were given, in the form of subsidy. This really saved the oil palm industry of India to a large extent.

Research support

In the initial periods of oil palm development in the country during 1970-90, research was mainly confined to rainfed oil palm at CPCRI Research Centre, Palode. Work on pepper was carrying out at this centre initially and later on it was shifted to oil palm where breeding and pest management aspects were given priority. Seed gardens using the mother palms from Thodupuzha seed garden was established at this centre which has later become a big source for indigenous seed sprouts.

Establishment of National Research Centre for Oil Palm, Pedavegi: By establishing the NRC for Oil Palm at Pedavegi by ICAR, the Government crated research facilities for this unique crop, which further created confidence in the farming community. Since growing of oil palm by giving irrigation is a new venture in the world, the palms can have lot of variation by showing diseases and disorders. This needs detailed studies to draw the control measures. Systematic research at National level only can solve these problems and establishment of National Research Centre will definitely cater the needs of the growers.

Role of United Nations Development Programme (UNDP): UNDP extended its support to the Indian oil palm industry by sanctioning two mega projects *viz*., training of trainers in oil palm production and oil palm breeding for seed production worth 140 lakhs to NRCOP, Pedavegi. Ten members representing research, development and processing sectors visited Malaysia and underwent training on all the aspects of oil palm. After returning, these persons acted as trainers and trained 6000 farmers and 600 officers on oil palm cultivation. Apart from this, two scientists of NRCOP visited PNG and got trained in advanced seed production technologies that helped the industry in minimizing the losses and increased the productivity of seed sprouts. Two advanced breeding materials (elite Duras) were also procured from ASD Costa Rica to utilize them as mother palms and further use in breeding programme.

Support from TMOP: Technology Mission on Oilseeds and Pulses, Ministry of Agriculture, Government of India has supported the Indian oil palm industry in a big way by giving the seedling subsidy, cultivation subsidy in way of fertilizers, sanction of new posts in the State Departments of Horticulture exclusively for the sake of oil palm development, establishment of leaf analysis laboratories in both Andhra Pradesh and Karnataka states for the use of oil palm growers, establishment of processing mills under the aegis of public sector undertaking of State Government of Andhra Pradesh at Pedavegi and also subsidy on the establishment of processing mills by private entrepreneurs in all the potential states. Apart from these the TMOP also spared funds for arranging the training programmes for farmers in the form of tours to the already established gardens located in other areas and also for planting material of intercrops for rising in the oil palm gardens. The scheme on oil palm training sanctioned by TMOP during 1991 to the CPCRI, RC, Palode made a dent in the development of oil palm industry by giving training to many officers all over the country. However it was mainly on rainfed oil palm practices as no work was carried out on irrigated oil palm by that time.

Support from Union Government: After identifying the potentiality of the oil palm, the Union Government of India also extended its support by offering the subsidy for erecting the drip system for the oil palm gardens. Similarly the State Government of Andhra Pradesh also extended its support for oil palm cultivation by sanctioning the electricity connection on priority to oil palm growers. All these efforts made the Indian oil palm industry in to a successful launching in the initial years.

Having good resources of ground water for irrigation, congenial weather conditions necessary for cultivation, farmers awareness on the crop's potentiality, extension activities carried out by the State Departments of Horticulture in promoting the crop, issuing of subsidy for seed material as well as cultivation practices during the juvenile stage, active participation of private as well as state government undertakings in the development and processing, zonalization of the area, formation of project management committee and price fixation committee and reviewing them at quarterly interval are the few reasons for its successful launching. Establishment of Research Centres, low

production cost, obtaining higher yields with good management practices, low pest and disease problems, establishment of processing factories in each zone, opening of collection centres by the processing industries and lifting the FFB for processing and making the payment to the producers within the stipulated time are the few reasons for its take off in a big way.

Reasons for setback

GATT agreement under WTO, reduction of import duties on palm oil, large scale importation of crude palm oil from Malaysia and Indonesia, overall price reduction for palm oil in the international market, reduction of ground water table due to poor monsoon, non-availability of sufficient electricity for operating the bore wells, non establishment of byproduct extraction units and long gestation period are the few reasons for the set back of Industry which led to uprooting of the plantations in many areas. This was overcome by changing the Government policies and paved way for bright future of oil palm in India. The reasons in few states are specific to local conditions.

Rat and wild boars were observed as the causal agents for poor performance of oil palm in Baspadua area of South Tripura district adjacent to Bangladesh. Although oil palm was started during 1994-95 the poor yields due to lack of pollinating weevils could not give any momentum in area expansion. This ultimately resulted into closing of OPDP project in the area. In Assam, during 1980s the Assam Plantation Crops Development Corporation took up the oil palm cultivation in Karbi Anglong district near Khaziranga National Park to find the feasibility of the area. Due to lack of interest of State Government, the project was shelved in spite of the good performance of oil palm in Kahi Kuchi demonstration project.

In Gujarat, although oil palm cultivation was started in 1993 the footing was not strong enough to convince the farmers for oil palm cultivation. Initially due to lack of knowledge on oil palm cultivation to the farmers and later due to lack of processing mill facilities it has not come up properly. The only cooperative company being operative in the country in oil palm industry i.e., M/s Kalyan Agricultural Crops Sales and Processing Society is not effective in extension activities. In recent years, many processing companies have started their business in the state with the allocation of new areas.

The growth of the oil palm in Narayanapur of Chhattisgarh state, Karakala of Udipi and Padilu of Dakshina Kannada districts of Karnataka state is very good to take up oil palm cultivation. Due to existence of competent crop like arecanut the development could not be taken up. Since Yellow Leaf Disease (YLD) on arecanut is a serious problem on areca palms and not attacking oil palm, it is planned to take up oil palm in these two districts in recent years. In Chhattisgarh due to social problems and lack of interest by the government, oil palm development started very lately although the performance of the palms is very good in Narayanapur.

In Tamil Nadu the situation is different as the areas namely Karur and Trichy that have been identified for OPDP are drought prone and hence farmers did not show much interest in growing. Many places the palms were either in dried and abandoned conditions without irrigation. In some places even the seedlings were not planted in the field and on bunds itself. In Madurai district few palms in Agricultural College could be seen that were planted as avenue palms. In Theni district, the oldest plantation is existing where the planting material was brought directly from Malaysia without any quarantine certificate.

Regaining the momentum

With the involvement of Government of India, the industry regained its momentum and came to normalcy. The measures like Implementation of Market Intervention Scheme (MIS) to procure the oil palm fresh fruit bunches by giving subsidy, by enhancing the import duties on crude palm oil that is imported from other countries, encouraging the cultivation of intercrops and overall reduction of prices for agricultural commodities made the Industry to set on the right track.

Support from Malaysian Palm Oil Council (MPOC): With the successful reentry of the Industry after the setbacks of GATT under WTO during 1999-2002, many countries started looking towards Indian oil palm industry. A combined team of scientists from MPOB and IOPRI under the chairmanship of Dr. Mohd. Basri Wahid, the then Deputy Director General (R&D), MPOB visited the oil palm plantations of Andhra Pradesh and National Research Centre for Oil Palm, Pedavegi during August, 2004 to see the progress after set back. Later during the same year another team from Myanmar also visited the oil palm plantations and research centre. In the year 2011, MPOC arranged a study tour to few important persons of Indian vegetable oil industry including a scientist from DOPR to study their oil palm and palm oil. Later in 2012 one more team visited Malaysia mainly for exchange of oil palm germplasm and procurement of oil palm sprouts for the sake of Indian oil palm industry. All these indicate the successful revival of the Indian oil palm industry after the setbacks.

Research on oil palm

Although much of the research work was carried out in Malaysia, Indonesia, Nigeria, etc., but most of them were confined to rainfed oil palm. On irrigated crop no specific work was done anywhere in the world except a few trials in Thailand on irrigation aspects. With the establishment of National Research Centre for Oil Palm at Pedavegi and subsequent merging of CPCRI Research Centre, Palode to

NRCOP further strengthened the research on irrigated oil palm. Upgradation of the Centre to the Directorate level is another important step in oil palm research. The Palode Centre is mostly concentrating on the seed production aspects while Pedavegi station is doing on all aspects of oil palm including breeding, production, protection, post harvest technology and computer applications. The achievements of the Directorate are worth to mention. These include the selection and development of promising Dura mother palms from commercial plantations of Maharashtra, Andhra Pradesh and Little Andaman plantations, development of 11 new oil palm hybrids and testing them under AICRP on Palms trials, development and selling of license agreement on commercialization of oil palm tissue culture protocol, standardization of oil palm based cropping systems with heliconia, red ginger, bush pepper, guinea grass and cocoa in adult oil palm plantations, development of Diagnosis and Recommendation Integrated System (DRIS) norms and optimum leaf nutrient concentration ranges, development of a simple water extraction method for estimation of potassium concentration in oil palm leaf, standardization of use of spectro radiometer to detect potassium and magnesium deficiencies in oil palm, designing and development of height adjustable hydraulically elevated platform to reach up to a height of 5 m for harvesting FFB from tall palms and development of ablation tool, development of integrated pest and disease management practices for rhinoceros beetle, psychid and leaf web worm, basal stem rot and stem wet rot, training to the officers and farmers of all the oil palm growing states including NEH region on oil palm cultivation, pest and disease management etc., and development of oil palm Kisan Mobile Message Services to send to all oil palm growers of the country in four languages.

The project on establishment of Leaf Analysis Laboratory (LAL) to analyze the oil palm leaf samples for various nutrient levels and advise the farmers for correct nutrition which was sanctioned by TMOP during 1996 is an important link between the institute and farmers. Similarly another project sanctioned by TMOP on Research cum demonstration of oil palm genotypes under varied environments using cross combinations obtained from ASD Costa Rica at four different agro-climatic locations of the country is also a long run one to study the performance of oil palm genotypes under varied environments in order to evolve location specific hybrids and base future seed production programmes. The other centres where the trials were conducted are Bhimankolli in Karnataka, Aduthurai in Tamil Nadu and CPCRI RC, Palode. It has also sanctioned a project on strengthening of training on oil palm production technology worth 38.33 lakhs to train the field officers and farmers on various aspects of oil palm cultivation. Whereas under AP Cess fund scheme of ICAR, many projects were sanctioned to carry out research on oil palm including pest problems, pollinators, development of computer software for seed gardens, reestablishment of oil palms uprooted during cyclones etc. Above all the first research project from ICAR on oil palm as adhoc scheme was sanctioned to Acharya N G Ranga Agricultural University to survey and monitor the pests and diseases problems during 1994-96.

During 1999-2002 many projects under NATP with World Bank assistance were sanctioned to the Centre including production, protection and harvest and post harvest technology development. Later on under ISOPOM and RKVY of TMOP, few projects on oil palm improvement and extension activities were carried out.

Oil palm was included under All India Coordinated Research Project (AICRP) on Palms during 1987 as component crop to carry out research work at four centres of the country on irrigation and fertilizer requirement of the crop. In the recent years the varietal performance is also being taken up in these centres. To test the adaptability of oil palm in different locations of the country *viz*., Kahi Kuchi, Negicherra, demonstration projects were conducted using planting material from Palode centre of CPCRI.

The work on development of inter specific hybrids using *Elaeis guineensis* and *E. oleifera* parents for dwarf and other characters has been taken up at both Palode and Pedavegi centres. The African germplasm that was collected under explorations were planted at different locations to further test their adaptability in different agro climatic areas of the country *viz*., Adilabad, Nellore, Mohit Nagar etc., so as to utilize them in the breeding programmes.

Some of the findings emerged from the Indian oil palm research are the first time reports in the world. These include new pest species like *Sylvanus* sp. feeding on leaf tips, black slug, *Laevicaulus alte* feeding on one day old nursery plants, Shoot borer, *Sesamia inferens* feeding on both primary as well as secondary nursery plants, bamboo rat, *Cannomys badius* feeding on the roots of the newly planted oil palms. In case of diseases, potty virus and spear rots were the first reports from India. The stem wet rot and bunch end rot diseases were also reported only in irrigated oil palm plantations. The management practices that were developed for the bud rot as well as stem wet rot put the industry in sound position unlike in other countries. In the recent years, Indian oil palm industry is facing the problem from Basal stem rot (Ganoderma) disease which is a dreaded one.

The establishment of pollinating weevil, *Elaeidobius kamerunicus* in all the released areas irrespective of abnormal environmental conditions is a good sign for the industry. This could be due to the development of new biotypes resistant to weather conditions.

Future scenario of Indian oil palm

Oil palm is having great future with its high productivity of 4-6 t of oil per ha which is far above to all other oilseed crops. The world area and production of oilseeds which were 141.98 million ha and 223.20 million tonnes in 1995-96 reached about 250 million ha and 448 million tonnes by 2009-10 respectively. The current world production of oil seeds and vegetable oils is reported to be sufficient to meet the global demand. However, increasing demand for use of vegetable oils in manufacturing bio-diesel have put the oil seeds stocks under pressure. Indian oil palm is still much more progressive as it is a potence rainfed crop in terms of productivity.

The Indian economy is the 12th largest in the world by nominal value and the 4th largest by purchasing power parity (PPP). The increasing *per capita* income led to enhanced consumption of edible oils. The gap between the domestic production and the requirement became widened at an alarming rate. The *per capita* consumption of edible oils in India has increased considerably in the last one decade but is still far below that of developed countries and also lower than many developing countries. The oil demand for industrial use is also likely to grow in the coming years. Palm oil from Indonesia and Malaysia is dominating the country's import basket of edible oils due to its competitive prices when compared to alternate oils. In spite of continuing efforts to increase domestic production and productivity, not much headway has been made. Total imports for the calendar year 2009, compared to 2008, showed an increase of 30%. During 2011-12, the rate of growth of imports of edible oils was 6.99% while the *per capita* consumption of edible oils grew at a rate of 5.65%. Palm group of products were the major beneficiary in absolute quantity terms. Imports, as a percentage of total consumption, have now crossed the psychological barrier of 50%, in the process making palm oil the single largest consumed oil in the country. Whilst efforts to increase domestic production continue, practically speaking, India's dependence on imports is unlikely to abate in the near future. Palm oil, which accounted for 80% of the total import basket in 2009, will continue to be the major vegetable oil consumed. This golden crop is best positioned in all ways, such as pricing, logistics, nutritional values, versatile usage and being user friendly, to take care of the needs of the Indian consumer. The trend of vegetable oils production over the years did help to a considerable extent in reducing imports. On the contrary, the Government policy allowed greater freedom to open market and encouraged healthy competition rather than protection or control.

Indian products using palm oil are increasingly exported to environmentally conscious markets in EU (European Union) and several OECD (Organization for Economic Co-operation and Development) member countries. It would be useful to make use of the consumer preferences in these markets and institutions including NGOs to promote the use of sustainable palm oil by the Business and Industry (B&I) in India. The efforts to supply palm oil at cheap prices to India as well as other export markets would add tremendous pressure on High Conservation Value Forests (HCVF) in Indonesia, Malaysia and elsewhere. India can play an important role in supporting the South East Asian countries to their efforts to conserve HCVF and biodiversity. India can make use of Indo-ASEAN partnership to promote "sustainable palm oil" by constructively engaging the key stakeholders in both regions. There is considerable scope to engage B&I to adopt environmentally credible business practices, actively participating the initiatives such as RSPO and make a commitments to "sustainable palm oil" as and when it is available. To achieve this, a "step wise" approach is suitable for B&I in India.

The average fat intake of 29 g/head/day is adequate to meet the nutritional needs, which translates into annual vegetable oils requirement of 10.585 kg/annum/person as stated by Nutrition Advisory Committee of the ICMR. The current *per capita* consumption of 14.2 kg/annum is much higher than nutritional needs. The consumption levels of edible oils are beginning to increase to alarming levels as against the recommended 30g/day to meet average physiological needs. The demand for vegetable oils is both income and price elastic. Demand for food grains is constant and stable and can only meet the population growth, whereas demand for vegetable oil increases with increase in population, increase in standard of living (income) and increased use for industrial, pharmaceutical, nutraceutical and cosmetic purposes, etc. Thus, the vegetable oil consumption trends for vegetable oils continuously increases at increasing rate.

The supply of vegetable oil has increased at the rate of 2% per annum in the past 25 years, while demand grew at the rate of 5% per annum. For a projected Indian population of 1685 million by 2050, 17.84 million tonnes of vegetable oils is required to meet the fat nutrition. This is equivalent to roughly 59.41 million tonnes of oilseeds. If 25% of vegetable oil is met from crops other than annual oilseeds, then the country needs to produce just 44.56 million tonnes of oilseeds by 2050 to meet fat nutrition of the projected population. Oil palm is likely to play a major role in augmenting the supply of 25% vegetable oil in the country. By 2050 even if an area of 8 lakh ha is covered under oil palm, the country must be able to produce about 3.2 m t of oil. There is a need for proper policy back-up along with remunerative prices for sustaining the long-term commitment of the farmers to oil palm.

A newer dimension of vegetable oil requirement for industrial use is estimated to grow by 15% in 2020, 20% in 2030 and 25% in post-2040, thus requiring around 3.57, 6.34, 9.69 and 10.61 million tonnes in 2020, 2030, 2040 and 2050, respectively. The Indian trade industry, therefore, predicts much greater expansion. The total vegetable oil

requirement is thus estimated at 25.26, 29.47, 34.27 and 35.90 million tonnes during 2020, 2030, 2040 and 2050, respectively, which is a gigantic task for the country to increase its domestic production with the nine annual oilseed crops. The contribution of vegetable oil availability from secondary sources including arboreal tree species like oil palm and coconut (20%) is estimated at 5.05, 5.89, 6.85 and 7.18 million tonnes during 2020, 2030, 2040 and 2050, respectively. As per the population estimates, the Indian middle-class population is expected to touch one billion over the next two decades. The middle class population would be the major consumer of edible oils in the country. The country is meeting now more than 50% of its oil requirement through imports resulting in huge drain on our foreign exchange. The current import bill is around ₹ 56,000 crores annually.

Research priorities

For the success of Indian oil palm industry, there is a need to carry out research prioritization to evolve drought resistant oil palm varieties that are suitable to low rainfall areas, producing sustainable yield with low irrigation, compactness with less height and resistant to pest and diseases. Palms having small leaves to create low pressure on the petiole and ultimately avert leaf breaking and there by crown collapsing are needed to sustain heavy cyclone and swirl wind in coastal areas. Research should be intensified to obtain higher yields with low inputs of fertilizers and irrigation, higher income from unit area by raising various inter and multiple crops in the oil palm gardens. Screening of different mulch materials to arrest the evaporation from the gardens should be tried.

Research on Development of IPM and IDM practices for the individual pests and diseases and thereby for the whole complex of palms is essential to keep the palms in healthy and yielding condition. Work on evolving the best method of weed control practices using chemical and mechanical methods without having any antagonistic effect on the palm yield should be tried. Efforts on mechanization of various cultivation operations should be drawn to lessen the labour intensity. Development of harvesting tools for the fresh fruit bunches with less manual work force is the immediate task to be carried out.

Quality research on the post harvest technology and value addition of palm oil for the utmost utilization of by-products is another important aspect. Byproducts from palm oil and palm kernel oil namely beta-carotene, tocopherols and tocotrienols (Vitamin E) and other important oleo chemical products that can be useful for pharmaceutical industry should be explored. The palm oil mill effluent (POME), which is the best input material for fresh water aquaculture, needs to be tested by conducting research in a systematic manner. The empty fruit bunches, cut leaves and the mesocarp waste need to be explored for utilizing them fully either for vermicompost preparation or for other domestic purposes.

To mitigate the adverse effect of the palm oil price fluctuations in the international market and there by on the domestic produce, the processing factories should be insisted for extraction of by products and other value added products. Of these beta carotene extraction and other olein units are important ones. Extraction of Vitamin A and Vitamin E from the palm oil is the priority item, which has lot of international demand. Similarly the extraction and preparation of chlorophyll tablets from the leaves is one field which needs attention.

Work on genetic modification of the crop by identifying and incorporating the drought resistant genes to lessen the water requirement of the palms should be carried out. Tissue culture should be given top priority for getting true to type material having high yield, high OER (oil extraction rate) and dwarfness/compact palms and for disease resistance. Development of semiclonal and biclonal planting material utilizing the tissue culture plants should be made with desirable characters.

Height is the serious problem for carrying out all cultivation practices in oil palm like pruning of leaves, harvesting of bunches and even for crown cleaning and spraying operations. At the same time modification of leaf articulation is also essential. Presently the leaves are oriented in 45° angle to the stem initially and later when fruit bunch is emerged out in between the leaves and stem then it bends and reaches to 90° angle. If male flower emerges instead of female, the leaf bending is only nominal. This affects the photosynthetic rate of the leaf as the sunrays fall slanty over the leaf, which affects the function of chloroplasts. Since all the chloroplasts in the leaf are not fully exposed to sunlight, they function partially, which affects the yield. To best utilize the chloroplast cells, modification in the leaf articulation through genetic modification of the palms should be carried out. Along with higher returns, this will also ease the harvesting of the fruit bunches as the stalk portion is so intact in between the leaf and stem portion making it difficult to cut so far.

Apart from this, the intactness of the leaf with stem also affects the pollination and fruit set, as many flowers (the lower spikes) are not fully exposed to the pollen grains. This is due to lack of space between leaf and stem, which do not allow the weevils to fly over and spread the pollen. This ultimately affects the fruit setting followed by yield loss. Oil palm being entomophilous crop needs the assistance of an insect called *Elaeidobius kamerunicus*, which multiplies in the male flowers and assists in pollination. However these weevils do not assist to any other crops except oil palm. The chemical 'estragole' found in the pollen may be the hardship for other insects like honeybees to involve in pollination. If the problem of pungency is solved by means of genetic manipulation as seen in many solanaceous crops, the

honeybees can be incorporated into system, which may increase the yield levels.

In India the ratio of male female flowers in oil palm is 1:1. These are emerged out in circles with all males followed by females and vice versa. If this pattern is altered to get more females and fewer male cycles and also the mixed population of both males and females, higher yields can be obtained and at the same time the pollination problem can also be solved. Efforts should be made in these lines.

Byproduct utilization is an important aspect in oil palm where carotenoids, tocopherols and tocotrienols are extracted from palm oil. The quantity of these varies from species to species with maximum in oleifera varieties compared to guineensis and other crosses. Hence, it is necessary to bring out the genetic modification or through hybridization process of the palm to draw maximum content of the Carotenoids and Vitamin E.

Crop production

Oil palm being grown as irrigated crop in the country is getting maximum importance in the nutrients as well as irrigation application. This leads to the premature height increment of the palms making harvesting difficult at very young age. This also leads to nutritional imbalances and arresting the secondary nutrient uptake. To correct the deficiency disorders it is essential to analyze the 17^{th} leaf, which is very difficult to the growers to identify and even, cut it for analysis. All these lead to labour intensiveness and low profits. Work should be carried out to draw DRIS norms for every mandal or village levels to avoid the unnecessary usage of fertilizers.

Application of fertilizers is one of the aspects, which need lot of research. In the subtropical areas like India application of nitrogenous fertilizers in the form of urea may lead to evaporation as it is hygroscopic. If ammonium fertilizers are recommended, they are costly and may cause succulence for pest attack. Apart from nitrogenous fertilizers, the use of potash and phosphate fertilizers is having the problem of leaching and not available to palms. Hence fertigation trials need to be carried out which will increase the fertilizer use efficiency and labour saving.

Mulching is an important aspect to be followed in the tropical and subtropical areas like India to reduce evaporation losses. Unlike in Malaysia cover crops like Calopogonium and Pueraria cannot be grown due to social problems and hence work should be carried out on utilization of plastic mulches, which can control the weed growth as well as evaporation losses from soil. To control the weed growth inter cultivation in between oil palm rows is a common practice that may lead to root damage and may affect the physiology of the palms by producing male flowers.

Indian soils are rich in potash and hence is not a limiting factor. However in many areas palms are showing potash deficiency symptoms even after the application of excess amount of K fertilizers. The relation between N and K needs to be studied thoroughly. At the same time the effect of Mg should also be explored in the context of N and K as the imbalance of these two nutrients may lead to the Mg deficiency symptoms on leaves.

Irrigation is the major impediment for oil palm growth in the oil palm potential areas of the country. A monthly average of 150 mm rainfall is essential for oil palm and deviation of this during any month will lead to the change in the basic physiology of the palm and reflects on yield. Since water is a limiting factor, judicious use of irrigation is essential. For this purpose efforts should be made to draw different application methods where water is saved effectively and utilized 100%.

Growing intercrops is must for sustainability and profitability of oil palm cultivation in the country. Research on best and profitable intercrop in relation to yields and utilization of inputs should be carried out for different age groups. This also warrants taking up the spacing trials especially suitable for oil palm.

Plant protection

Leaf eating caterpillars *viz*., leaf web worm, psychid and slug caterpillars are serious pests on Indian oil palm. Their incidence is severe due to existence of high humidity and poor penetration of sunlight due to intermingling of leaves of adjacent palms. Research work on integrated management of these pests by exploring all the methods need to be carried out. Economic threshold levels for these pests in relation to yield losses need to be drawn. Work on other possible methods of management including bioagents and pheromones need to be taken up.

Instead of developing IPM practices for every pest it is essential to draw Integrated Management Practices for the whole crop and whole year or for each season forecasting the pest population. At the same time the pest population on intercrops should also be taken care off. For this purpose IPM practices for the mixed/intercrops should also be developed.

Apart from insects, oil palm plantations are also infested with avian and mammalian pests. For the control of avian pests, research on modern tools should be explored particularly the roosting sites should be targeted. In case of mammalian pests rats are the major problems on both FFB as well as on main palms. To manage these pests simple and effective practices are being followed in Malaysia where barn owl is allowed to stay in the gardens to multiply their population and feed on the rats. This is found most effective, less expensive and simple and should be tried in India also. Utilization of nectariferous plants by raising on the borders of oil palm plantation need to be studied to find their effect

in harboring the natural enemies of the pests species. In the recent years monkeys are creating nuisance and problems to oil palm plantation and hence there is an urgent need to take up management trails on priority.

Indian oil palm is infected with many diseases and disorders although these were not seen in its native country. The causal organisms for bud rot and stem wet rot diseases need to be identified. Research on these aspects should be conducted to draw easy and effective management technology. Since surgering the bud rot affected palms is a cumbersome, simplified techniques of disease control should be explored. Use of bio-agents and organic amendments should be tried as one of the tools for the IDM practices.

Effect of high temperatures and low humidity on the palm growth and yield and the disorders should be well tried in the pathological angle. Since the palms attain very tall height, it is difficult to carry out the plant protection operations. A suitable methodology should be evolved to overcome this problem. Possibilities of using stem injection technology need to be studied.

Value addition and post harvest technology

This is the important field in oil palm research wherein considerable work can be done to stay on par with other countries. Of these the byproduct extraction and utilization is the most important aspect which demands immediate research. Since palm oil is the rich source of beta-carotene and tocopherols and tocotrienols, maximum importance should be given for the extraction of these items, which make the country competent with others. The new methods of extraction like saponification, urea processing, adsorption, selective solvent extraction, molecular distillation and trans esterification, though difficult to perform, should be tried. However recent extraction methods namely conversion of palm oil tryglycerides into volatile methyl esters and recovering the carotenoids from these esters using adsorption or solvent extraction method and by the selective adsorption of carotenoids obtained from reverse phase adsorption material with the esters of high polarity being first eluted out from the column should be tried. With these two methods, higher concentration of carotenoids can be obtained. Since oil palm leaves also contain carotenoids, extraction from these should also be explored. Stearic acid is the component of the palm oil, which is obtained along with the olein in considerable amounts. The best use of these products should be explored under value addition research.

Harvesting of FFB is a perennial problem in oil palm. Efficient tools that can be operated with motorized mechanism should be tried. These can give increased efficiency over the manual operation. So far the correct ripening stage that is fit for harvest of FFB to extract maximum oil is not reported in India as it varies due to the climatic conditions. Hence work should be carried out on this aspect to find out the correct stage of FFB for harvest to draw maximum oil extraction ratio in the mills. Oil Extraction Ratio of the FFBs of oil palm in Indian conditions is recorded upto the tune of 18-20%, which is quite less compared to Malaysia and Nigeria. Work on high oil recovery methods should be carried out. For this sake development of oil palm new varieties that have maximum oil content should be explored. In this regard work on temperature and pressure needed to obtain maximum recovery of oil should be tried.

Free fatty acid content is the important character in the oil extracted from FFB. Since it increases with the lipase activity in the fruits after harvest, research should be carried out on keeping the FFA content at lower levels. Utilization of empty fruit bunches after the extraction of oil needs to be studied particularly to utilize them in the preparation of fertilizer instead of using them as fuel and mulch. This is more practiced in the countries like Malaysia and Indonesia. Since the mesocarp of oil palm is having lot of cellulose and low contents of lignin, use of this material for the manufacturing of mattresses or the yarn is of little strength. Decomposition of such material is very fast and hence longevity is doubtful. It is necessary to find out the alternative uses of these products.

Effluents in palm oil processing mills are available in bulk, which can be cashed by finding out the best use as food material for fishes. Efforts should be made to make this slurry in to cake formation and market it to the fish growers and as good compost.

Oil palm leaves are rich in chloroplasts and chlorophyll content. In Malaysia where the oil yield reached to saturation, exploitation of the leaves for the preparation of chlorophyll tablets, which have the pharmaceutical importance in western countries, is being carried out. Efforts should be made to utilize the cut/pruned leaves for this purpose. Keeping the above things in mind, research priorities for Indian oil palm need to be changed and recasted.

Policy issues

Regulation of import of vegetable oils through adoption of appropriate import policy aiming at increased domestic production needs to be done. The need for achieving self sufficiency in vegetable oil should be seen in the context of improved livelihood, higher profitability to farmers and for processing industry. Encouraging the establishment of large scale captive plantations and specialized oil palm seed gardens by declaring it as a plantation crop and also ensuring proper pricing policy for profitability is needed. Creation of conducive environment to strengthen private participation in collaborative research on the lines of MPOB, Malaysia, development, extension and marketing operations is essential for the success of the industry.

As mentioned by Dr. R.S. Paroda, steps should be taken to avoid diversion of edible oils for biodiesel production and

other industrial uses. The industry should also be involved in supporting technology development and extension activities. Revival of Oilseed Mission, through a special purpose vehicle, with greater thrust on 5 Ps: Priorities, Policies, Productivity, Profitability and Private sector participation, with emphasis on increased oilseed production in the country be the highest priority of the Government. Greater emphasis and investments on public awareness about rationalization of vegetable oil consumption for proper health becomes our national priority.

Institutional linkages

The research, development and technology dissemination infrastructure existing for Indian oil palm industry is not so effective to deliver the results to the end user. These need to be studied critically for identifying the gaps/lacunae and efforts should be made to plug them to obtain efficient and functional institutional support in future for the success of oil palm.

Natural resource management

Indian oil palm is unique as it is cultivated by giving irrigation using underground sources. Since water is a key factor for getting high yields, their use should be done with utmost care as excess use may lead to depletion of ground water table and increase in pest and disease problems. Watershed management with appropriate rainwater harvesting both *in situ* with proper disposal and storage farm ponds provide excellent opportunity to mitigate the expected problem. Management of soil and water conservation and its economic use to enhance the profitability through achieving 'more crop (oil) per drop' of water are need to be practiced.

Development

Establishing strong linkages among processors, farmers and development officers of the Departments of Horticulture/Agriculture will lead to the success of the Industry. Expansion of oil palm cultivation in new areas like Bihar, Arunachal Pradesh and other north eastern states need to be done with utmost care by confirming the logistic support. Dissemination of available technologies to the end users needs to be done on priority.

Encouragement of joint ventures

As the oil palm germplasm is very narrow based, it gives lot of inbreeding as the existing mother palms are very few. With these it is difficult to improve the productivity per unit area. Hence if encouraged the joint ventures with the Malaysians or Indonesians, high yielding varieties of those countries can be introduced which will further benefit the Industry. M/s Godrej Agrovet Ltd (GAVL) is having such a venture with one of the largest plantation firms in the world, M/s IJM Plantations Berhad. All the oil palm companies should follow in those lines for the benefit of themselves as well as Indian oil palm industry.

Indian oil palm industry which started from rubbles has successfully completed two decades venturing profits to all the stakeholders including farmers and processors. High demand for vegetable oil due to increased population further aggravates the requirement in the coming decades. High productivity over other annual oilseed crops fetches the edge for success in short span. The success is a combined effort of enthusiastic farmers, processors, development personnel representing State Department of Horticulture and Agriculture and finally the scientific community who developed technologies for sustainable oil palm industry. Since irrigated oil palm cultivation concept is new and unique in the world, making it success is a great task. By defining the appropriate policies, by bringing out adaptable research technologies for higher yield out put and by taking them to the end users the Indian oil palm industry will show the break through results to the entire world in the years to come. However, it needs enthusiasm, commitment and zeal in all the concerned.

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Callus induction studies in various explants in different genotypes of sesame (*Sesamum indicum* L.)

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ABSTRACT

The goal of this study was to develop a suitable protocol for callus induction in sesame, *Sesamum indicum* which can be further used for regeneration studies. The experiments were carried out using three explants *viz*., cotyledonary leaf, hypocotyls and primary leaf at different hormonal combinations and concentrations to study callus induction. There was significant difference in the response of explants to different hormone treatments although there is no genotypic difference with regard to explants. Results showed that callus induction was significantly influenced by explants type. Hypocotyls responded well for callus induction in most of the genotypes. The callus induction frequency was significantly reduced (36.5%) when 0.2 mg BA was used along with 0.2 mg/l NAA. Replacing this hormonal combination with 2.0mg/l BA and 0.2 mg/l NAA greatly improved the callus induction frequency (51.4%).

Keywords: Callus induction, Explants, Genotypes, Hormones, Sesame

Sesame (*Sesamum indicum* L.), an important oilseed crop, is naturalized in tropical areas around the world and is cultivated for its edible seeds. It is a source of high quality cooking oil and protein. India, China, Sudan and Burma are the major sesame producing countries that contribute to about 60% of the total world production of sesame seed. The world's largest exporter of sesame seeds was India with an average production of 0.62 million metric tonnes and the average productivity being 0.34 tonnes/ha against the world's average production of 3.84 million metric tonnes and the average productivity 0.49 tonnes/ha (FAO, 2012). Sesame is highly drought-tolerant. It has been called a survivor crop, with an ability to grow where most crops fail. However, it requires adequate moisture for germination and early growth. While the crop survives drought as well as presence of excess water, the yields are significantly lower in either condition. Moisture levels before planting and flowering impact yield most. The main limiting factors for high yields in sesame are: early senescence, photo sensitivity and susceptibility to various biotic and abiotic stresses. Since selection through conventional methods has not achieved any breakthrough in increasing yield levels (Sudhakar and Rangaswamy, 1989), alternative techniques like tissue culture and protoplast fusion will enhance the variability for oil and yield within a short span of time and under controlled conditions. Sesame is highly recalcitrant to regenerate *in vitro* conditions. However, many protocols for micropropagation (Rao and Vaidyanath, 1997; Sharma and Pareek, 1998), somatic embryos (Jeyamary and Jayabalan, 1997; Xu *et al*., 1997) have been reported with low frequency. The factors such as photoperiod, explants source, concentration of NAA, strength of medium, sucrose concentration, ammonium nitrate concentration, genotype, culture age and partial desiccation treatment have been reported to influence the yield of embryogenic calli (Lazzeri *et al*., 1987). Callus cultures derived from cotyledons and hypocotyls segments were induced to produce embryos, although induction frequencies were low (Ram *et al*., 1990). Tissue culture methods involving a callus phase or regeneration via somatic embryogenesis are known to produce stable variants (Armstrong and Phillips, 1988). Several opportunities now exist for sesame improvement as a result of recent developments in plant tissue culture and genetic manipulation of crop plants. Sesame plants can be regenerated from various explants *viz*., cotyledon, primary leaf, shoot apical meristems and hypocotyls segments. The present study presents findings of an experiment to work out a suitable protocol for callus induction in selected genotypes of sesame.

MATERIALS AND METHODS

The present investigation was carried out in the Tissue Culture Laboratory, Department of Genetics and Plant Breeding, College of Agriculture, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad during the year 2005-06. The investigation was carried out to develop suitable hormonal combinations to promote callus growth from various explants and to study the effect of various hormonal combinations on callus induction. MS medium was supplemented with various concentrations of different types of cytokinins and auxins. The five genotypes *viz*., JCS-402, Hima, RT-125, Swetha and Rajeswari were used for callus induction studies. The seeds were sterilized with 0.1% $HgCl_2$ for 5 to 8 minutes and then rinsed with sterile distilled water for three times of five minutes each to

remove any traces of mercuric chloride on seeds. The seeds were then transferred to the filter paper boats of sterile culture tubes. The 7 day old explants were excised from the seven day old aseptic seedlings and inoculated on to the culture medium for further studies.

Explants: Hypocotyls were cut into 0.75 to 1.0 cm segments and were inoculated transversely on the medium. Primary leaf and cotyledonary leaf were cut into two halves and placed transversely on the medium so that maximum cut end portion of the explants comes in contact with the medium. The concentrations and combinations of different hormones used in the study are presented here under:

Treatment	Hormonal combination in basal medium (mg/l)
T_1	BA(2.0) + NAA(0.1)
T_2	BA(0.2) + NAA(0.2)
T_3	BA(0.5) + NAA(0.2)
T_4	BA(1.0) + NAA(0.2)
T_5	BA(2.0) + NAA(0.2)
T_6	BA(0.5)
T_7	BA(0.2) + NAA(2.0)
T_8	TDZ(0.5) + NAA(0.2)

The effect of MS basal medium in combination with different hormones on callusing from various explants was analyzed by taking observations on the following parameters

$$\text{Callus induction (\%)} = \frac{\text{No. of explants with callus}}{\text{Total No. of explants inoculated}} \times 100$$

RESULTS AND DISCUSSION

In the present experiment, tissue culture studies were carried out to determine the variation in different explants *viz*., hypocotyls, cotyledonary leaf and primary leaf sesame genotypes *viz*., JCS-402, Hima, RT-125, Rajeswari and Swetha for different hormonal combinations and concentrations for callus induction (Fig. 1). In general, it was observed that hypocotyls explants expanded in length and width, cotyledonary and primary leaves in addition showed downward curling in all the treatments, 12 days after inoculation. Callus initiated from the cut surfaces of these explants after 17 to 21 days of culturing at cut portion which were in contact with the medium. Callus induction frequency was recorded at the end of fourth week from the date of inoculation of different explants of the five selected genotypes. The data was expressed as percentage of the ratio of number of explants in which callus was induced to the total number of explants inoculated. The data indicated differential response of genotypes, explants and hormonal treatments (Table 1).

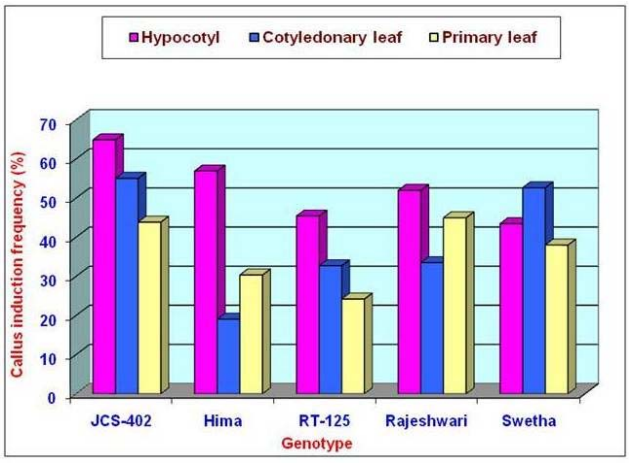

Fig. 1. Callus induction frequency (%) from various explants of sesame genotypes in different hormonal treatments

With cotyledonary leaf as explants: In the cv. JCS-402, the highest callus induction frequency of 86.9 was recorded on MS medium with 0.5mg/l BA and 0.2 mg/l NAA (T_3) followed by 68% callus induction in MS medium with 1mg/l BA and 0.2 mg/l NAA (T_4) and MS medium supplemented with 2mg/l BA and 0.1 mg/l NAA (T_1). Least callus induction frequency with cotyledonary leaf as explants (33.3%) was recorded on MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7). In the cv. Hima, the highest callus induction frequency of 32% was recorded on MS medium with 0.5mg/l BA and 0.2 mg/l NAA (T_3) followed by 21.8% callus induction in MS medium with 1mg/l BA and 0.2 mg/l NAA (T_4). Least callus induction frequency with cotyledonary leaf as explants (5%) was recorded on MS medium with 0.5mg/l TDZ and 0.2 mg/l NAA (T_8). In the cv. RT-125, the highest callus induction frequency of 50% was recorded on MS medium with 2mg/l BA and 0.2 mg/l NAA (T_5) followed by 41.1% callus induction in MS medium with 0.5mg/l BA (T_6). Least callus induction frequency with cotyledonary leaf as explants (15%) was recorded on MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7). In the cv. Rajeswari with cotyledonary leaf explants, the highest callus induction frequency of 86.5% was recorded on MS medium with 2mg/l BA and 0.2 mg/l NAA (T_5) followed by 71.1% callus induction in MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7). Least callus induction frequency with cotyledonary leaf as explants (40%) was recorded on MS medium with 0.5mg/l BA (T_6), MS medium supplemented with 0.5mg/l TDZ and 0.2 mg/l NAA (T_8), MS medium supplemented with 0.5mg/l and 0.2 mg/l NAA (T_3) and MS medium supplemented with 1mg/l and 0.2 mg/l NAA (T_4). In the cv. Swetha, the highest callus induction frequency of 60% was recorded on MS medium with 0.5mg/l BA and 0.2 mg/l NAA (T_3), followed by 44.4% callus induction in MS medium with 0.2mg/l BA and 0.2 mg/l NAA (T_2). Least callus induction frequency of 26.6% was recorded in MS medium with 0.5mg/l BA (T_5).

Table 1 Callus induction frequency (%) from various explants, hypocotyls (H), cotyledonary leaf (CL) and primary leaf (PL) in different hormonal treatments

Treat-ment	JCS-402				Hima				RT-125				Rajeshwari				Swetha				Total
	H	CL	PL	Mean	H	CL	PL	Mean	H	CL	PL	Mean	H	CL	PL	Mean	H	CL	PL	Mean	Mean
T_1	56.0	68.0	70.0	64.7	51.7	16.1	26.0	31.3	68.0	35.0	40.0	47.7	53.1	35.0	46.6	44.9	50.0	28.0	40.0	39.3	45.5
T_2	58.3	54.5	31.8	48.2	50.0	16.6	24.0	30.2	30.7	27.7	20.0	26.1	45.0	33.3	27.7	35.3	51.4	44.4	33.3	43.0	36.5
T_3	58.1	86.9	27.7	57.6	57.1	32.0	28.5	39.2	31.3	26.6	25.0	27.6	40.0	27.2	40.0	35.7	33.3	60.0	55.5	49.6	41.9
T_4	80.0	68.0	26.6	58.2	50.0	21.8	16.0	29.3	60.0	35.0	30.0	41.7	40.0	29.4	36.3	35.2	37.5	40.0	40.0	39.2	40.7
T_5	67.7	34.7	71.4	57.9	84.0	20.0	33.3	45.8	80.0	50.0	16.0	48.7	86.5	33.3	33.3	51.0	80.0	35.0	46.6	53.9	51.4
T_6	56.9	35.0	53.3	48.4	36.0	20.0	50.0	35.3	40.0	41.1	30.0	37.0	40.0	26.6	35.0	33.9	48.0	26.6	40.0	38.2	38.5
T_7	78.0	33.3	35.0	48.8	93.3	21.0	35.0	49.8	21.4	15.0	15.0	17.1	71.1	30.0	90.9	64.0	77.7	31.3	33.3	47.4	45.4
T_8	64.0	60.0	35.0	53.0	33.3	5.0	30.0	22.8	32.0	31.8	18.1	27.3	40.0	53.3	50.0	47.8	43.3	38.8	66.6	49.6	40.0
Mean	64.9	55.0	43.8	54.5	56.9	19.0	30.3	35.4	45.4	32.7	24.2	34.1	52.0	33.5	45.0	43.4	52.6	38.0	44.4	45.0	42.5

With hypocotyls as explants: In the cv. JCS-402 the highest callus induction frequency of 80 was recorded on MS medium with 1mg/l BA and 0.2 mg/l NAA (T_4) followed by 78% callus induction in MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7). Least callus induction with hypocotyls as explants was recorded in MS medium with 0.5mg/l BA (56.9%) (T_6). In the cv. Hima, the highest callus induction frequency of 93.3% was recorded on MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7) followed by 84% callus induction in MS medium with 2mg/l BA and 0.2 mg/l NAA (T_5). Least callus induction with hypocotyls as explants (33.3%) was recorded in MS medium with 0.5mg/l TDZ and 0.2 mg/l NAA (T_8). In the cv. RT-125, the highest callus induction frequency of 80 was recorded on MS medium with 2mg/l BA and 0.2 mg/l NAA (T_5) followed by 68% callus induction in MS medium with 2mg/l BA and 0.1 mg/l NAA (T_1). Least callus induction with hypocotyls as explants (21.4%) was recorded in MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7). In the cv. Rajeswari, the highest callus induction frequency of 53.3% was recorded on MS medium with 0.5mg/l TDZ and 0.2 mg/l NAA (T_8), followed by 35% callus induction in MS medium with 2mg/l BA and 0.1 mg/l NAA (T_1). Least callus induction with hypocotyls as explants (26.6%) was recorded in MS medium with 0.5mg/l BA (T_6). In the cv. Swetha, the highest callus induction frequency of 80% was recorded on MS medium with 2mg/l BA and 0.2 mg/l NAA (T_5) followed by 77.7% callus induction in MS medium with 0.2mg/l BA and 0.2 mg/l NAA (T_7). Least callus induction with hypocotyls as explants (33.3%) was recorded in MS medium with 0.5mg/l BA and 0.2 mg/l NAA (T_3).

With primary leaf as explants: In the cv. JCS-402, the highest callus induction frequency of 71.4% was recorded on MS medium with 2mg/l BA and 0.2 mg/l NAA (T_5) followed by 70% callus induction in MS medium with 2mg/l BA and 0.1 mg/l NAA (T_1). Least callus induction frequency of 26.6% was recorded in MS medium with 0.5mg/l BA and 0.2 mg/l NAA (T_3). In the cv. Hima, maximum callus induction frequency of 50% was recorded on MS medium with 0.5mg/l BA (T_6) followed by 35% callus induction in MS medium with 0.2mg/l BA and 2mg/l NAA (T_7). Least callus induction frequency with primary leaf as explants (16%) was recorded in MS medium with 0.5mg/l BA and 0.2 mg/l NAA (T_4). In the cv. RT-125, maximum callus induction frequency of 40% was recorded on MS medium with 2mg/l BA and 0.1 mg/l NAA (T_1) followed by 30% callus induction in MS medium with 1mg/l BA and 0.2mg/l NAA (T_4). Least callus induction frequency with primary leaf as explants (15%) was recorded in MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7). In the cv. Rajeswari, maximum callus induction frequency of 90.9% was recorded on MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7) followed by 50% callus induction in MS medium with 0.5mg/l TDZ and 0.2 mg/l NAA (T_8). Least callus induction frequency with primary leaf as explants (27.7%) was recorded in MS medium with 0.2mg/l BA and 0.2 mg/l NAA (T_2). In the cv. Swetha, with primary leaf as explants, maximum callus induction frequency of 66.6% was recorded on MS medium with 0.5mg/l TDZ and 0.2 mg/l NAA (T_8), followed by 55.5% callus induction in MS medium with 0.5mg/l BA and 0.2 mg/l NAA (T_3). Least callus induction frequency with primary leaf as explants (33.3%) was recorded in MS medium with 0.2mg/l BA and 2 mg/l NAA (T_7) and also on MS medium with 0.2mg/l BA and 0.2 mg/l NAA (T_2).

Rao and Vaidyanath (1999) reported callus and morphogenesis in sesame cv. Rajeshwari using hypocotyl and cotyledonary leaf explants. In the present studies, similar results were obtained using the same explants and genotypes JCS-402, Rajeshwari, Hima, RT-125 and Swetha. The most effective concentration of BA for callus induction and shoot regeneration was 2 mg/l irrespective of the concentrations of NAA from hypocotyl and cotyledon which

are in consonance with the results obtained by Younghee (2001). In the present study, highest number of somatic embryos was induced from NAA at different concentrations (Fig. 2), while Jeyamary and Jayabalan (1997) reported highest number of embryos with 2,4-D.

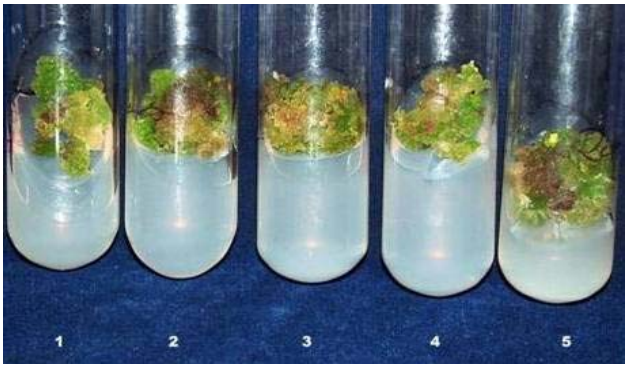

Fig. 2. Somatic embryogenesis from primary leaf explant on MS medium + 2 mg/l NAA + 0.2 mg/l BA at four weeks after inoculation
Genotypes : (1) JCS-402, (2) Hima, (3) RT-125, (4) Rajeswari and (5) Swetha

On the whole, the results reveal that among the eight media combinations studied, MS medium supplemented with 2.0mg/l BA and 0.2 mg/l NAA (T_5) recorded the highest callus percentage of 51.4 followed by MS medium supplemented with 0.2 mg/l BA and 0.1 mg/l NAA (T_1) (45.5%). MS Medium supplemented with 0.2 mg/l BA and 0.2 mg/l NAA (T_2) recorded the least callus induction of 36.5%. Further, of the three explants under study, hypocotyls responded well for callus induction in the selected genotypes JCS-402, Hima, RT-125, Rajeshwari and Swetha.

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Combining ability for kernel yield and its component traits in groundnut (*Arachis hypogaea* L.)

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ABSTRACT

Combing ability was estimated among eight parents for yield and its contributing traits in groundnut. Both *per se* performance and *gca* effects were considered for judging the genotype as best parent. The Virginia bunch genotype GG 21 and Spanish bunch genotypes TMV Gn 13 and VRI Gn 6 recorded significant *gca* effect for kernel yield, pod yield, number of mature pods and number of primaries. Hence, these genotypes were categorized as good combiners. The cross GG 21 x VRI Gn 6 registered significant *sca* effect for kernel yield, pod yield, number of mature pods and plant height; while VG 104 x VRI 3 recorded significant *sca* effect for kernel yield, pod yield, number of mature pods, number of secondaries and number of primaries. The former cross involves parents with good combiners. Hence, pedigree breeding method could be adopted to isolate desirable recombinants. However, the later cross involved parents with poor combiners. Hence, biparental mating followed by selection is recommended for the identification of desirable recombinants.

Keywords: General combining ability, Groundnut, Pedigree breeding, Specific combining ability

The cultivated groundnut (*Arachis hypogaea* L.) consists of six botanical types *viz*., var. *hypogaea,* var. *hirsute,* var. *fastigiata,* var. *peruviana,* var. *aequatoriana* and var. *vulgaris* (Holbrook and Stalker, 2010). Of which *vulgaris* type occupied majority of the groundnut area in India. The progress of groundnut research is slow due to its narrow genetic base and lack of adequate genetic variability in the available germplasm. Above all, most of the traits are governed by non-additive gene action which makes the selection difficult. In spite of these genetic hurdles, tremendous achievements were made in developing several high yielding varieties/genotypes. Choice of desirable parent for hybridization is the crucial step of any crop breeding programme. Hence, the present investigation is made to ascertain the nature of gene action governing yield and its component traits in groundnut. Combining ability is an efficient tool which helps in the identification of desirable parent. The selected good combiner could be later utilized in the crossing programme to bring out desirable combination of genes, which in turn helps to formulate suitable breeding strategy to develop high yielding genotypes with desirable agronomic traits.

MATERIALS AND METHODS

The experimental materials of this study consists of eight genotypes which includes four lines (GG 21, VG 104, TCGS APNL 888 and K 134) and four testers (TMV Gn 13, VRI Gn 6, VRI Gn 7 and VRI 3). The characteristic features of the genotypes are appended in Table 1. The four lines were crossed with four testers in a L x T mating fashion and the resultant F_1 hybrids were raised along with the parents during *kharif* 2010 in a Randomized Complete Block Design with three replications in the New Farm of Regional Research Station, Vridhachalam, Tamil Nadu. The hybrids were raised in 10 rows of 5m length while, parents were raised in 5 rows of 5m length. The spacing adopted was 30 x 15 cm. Twenty plants were selected at random in each replication and observations were recorded for plant height, number of primaries, number of secondaries, number of mature pods, pod yield, kernel yield/plant and shelling out turn. The data was analysed statistically as per the method suggested by Kempthorne (1957).

Table 1 Characteristic features of the eight genotypes of groundnut

Name of the genotype	Habit group	Pedigree	Year of release	Special features
GG 21	VB	Somnath x NcAc 2232	2004	Bold kernels with tan colour testa
K 134	SB	Kadiri 3 x JL 24	1993	Tolerant to drought and leaf spot diseases.
VG 104	SB	ICGV 86950 x VRI Gn 5	-	High yielding type
TCGS APNL 888	SB	TIR 46 x JUG 37	-	High yielding type
TMV Gn 13	SB	Selection from Pollachi Red	2006	Tolerant to terminal water stress, red kernel testa
VRI Gn 6	SB	ALR 2 x VG 9513	2006	Tolerant to LLS, rust and PBND
VRI Gn 7	VB	TMV 1 x JL 24	2008	Suitable for rainfed condition
VRI 3	SB	J 11 x Robut 33-1	1990	Early maturity, suitable for intercropping in sugarcane

VB - Virgnina Bunch; SB - Spanish Bunch

RESULTS AND DISCUSSION

The mean square due to lines and testers are highly significant for all the traits indicating the diverse nature of parents studied (Table 2). Obviously, due to the diverse nature of the lines and testers, the crosses between them are also found to be significant for all the traits. Significant nature of line x tester interaction indicated the importance of specific combining ability. The variance due to *sca* was greater than the variance due to *gca* for all the traits which indicated the preponderance of non-additive gene action in the expression of these traits (Table 2). Non-additive gene action for these traits was earlier reported by Senthil and Vindhiyavarman (1998), Rudraswamy *et al.* (2001), Jayalakshmi *et al.* (2002), Mathur *et al.* (2003), Rekha *et al.* (2009) and Mothilal and Ezhil (2010). Upadhyaya *et al.* (1992) observed non-additive gene action for pod and kernel yield and shelling outturn. Vindhiyavarman and Raveendran (1994) reported non-additive gene action for number of pods and pod yield.

***Per se* performance of parents**: The first criterion of choosing desirable parent is it's *per se* performance for the trait of interest. Among the eight parents evaluated in the present study, the line parent GG 21, recorded significantly superior *per se* performance for kernel yield, pod yield, number of mature pods, number of secondaries and number of primaries (Table 3). Hence, the parent may be chosen as a best parent. The tester parent VRI Gn 7, is observed significantly higher *per se* performance for number of primaries alone. Rest of the parents is not significant for most of the traits studied.

***GCA* effects of parents**: Cases, where high *per se* performing parents may not transmit their superior traits to their offsprings. Hence, general combining ability effect is considered as the second criterion of selection of superior parents. Table 4 illustrates *gca* effects of parents for various traits studied. The line parent GG 21 recorded significant *gca* effect for kernel yield, pod yield, number of mature pods and number of primaries. The tester parent TMV Gn 13 is also observed significant *gca* effect for kernel yield, pod yield, number of secondaries and number of primaries. However, it noticed negatively significant *gca* effect for number of mature pods which is one of the important yield contributing trait. Another tester parent VRI Gn 6 showed significant *gca* effects for all the traits except plant height. For shelling outturn, two parents *viz*., K 134 and VRI Gn 7 were observed significant *gca* effect. Selection of parents based on *gca* effects is more reliable than *per se* performance of parents alone. Based on *gca* effects, the parents *viz.,* VRI Gn 6, TMV Gn 13 and GG 21 were adjudged as good combiners for yield and one or more yield components.

***Per se* performance of crosses**: Perusal of the *per se* performance of 16 crosses revealed that, the cross GG 21 x VRI Gn 6 registered significantly higher *per se* performance for kernel yield, pod yield, number of mature pods, number of secondaries, number of primaries and plant height (Table 5). Another cross VG 104 x TMV Gn 13 recorded significantly superior *per se* performance for pod yield and kernel yield alone. However, the cross GG 21 x TMV Gn 13 observed significantly superior *per se* performance for pod yield and number of secondaries.

Table 2 Analysis of variance of combining ability for yield and its components in groundnut

Source of variation	df	Mean squares						
		Plant height	Number of primaries	Number of secondaries	Number of mature pods	Pod yield (g)	Kernel yield (g)	Shelling outturn (%)
Replication	2	0.302	0.00	0.405	0.283	1.398	1.264	0.400
Treatment	23	88.661**	5.049**	4.892**	34.972**	58.686**	29.039**	13.588**
Parent	7	94.45**	6.868**	3.729**	75.374**	78.716**	38.062**	30.898**
Parent vs Crosses	1	777.88**	9.139**	0.770	2.454	137.880**	83.701**	9.664
Crosses	15	40.007**	3.928**	5.710**	18.285**	44.06**	21.184**	5.772
Lines	3	38.591**	1.958**	1.501*	6.847*	54.535**	25.946**	7.023**
Tester	3	9.046	10.802**	22.010**	55.203**	80.741**	36.394**	5.985**
Line x Tester	9	50.800**	2.293**	1.671**	9.792**	28.341**	14.527**	5.284**
Error	26	3.425	0.321	0.356	1.761	2.929	1.716	0.946
σ^2 gca		-0.5621	0.0852	0.2099	0.4423	0.8187	0.3467	0.0254
σ^2 sca		23.6873	0.9861	0.6615	4.0153	12.706	6.4056	2.1689
σ^2gca / σ^2 sca		-0.023	0.086	0.317	0.110	0.064	0.054	0.011

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

Table 3 *Per se* performance of parents for yield and yield components

Parents	Plant height (cm)	Number of primaries	Number of secondaries	Number of mature pods	Pod yield (g)	Kernel yield (g)	Shelling outturn (%)
Lines							
GG 21	43.25	7.75**	4.25*	27.50**	27.22**	19.26**	71.20
VG 104	42.78	6.55	2.86	12.98	12.58	9.14	72.10
K 134	40.92	3.75	0.75	8.66	6.78	4.38	63.16
TCGS APNL 888	34.48	3.93	1.39	14.15	15.76	10.25	71.84
Testers							
TMV Gn 13	56.25	4.00	2.17	7.41	8.33	6.44	75.25
VRI Gn 6	40.99	4.10	2.75	12.93	12.13	9.24	75.01
VRI Gn 7	42.74	8.26**	3.80	11.06	11.96	9.18	74.94
VRI 3	52.25	4.66	0.50	12.84	11.09	8.28	73.80
General Mean	38.52	5.99	2.49	13.76	15.63	11.39	72.81
CD (P=0.05)	5.12	1.08	1.44	2.808	3.879	3.21	3.93
CD (P=0.01)	6.95	1.47	1.95	3.813	5.265	4.36	5.34

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

Table 4 Estimates of general combining ability (*gca*) effects for yield and yield components

Parents	Plant height (cm)	Number of primaries	Number of secondaries	Number of mature pods	Pod yield (g)	Kernel yield (g)	Shelling outturn (%)
Lines							
GG 21	3.08**	0.52*	0.29	1.30*	3.65**	2.53**	-1.06**
VG 104	-0.08	-0.06	0.20	-0.03	0.12	0.04	-0.50
K 134	-1.03	-0.65**	0.16	-0.83	-1.80**	-1.32*	0.87*
TCGS APNL 888	-1.98**	0.18	-0.65**	-0.44	-1.97	-1.25*	0.69
S.E.(gi)	0.51	0.11	0.17	0.51	0.42	0.37	0.09
Testers							
TMV Gn 13	-0.29	0.44*	1.11**	-2.02**	1.47*	1.11*	0.15
VRI Gn 6	0.61	1.43**	1.72**	3.86**	3.14**	2.22**	-0.02
VRI Gn 7	-1.36	-1.14**	-1.26**	-0.86	-4.26**	-2.65**	0.99*
VRI 3	1.04	-0.73**	-1.57**	-0.98	-0.35	-0.68	-1.12**
S.E. (g_i)	0.35	0.09	0.12	0.36	0.27	0.29	0.05

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

Table 5 *Per se* performance of 16 crosses for yield and yield components

Crosses	Plant height (cm)	Number of primaries	Number of secondaries	Number of mature pods	Pod yield (g)	Kernel yield (g)	Shelling outturn (%)
GG 21 x TMV Gn 13	38.37	6.96	4.60**	12.69	21.10*	14.99	70.43
GG 21 x VRI Gn 6	46.43**	8.27**	5.05**	23.32**	30.42**	22.03**	72.24
GG 21 x VRI Gn 7	32.40	5.80	1.30	12.50	13.06	10.14	74.93
GG 21 x VRI 3	37.81	6.27	0.50	12.37	17.32	12.25	70.65
VG 104 x TMV Gn 13	32.25	4.86	2.76	12.29	17.27	12.63	72.97
VG 104 x VRI Gn 6	35.39	7.98**	4.79**	15.51	16.65	12.34	74.00
VG 104 x VRI Gn 7	36.63	5.47	1.31	12.33	11.99	9.16	74.09
VG 104 xVRI 3	38.08	6.66	2.25	15.45	21.89**	15.33*	69.44
K 134 x TMV Gn 13	31.11	7.09	5.02**	11.45	18.06	13.55	74.87
K 134 x VRI Gn 6	32.57	7.74*	3.47	15.45	15.76	11.49	74.03
K 134 x VRI Gn 7	39.84	3.88	1.98	13.94	13.32	10.18	73.63
K 134 x VRI 3	35.06	3.89	0.48	11.51	12.97	8.78	73.47
TCGS APNL 888 x TMV Gn 13	39.80	8.06**	2.38	11.18	16.78	12.57	74.85
TCGS APNL 888 x VRI Gn 6	30.72	6.92	3.89*	16.85*	17.02	12.30	72.14
TCGS APNL 888 x VRI Gn 7	28.36	5.50	0.66	13.47	11.90	9.21	73.80
TCGS APNL 888 x VRI 3	35.89	5.46	0.79	12.45	13.71	10.20	74.49
General Mean	35.67	6.30	2.58	13.92	16.83	12.32	73.13
CD (P=0.05)	3.942	1.206	1.272	2.827	3.645	2.790	2.072
CD (P=0.01)	5.460	1.671	1.762	3.915	5.048	3.864	2.869

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

***SCA* effects of crosses**: In contrast to the *gca* effect being attributed to additive genetic effects, *sca* effects denote dominance and epistatic effects that are non-fixable components of genetic variation. The cross GG 21 x VRI Gn 6 registered significant *sca* effect for kernel yield, pod yield, number of mature pods and plant height (Table 6). Appreciably their *per se* performance for kernel yield, pod yield and number of mature pods was also significantly higher. In this cross the parents involved are good combiners for the aforesaid traits. Such crosses could be exploited through pedigree breeding which may throw superior performing segregants in the later generations. The cross VG 104 x VRI 3 exhibited significant *sca* effects for kernel yield, number of mature pods, number of secondaries and number of primaries. The cross also exhibited higher *per se* performance for pod and kernel yield. The cross involved parents with poor combiners indicating operation of non-additive gene action in controlling these traits. Hence, biparental mating followed by selection might be worthwhile for fostering greater recombination in this cross (Francies and Ramalingam, 1999).

From the foregoing discussion, it was concluded that the parents GG 21, TMV Gn 13 and VRI Gn 6 could be extensively used in the hybridization programme as these genotypes possessed good combiners for kernel yield, pod yield, number of mature pods and number of primaries. The cross GG 21 x VRI Gn 6 involved parents with good combiners. Hence, pedigree method of breeding could be effectively executed to identify desirable recombinants. However, the cross VG 104 x VRI 3 involved parents with poor combiners. Biparental mating followed by selection may be recommended for developing genotypes with desirable attributes.

Table 6 Estimation of specific combining ability (*sca*) effects for yield and yield components

Crosses	Plant height	Number of primaries	Number of secondaries	Number of mature pods	Pod yield (g)	Kernel yield (g)	Shelling outturn (%)
GG 21 x TMV Gn 13	-0.09	-0.30	0.63	-0.51	-0.85	-0.97	-1.78*
GG 21 x VRI Gn 6	7.07**	0.01	0.46	4.24**	6.80**	4.96**	0.20
GG 21 x VRI Gn 7	-4.99	0.11	-0.30	-1.86	-3.16*	-2.07*	1.88*
GG 21 x VRI 3	-1.98	0.17	-0.79	-1.88	-2.80*	-1.92	-0.30
VG 104 x TMV Gn 13	-3.06*	-1.83**	-1.13*	0.42	-1.15	-0.85	0.19
VG 104 x VRI Gn 6	-0.80	0.31	0.29	-2.24*	-3.43*	-2.24*	1.40
VG 104 x VRI Gn 7	2.40	0.37	-0.20	-0.70	-0.71	-0.56	0.48
VG 104 x VRI 3	1.49	1.15*	1.04*	2.53*	5.29**	3.65**	-2.07**
K 134 x TMV Gn 13	-3.25*	1.00*	1.17*	0.39	1.55	1.44	0.72
K 134 x VRI Gn 6	-2.68	0.66	-0.99*	-1.50	-2.41	-1.73	0.06
K 134 x VRI Gn 7	6.56**	-0.63	0.51	1.71	2.56	1.83	-1.35
K 134 x VRI 3	-0.68	-1.03*	-0.69	-0.60	-1.70	-1.54	0.58
TCGS APNL 888 x TMV Gn 13	6.40**	1.13*	-0.66	-0.29	0.45	0.39	0.88
TCGS APNL 888 x VRI Gn 6	-3.58*	-0.99*	0.24	-0.50	-0.97	-0.99	-1.66*
TCGS APNL 888 x VRI Gn 7	-3.97**	0.15	-0.01	0.85	1.31	0.79	-1.01
TCGS APNL 888 x VRI 3	1.16	-0.29	0.43	-0.06	-0.79	-0.19	1.79*
S.E(Si_j)	1.850	0.566	0.597	1.327	1.711	1.310	0.972
CD (P=0.05)	3.942	1.206	1.272	2.827	3.645	2.790	2.072
CD (P=0.01)	5.460	1.671	1.762	3.915	5.048	3.864	2.869

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

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Stability analysis for traits related to water use efficiency in sunflower (*Helianthus annuus* L.)

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ABSTRACT

The present study was conducted to evaluate the stability of 41 genotypes with respect to various morphophysiological traits affecting water use efficiency in sunflower. The four water stress environments were created by skipping irrigation at different plant growth stages. The data were recorded for canopy temperature (°C), photosynthetic capacity, leaf area index, leaf water potential (mpa), days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), 100-seed weight (g), seed yield/plant (g) and oil content (%). The analysis of variance revealed that the genotypes and environment (linear) showed significant interaction for all the traits under study which indicated that phenotypic expression of all the genotypes for these characters was influenced significantly by environments. The pooled deviations for all the characters were significant indicating that the performance of genotypes varied in different environments. The phenotypic stability of genotypes was measured by three parameters namely mean performance over environments, regression coefficient and deviation from regression line. The genotypes *viz*., P112R, NDLR1 and 7-1-B for days to 50% flowering ; P107RP2, P112R, 304B and 52B for days to maturity; P93R, P69R and P115R for seed yield/plant; P124R and 45B for 100-seed weight and P93R, 95C1R and P91R for oil content showed stable performance over different water stress environments. None of the genotypes was found stable for plant height.

Keywords: Morphophysiological parameters, Sunflower, Water use efficiency

A breeder's objective is to develop cultivars with high and stable yield having high oil content which is an important aspect of any oilseed crop (Balalic *et al*., 2011). It is important to understand the effect of different environments on seed yield and oil content and to identify suitable genotypes which can give optimum yield and oil content under different growth environments. Moreover, the present alarming situation of depleting underground water advocates saving of water. Thus to cope with such a situation the water use efficient genotypes need to be identified so that, the number of irrigations can be reduced. Stable yield of a variety means that its rank relative to other varieties remains unchanged in a given environment i.e., maximum stability occurs with equal ranks in different environments. A variety is considered adaptive or stable if it has a high mean yield, but a low degree of fluctuation in yielding ability when grown in diverse environments (Arshad *et al*., 2003 and Tuba and Dogan, 2006). The present research work was undertaken to study stability of performance of germplasm lines with respect to various morphophysiological parameters affecting water use efficiency across different irrigation levels with an objective to identify few water use efficient lines for future use in breeding programmes.

MATERIALS AND METHODS

The experimental material comprised 41 lines of sunflower comprising 16 maintainer lines and 25 restorer lines (Table 1). Of these, 30 lines have been introduced from other research stations *viz*., R273, RCH8297, RHA297 from DOR, Hyderabad; 234B from UAS, Bangalore and 11 lines have been developed at PAU, Ludhiana. The experiment was repeated four times to create four different environments by providing following irrigation regimes: W_1: (Irrigation level 01) Irrigating the plots during the entire growth cycle to maintain the soil water content close to field capacity; W_2: (Irrigation level 02) Withholding of 2nd irrigation i.e., before button stage and there after complete withholding of irrigations after soft dough stage; W_3: (Irrigation level 03) Withholding of irrigation at 50% flowering stage and soft dough stage thereafter complete withholding of irrigations after hard dough stage; W_4: (Irrigation level 04) Withholding of irrigation at anthesis completion stage and there after complete withholding of irrigation after soft dough stage. The genotypes were assessed for their stability of performance over environments as suggested by Eberhart and Russell (1966). The canopy temperature was measured by Infrared thermometer in intact plants of each plot. The unit of measurement was degree centigrade (°C). Flaurometer reading was considered to study the PS II activity by chlorophyllflauro meter (Model -0530P).

RESULTS AND DISCUSSION

Analysis of variance revealed significant due to genotype and environment for all the characters studied (Table 2). According to Eberhart and Russell (1996) model, the genotype x environment interaction was further partitioned into linear and non-linear components. The pooled analyses of variance revealed that variance due to pooled deviations

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were highly significant (Table 2). Thus, it showed the significant role of non-linear components of genotype x environment interaction in determining the stability of performance of all the characters. The variances due to genotypes were significant for all the characters which indicated that sufficient genetic variability was present among the genotypes under investigation. The environments (linear) were significant against pooled deviations for all the characters, whereas genotype x environment (linear) interactions were significant against pooled deviations for biological yield and harvest index. These results indicated that variation in the performance of genotypes when grown over these environments is predictable for leaf water potential, leaf area index, canopy temperature, photosynthetic capacity, days to 50% flowering, days to maturity, plant height (cm), head diameter (cm), 100-seed weight (g), seed yield/plant (g) and oil content (%). The variation due to pooled deviation was significant for all the characters, which indicated that genotypes differed with respect to their stability. The perusal of the stability analysis of variance presented in Table 2 revealed that pooled deviations were significant against pooled error and environment (linear) was significant against pooled deviations for all the characters under study.

Based on three parameters of stability i.e., mean performance across four environments, regression coefficients and deviations from regression line, a genotype is considered to be stable if it shows high mean value i.e., above average performance, unity regression coefficient (bi) with non-significant deviation from regression line (δ^2di). These stability parameters are presented in Tables 3 to 5 and character wise results are elaborated as follows:

Physiological parameters: The mean canopy temperature (mean of five plants from each row) presented in Table 3 revealed that twenty genotypes performed above average. The genotype P-107-R-P2 registered the highest canopy temperature (29.3) followed by P-94-R (29.3), P-91-R (28.9), P-93-R (28.8), 3376-R (28.6), P-110-R (28.5), P-119-R (28.5), 44-B (28.4), P-75-R (28.4), 395-B (28.9), 304-B (28.7) and 11-B (28.2). Stability parameters (Table 3) indicated that genotypes, P-93-R, 3376-R, P-119-R, 40-B and RCR-8297 showed unit regression and highly significant deviations from regression line except 3376-R and P-119-R. The genotypes P-107-R-P2, P-69-R and 11-B had shown high mean and below average response to environmental changes (b<1) which indicated their suitability for poor environments but, their performance is unpredictable. The genotypes P-93-R, P-94-R, 10-B and 36-B exhibited high mean and above average response to environmental changes (b>1) hence they are expected to perform well under favourable environments but their performance would be unpredictable. Genotypes P-61-R, 95-C-1-R, P-112-R, P-121-R, NDLR-2, 304-B and 395-B, would be suitable to poor environments with predictable performance as they exhibited high mean, below average response to environments (b<1) and no significant deviation from regression line.

Table 1 List of 41 sunflower genotypes tested for stability analysis

Genotypes/Source	Genotypes/Source	Genotypes/Source	Genotypes/Source	Genotypes/Source
1 P61R/RHA-61	10 P100R/LIPO-8-1	19 P119R/1538-1	28 11B/PAU, Ludhiana	37 52B/PAU, Ludhiana
2 R273/DOR, Hyderabad	11 P110R/RHA 855	20 P121R/GP6-35	29 304B/Bangalore	38 53B/PAU, Ludhiana
3 P93R/GP2-378	12 P87R/OPH-15-1	21 P124R/OPH-29-4-1	30 395B/Perendovic 301	39 36B/PAU, Ludhiana
4 95C1R/Bangalore	13 P89R/GP4-280	22 NDLR2/Nandyal	31 7-1-B/Andhra Pradesh	40 RCR8297/DOR, Hyderabad
5 P91R/GP4-357	14 P75R/OPH-34-1-1	23 NDLR1/Nandyal	32 45B/PAU, Ludhiana	41 RHA297/DOR, Hyderabad
6 P107RP2/OPH	15 P94R/GP2-661	24 44B/-	33 47B/PAU, Ludhiana	
7 P107RP1/OPH	16 P111R/GP2-2861	25 40B/PAU, Ludhiana	34 48B/PAU, Ludhiana	
8 P69R/IL-50-1	17 P112R/DRS1-414	26 10B/PAU, Ludhiana	35 49B/PAU, Ludhiana	
9 3376R/DOR, Hyderabad	18 P115R/GP2-237	27 234B/Bangalore	36 50B/PAU, Ludhiana	

Table 2 Analysis of variance for stability of different characters

Source of variation	d.f.	Mean Squares										
		CT	PS	LAI	WP	DF	DM	PH	HD	SY	SW	OC
Genotypes	40	1.35**	1.80**	1.25**	0.99**	4.62**	5.00**	4.25**	5.00**	3.56**	5.00**	5.40**
Env.+ (Env x Geno)	123	28.20**	35.42**	35.61**	31.59**	5.76**	7.81**	10.75**	4.25**	3.45**	8.86**	6.25**
Env.(linear)	1	4,266.32**	0.06	1.71**	2.52**	111.82**	204.27**	8,291.35**	141.66**	1,408.24**	61.23**	729.67**
Geno x Env.	40	1.68**	43.66**	3.16**	43.01**	1.43**	3.54**	205.86**	2.06**	33.64**	0.21**	16.56**
Pooled deviation	82	0.56**	32.11**	51.85**	28.13**	0.63**	0.53**	0.60	0.57**	0.53*	0.45**	0.47
Pooled error	320	0.19	0.02	0.30	0.05	0.31	0.23	2.44	0.09	0.47	0.02	1.05

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

CT : Canopy Temperature; PS : Photosynthetic Capacity; LAI : Leaf Area Index; LWP : Leaf Water Potential; DF: Days to 50% Flowering; DM : Days to Maturity; PH: Plant Height; HD : Head Diameter; SY : Seed Yield/Plant; SW : 100-Seed Weight; OC : Oil Content

The perusal of the Table 3 revealed that the genotypes P-75-R, 40-B and 395-B (0.75) recorded the highest photosynthetic capacity followed by 95-C-1-R (0.74), P-91-R (0.73), P-100-R (0.73), P-111-R (0.72) and 3376-R (0.71). All genotypes showed regression less than unity, except P-69-R, P-107-R-P1, P-124-R, P-115-R and 3376-R. The stability parameters indicated that the genotypes P-91-R, P-100-R, P-94-R, P-111-R, P-112-R, 44-B, 40-B and 45-B had shown above average mean performance and below average response to environments (b<1) but exhibited significant deviation from regression line thus these are suitable for unfavourable environments but their performance is unpredictable. While the genotypes P-69-R, 3376-R and P-115-R exhibited high mean, above average response (b>1) and significant deviations from regression line hence are suitable to favourable environments but with unpredictable performance. Genotypes 40-B and 11-B were found to be stable for photosynthetic capacity across the environments. Sufficient variability was observed among the genotypes for leaf area index (Table 3). The data revealed that leaf area index was highest in RHA-297 (0.99). The genotypes 36-B (0.94), P-112-R (0.95), P-100-R (0.89), 10-B (0.80), P-110-R (0.70), 44-B (0.54), 10-B (0.53) and P-121-R (0.56) showed above average mean performance. The genotypes P-121-R and 50-B exhibited unity regression coefficient but exhibited significant deviations from regression line hence will perform better over favourable environment but their performance will be unpredictable. It was further observed that, genotypes P-100-R, 40-B and 36-B showed high mean, below average response (b<1) and no significant deviations from regression line hence are suitable to poor environments with predictable performance. However the genotype P-94-R exhibited high mean, above average response and no significant deviation from regression line therefore suitable for favourable environments and their performance would be predictable.

The mean performance of genotypes over the environments (Table 3) revealed that the genotype 52-B (-1.96) had the highest, whereas 11-B (-3.21) had the lowest mean value for leaf water potential. Stability parameters revealed that genotypes P-107-R-P2 (-1.69), 45-B (-2.03), P-75-R (-2.03), RHA-297 (-2.16), 40-B (-2.31), P-61-R (-2.36), P-119-R (-2.36), 44-B (-2.51), P-121-R (-2.56), 36-B (-2.63) and 234-B (-2.66) exhibited above average mean performance. All genotypes expressed below unity regression (b<1) except P-87-R, P-111-R, 10-B and 11-B. Among all, only five genotypes i.e., P-112-R, P-121-R, 10-B, 234-B and 45-B were found stable and ideal for leaf water potential as it exhibited above average mean performance, below unity regression and non-significant deviation from regression line. The genotypes P-75-R, 7-1-B and 52-B had high mean, below average response to environmental changes (b<1) and significant deviations from regression line hence, they are suitable for poor environments but, their performance is unpredictable. The genotype 10-B can be suitable for favourable environments as they possessed high mean and above average response to environmental changes (b>1) with predictable performance. Earlier study by Ahmad *et al*. (2009), Ghafoor and Ahmad (2005) and Rao *et al*. (2004) have been mainly confined to morphological traits only. No relevant literature pertaining to these parameters for physiological traits is available till now and this is the first study to evaluate physiological traits for stability parameters.

Morphological parameters: The mean performance of different genotypes presented in Table 4 revealed that genotype P-112-R (75.75) took maximum days to 50% flowering followed by P-111-R (73.26), NDLR-1 (74.58), 234-B (67.00), 7-1-B (66.58), 10-B (66.2), 395-B (66.67), RCR-8297 (66.17), RHA-297 (66.00), 36-B (65.92), 53-B (65.17), P-107-R-P1 (65.08) and P-93-R (65.00). High amount of variability was indicated from this character. The presence of high amount of variability among different genotypes in sunflower for days to flowering has also been reported by Rao *et al*. (2004). Stability parameters indicated that the genotypes i.e. P-93-R and P-91-R had unit regression and significant deviation from regression line, however, the genotypes P-112-R, NDLR-1 and 7-1-B also showed unit regression but no significant deviation from regression line. Hence these genotypes will perform better over better environment with predictable performance i.e. can be considered as stable genotypes. The genotypes P-115-R, P-124-R, 10-B, 234-B, 45-B, 53-B, 36-B, RCR-8297 and RHA-297 had high mean, below average response (b<1) and significant deviations from regression line, hence they are suitable to poor environments with unpredictable performance.

The mean performance for days to maturity over four environments given in Table 4 revealed that 53-B (94.75) had the maximum number of days to maturity. The other genotypes which recorded above average days to maturity were P-94-R (94.17), 52-B (94.08), P-93-R (93.67), 95-C-1-R (93.92), 44-B (93.42), P-112-R (93.25), 10-B (93.17), P-91-R (93.08) and P-111-R (92.67). The "b" value for all these genotypes was non-significant except P-107-R-P1, P-115-R, 10-B, 53-B and 36-B whereas deviations from regression line were significant except P-107-R-P2, P-112-R, 44-B, 304-B and 42-B.

The stability parameters (Table 4) showed that the genotypes P-107-R-P2, P-112-R, 304-B, and 52-B had shown high mean, below average response to environments (b<1) and no significant deviation from regression line thus these genotypes are expected to do well under poor

environments, and their performance would be predictable. While the genotype 44-B showed high mean above average response (b>1) and no significant deviation from regression line hence these genotypes are suitable to favorable environment and its performance is predictable.

The data presented in Table 4 showed that P-112-R (190) recorded the maximum height followed by P-111-R (151.67), 45-B (147.17), 95-C-1-R (139.17), P-89-R (137.83), P-75-R (132.67), NDLR-1 (132.33) and P-91-R (131.00), 44-B (130.17), 7-1-B (127.92), P-119-R (127.33), P-87-R (127.25), 53-B (126.58), RCR-297 (126.00), NDLR-2 (125.42), P-93-R (124.50) and 50-B (121.42). All the genotypes exhibited regression coefficient less than unity, but exhibited significant deviations from regression line. Similar observations were made by Ahmad *et al.* (2009) while studying the stability of plant height. None of the genotypes fulfilled all the three requirements for a stable genotype, therefore it can be concluded that all the genotypes under investigation were significantly influenced by the environments and no genotype was found to be stable across these environments.

The mean performance of genotypes (Table 4) showed that 53-B (15.10) recorded the maximum head diameter followed by P-91-R (14.92), P-112-R (14.88), 47-B (14.78), P-75-R (14.34), P-121-R (14.07), P-107-R-P1 (13.65), 48-B (13.51), 234-B (13.50), 49-B (13.30) and P-69-R (13.13). All the genotypes exhibited less than unity regression coefficient, except NDLR-1. Rao *et al*. (2004) also found that linear component of G x E interaction was significant whereas non-linear component of G x E interaction was not significant for head diameter. The genotypes P-107-R-P2, P-75-R, P-112-R, P-115-R, 47-B, 48-B and 50-B had high mean, below average response (b>1) and no significant deviation from regression line hence these genotypes are suitable to poor environment with predictable performance. Genotype NDLR-1 exhibited high mean, above average response (b<1) and significant deviations from regression line are suitable to favourable environments but, their performance is unpredictable.

Agronomic parameters: The mean seed yield/plant presented in Table 5 indicated that the genotypes P-87-R (52.12), P-111-R (44.18), P-107-R-P1 (42.56), P-75-R (38.76) and P-89-R (38.42) showed above average performance in the environments. The genotypes P-107-R-P1, P-75-R, P-119-R, NDLR-2 and 40-B exhibited high mean, above average response to environmental changes (b>1) and significant deviation from regression line hence, suitable for favourable environments but, its performance is unpredictable. Genotypes P-61-R and R-273 exhibited below average response to environmental changes (b<1), no significant deviations from regression line hence could be considered as stable but their yield performance is below the mean performance so cannot be recommended as high yielding water use efficient genotypes. Genotypes P-93-R, P-69-R and P-115-R recorded high mean performance, regression coefficients near to unity and no significant deviation from regression line. Therefore these genotypes will be suitable for poor environments (water stress conditions at different stages of crop growth) with predictable performance. Whereas, genotypes P-94-R and P-121-R exhibited high mean, above average response to environmental changes (b>1) and no significant deviation from regression line hence will be better for better environments and their performance will be predictable. Similar results for seed yield/plant were discussed by Balalic *et al*. (2011).

Twenty-one genotypes namely 7-1-B (10.75) with the highest mean performance, followed by P-89-R (7.19), P-124-R (6.96), 11-B (6.87), P-94-R (6.83), P-93-R (6.78), 53-B (6.67), 10-B (6.55), 40-B (6.53), 44-B (6.48), P-69-R (6.47), P-115-R (6.45), P-111-R (6.44), 52-B (6.43), P-61-R (6.42), NDLR-2 and 234-B (6.38), 45-B (6.27), 49-B (6.13), P-75-R (6.16), 49-B (6.13) and 47-B (6.08) showed higher 100-seed weight than the average mean (Table 5). Ahmad *et al.* (2009) also found that linear as well as non-linear components of G x E interaction were significant for 100-seed weight. Three genotypes namely P-61-R, P-89-R and P-75-R exhibited higher mean than the average, unity regression and no significant deviation from regression line, hence these genotypes are suitable to favourable environment with predictable performance. However genotypes P-94-R, 7-1-B, 47-B, 49-B, 52-B and 53-B exhibited higher mean than the average, unity regression but deviated significantly from regression line. The genotype P-124-R and 45-B fulfilled all three stability criteria with below average response (b<1) and non-significant deviation from regression line thus are suitable to unfavorable environments and their performance is predictable.

Sufficient variability was observed among the genotypes for oil content as reported by Balalic *et al.* (2011) in earlier studies. The perusal of Table 5 revealed that oil content was the highest in 52-B (42.56). The genotypes RCR-8297 (42.44), RHA-297 (41.91), 304-B (41.83), P-115-R (41.53), P-89-R (41.53), 234-B (41.47), 48-B (41.41), P-87-R (41.38), 50-B (41.37), P-111-R (41.33), P-100-R (41.30), P-69-R (40.73), P-110-R (40.56), 95-C-1-R (40.47), 395-B (40.34), P-124-R (40.17) and P-93-R (39.67) showed above average mean performance. All the genotypes exhibited regression coefficient less than unity but exhibited significant regression coefficient except P-93-R, 95-C-1-R and P-91-R. The genotypes P-94-R, NDLR-1, P-94-R and 3376-R had fulfilled the two criteria i.e. the regression coefficient and non-significant deviation from regression line showed that it was stable for oil content but its mean performance was below average hence cannot be considered as an ideal genotype. Significant G x E interaction for oil content were earlier noticed by Rao *et al.* (2004) and Ghafoor and Ahmad (2005).

From the results it is indicated that, genotypes 52-B, RCR-8297, RHA-297, P-115-R, P-89-R, P-87-R, P-111-R, R-273, 47-B, 48-B, 49-B, 50-B, 52-B and 234-B showed high mean, below average response (b<1) and significant regression coefficient for all yield associated traits. The genotypes P-93-R , 95-C-1-R and P-91-R having high mean for seed yield/plant, below average response to environments (b<1) and no significant deviation from regression line thus these would be suitable for unfavorable environments with predictable performance i.e., genotypes can be considered as stable over different environments. The ultimate aim of any breeding programme being high seed yield accompanied by high oil content, the genotypes P-93-R, P-69-R, and P-115-R which recorded high mean seed yield and no significant deviation from regression line could be considered as suitable genotypes for water stress conditions, which can be attributed to high photosynthetic capacity of these lines.

Table 3 Mean performance, regression coefficient (bi) and deviation from regression (δ^2di) for physiological characters

Inbred line	Canopy temperature (^{0}C)			Photosynthetic capacity			Leaf area index			Leaf water potential (mpa)		
	Mean	bi ± S.E.	δ^2di	Mean	bi ± S.E.	δ^2di	Mean	bi ± S.E.	δ^2di	Mean	bi ± S.E.	δ^2di
P-61-R	28.37	0.89 ± 0.05	0.36	0.67	0.23**± 0.06	0.13	0.40	0.82* ± 0.31	0.89*	-2.36	0.52*± 0.11	0.24
R-273	27.68	1.01 ± 0.04	0.17	0.65	0.24**± 0.03	0.05	0.38	1.25 **± 0.34	0.27**	-2.56	0.25*± 0.12	0.25
P-93-R	28.79	1.00 ± 0.08	0.76*	0.72	0.24*± 0.12	2.18**	0.39	1.24 *± 0.35	0.13	-3.01	0.16**± 0.08	0.14
95-C-1-R	27.98	0.73**± 0.01	0.02	0.74	0.25*± 0.17	1.07	0.36	1.64 ± 0.65	1.43**	-2.72	0.22**± 0.07	0.08
P-91-R	28.98	0.90 ± 0.06	0.48	0.73	0.3± 0.12	1.88*	0.38	1.29 *± 0.32	1.70**	-2.87	0.05**± 0.02	0.10
P-107-R-P_2	29.31	0.97 ± 0.16	2.87**	0.66	0.86 ± 0.06	0.44	0.42	1.67 **± 0.35	0.03	-1.69	0.32**± 0.05	0.10
P-107-R-P_1	28.38	0.87**± 0.02	0.08	0.63	1.03 ± 0.05	0.30	0.46	0.84 *± 0.30	2.40**	-2.78	0.12**± 0.05	0.12
P-69-R	28.28	0.95 ± 0.11	1.35**	0.73	1.11 ± 0.11	1.37**	0.38	1.28 ± 0.34	1.47**	-2.99	0.21**± 0.02	0.02
3376-R	28.59	1.11 ± 0.05	0.35	0.71	1.02 ± 0.08	0.84**	0.51	0.87 *± 0.38	2.07**	-2.63	0.13**± 0.03	0.05
P-100-R	27.93	0.95 ± 0.09	0.95**	0.73	0.80 ± 0.12	1.72**	0.89	0.75 ± 0.33	0.04	-3.03	0.84*± 0.03	0.10
P-110-R	28.51	1.15**± 0.01	0.04	0.69	0.68**± 0.68	0.01	0.70	0.80 **± 0.40	0.35	-2.97	0.84 ± 0.07	0.54
P-87-R	27.97	1.17*± 0.04	0.25	0.70	0.25**± 0.08	1.83	0.53	1.29 *± 0.45	0.07	-2.59	1.12*± 0.05	0.30
P-89-R	27.08	1.19*± 0.05	0.30	0.68	0.07**± 0.04	0.90	0.42	1.63 ± 0.42	2.14**	-2.65	0.78 ± 0.05	0.37
P-75-R	28.39	1.20**± 0.02	0.07	0.75	0.09**± 0.02	0.43	0.42	0.93 ± 0.41	0.45	-2.03	0.96 ± 0.31	1.81**
P-94-R	29.27	1.10 ± 0.09	0.96**	0.74	0.86 ± 0.47	0.25**	0.57	1.35 ± 0.36	0.32	-3.13	0.69 ± 0.24	0.19
P-111-R	27.65	1.11 ± 0.08	0.78*	0.72	0.64 ± 0.26	0.10**	0.43	1.27 **± 0.38	0.54	-2.70	1.11*± 0.23	0.15
P-112-R	28.05	1.10 ± 0.08	0.76*	0.73	0.85 ± 0.37	0.21*	0.95	1.40 *± 0.37	0.74	-2.66	0.88 ± 0.20	0.15
P-115-R	28.6	1.09*± 0.02	0.08	0.69	1.11 ± 0.89	1.11**	0.32	0.89 ± 0.38	0.17	-3.21	0.99 ± 0.03	0.13
P-119-R	28.47	1.11 ± 0.05	0.33	0.67	0.87 ± 0.34	0.17**	0.29	1.67 ± 0.39	0.67	-2.36	1.10**± 0.02	0.08
P-121-R	28.25	1.11 ± 0.06	0.38	0.70	0.69 ± 0.24	0.19	0.56	0.81 ± 0.29	1.57**	-2.56	0.98 ± 0.04	0.21
P-124-R	28.56	0.84*± 0.03	0.10	1.16	1.11*± 0.23	0.15	0.47	1.61 ± 0.29	1.38**	-3.01	0.36 ± 0.20	0.14
NDLR-2	28.38	0.84 ± 0.07	0.54	0.70	0.28 ± 0.20	0.15	0.52	1.24**± 0.59	0.12	-2.78	0.70**± 0.02	0.00
NDLR-1	27.15	1.12*± 0.05	0.30	0.70	0.80 ± 0.20	0.18	0.38	0.97 ± 0.27	0.21	-2.99	0.44*± 0.09	0.03
44-B	27.95	0.78 ± 0.05	0.37	0.71	0.33 ± 0.22	1.18**	0.54	1.81 **± 0.74	0.06	-2.51	0.53*± 0.12	0.06
40-B	28.43	1.05 ± 0.09	0.95*	0.75	0.77 ± 0.12	0.16	1.04	0.98 ± 0.35	0.04	-2.31	0.17**± 0.01	0.00
10-B	27.76	1.02 ± 0.08	0.69*	0.62	0.28 ± 0.13	0.02	0.53	0.81**± 0.20	0.45	-2.26	1.13 ± 0.40	0.45
234-B	27.26	0.83 ± 0.07	0.57*	0.67	0.59*± 0.28	0.08	0.47	1.32 ± 0.33	0.39	-2.66	0.58 ± 0.37	0.39
11-B	28.22	0.98 ± 0.15	2.65*	0.71	0.83 ± 0.13	0.39	0.33	1.59 **± 0.36	0.61	-3.21	1.12 ± 0.47	0.61
304-B	28.36	0.80 ± 0.03	0.11	0.73	0.58*± 0.42	0.09	0.49	0.77 ± 0.45	0.08	-2.96	0.27 ± 0.17	0.08
395-B	28.38	0.99 ± 0.03	0.13	0.75	0.45 ± 0.10	0.89*	0.45	1.08* ± 0.14	0.05	-2.90	0.52**± 0.44	0.05
7-1-B	26.96	1.10**±0.02	0.08	0.64	0.65 ± 0.28	0.27**	0.35	0.91± 0.41	2.03**	-2.61	0.50 ± 0.20	0.99**
45-B	28.13	0.98 ± 0.04	0.21	0.63	0.75 ± 0.28	0.13	0.33	1.04 ± 0.22	0.08	-2.03	0.85 ± 0.16	0.21
47-B	27.32	1.10*± 0.02	0.06	0.71	0.81 ± 0.64	1.43**	0.34	0.97**± 0.37	1.65**	-3.13	0.76 ± 0.49	0.14
48-B	27.84	0.93*± 0.01	0.03	0.70	0.70 ± 0.29	1.70**	0.32	1.64 ± 0.39	0.85	-2.70	0.28 ± 0.13	0.02
49-B	27.48	1.11**± 0.02	0.05	0.70	0.50 ± 0.09	0.03	0.46	0.92 ± 0.40	0.27**	-2.66	0.59*± 0.28	0.08
50-B	27.19	0.84*± 0.04	0.26	0.66	0.36 ± 0.20	0.14	0.54	1.01 ± 0.29	0.06	-2.87	0.33 ± 0.13	0.39
52-B	27.98	0.86 ± 0.06	0.44	0.75	0.28**± 0.10	2.08	0.42	1.63*± 0.30	0.45	-1.69	0.58*± 0.42	0.09
53-B	27.82	1.03 ± 0.05	0.30	0.75	0.08**± 0.00	0.00	0.34	0.68* ± 0.36	1.75*	-2.78	0.45 ± 0.10	0.89*
36-B	27.73	1.11 ± 0.11	1.37**	0.65	0.05**± 0.01	0.05	0.94	0.62 ± 0.36	0.26	-2.56	0.40*± 0.13	0.32
RCR-8297	28.15	1.02 ± 0.08	0.84**	0.72	0.08**± 0.01	0.06	0.37	0.62 ± 0.36	0.14	-3.06	0.24**± 0.05	0.54
RHA-297	27.81	0.80 ± 0.12	1.72**	0.74	0.53**± 0.20	0.06	0.99	0.59* ± 0.12	0.29**	-2.16	0.22*± 0.20	0.74
Mean	28.0± 0.25			0.7± 0.07			0.49± 0.03			-2.66 ± 0.12		

Table 4 Mean performance, regression coefficient (bi) and deviation from regression (δ^2di) for morphological characters

Inbred line	Days to 50% flowering			Days to maturity			Plant height (cm)			Head diameter (cm)		
	Mean	bi ± S.E.	δ^2di	Mean	bi ± S.E.	δ^2di	Mean	bi ± S.E.	δ^2di	Mean	bi ± S.E.	δ^2di
P-61-R	63	0.77 ± 0.30	0.25	90	0.64*± 0.09	0.04	120.08	0.08**± 0.03	0.32	10.2	0.72 ± 0.21	0.16
R-273	64	0.87 ± 0.08	0.02	91	0.59 ± 0.19	0.18	118.42	0.01**± 0.00	0.02	9.8	0.78 ± 0.10	0.04
P-93-R	65	1.21 ± 0.93	2.40**	94	0.68 ± 0.22	2.34**	124.50	0.57**± 0.10	2.13	14.6	0.82 ± 0.26	2.33**
95-C-1-R	63	0.71 ± 0.36	1.47**	94	0.58 ± 0.51	1.31**	139.17	0.73**± 0.10	1.08	9.5	0.71 ± 0.61	1.30**
P-91-R	63	1.26 ± 0.87	2.07**	93	0.57 ± 0.46	1.62**	131.00	0.28**± 0.10	2.08	14.9	0.75 ± 0.34	1.95**
P-107-R-P_2	63	0.75 ± 0.12	0.04	95	0.78 ± 0.19	0.19	115.42	0.08**± 0.00	0.00	13.1	0.66 ± 0.12	0.05
P-107-R-P_1	65	0.54**± 0.16	0.01	90	0.39**± 0.06	0.02	126.50	0.05**± 0.01	0.05	13.7	0.48**± 0.44	0.01
P-69-R	64	0.71 ± 0.15	0.07	91	0.47 ± 0.19	0.19	94.92	0.08**± 0.00	0.00	14.7	0.63 ± 0.13	0.07
3376-R	64	0.24 ± 0.88	2.14**	89	0.61 ± 0.38	1.86**	124.17	0.43**± 0.10	2.03	8.7	0.76 ± 0.33	2.03**
P-100-R	63	0.69 ± 0.18	0.09	90	0.47 ± 0.19	0.18	118.33	0.08**± 0.68	0.01	11.5	0.62 ± 0.15	0.08
P-110-R	62	0.65 ± 0.12	1.75**	91	0.69 ± 0.50	1.28**	109.33	0.25**± 0.08	1.83	11.8	0.69 ± 0.37	1.65**
P-87-R	62	0.40 ± 0.59	0.96**	91	0.60 ± 0.15	0.69**	127.25	0.07**± 0.04	0.90	15.1	0.49 ± 0.44	0.85
P-89-R	64	0.68 ± 0.37	0.38	91	0.63 ± 0.15	0.12	137.83	0.09**± 0.02	0.43	13.5	0.65 ± 0.28	0.27**
P-75-R	63	0.81 ± 0.28	0.22	91	0.63 ± 0.56	0.12	132.67	0.72**± 0.12	0.17	14.3	0.75 ± 0.28	0.13
P-94-R	63	0.84 ± 0.26	1.60**	94	0.52 ± 0.43	1.57**	114.33	0.95**± 0.14	1.05	13.2	0.81 ± 0.64	1.43**
P-111-R	76	0.80 ± 0.22	1.78**	93	0.84 ± 0.15	1.38**	151.67	0.12**± 0.03	1.83	14.2	0.70 ± 0.29	1.70**
P-112-R	76	1.11 ± 0.08	0.02	93	0.85 ± 0.20	0.12	196.00	0.55**± 0.01	0.22	14.9	0.80 ± 0.09	0.03
P-115-R	65	0.70 ± 0.23	0.15	92	0.56*± 0.11	0.21	118.75	0.08**± 0.01	0.06	14.5	0.76 ± 0.20	0.14
P-119-R	61	0.78*±0.03	0.00	88	0.36*± 0.08	0.06	127.33	0.53**± 0.20	0.06	12.6	0.70**± 0.02	0.00
P-121-R	61	0.50*±0.08	0.02	91	0.43**± 0.11	0.04	89.17	0.69**± 0.16	0.08	14.1	0.44*± 0.09	0.03
P-124-R	68	0.58 ± 0.18	0.09	93	0.12*± 0.01	0.07	102.92	0.19**± 0.00	0.06	13.3	0.53*± 0.12	0.06
NDLR-2	62	0.17**±0.01	0.00	92	0.88**± 0.42	0.00	125.42	0.16**± 0.01	0.00	14.5	0.15**± 0.05	0.00
NDLR-1	75	1.13 ± 0.40	0.45	92	0.50 ± 0.33	0.90**	132.33	0.81**± 0.30	0.06	14.8	1.11 ± 0.35	0.42**
44-B	63	0.58 ± 0.37	0.39	93	1.10 ± 0.17	0.56	130.17	0.14**± 0.05	0.18	13.9	0.52 ± 0.33	0.39*
40-B	63	1.12 ± 0.47	0.61	90	0.22 ± 0.10	0.16	115.83	0.09**± 0.05	0.67	12.9	0.52 ± 0.33	0.38*
10-B	66	0.77 ± 0.17	0.08	93	0.52**± 0.44	0.05	110.42	0.10**± 0.06	0.12	11.7	1.11*± 0.33	0.08
234-B	67	0.60 ± 0.57	0.89	91	0.50 ± 0.20	0.99**	121.25	0.64**± 0.10	0.55	13.5	0.24 ± 0.14	0.83**
11-B	63	0.75 ± 0.17	0.08	93	0.85 ± 0.16	0.21	99.42	0.57**± 0.14	0.00	12.6	0.56 ± 0.49	0.08
304-B	63	1.10 ± 0.37	0.39	92	0.76 ± 0.49	0.14	82.75	0.30**± 0.09	0.78	11.6	0.66 ± 0.15	0.34**
395-B	66	0.67 ± 0.32	2.04**	89	1.10 ± 0.05	1.20**	107.67	0.11**± 0.05	2.22	12.9	0.96 ± 0.31	1.81**
7-1-B	67	1.13 ± 0.32	0.29	92	0.28 ± 0.13	0.02	127.92	0.38**± 0.23	0.66	16.3	0.69 ± 0.24	0.19
45-B	65	0.28 ± 0.25	0.18	88	0.59*± 0.28	0.08	147.17	0.65**± 0.23	0.20	12.4	1.11*± 0.23	0.15
47-B	59	0.92 ± 0.19	0.11	90	0.33 ± 0.13	0.39	131.92	0.53**± 0.26	0.03	14.8	0.68 ± 0.20	0.15
48-B	57	0.34 ± 0.27	0.21	91	0.58*± 0.42	0.09	108.83	0.26**± 0.08	0.26	13.5	0.80 ± 0.20	0.18
49-B	60	0.73 ± 0.53	1.35**	93	0.45 ± 0.10	0.89*	95.75	0.20**± 0.05	1.31	13.3	0.33 ± 0.22	1.18**
50-B	62	0.52 ± 0.27	0.20	88	0.46*± 0.35	0.05	121.42	0.53**± 0.22	0.29	14.3	0.57 ± 0.12	0.16
52-B	64	0.73 ± 0.40	0.45	94	0.87 ± 0.03	0.65	119.25	0.65**± 0.30	0.18	12.9	0.49 ± 0.21	0.43**
53-B	65	0.87 ± 0.20	0.12	95	0.46**± 0.21	0.01	126.58	0.68**± 0.36	0.27	15.1	0.79 ± 0.14	0.08
36-B	66	0.74 ± 0.30	1.50**	92	0.45 ± 0.12	1.09**	93.50	0.23**± 0.08	1.58	14.1	0.64 ± 0.35	1.41**
RCR-8297	66	0.41 ± 0.27	0.20	95	0.36*± 0.15	0.11	126.00	0.50**± 0.29	0.18	9.1	0.40 ± 0.21	0.16
RHA-297	66	0.94 ± 0.48	0.64	90	0.32 ± 0.22	0.52	114.25	0.56**± 0.23	0.64	11.0	0.42 ± 0.13	0.61**
Mean	64.46 ± 0..31						120.91±0.64			13.10±0.16		

Table 5 Mean performance, regression coefficient (bi) and deviation from regression (δ^2di) for agronomic characters

Inbred line	Seed yield/plant (g)			100-seed weight (g)			Oil content (%)		
	Mean	bi ± S.E.	δ^2di	Mean	bi ± S.E.	δ^2di	Mean	bi ± S.E.	δ^2di
P-61-R	21.9	0.83± 0.06	0.13	6.4	1.17 ± 0.16	0.04	39.2	0.34**± 0.03	0.24*
R-273	16.0	0.73± 0.03	0.05	5.4	0.98 ± 0.46	0.32**	37.1	0.26*± 0.15	0.44
P-93-R	35.5	0..88± 0.12	2.18	6.8	0.97 ± 0.10	1.17**	39.7	0.73 ± 0.12	1.19
95-C-1-R	9.3	0.29± 0.17	1.07	3.6	1.14 ± 0.64	0.61**	40.5	0.77 ± 0.22	0.90
P-91-R	22.4	1.05 ± 0.12	1.88*	5.2	1.11 ± 0.89	1.11**	41.2	1.37 ± 0.22	0.91
P-107-R-P_2	28.7	0.91± 0.03	0.05*	6.3	0.86 ± 0.47	0.25**	39.2	0.22*± 0.14	0.37
P-107-R-P_1	42.6	1.01**± 0.12	0.02	5.6	0.64 ± 0.26	0.10**	35.8	1.18**± 0.08	0.12
P-69-R	30.3	0.77± 0.03	0.05	6.5	0.85 ± 0.37	0.21*	40.7	0.81*± 0.13	0.32
3376-R	17.1	0.33*± 0.23	1.89*	4.0	1.11 ± 0.89	1.11**	36.2	1.34 ± 0.25	1.11
P-100-R	24.6	0.57± 0.03	0.05	5.9	0.87 ± 0.34	0.17**	41.3	0.82*± 0.12	0.29
P-110-R	24.8	0.49*± 0.12	1.62*	5.8	1.10 ± 0.86	1.15**	40.6	0.35*± 0.20	0.77*
P-87-R	52.1	0.15*± 0.14	0.76	5.3	1.10 ± 0.46	0.32**	41.4	0.51*± 0.13	0.30
P-89-R	38.4	0.62± 0.08	0.24**	7.2	1.11 ± 0.17	0.04	41.5	0.63**± 0.00	0.04
P-75-R	38.8	1.31± 0.04	0.77*	6.2	1.12 ± 0.12	0.02	39.9	0.73*± 0.07	0.11
P-94-R	29.9	1.23± 0.18	1.16	6.8	1.15 ± 0.75	0.84**	36.6	0.88± 0.26	1.12
P-111-R	44.2	0.66**± 0.22	1.67*	6.4	0.92 ± 0.26	1.12**	41.3	0.32*± 0.22	0.89
P-112-R	25.7	0.91± 0.05	0.10	5.8	1.13 ± 0.58	0.51**	38.8	0.88*± 0.18	0.60
P-115-R	35.3	0.92± 0.05	0.12	6.5	0.81 ± 0.34	0.17**	41.5	0.52*± 0.11	0.24
P-119-R	31.8	1.26± 0.16	0.26*	5.4	0.93 ± 0.36	0.19**	39.8	0.95*± 0.12	0.25
P-121-R	39.3	1.63± 0.25	0.05	5.9	0.85 ± 0.30	0.13**	38.0	1.16**± 0.08	0.14
P-124-R	31.7	0.75*± 0.02	3.03**	7.0	0.83 ± 0.13	0.02	40.2	1.22**± 0.07	0.08
NDLR-2	38.0	1.68**± 0.03	0.65*	6.4	0.91**± 0.73	0.85	40.4	1.05**± 0.02	0.10
NDLR-1	24.9	0.96± 0.09	0.31	5.7	1.16 ± 0.75	0.84**	37.2	0.61 ± 0.27	1.13
44-B	29.5	0.74*± 0.09	0.34	6.5	0.70 ± 0.36	0.48**	38.4	0.68*± 0.19	0.64**
40-B	34.6	1.01**± 0.09	0.28	6.5	1.18* ± 0.14	0.03	41.3	0.94**± 0.06	0.07
10-B	28.1	1.45*± 0.05	0.09	6.6	0.32 ± 0.26	0.10*	36.1	0.70**± 0.06	0.08
234-B	28.1	0.67± 0.14	0.71**	6.4	0.96 ± 0.68	0.69**	41.5	0.65*± 0.23	0.94
11-B	30.6	0.39± 0.04	0.06*	6.9	0.91 ± 0.39	0.22**	34.8	1.23*± 0.14	0.36
304-B	13.7	1.74*± 0.11	0.45	6.0	1.13 ± 0.39	0.62**	41.8	0.90*± 0.16	0.49
395-B	23.6	1.25± 0.12	1.75*	5.3	1.15 ± 0.80	0.97**	40.3	0.78*± 0.17	0.53
7-1-B	23.1	0.97**± 0.08	0.26	11.0	1.17 ± 0.54	0.44**	38.0	0.50*± 0.14	0.39
45-B	28.3	0.78± 0.06	0.14	6.3	0.75 ± 0.19	0.05	39.1	0.67**± 0.03	0.08
47-B	30.1	1.19*± 0.06	0.15	6.1	1.10 ± 0.59	0.52**	38.9	1.25*± 0.02	0.71*
48-B	28.9	0.86± 0.07	2.18*	5.6	0.60 ± 0.26	0.10*	41.4	0.89± 0.51	0.45
49-B	31.4	0.62± 0.17	1.06**	6.1	1.13 ± 0.53	0.42**	41.5	0.40*± 0.13	0.32
50-B	25.5	1.60± 0.06	0.16	5.8	0.89 ± 0.26	0.10*	41.4	0.24**± 0.05	0.54
52-B	22.7	1.60± 0.10	0.35	6.4	0.94 ± 0.58	0.95**	42.6	0.22*± 0.20	0.74
53-B	34.5	0.46± 0.05	0.10*	6.7	1.11 ± 0.35	0.19**	35.4	0.33*± 0.09	0.17
36-B	23.6	1.52± 0.11	1.39	6.0	0.94 ± 0.58	0.96**	39.7	1.32*± 0.19	0.67
RCR-8297	13.3	0.79± 0.05	0.12	4.3	0.75 ± 0.10	0.15	42.4	0.21**± 0.04	0.28
RHA-297	13.6	0.69± 0.13	0.62	4.3	0.85 ± 0.35	0.50**	41.9	0.16*± 0.14	0.39
Mean	28.4±0.39			6.1 ± .08			39.6 ± 0.60		

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Stability analysis in safflower (*Carthamus tinctorious* L.)

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ABSTRACT

The experiments were carried out at College of Agriculture, Indore in *rabi* season for consecutive three years *viz*., 2007-08, 2008-09 and 2009-10 with 28 genotypes of safflower. The observations were recorded on days to 50% flowering, days to maturity, plant height, branches/plant, capitula/plant, seeds/capitulum, hull content, 100-seed weight, seed yield/plant and harvest index. Analysis of variance revealed highly significant differences among genotypes for all the characters during all the three years. Non-significance of chi-square value suggested that the error variances were homogenous for all the traits under study. Pooled analysis indicated that the genotypes and environments differed among themselves and the genotypes showed differential performance over varying environments i.e., years/locations. The stability analysis as per the Eberhart and Russell model suggested the existence variability in the experimental materials and all the three environments differed significantly among themselves. Genotype x Environment (linear) was significant for days to maturity, number of capitula/plant and harvest index suggesting that the predictable portion of G x E interaction was more pronounced for the expression of these characters. The pooled deviation was significant for number of branches/plant, plant height, number of seeds/capitulum, hull content, 100-seed weight, days to maturity, number of capitula/plant, seed yield/plant and harvest index indicating the predominance of unpredictable portion of G x E interaction for the expression of these characters. Stable performance was exhibited by genotypes JSI-124 and JSI-135 for seed yield/plant and JSI 134 for earliness in maturity.

Keywords: Genotype x Environment interaction, Safflower, Stability parameters, Stable genotypes

Safflower (*Carthamus ticntorius* L.) commonly known as *Kusum* or *Kardi* is one of the important oilseed crops of *rabi* season, belonging to family Compositae or Asteraceae. In India, safflower occupies 271 thousand hectares in terms of area with its annual production of 171 thousand tonnes and productivity of 632 kg/ha during 2009-10 (Anonymous, 2010). It was evident from the data that the area, production and productivity of safflower were reducing in the state of Madhya Pradesh and in the country. This may be due to the well known fact that safflower is grown on the diminishing residual soil moisture and its productivity fluctuates with the availability of moisture in the soil profile. Thus, one of the major constraints for its low productivity was found to be drought. Due to this, productivity fluctuated greatly over years and locations. Selection for yield based on the phenotype, which is influenced considerably by genotype x environment (G x E) interaction would not be rewarding. Thus, studies on G x E interaction facilitates in identification of stable genotypes. Keeping in view, the present investigation was carried out with an aim to identify stable safflower genotypes to enhance production of safflower in Malwa region of Madhya Pradesh state.

MATERIALS AND METHODS

The experimental material consisted of 28 safflower genotypes evaluated for consecutive three years *viz*., 2007-08, 2008-09 and 2009-10 at experimental area of All India Coordinated Research Project on Safflower, College of Agriculture, Indore, Madhya Pradesh. Annual rainfall (mm) during the course of study was recorded as 911.6, 630.0 and 1074.1 mm in years 2007-08, 2008-09 and 2009-10, respectively. The soil of the experimental area is clay loam i.e., Vertisol. The experiment was conducted in Randomized Block Design with three replications in each year. The data were recorded on days to 50% flowering, days to maturity, plant height, number of branches/plant, number of capitula/plant, number of seeds/capitulum, hull content, 100-seed weight, seed yield/plant and harvest index each year. For recording data, five competitive plants were selected randomly from each plot. The data were subjected to the statistical analysis for the design of experiment. The homogeneity of error variances was tested by Bartlett's test before going for pooled analysis of variance. Stability analysis was carried out as per the model suggested by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

Analysis of variance was carried out for all the ten characters during the three years *viz*., 2007-08 (E_1), 2008-09 (E_2) and 2009-10 (E_3) and revealed that the genotypes differed significantly for all the 10 traits in all the three environments. The error variances for the three environments were tested for homogeneity by the Bartlett's test before going for pooled analysis of variance. The non significance of chi-square value suggested that the error variances were homogenous for all the traits under study. The pooled

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analysis of variance was carried out for all the characters and the results are presented in Table 1.

Genotypes, environments and Genotype x Environments interactions were highly significant for all the traits under study indicating that the genotypes and environments differ among themselves and the genotypes exhibited differential performance over varying environments i.e., years/locations. The ranking of the genotypes tested under different environments changes with the change of environmental factors. This is because of the existence of genotypes x environment interaction. Thus, the yield fluctuates extensively over years/ locations. The large effect of G x E interaction reduces the progress under selection (Comstock and Moll, 1963). Thus, it becomes imperative to isolate genotypes showing stable performance for sustainable crop production over years/locations.

Stability analysis: Analysis of variance for stability was carried out as per Ebarhart and Russell (1966) Model. Stability analysis revealed that significant differences amongst genotypes were observed for all the traits under study, indicating the existence of sufficient variability in the experimental material (Table 2). All the three environments differ significantly for all the characters suggesting that all the three environments differ significantly among themselves. The Environment + (Var. x Env.) was significant for number of branches/plant, plant height, days to maturity, number of capitula/plant, seed yield/plant and harvest index. The Environment (linear) was significant for all the traits except for harvest index. The Genotype x Environment (linear) was significant for days to maturity, number of capitula/plant and harvest index suggesting that the predictable portion of G x E interaction was more pronounced for the expression of these characters.

Pooled deviation was significant for number of branches/plant, plant height, number of seeds/capitulum, hull content, 100-seed weight, days to maturity, number of capitula/plant, seed yield/plant and harvest index indicating the predominance of unpredictable portion of G x E interaction for the expression of these characters.

The present investigations were in agreement with the findings of Hegde *et al.* (1997) for seed yield, number of branches/plant, plant height, number of seeds/capitulum; Mandal and Banerjee (1997) for seed yield and yield components; Patil *et al.* (1999) for seed yield, days to flowering and days to maturity; Beena *et al.* (2002) for 100-seed weight, days to maturity, days to 50% flowering, seed yield and Matho and Matho (2007) for days to 50% flowering, days to maturity and seed yield.

Environmental indices: The environment is the external condition that affects the expression of genes in an individual/genotype. Environment has various component factors like soil type, climatic conditions, topography etc. Each of these factors influences the performance of a genotype. Environmental variation can be classified as micro-environment and macro-environment (Comstock and Moll, 1963) or predictable and unpredictable factors (Allard and Bradshaw, 1964). Out of various environmental factors, some factors favour and some factors do not favour the expression of genes in individuals. Thus, a biometrical parameter like environmental indices gives an idea regarding which environment was favourable or not for the expression of a particular trait. The environmental indices for all the traits in all the environments under present investigation are depicted in Table 3. The environmental index was positive for all the traits except plant height, days to 50% flowering and harvest index indicating favourable influence of E_1 for the expression of these traits. Environment E_2 was also favourable for the expression of all the traits except hull content and seed yield/plant. The environment E_3 was unfavourable as the environmental index was negative for all the traits under study.

Stability parameters: According to Ebarhart and Russell (1966) a desirable genotype is one with high mean, unit regression coefficient (bi=1) and deviation from regression (s^2di) should be as low as possible. Thus, these three parameters were considered for identifying the stable genotype for different characters under study.

The genotypes having high mean with unit regression coefficient and least deviation from regression are considered as stable genotypes. The genotypes which show high mean, but regression coefficient more than one and least deviation from regression coefficient were considered as responsive under favourable environmental condition and the genotypes with high mean, regression coefficient less than one and minimum deviation from regression were considered as responsive in poor environmental conditions. The genotypes were classified on the basis of stability parameters mean regression coefficient and deviation from regression coefficient (Table 4).

The genotypes JSI-129 and JSI-133 recorded earliness for flowering and regression coefficient was less than one suggesting that they were responsive even under unfavourable environmental conditions for days to 50% flowering. None of the genotypes showed stable performance for this trait.

The genotypes *viz.*, JSI-124, JSI-135, JSI-132 and JSI-113 were responsive under poor environment for number of branches/plant, as they exhibited high number of branches, regression coefficient less than one and negligible deviation from regression. Under favourable environment the JSI-116, JSI-117, JSI-126 and JSI-128 were responsive as they recorded high general mean, regression coefficient value more than one and minimum deviation from regression.

The entries namely, JSI-120, JSI-97, JSI-135, JSI-118,

JSI-126, JSI-125 and JSI-137 recorded high mean nearly one regression coefficient and deviation from regression was low for plant height indicating that the genotypes were stable for the trait plant height, JSI-112 recorded high mean, regression coefficient was less than one and deviation from regression (s^2di) was low indicating that JSI-112 was responsive to poor environmental conditions for plant height. The genotype JSI-7 was responsive under favourable environmental condition as it showed high mean with regression coefficient more than one and deviation from regression was low for plant height.

High general mean, regression coefficient nearly equal to unity and s^2di was negligible for the genotype JSI-122 indicating its stable performance for number of seeds/capitulum. Genotypes JSI-124, JSI-123 and JSI-128 showed high mean, less than unity regression of coefficient and low deviation from regression indicating that these genotypes were responsive even under unfavourable environmental conditions. Genotypes JSI-135 and JSI-109 had high mean, more than one regression coefficient and low deviation from regression coefficient for these characters suggesting that these genotypes were responsive under favourable environmental conditions. The genotypes *viz*., JSI-120, JSI-97 and JSI-118 had low hull content, regression coefficient nearly one and low deviation from regression indicating that these genotypes were stable for this trait under changing environments. JSI-126 possessed low general mean, regression coefficient less than one and low deviation from regression indicating that JSI-126 was responsive even under poor environmental conditions for hull content.

None of the genotypes were found to be stable for 100 seed weight. The entries JSI-123 and JSI-133 were responsive for unfavourable environment for 100-seed weight as they recorded high seed index, regression coefficient is less than one and low deviation from regression coefficient. JSI-130 and JSI-126 recorded high mean, regression coefficient more than one and low deviation from regression coefficient indicating that these genotypes exhibited good performance under favourable environment conditions for 100-seed weight.

Genotype JSI-134 was responsive to unfavourable environment for earliness in maturity as it had early to mature, regression coefficient is less than one and low deviation from regression coefficient. None of the genotypes were found to be stable for the trait days to maturity.

The entry JSI-119 had high number of capitula/plant, regression coefficient less than one and negligible deviation from regression coefficient indicating that it was responsive to unfavourable environmental conditions for number of capitula/plant. The entries JSI-120, JSI-135 and JSI-128 recorded high general mean, regression coefficient more than one and minimum deviation from regression coefficient suggesting that they were responsive to favourable environmental conditions for number of capitula/plant.

The genotypes JSI-124 and JSI-135 exhibited regression coefficient nearly equal to unity, high seed yield and deviation from regression coefficient was low indicating that these genotypes show stable performance for this character. The entries JSI-112, JSI-118, JSI-128 and JSI-122 recorded regression coefficient more than one, high mean and low deviation from regression coefficient suggesting that these genotypes were responsive under favourable environmental conditions for seed yield/plant. None of the genotypes was responsive under poor environmental conditions for seed yield/plant.

Table 1 Pooled analysis of variance for the traits under study

Source	Df	Days to 50% flowering	Branches/ plant	Plant height	Seeds/ capitulum	Hull content	100 seed weight	Days to maturity	Capitula/ plant	Seed yield/plant	Harvest index
Varieties	27	190.3**	29.7**	2034**	202.4**	50.8**	4.38**	284.5**	236.1**	238.5**	349.0**
Environments	2	215.0**	50.0**	4952**	860.5**	1351**	2.93**	683.6**	631.7**	733.9**	182.1**
Var x Env	54	120.9**	12.0**	397.7**	96.4**	51.4**	1.87**	76.4**	89.8**	104.5**	180.1**
Pooled Error	162	31.7	0.73	0.89	0.54	0.59	0.15	1.18	0.70	0.69	1.96

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

Table 2 Analysis of variance for stability for all the traits of safflower

Source	Df	Days to 50 % flowering	Branches/ plant	Plant height	Seeds/ capitulum	Hull content	100 seed weight	Days to maturity	Capitula /plant	Seed yield /plant	Harvest index
Varieties	27	190.3**	29.7**	2034**	202.4**	50.8**	4.38**	284.5**	236.1**	238.5**	349.0**
Environments	2	215.0**	50.0**	4952**	860.5**	1351**	2.93**	683.6**	631.7**	733.9**	182.1**
Environment + (Var. x Env)	56	41.4	9.81**	717.4**	41.2	32.6	0.63	105.9**	36.3**	120.9**	60.1*
Environment (linear)	1	143.3*	333.3**	3301**	573.6**	900.2**	1.95*	455.7**	421.1**	4892**	121.4
Var x Env (linear)	27	39.8	4.28	138.3	36.1	11.9	0.74	35.0*	47.9**	29.9	86.2**
Pooled deviation	28	39.3	3.59**	122.3**	27.1**	21.6**	0.48**	15.3**	11.4**	38.3**	32.6**
Pooled error	162	31.7	0.73	0.89	0.54	0.59	0.15	1.18	0.70	0.69	1.96

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

Table 3 Environmental index values over three environments

Character	Environmental index		
	E_1	E_2	E_3
Days to 50% flowering	(-) 0.36	1.30	(-) 0.95
Branches/plant	0.09	0.26	(-) 0.36
Plant height	(-) 0.17	0.44	(-) 0.28
Seeds/capitulum	0.01	0.13	(-) 0.14
Hull content	0.36	(-) 0.01	(-) 0.34
100-seed weight	0.02	0.02	(-) 0.05
Days to maturity	0.09	0.54	(-) 0.64
Capitula/plant	0.06	0.23	(-) 0.29
Seed yield/plant	0.44	(-) 0.09	(-) 0.35
Harvest index	(-) 0.12	0.41	(-) 0.30

Table 4 Grouping of safflower genotypes based on stability parameters

Characters	Average response and stable (Mean>GM, bi=1, s^2di=0)	Responsive for favourable and stable (Mean > GM, bi>1, s^2di=0)	Responsive for poor environment and stable (Mean >GM, bi<1, s^2di=0)
Days to 50% flowering	-	JSI-129, JSI-133,	-
Number of branches/plant	-	JSI-135, JSI-124, JSI-113,	JSI-116, JSI-117, JSI-126, JSI-128,
Plant height	JSI-120, JSI-137, JSI-97, JSI-118, JSI-135, JSI-126, JSI-125	JSI-112	JSI-117
Number of seeds/capitulum	JSI-122	JSI-124, JSI-123, JSI-128	JSI-135, JSI-109
Hull content	JSI-120, JSI-97, JSI-118	JSI-126	-
100-Seed weight	-	JSI-133, JSI-123	JSI-130, JSI-126
Days to maturity	-	JSI-134	
Number of capitula/plant	-	JSI-119	JSI-120, JSI-128, JSI-135
Seed yield/plant	JSI-124, JSI-135	JSI-112, JSI-118, JSI-128, JSI-122	-
Harvest index	-	JSI-119	JSI-129

Genotype JSI-119 was responsive under poor environment for harvest index as it exhibited high general mean, regression coefficient is less than one and deviation from regression coefficient was negligible. JSI-129 had high mean, regression coefficient is more than one and deviation from regression was low suggesting that JSI-129 was responsive under favourable environmental conditions for the harvest index. None of the genotypes was found to be stable for this trait.

It can be concluded from the present study that the entries JSI-124 and JSI-135 can be recommended for general cultivation and JSI-112, JSI-118, JSI-128, JSI-122 for cultivation under favourable conditions for enhancing production of safflower in the region.

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Production potential, sustainability and energetics of groundnut based intercropping systems in Upper Krishna Project command area of Karnataka

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ABSTRACT

The field experiment conducted to evaluate the productivity and energetics of groundnut based intercropping systems during *rabi*/summer in UKP (Upper Krishna Project) command area of Karnataka revealed higher groundnut equivalent yield (GEY, 2.40 and 2.41 t/ha, respectively), monetary returns (Gross returns ₹ 84045 and ₹ 84180, net returns ₹ 64522 and ₹ 64220, and B:C ratio of 3.29 and 3.21, respectively) and energy output (12.61 x 10^6 and 12.82 x 10^6 K cal/ha, respectively) with groundnut + sesame in 4:2 and 5:1 row proportions followed by groundnut + maize in 4:2 row ratio (2.19 t/ha GEY, ₹ 76531 gross returns, ₹ 55981 net returns, 2.73 B:C ratio, and 16.15 x 10^6 K cal/ha energy output). Groundnut + sunflower was not advantageous over sole groundnut (2.01 and 1.99 t/ha yield equivalent, ₹ 68786 gross returns, ₹ 49058 net returns, 2.49 B:C ratio, and 11.14 x 10^6 K cal/ha energy yield). While, sole crops of maize, sunflower and sesame were poor in their productivity in comparison to groundnut. Thus, on-farm groundnut crop diversification through intercropping was advantageous during *rabi*/summer in UKP command area of Karnataka.

Keywords: Cropping systems, Economics, Energetics, Groundnut

Groundnut (*Arachis hypogaea* L.) is the prime oilseed crop of the country (2010-11) which ranks first in area (5.9 m.ha) second in production (8.3 mt) and fifth in productivity (1,406 kg/ha) (Economic Survey, 2013) in the world after the USA, China, Indonesia and Nigeria. However, the crop is losing its ground to other potential crops due to low productivity, high seed cost and the drudgery associated with crop harvest and threshing. The latter being a matter of concern in view of labour scarcity and cost. Already in TBP (Tungabhadra) and UKP (Upper Krishna Project) command area of Karnataka the crop has lost its pre-eminence position to commercial crops like Bt cotton and paddy. This is not a welcome situation as the country is not in a good position with regard to vegetable oilseed production and also other oilseeds from nutritional point of view. To meet the recommendation of Indian Council of Medical Research (ICMR) of 20 g edible oil/day/person by 2020 AD, India requires around 20.3 million tonnes of edible oil. Hence, it is essential not to lose any area under the crop; instead efforts need to be made to bring non-traditional areas under the crop besides making the crop and/or the system more productive through on-farm crop diversification *viz*., intercropping or through any other means. Interestingly, groundnut continues to occupy larger area in *rabi*/summer conditions more so under bore well irrigation on red soil in north-east dry zone of Karnataka. Therefore, efforts are needed to enhance productivity of the crop/system and retain growers' interest in the crop to augment oilseed production.

In recent days there is growing interest in diversified agriculture production systems to obtain improved crop protection, increased productivity and profitability offered by many intercropping systems. This may be due to some of the established and speculated advantages for intercropping systems such as higher yields, greater land use efficiency and improvement of soil fertility through the addition of nitrogen fixation and exertion from the component of legume (Oferi and Stern, 1987). Food and Agricultural Organization also conceptualized the idea of integrated use of all possible resources and cropping system for better resource use.

Already, sole sesame is grown on 3.91 lakh ha in India and has been found potential as second crop after paddy in irrigation commands. However, the potential of maize and sunflower has not been ascertained particularly as intercrops during *rabi*/summer season though they are known for their potential during rainy season. *Rabi*/summer groundnut need to be evaluated specifically in intercropping system to record land and energy use efficiency. Therefore, present experiment was envisaged to assess the possibility of inclusion of other oilseed crops and potential cereal yielder like maize as intercrop, and their productivity and energitics in *rabi*/summer conditions in Zone 2 of Karnataka under irrigation.

MATERIALS AND METHODS

The field experiment was conducted for three years during *rabi*/summer at College of Agriculture, Bheemarayanagudi in the Upper Krishna Project irrigation command falling in the North Eastern Dry zone, with semi-arid climate characterized by short monsoon, mild winter and hot summer during the growing seasons of 2010-11 to 2012-13. It is located at 15° 45' to 17° 30' North

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latitude and 75° 15' to 77° 31' East longitude and at 411 m mean sea level. The soil of experimental plot was medium black with low available nitrogen (240 kg/ha), medium phosphorus (40 kg P_2O_5/ha) and high potassium (340 kg K_2O/ha) contents. There were ten treatments comprising of groundnut (cv. TMV-2) + maize (cv. All rounder), groundnut + sunflower (cv. GK-202) and groundnut + sesame (cv. E-8) at 4:2 and 5:1 proportions along with and sole groundnut, maize, sunflower and sesame. A uniform row spacing of 30 cm was adopted under intercropping systems with recommended intra row spacing for the component crops. In 4:2 row proportions the intercrop rows were spaced at 30 cm apart irrespective of the normal row spacing followed for the crop. While, in sole systems recommended spacing of 30 x 10/15 cm for groundnut and sesame and 60 x 20 cm for maize and sunflower was followed. The experiment was laid in Randomized Block Design with three replications. Crops were sown during the last week of October. All the crops were given recommended doses of nutrients according to the population levels of component crops in comparison to sole optimum. In addition, groundnut was supplied with gypsum at 500 kg/ha. Half the dose of nitrogen and full doses of phosphorus and potassium were applied at seed dibbling and remaining nitrogen was top dressed as per recommendation. Prophylactic measures were adopted to control the sucking pests. Weeds were controlled by hand weeding and intercultural operations. Yield observations and yield were recorded at harvest and pooled data were subjected to statistical analysis. Besides, protein, carbohydrates, fat and energetics were estimated using the nutritive values (Gangwar *et al*., 2003; Renuka *et al*., 2005). Protein, carbohydrate and fat, and energy yields expressed in terms of million g (10^6 g) or ton and million k calories (10^6 k cal) respectively taking into consideration component crops of the systems. Further, economics of the experiment was also worked out. The data was subjected to statistical analysis and interpretation. Based on the yield data sustainable yield index (SYI) was worked out using the formula:

$$SYI = \frac{A - Y}{Y_{max}} \times 100$$

A = Mean of particular treatment
Y = Standard deviation of particular treatment
Y_{max} = Potential yield in different years and treatments

RESULTS AND DISCUSSION

Performance of crops: The component crop yields varied significantly between sole and intercropped situation and in general the yield was the highest under sole cropping (Table 1). In groundnut under intercropping, yield reductions were rather of higher magnitude in groundnut + maize/sunflower system particularly in 4:2 row proportions having higher proportion of intercrop population. Interestingly, inclusion of sesame did not cause any significant variation in groundnut yield (1.86 and 1.95 t/ha with 4:2 and 5:1, respectively). It is easy to infer that sunflower and maize morphologically being tall besides being exhaustive had more limiting effect on the performance of groundnut in comparison to sesame, the latter being of moderate height and with lower foliage and yield potential has lesser demands on shared resources particularly space and light.

The point worth noting here is that the extent of reduction in groundnut yield under intercropping was not in tune with the variation in population in comparison to sole optima. In other words, in 4:2 row proportion the population of groundnut was 67% (with expected yield 1.31 t/ha when equated with sole yield) and in 5:1 row ratio it was 83% (with expected yield 1.64 t/ha) of sole (1.97 t/ha). When absolute intercrop yields of groundnut were compared with sole yield, it was more than expected with maize in 4:2, and with sesame at both the row ratios, while in sunflower it almost followed population level. The performance of groundnut in fact improved in the former combinations with no suppressing effect by intercrops as reasoned out initially. In fact, there was cognizable complimentary effect.

Of the intercrops, yield was higher with maize followed by sunflower and the lowest was with sesame and yield also varied between the two row proportions (Table 1). The variation in yield was mainly in accordance with the population level of the component crop 4:2 row proportions with higher intercrop population always yielded high. Maize being cereal and known for its yielding ability produced more yield than others.

When the yields of intercrops were compared with their sole keeping the population levels in view it was found that almost all combinations except groundnut + sesame, had lower than expected yield (2.56 and 1.28 t/ha in maize, 1.04 and 0.52 t/ha in sunflower and 0.39 and 0.14 t/ha in sesame in 4:2 and 5:1 row proportions, respectively). Interestingly and contrary to expectation, it was not maize or sunflower but groundnut, in spite of being legume, that was dominating the system and competing with intercrops reducing their yields substantially in comparison to respective sole optima. It is easy to attribute this behaviour to closer planting (30 cm apart rows within the pair) of maize and sunflower in 4:2 row proportions, but the fact remained same even when single row was alternated after every five lines of groundnut. Complimentary effects were conspicuous only with sesame and the observations were only partially in line with Das *et al*. (1991).

Further, the primary yield variations of component crops could be traced even in groundnut yield equivalent (Table 1). Groundnut + sesame both at 4:2 and 5:1 row proportions (2.40 and 2.41 t/ha, respectively) excelled over sole maize, sunflower and sesame as well as intercropping of groundnut + maize in 5:1 row proportion. The yields with former systems were 21% higher over sole groundnut. The parity in

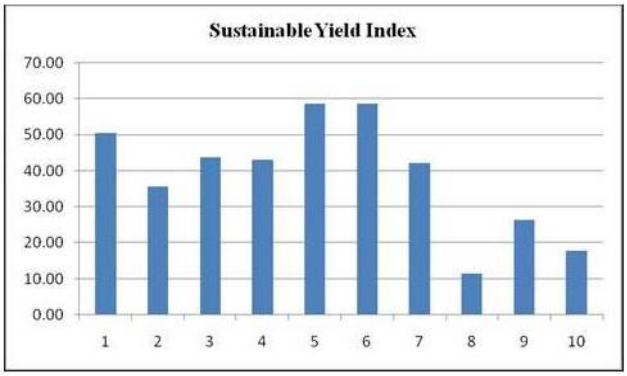
most of systems could be attributed to dominating groundnut component which had compensated the reductions in maize and sunflower adequately and efficiently. This was possible due to leaf orientation and delayed senescence of leaves in maize and sunflower. Similar results were also obtained by Reddy and Willey (1981). The results also corroborate well with Anilkumar and Thakur (2006).

Besides recording higher system productivity, groundnut + sesame recorded higher sustainability of yields as revealed by sustainable yield index (SYI) during *rabi*/summer conditions (Fig.1). SYI values (%) with the former treatments were 58.82 and 58.67, respectively with 4:2 and 5:1 row proportions which were substantially high in comparison to sole groundnut (42.16) while groundnut + maize (4:1) had moderate value (50.59). All other crop/systems had lower indices and the lowest was observed in sole maize (11.51).

Table 1 Crop yield, groundnut equivalent yield, energetics and economics of different intercropping systems in groundnut

Cropping system	Seed yield (t/ha)		Groundnut equivalent yield (t/ha)	Energetics of different cropping systems				Gross returns (₹/ha)	Net returns (₹/ha)	B : C ratio
	Groundnut	Component crop		Protein yield (10^6 g/ha)	Carbohydrate yield (10^6 g/ha)	Fat yield (10^6 g/ha)	Energy (10^6 K cal/ha)			
Groundnut + maize (4:2)*	1.47	2.29	2.19	0.62	1.90	0.67	16.15	76531	55981	2.73
Groundnut + maize (5:1)	1.47	1.02	1.79	0.48	1.06	0.63	11.84	62751	41856	2.01
Groundnut + sunflower (4:2)	1.33	0.79	2.01	0.49	0.49	0.95	12.45	70329	49989	2.47
Groundnut + sunflower (5:1)	1.62	0.43	1.99	0.49	0.50	0.87	11.83	69503	48258	2.28
Groundnut + sesame (4:2)	1.86	0.36	2.40	0.53	0.57	0.93	12.61	84045	64522	3.29
Groundnut + sesame (5:1)	1.95	0.30	2.41	0.54	0.58	0.93	12.82	84180	64220	3.21
Sole groundnut	1.97	-	1.97	0.49	0.51	0.79	11.14	68786	49058	2.49
Sole maize	-	3.85	1.15	0.43	2.55	0.14	13.18	40201	21451	1.15
Sole sunflower	-	1.56	1.55	0.31	0.28	0.81	9.65	54124	37386	2.25
Sole sesame	-	0.84	1.32	0.15	0.20	0.42	4.83	46080	30905	2.05
SEm ±	0.12	-	0.15	0.04	0.08	0.06	0.88	5381	5381	0.27
C D (P=0.05)	0.38	-	0.46	0.11	0.23	0.18	2.61	15990	15990	0.81

*Figures within the bracket indicate row proportions of component crops



1. Groundnut+maize (4:2), 2. Groundnut+maize (5:1), 3. Groundnut + sunflower (4:2), 4. Groundnut+sunflower (5:1), 5. Groundnut+sesame (4:2), 6. Groundnut+sesame (5:1), 7. Groundnut, 8. Maize, 9. Sunflower and 10. Sesame

Fig. 1. Sustainable yield index (SYI) (%) from groundnut based cropping systems

Energetics: The energetics of the systems revealed significantly higher protein yield (0.62 x 10^6 g/ha) with groundnut + maize (4:2), distantly followed by groundnut + sesame (0.53 and 0.54 x 10^6 g/ha, respectively with 4:2 and 5:1), the latter was at par with others except sole sunflower (0.31 x 10^6 g/ha) and sesame (0.15 x 10^6 g/ha). This could be attributed to nitrogen content in grains and higher crop yields in above systems.

Carbohydrate also varied significantly and sole maize recorded significantly higher carbohydrate yield (2.55 x 10^6 g/ha) which was superior to all other treatments and the lowest yield was recorded with sole sesame (0.20 x 10^6 g/ha). Oilseed + oilseed combinations, in general had a little higher than one-fourth over sole sesame. This was because of the fact that oilseed crops are poor sources of carbohydrates unlike cereal like maize.

Similarly, treatments revealed significant differences in fat yield (Table 1). Unlike carbohydrates, oilseed + oilseed i.e. groundnut + sunflower/sesame recorded higher fat yield (0.79 - 0.95 x 10^6 g/ha) than maize, groundnut + maize or sole sesame. Expectedly, sole maize being cereal had the lowest fat production among all (0.14 x 10^6 g/ha). Energy produced in different treatments also varied significantly; groundnut + maize with 4:2 proportion recorded the highest energy yield (16.15 x 10^6 K cal/ha). All other intercropping systems were intermediate including sole maize (13.18 x 10^6 K cal/ha) while, the lowest was in sole sesame (4.83 x 10^6 K

cal/ha). This was attributable to yield and energy content of different crops/cropping systems. Earlier, Pandey *et al*. (2003) reported that intercropping groundnut in maize was productive and energetically viable compared to either of sole crops.

Economics: The economics revealed significant variations in gross and net returns and B:C ratio (Table 1 and Fig. 2). Among all, significantly higher gross and net returns were obtained with groundnut + sesame (₹ 84045/- and ₹ 84180/- gross returns and ₹ 64522/- and ₹ 64220/- net returns, respectively with 4:2 and 5:1 row proportions). This was due to higher yield and higher market price of component crops of the system. Groundnut + maize (4:2) was next in line (₹ 76531/- and ₹ 55981/- gross and net returns, respectively).

1. Groundnut+maize (4:2), 2. Groundnut+maize (5:1), 3. Groundnut+sunflower (4:2), 4. Groundnut+sunflower (5:1), 5. Groundnut+sesame (4:2), 6. Groundnut+sesame (5:1) 7. Groundnut, 8. Maize, 9. Sunflower 10. Sesame

Fig. 2. Net returns (₹/ha) from groundnut based cropping systems

While, groundnut + maize (5:1), groundnut + sunflower (4:2/5:1) were at parity with sole groundnut, the existing system whereas none of the other sole systems had competing returns in comparison to sole groundnut (₹ 49058/- of net returns). B:C ratio more or less followed similar trend. Groundnut + sesame recorded highest B:C ratio (3.29 and 3.21 with 4:2 and 5:1 row proportions, respectively) followed by 4:2 row proportion of groundnut + maize (2.73) which were significantly superior to sole groundnut (2.49). Groundnut + sunflower (4:2) and sole groundnut were at par. Sole maize had the lowest B:C ratio (1.15) among all. Such advantages with intercropping systems were also reported by Padhi and Panigrahi (2006).

Thus, keeping in view the higher groundnut yield equivalent, sustainability yield index and net returns crop diversification through intercropping of groundnut + sesame (4:2 or 5:1 row proportion) followed by groundnut + maize (4:2) could be adopted during *rabi*/summer in UKP command of Karnataka instead of sole groundnut.

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Influence of pre and post-emergence herbicides in groundnut (*Arachis hypogaea* L.)

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ABSTRACT

A field experiment was conducted at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh for three consecutive years during 2007-08 to 2009-10 to evaluate pre and post-emergence herbicides in rainy season groundnut. The experiment comprising nine weed control treatments of pre and post-emergence herbicides along with weedy check and weed free check was conducted in Randomised Block Design with three replications on medium clay soils with pH 7.9. The experimental field was infested with *Echinochloa* spp., *Dinebra retroflexa, Digitaria sanguinalis, Indigofera glandulosa, Commelina benghalensis, Phyllanthus niruri, Euphorbia hirta, Digera arvensis, Cynodon dactylon, Tridax procumbens* and *Cyperus rotundus.* Among the monocots and sedges, *Echinochloa* spp. and *Cyperus rotundus* were predominant. Complete weed free condition recorded highest dry pod, haulm and kernel yield (2773, 3934 and 1997 kg/ha, respectively). Among the herbicidal treatments, pendimethalin 1 kg/ha + quizalofop ethyl @ 50 g/ha at 20 days after sowing (DAS) recorded the lowest monocot (3.81/m^2), dicot (3.63/m^2), sedges (3.83/m^2) weed density, dry weight of weeds (133 g/m^2), weed control efficiency (84.2%) at 60 DAS and weed index (4.6%). The same treatment combination recorded significantly higher dry pod yield (2645 kg/ha), haulm yield (3424 kg/ha), kernel yield (1902 kg/ha), gross return (₹ 66360/ha), net return (₹ 42190/ha) and B:C ratio (2.75).

Keywords: Groundnut, Herbicide, Post-emergence, Pre-emergence, Weed control efficiency

India is the chief producer of groundnut in the world by growing about 4.93 million ha of groundnut with the total production of 5.64 million t and yield of 1140 kg/ha (Anonymous, 2010). India accounts about 40% of the world area and 30% of the world production of groundnut. The demand for edible oil is rising day by day and area as well as productivity of this crop declined drastically. Therefore, concentrated efforts are being made to increase and to stabilize the oilseed production in the country. Groundnut is the most popular oilseeds crop of *kharif* (rainy) season. Among the various factors responsible for low yields of groundnut, severe infestation of weeds during the early crop growth period is one of the constraints. Weeds compete with crop for soil moisture, nutrients and light and reduce the yield. They also harbour and serve as alternative host for pest and diseases. The critical period of crop weed competition in groundnut was observed during initial 4 to 8 weeks (Bhalel *et al*., 2012). The loss in yield of groundnut pods due to weed competition ranged from 30 to 40% (Chandrasingh and Gupta, 1973). Present investigation aims to control early weeds of the groundnut crop during rainy season with the help of combinations of pre and post applied herbicides. With this in view, an investigation of weed management in groundnut was conducted to study the relative efficacy of herbicides to control weeds.

MATERIALS AND METHODS

The experiment was conducted at Main Oilseeds Research Station Farm, Junagadh Agricultural University, Junagadh during *kharif* season of 2008 to 2010 in order to find suitable pre and post-emergence herbicide for the control of weeds during early growth stage of groundnut crop. The experimental field was medium clay soils with pH 7.9. Soil of the experimental site was low in nitrogen (231 kg/ha), medium in phosphorus (26 kg/ha) and high in potash (411 kg/ha). Plot size was 3.6m x 4.0m and 2.4m x 3.0m gross and net, respectively. The crop was sown at 60 x 10 cm spacing with 125 kg/ha seed rate and fertilizer dose of 12.5 kg/ha N and 25.0 kg/ha P_2O_5 with cultivar 'GG 20'. A set of eleven treatment combinations with pre-emergence pendimethalin and post-emergence herbicide quizalofop ethyl and imazethapyr along with weedy check and weed free check was made and replicated thrice in Randomized Block Design. The pre-emergence herbicides was sprayed immediately after sowing on wet soil and the post-emergence herbicides were applied 20 days after sowing (DAS) with the help of knapsack sprayer at discharge rate of 500 l/ha. Weed population and weed dry matter, taken at 30 DAS was recorded by using the quadrate measuring 1 m^2/plot. The economic analysis of each treatment was done on the basis of prevailing market price of inputs used and output obtained under each treatment. Data on weed density and weed biomass were transformed using $\sqrt{x+0.5}$ transformations. The weed control efficiency (WCE), weed index (WI) and B: C ratio was worked out. The weed control efficiency was calculated as:

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where, DWC = Dry weight of weeds in unweeded control plot, DWT = Dry weight of weeds in treated plot.

The weed index was derived as:

$$WI = \frac{X - Y}{X} \times 100$$

Where, X = yield from weed free treatment, Y = yield from weed treatment for which WI is to be calculated.

RESULTS AND DISCUSSION

Weed flora: Species wise weed recorded in the experimental field of groundnut during *kharif* season at 60 DAS indicated that there was predominance of monocot weeds. The major weed flora of the experiment plots were *Echinochloa* spp., *Dinebra retroflexa, Digitaria sanguinalis, Indigofera glandulosa, Commelina benghalensis, Phyllanthus niruri, Euphorbia hirta, Digera arvensis, Cynodon dactylon, Tridax procumbens* and *Cyperus rotundus.* Out of these, the first five species contributed about 80% of total weed density recorded at 60 DAS. Among the monocots *Echinochloa* spp. was predominant and *Cyperus rotundus* predominant among sedges. The predominance of monocot and sedge weeds have been reported by several workers (Gowda *et al.,* 2002; Deore *et al.,* 2009; Mundra and Maliwal, 2012).

Weed density and weed drymatter production: Data revealed that different treatment exhibited significant influence on weed density and drymatter of weeds. The density and dry weight of weeds were maximum under weedy plots. However, reduction in density and dry weight of weeds was observed when weeds were controlled either through chemical or mechanical means. Among all the herbicidal treatment, pre-emergence application of pendimethalin 1 kg/ha + post-emergence application of quizalofop ethyl @ 50g/ha at 20 DAS recorded significantly least number of monocot weed (3.81/m^2), dicot (3.63/m^2), sedges (3.83/m^2) and weed drymatter (133 g/m^2) than any other treatment except weed free check (Table 1). This might be due to control of weeds during early growth stage by pre-emergence application of pendimethalin and post emergence application of quizalofop ethyl at 20 DAS. The treatment combination of pre and post-emergence applied herbicides after sowing and 20 DAS was able to control the additional infestation of weeds in groundnut crop. Further, crop covers the soil surface and smothers the growth of weeds resulted into least number of weeds at later stage of crop (Malunjkar *et al*., 2012).

Weed control efficiency and weed index: The highest weed control efficiency at 60 DAS was found under weed free check treatment (98.7%). The treatment pre-emergence application of pendimethalin @ 1 kg/ha + post-emergence application of quizalofop ethyl @ 50g/ha at 20 DAS was recorded highest weed control efficiency (84.2%) than any other weed control treatment (Table 1) except weed free check (98.7%). The lowest weed index was also noticed in same treatment (4.6%). The yield reduction up to 62.3% was recorded if field kept un-weeded. This might be due to the continuous competition of groundnut crop with the obnoxious weed species for nutrient and moisture. Ramkrishna *et al.* (1990), Bhalel *et al.* (2012) and Malunjkar *et al.* (2012) observed the similar trend in efficacy of herbicide in groundnut crop.

Yield and economics: The data presented in Table 2 indicate that pod and haulm yield of groundnut was influenced significantly by the various treatments. The weed free treatment recorded significantly highest pod (2773 kg/ha) and haulm (3943 kg/ha) yield than rest of the treatments. However pod yield remained at par with pre-emergence application of pendimethalin @ 1 kg/ha + one hand weeding at 30 DAS, pre-emergence application of pendimethalin @1 kg/ha + post-emergence application of quizalofop ethyl @ 50 g/ha at 20 DAS and pre-emergence application of pendimethalin @ 1 kg/ha + post-emergence application of imazethapyr @ 50g/ha at 20 DAS. Among the different herbicides, pre-emergence application of pendimethalin 1 kg/ha + post-emergence application of quizalofop ethyl @ 50g/ha at 20 DAS recorded significantly higher dry pod yield (2645 kg/ha) than rest of the herbicide treatments. But it remained at par with pendimethalin @ 1 kg/ha as a pre-emergence + 1 HW at 30 DAS and pendimethalin @ 1 kg/ha as a pre-emergence + imazethapyr @ 50g/ha as a post-emergence at 20 DAS. The significantly higher haulm yield (3424 kg/ha), kernel yield (1902 kg/ha) with maximum gross returns (₹ 66360/ ha), net returns (₹ 42190/ha) and B:C ratio (2.75) also recorded by the pre-emergence application of pendimethalin 1 kg/ha + post-emergence application of quizalofop ethyl @ 50 g/ha at 20 DAS (Table 2). This might be due to the lower weed population, dry weight of weeds and weed index which were negatively correlated with pod yield. Pod, haulm and kernel yields attained the minimum value (1046, 1823 and 715 kg/ha, respectively) when weeds were not controlled throughout the season. This caused severe competitive stress on crop plants for growth resources and led to inferior yield attributing traits hence had minimum pod, haulm and kernel yield. These results are in close conformity with the findings of Roy *et al.* (2003), Sasikala *et al.* (2007), Dubey *et al.* (2010) and Malunjkar *et al.* (2012). Thus, efficient and profitable management of weeds through pre-emergence application of pendimethalin 1 kg/ha + post-emergence application of quizalofop ethyl @ 50 g/ha at 20 DAS was most effective in controlling weeds in groundnut during rainy season.

Table 1 Effect of treatments on weed index and weed control efficiency (Pooled data of three years)

Treatment	Weed density/m^2 at 60 DAS			Weed dry matter at 60 DAS (g/m^2)	Weed control efficiency at 60 DAS %	Weed index %
	Monocot weeds	Dicot weeds	Sedges			
Weedy check	7.33 (50.20)*	6.77 (45.42)	4.04 (16.10)	842	-	62.3
Weed free	0.71 (0.00)	0.71 (0.00)	1.59 (2.10)	11.2	98.7	0.0
Pendimethalin @ 1 kg/ha PE + one HW at 30 DAS	4.13 (17.00)	3.73 (13.47)	3.39 (11.07)	176	79.1	9.8
Quizalofop ethyl @ 50g/ha at 20 DAS PoE	5.46 (25.30)	4.64 (21.19)	3.85 (14.40)	361	57.1	20.7
Quizalofop ethyl @ 75g/ha at 20 DAS PoE	5.04 (24.65)	4.61 (20.73)	3.79 (13.90)	321	61.9	25.8
Quizalofop ethyl @ 100g/ha at 20 DAS PoE	4.85 (23.00)	4.55 (20.30)	3.80 (14.03)	261	69.0	26.5
Imazethapyr @ 50g/ha at 20 DAS PoE	5.51 (30.00)	5.24 (27.00)	3.70 (13.30)	362	57.0	24.5
Imazethapyr @ 75g/ha at 20 DAS PoE	5.33 (27.98)	5.05 (25.10)	3.68 (13.17)	330	60.8	22.7
Imazethapyr @ 100g/ha at 20 DAS PoE	4.97 (24.24)	4.69 (21.58)	3.77 (13.77)	266	68.4	27.6
Pendimethalin @ 1 kg/ha PE + T_4	3.81 (13.99)	3.63 (12.74)	3.83 (14.20)	133	84.2	4.6
Pendimethalin @ 1 kg/ha PE+ T_7	3.91 (14.80)	3.82 (14.17)	3.84 (14.23)	156	81.5	7.5
S.Em. ±	0.17	0.21	0.19	12.12	-	-
C.D.(P=0.05)	0.51	0.63	0.55	35.76	-	-

*Original figures in parenthesis were subjected to square root transformation ($\sqrt{(x+0.5)}$) before statistical analysis DAS- days after sowing; HW- Hand weeding; PE- Pre-emergence application; PoE- Post-emergence application

Table 2 Yield attributes and economics of groundnut as influenced by different treatments (Pooled data of three years)

Treatment	Pod yield (kg/ha)	Haulm yield (kg/ha)	Kernel yield (kg/ha)	Shelling (%)	100 kernel weight (g)	Gross returns (₹)	Cost of production (₹)	Net returns (₹)	B:C ratio
Weedy check	1046	1823	715	68.38	30.62	27181	20000	7181	1.36
Weed free	2773	3943	1997	72.02	34.58	70278	26000	44278	2.70
Pendimethalin @ 1kg/ha PE + one 1HW at 30 DAS	2502	3321	1747	69.81	32.95	62937	22970	39967	2.74
Quizalofop ethyl @ 50g/ha at 20 DAS PoE	2200	3244	1557	70.78	33.68	57088	21200	35888	2.69
Quizalofop ethyl @ 75g/ha at 20 DAS PoE	2057	2812	1453	70.62	32.64	51906	21725	30181	2.39
Quizalofop ethyl @ 100g/ha at 20 DAS PoE	2039	2682	1419	69.58	32.86	51241	22250	28991	2.30
Imazethapyr @ 50g/ha at 20 DAS PoE	2093	3039	1509	72.08	33.76	54217	20950	33267	2.59
Imazethapyr @ 75g/ha at 20 DAS PoE	2143	2728	1542	71.95	31.98	54745	21350	33395	2.56
Imazethapyr @ 100g/ha at 20 DAS PoE	2009	2778	1405	69.95	31.99	50758	21750	29008	2.33
Pendimethalin @ 1 kg/ha PE + T_4	2645	3424	1902	71.91	33.86	66360	24170	42190	2.75
Pendimethalin @ 1 kg/ha PE+ T_7	2564	3369	1806	70.44	33.78	64428	23920	40508	2.69
S.Em.±	112	135	82	0.53	0.65	-	-	-	-
C.D. (P=0.05)	316	383	231	1.50	1.84	-	-	-	-

HW-Hand weeding; PE- Pre-emergence application; PoE- Post-emergence application

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Effect of irrigation scheduling at critical growth stages and fertility levels on growth, yield and quality of summer sesame (*Sesamum indicum* L.)

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ABSTRACT

A field experiment was conducted with sesame during summer season of 2007 and 2008 on clayey soil of Cotton Research Centre, Khapat farm, Junagadh Agricultural University, Porbandar, Gujarat to find out the combined effect of irrigation at critical growth stages and fertility levels on growth, yield attributes, yields and quality of sesame. The treatments consisted 24 possible combinations of four levels of irrigation in main plot and six levels of fertility in sub-plot. The results revealed that irrigating the crop at branching, flowering, capsule and seed development stages with the application of 75:50:50 kg $NP_2O_5K_2O$/ha were found significant for number of effective branches/plant, length of capsule, number of capsules/plant, number of seed/capsule, seed yield/plant, seed yield and stover yields of sesame, harvest index, 1000-seed weight, protein and oil content in seed, oil yield and nitrogen, phosphorus and potassium uptake. Whereas water use efficiency was maximum when the crop was irrigated at flowering and capsule development stages only.

Keywords: Fertility levels, Irrigation schedules, Sesame, Water use efficiency

Sesame (*Sesamum indicum* L.) is one of the most ancient oilseed crops of India. The crop is cultivated almost throughout India for its high quality oil and has tremendous potential export of sesame in the world. Sesame is mainly grown during *kharif* season in Gujarat and grown in 2.46 lakh ha and total production is 1.16 lakh tonnes with productivity of 471 kg/ha. However, with increase in availability of irrigation water in the state, the area under summer cultivation is increasing day by day due to more productivity, higher market price and net monetary returns. Summer crop is generally grown after harvest of wheat in Saurashtra region of Gujarat state. To achieve higher productivity potential, irrigation scheduling and balanced fertilization are the key factors. Narang and Gill (1998) reported that seed yield of summer sesame increased with increase in the number of irrigations. Keeping in view, fast ever diminishing water resources and increasing competition from and within agriculture for water, its economical and efficient utilization becomes quite imperative. Under limited water supply, higher seed yield can be obtained by scheduling irrigation at critical growth stages of crop growth (Choradia and Gaur, 1986). It is well established fact that there is a positive correlation between nutrient application and productivity. Therefore, supply of balanced nutrients is considered as one of the basic needs to achieve the potential yield. Very little work has so far been carried out on irrigation scheduling and nutritional requirement of summer sesame crop under Saurashtra region. Hence, the present investigation was undertaken to study the effect of irrigation scheduling at critical growth stages and fertility levels on growth, yield and quality of summer sesame under medium black calcareous soils of South Saurashtra region.

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MATERIALS AND METHODS

A field experiment was conducted during summer season of 2007 and 2008 at Cotton Research Centre, Khapat farm, Junagadh Agricultural University, Porbandar, Gujarat. The soil was clayey in texture with pH 7.7, EC 0.74 dS/m, available N 270 kg/ha, available P_2O_5 38.8 kg/ha and available K_2O 278 kg/ha, respectively. The experiment was laid out in a split plot design with 4 replications. All possible 24 treatment combinations consisting of four irrigation schedules at critical growth stages *viz*., I_1- irrigation at branching + flowering + capsule development + seed development stage, I_2- irrigation at branching + capsule development + seed development stage, I_3- irrigation at branching + flowering + seed development stage and I_4- irrigation at flowering + capsule development stage as main plot treatments, six fertility levels *viz*., F_1-Control, F_2-25.0:12.5:00 $NP_2O_5K_2O$ kg/ha, F_3-50.0:25.0:00 $NP_2O_5K_2O$ kg/ha, F_4-50.0:50.0:25.0 $NP_2O_5K_2O$ kg/ha, F_5-75.0:50.0:00 $NP_2O_5K_2O$ kg/ha and F_6-75.0:50.0:50.0 $NP_2O_5K_2O$ kg/ha as sub-plot treatments. Sesame variety Gujarat Til-2 was sown in rows at 30cm apart on 15th and 10th February 2007 and 2008, respectively. Half dose of nitrogen and full dose of phosphorus and potassium was applied at the time of sowing in the form of urea, single super phosphate and muriate of potash as per treatments and remaining half dose of nitrogen was given at branching stage in the form of urea. A common irrigation was given immediately after sowing the crop for satisfactory seed

germination and proper establishment of crop. Rest of the irrigations of 50 mm depth were given as per treatments. The quantity of irrigation water was measured with 7.5cm throat Parshall Flume installed under free flow condition in the water channel. Other agronomical operations were followed as per recommendations made for the sesame in the region. The five plants were randomly selected from each net plot. Each selected plant was labelled for easy identification. The same five plants were harvested separately for post-harvest study. The mean of five observation plants were used for calculating sampling values of growth parameters, yield attributes, yields and qualiy parameters. Protein content, oil content and NPK content and uptake were estimated by standard methods. The experimental data were statistically analyzed for level of significance and pooles analysis for both the season.

RESULTS AND DISCUSSION

Effect of irrigation on growth, yield attributes and yield: Significantly maximum plant height, more number of branches/plant, capsules/plant, length of capsule, seeds/capsule, higher seed yield/plant and 1000-seed weight, seed (971 kg/ha) and stover yields (1325 kg/ha) as well as harvest index were recorded when the crop was irrigated at branching+flowering+capsule and seed development stages (I_1). Whereas, minimum values of growth and yield attributing characters as well as yields were observed when irrigations was given at flowering and capsule development stages (I_4) (Table 1). The mean seed yield increased under I_1 over I_2, I_3 and I_4 were to the tune of 27.8, 45.1 and 47.6%, respectively. The per cent increase in stover yield in I_1 over I_2, I_3 and I_4 were to the tune of 6.8, 9.6 and 19.0%, accordingly. Increase in yield under I_1 might be due to the fact that crop might have received right quantity of irrigation water at right crop growth stage and hence, soil moisture content remained optimum in the surrounding root zone area which finally resulted in improvement in number of branches, capsules/plant, seeds/capsule, seed yield/plant as well as higher uptake of nutrients by plant might have increased LAI, LAD and NAR resulting in more efficient partitioning of drymatter to the yield attributing parts of plant. The findings are in close agreement with the results obtained by Patra (2001) and Chang *et al*. (2005).

Table 1 Effect of irrigation schedules and fertility levels on growth, yield attributes and yields of summer sesame (pooled data of two years)

Treatment	Plant height (cm)	No. of branches/ plant	No. of capsules/ plant	Length of capsule (cm)	No. of seeds/ capsule	1000-seed weight (g)	Seed yield /plant (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Irrigation Level										
I_1	73.19	3.50	48.79	2.03	59.90	3.12	4.06	971	1325	42.31
I_2	71.16	3.15	46.34	2.02	58.71	3.09	3.74	760	1240	38.02
I_3	65.42	2.90	43.61	1.86	55.78	2.95	3.56	669	1209	35.66
I_4	64.98	2.67	42.34	1.84	53.88	2.93	3.37	658	1113	37.28
C.D. (P=0.05)	2.46	0.19	1.26	0.07	2.15	0.10	0.16	39	57	1.34
Fertility level										
F_1	66.43	2.72	41.80	1.85	53.45	2.93	3.22	711	1122	38.77
F_2	66.53	2.94	43.99	1.89	55.11	2.97	3.37	730	1200	37.75
F_3	68.05	3.04	44.40	1.93	56.53	3.00	3.59	746	1224	37.79
F_4	69.54	3.05	45.87	1.96	57.33	3.03	3.73	776	1229	38.31
F_5	70.52	3.27	47.30	1.98	59.93	3.10	4.03	786	1268	38.19
F_6	71.07	3.31	48.24	2.00	60.04	3.11	4.15	836	1287	39.10
C.D. (P=0.05)	2.43	0.16	1.24	0.06	1.88	0.07	0.14	35	46	NS
I x F interaction	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Quality parameters: Different irrigation schedules significantly affected the protein and oil content as well as oil yields (Table 2). Significantly more protein (27.57%) and oil content (52.62%) as well as oil yield of 511 kg/ha were observed under irrigation schedule at branching, flowering, capsule development and seed development stage (I_1). The probable reason for increase in protein and oil content might be due to higher irrigation level because protein content in seed was directly reflected to nitrogen content and uptake by seed. The increased uptake of nitrogen and water which in turn enhanced assimilation of amino acid leading to increased synthesis of protein. The results are consistent with the findings of Dutta *et al.* (2000) for the highest oil yield. Mondal *et al.* (1997) found that oil and protein yields were increased as irrigation frequency increased.

Nutrient uptake: Significantly maximum NPK uptake of 71.63, 14.16 and 20.20 kg/ha, respectively were recorded when crop was irrigated at branching, flowering, capsule development and seed development stages (I_1) (Table 2). The higher uptake of nutrients under I_1 irrigation schedule might be due to the cumulative effect of higher N, P, K content in seed and stover; and higher seed as well as stover yields. Absorption of nutrients by the plant root is influenced by the concentration gradient of available nutrients in soil solution, potential of soil to replenish the nutrient pool

adjacent to the roots and ability of plant roots to absorb and translocate nutrients. The increase in solubility of nutrients with increase in water content in soil due to higher irrigation frequencies under crop irrigated at branching, flowering, capsule development and seed development stage (I_1) with shorter interval might be responsible for higher uptake of nutrients. Results of nutrient uptake confirms the findings of Nikam *et al*. (1994), Ashok Kumar *et al.* (1996), Dutta *et al.* (2000) and Kundu and Singh (2006).

Effect of fertility levels on growth, yield attributes and yields: Application of 75.0:50.0:50.0 $NP_2O_5K_2O$ kg/ha (F_6) recorded significantly higher values of all the growth and yield attributes as well as seed and stover yields (Table 1). Significantly higher seed and stover yields of 836 and 1287 kg/ha, respectively were recorded under F_6 and remained at par with F_5 (75.0:50.0:00 $NP_2O_5K_2O$ kg/ha). The per cent increase in seed and stover yields under F_6 over control (F_1) were to the tune of 17.6 and 14.7%, respectively. Increase in growth and yield attributes with the higher level of NPK might be due to the fact that balanced nutrient supply increases the absorptive power of soil for cation and anion, created a situation favourable for higher uptake of NPK by plant. These absorbed ions are released slowly for the entire growth period resulted in better nutrient availability at active growth of the crop and increases observed in growth parameters. The findings are in close vicinity with the results obtained by Patra (2001). Higher fertility with the application of 75.0 kg N along with 25.8 kg P/ha and 49.8 kg k/ha increased the growth attributes over lower levels of fertility (Sarkar and Pal, 2005). The overall improvement in vegetative growth of the plant due to application of higher dose of fertilizer which favourably affected yield attributing characters *viz*., number of capsules/plant, length of capsule, number of seeds/capsule, seed yield/plant and test weight. These increase in seed and stover yields of sesame with higher level of NPK application evidently resulted from overall improvement in growth and yield attributing characters. Higher seed and stover yields under 75.0:50:0:50.0 $NP_2O_5K_2O$ kg/ha were also probably a consequence of greater amount of nutrient uptake by the seed and stover. The increase in yield with increased fertilizer level is in close conformity with the findings of Prakasha and Thimmegowda (1992), Itnal *et al*. (1993), Kathiresan (2002) and Thanunathan *et al*. (2006) obtained higher seed yield with higher number of seed.

Quality parameters: Protein and oil content as well as oil yield were significantly increased with 75.0:50.0:50.0 $NP_2O_5K_2O$ kg/ha (F_6) over rest of the treatments on pooled data basis (Table 2). Higher content of protein under higher level of fertility might be the reason of higher content and uptake of nitrogen by seed under this treatment. The results are in conformity with the findings of Kene *et al.* (1991), Mankar *et al.* (1995) and Patra (2001).

Nutrient uptake: Application of higher dose of 75.0:50.0:50.0 $NP_2O_5K_2O$ kg/ha to summer sesame resulted in significantly higher NPK uptake of 65.38, 13.22 and 19.03 kg NPK/ha, respectively. The increase in uptake of nutrients by sesame crop appears due to the cumulative effect of increased seed and stover yields. The application of N, P and K might have increased their concentration in soil solution which increased their availability and uptake by plant. The results are substantiate the findings of Kene *et al.* (1991), Mondal *et al.* (2001) and Patra (2001).

Interaction effect of irrigation and fertility levels: Data of two years revealed presence of significant interaction of irrigation and fertility levels (IxF). Significantly, the higher growth components, yield attributes and seed and stover yields, harvest index, protein content, oil yield and N uptake were recorded when crop was irrigated at branching, flowering, capsule development and seed development stages along with application of 75.0:50.0:50.0 $NP_2O_5K_2O$ kg/ha (I_1xF_6). Treatment combination I_1F_6 recorded significantly higher seed yield than rest of the combinations, but it remained at par with I_1F_5 combinations (irrigation at branching, flowering, capsule development and seed development stages along with application of 75.0:50.0:00 $NP_2O_5K_2O$ kg/ha). Due to application of sufficient amount of water along with optimum amount of nutrients might have increased physiological processes like cell division and cell expansion which resulted favourable growth conditions. These results are in close agreement of the results obtained by Khade *et al.* (1996) and Ravinder *et al.* (1996).

Water use efficiency: Significantly higher water use efficiency of 3.29 kg/ha-mm was recorded under irrigation at flowering and capsule development stage (I_4). The lowest water use efficiency was observed under higher irrigation level i.e., irrigation at branching, flowering, capsule development and seed development stages (I_1). The transpiration, evaporation and excessive vegetative growth and development increased yield attributes and finally seed and stover yields might be due to higher water use and ultimately lower water use efficiency. These results completely collaborate with the findings of Mitra and Pal (1999). In case of fertility levels, higher water use efficiency of 3.34 kg/ha-mm was found when crop was fertilized with 75.0:50.0:50.0 $NP_2O_5K_2O$ kg/ha (F_6) which was at par with the fertility level F_5 (75.0:50.0:00 NP_2O_5 K_2O kg/ha).

Table 2 Effect of irrigation schedules and fertility levels on total NPK uptake, protein and oil content, oil yield and water use efficiency (Pooled data of two years)

Treatment	Nutrient uptake (kg/ha)			Protein content	Oil content	Oil	WUE
	N	P	K	(%)	(%)	yield (kg/ha)	(kg/ha-mm)
Irrigation Level							
I_1	71.63	14.16	20.20	27.57	52.62	511	3.24
I_2	58.63	11.54	17.50	27.07	51.98	395	3.04
I_3	53.33	10.14	15.39	27.01	51.45	345	2.67
I_4	50.15	9.27	14.03	26.80	50.73	334	3.29
C.D. (P=0.05)	2.72	0.52	0.95	0.22	NS	26	0.15
Fertility level							
F_1	50.84	9.42	14.93	26.21	49.83	353	2.86
F_2	55.33	10.45	15.92	26.85	50.65	372	2.93
F_3	57.74	10.90	16.25	27.10	51.70	386	2.99
F_4	59.25	11.57	17.22	27.09	51.95	405	3.09
F_5	62.07	12.11	17.34	27.58	52.45	413	3.16
F_6	65.38	13.22	19.03	27.85	53.58	448	3.34
C.D. (P=0.05)	2.06	0.42	0.65	0.20	1.63	21	0.14
I x F interaction	Sig.	NS	NS	Sig	NS	Sig	-

Table 3 Interaction effect of irrigation and fertility levels on growth, yield attributes and seed yield (Pooled data of two years)

Levels of irrigation / Fertility levels	No. of branches/plant				No. of capsules/plant				Length of capsule (cm)			
	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
F_1	3.09	2.83	2.60	2.38	43.7	42.7	40.6	40.2	1.95	1.93	1.82	1.72
F_2	3.18	2.98	3.00	2.63	46.6	44.7	41.9	42.7	2.00	1.94	1.85	1.77
F_3	3.48	3.13	2.83	2.73	47.9	45.7	43.8	40.1	1.97	1.98	1.94	1.84
F_4	3.60	3.40	2.79	2.43	49.2	46.3	43.4	44.6	1.95	1.97	1.95	1.98
F_5	3.69	3.23	2.97	3.20	51.4	47.0	45.5	44.9	2.11	2.12	1.82	1.88
F_6	3.98	3.35	3.23	2.68	53.9	51.2	46.4	41.4	2.19	2.18	1.81	1.84
C.D. (P=0.05)				0.31				2.48				0.11
	No. of seeds/capsule				Seed yield (g/plant)				1000-seed weight (g)			
	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
F_1	57.15	55.30	52.58	48.78	3.51	3.34	3.10	2.92	2.97	3.02	2.83	2.92
F_2	60.13	56.43	53.83	50.08	3.69	3.35	3.31	3.12	3.02	3.07	2.88	2.90
F_3	60.15	59.83	54.35	51.80	3.97	3.38	3.55	3.47	3.08	2.99	2.92	2.98
F_4	61.10	59.08	51.73	57.43	4.19	3.87	3.62	3.25	3.19	3.04	3.01	2.87
F_5	59.53	58.13	61.73	59.35	4.15	3.94	4.09	3.93	3.14	3.13	3.07	3.05
F_6	61.33	63.50	60.50	54.85	4.85	4.57	3.68	3.51	3.31	3.30	2.98	2.83
C.D. (P=0.05)				3.76				0.27				0.14

Table 4 Interaction effects of irrigation and fertility levels on yield attributes and seed yield (Pooled data of two years)

Levels of irrigation/ Fertility levels	Stover yield (kg/ha)				Seed yield (kg/ha)				Harvest index (%)			
	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
F_1	1208	1219	1094	1021	914	682	597	653	44.38	35.86	35.55	39.27
F_2	1289	1240	1163	1107	879	713	692	636	40.60	36.52	37.24	36.64
F_3	1363	1232	1221	1081	928	740	683	632	40.47	37.77	35.94	36.99
F_4	1310	1219	1231	1157	1046	768	671	621	44.32	38.74	35.28	34.89
F_5	1426	1260	1274	1114	972	793	663	717	40.41	38.66	34.28	39.39
F_6	1351	1271	1274	1197	1086	865	706	689	43.69	40.57	35.65	36.47
C.D. (P=0.05)				80				69				2.71
	Oil yield (kg/ha)				Protein content (%)				Nitrogen uptake (kg/ha)			
	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
F_1	450	342	301	321	26.63	26.13	26.23	25.87	61.76	51.16	44.95	45.49
F_2	451	374	351	311	27.28	26.46	27.15	26.53	65.93	54.22	52.71	48.48
F_3	496	376	357	315	27.96	27.14	26.21	27.08	70.19	58.25	53.45	49.08
F_4	567	399	340	313	27.57	27.15	27.00	26.65	75.21	57.78	53.75	50.26
F_5	510	424	343	375	28.07	27.72	27.50	27.02	75.48	62.92	56.00	53.87
F_6	594	454	375	367	27.91	27.82	27.99	27.68	81.22	67.43	59.14	53.72
C.D. (P=0.05)				38				0.40				4.11

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Effect of integrated nutrient management on growth, yield and economics of niger [*Guizotia abyssinica* (L.f.) Cass.]

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ABSTRACT

Field experiment was conducted on niger cv. Utkal Niger 150 (ONS-150) at Regional Research and Technology Transfer Station (OUAT), Semiliguda, Koraput, Odisha during *kharif* season for three years (2008-10) under rainfed condition to find out the effect of bio-fertilizers and green manuring integrated with chemical fertilizers on growth and yield of niger. Results revealed that application of 75% recommended dose of fertilizer integrated with *Azotobacter* and phosphorus solubilizing bacteria (PSB) recorded the highest seed yield of 405 kg/ha with net monetary return of ₹ 4083/ha and B:C ratio of 1.50 followed by recommended dose of fertilizer alone 386 kg/ha with net monetary return of ₹ 3650/ha and B:C ratio of 1.45. Application of 50% recommended dose of fertilizer + *Azotobacter* + PSB recorded seed yield of 370 kg/ha with net monetary return of ₹ 3313/ha and B:C ratio of 1.42.

Keywords: Bio-fertilizer, Economics, Green manure, Niger, Seed yield

Niger [*Guizotia abyssinica* (L.f.) Cass.] is an edible oilseed crop which is grown by the poor farmers mainly in tribal areas under rainfed conditions. The niger seed contains 38 to 43% oil and de-oiled cakes contain more crude proteins (40-42%) than most of the other oilseed cakes (Seegler, 1983). The cultivation of niger crop in India is confined mainly to the states of Madhya Pradesh, Chhattisgarh, Odisha and Maharashtra. It is also raised to the lesser extent in Karnataka, Bihar, Jharkhand, Gujarat and Andhra Pradesh. India is the prime producer of niger in the world, which was grown over an area of 3.8 lakh ha with a production of 1.2 lakh tonnes and productivity of 310 kg/ha. In Odisha, it is grown in an area of 0.86 lakh ha with a production of 0.36 lakh tonnes and productivity of 420 kg/ha (Anonymous, 2012). The use of costly chemical fertilizers can be minimized or replaced with the use of bio-fertilizers and green manures. The information pertaining to the effect of bio-fertilizers and green manuring either alone or in combination with each other, as well as inorganic fertilizers on niger crop is very meager in the region. Thus, the present study was undertaken with the objective of evaluating the integrated use of green manuring, bio-fertilizers and inorganic fertilizers on growth, seed yield and economics of niger production.

MATERIALS AND METHODS

The field experiment was conducted on niger cv. Utkal Niger 150 (ONS-150) at research farm of Regional Research and Technology Transfer Station (OUAT), Semiliguda (Odisha) during *kharif* season for three years (2008-10). The soil of the experiment field was red, sandy to clay loam in texture, acidic in reaction (pH 5.8) with available N (170 kg/ha), P (16 kg/ha) and K (145 kg/ha) contents. Ten treatments of different nutrient management practices as indicated in Table 1, were tested in Randomized Block Design with four replications. The niger seeds of variety ONS-150 was sown in the rows of 30 cm apart in the first week of September. The intra-row spacing of 10 cm was maintained by thinning operation. The thinning and weeding operations were performed on 15 and 21 days after sowing (DAS) in every year of the experimentation. The crops for green manuring *viz*., sunhemp and cowpea were sown prior to 45 days of sowing. These crops were incorporated into the soil at the time of land preparation for main crop. The desired quantity of niger seeds (treatment wise) were inoculated with *Azotobacter* and phosphate solubilizing bacteria (PSB) @ 100 g/kg seed and dried in shade before sowing. The recommended dose of fertilizer (40:40:20 kg NPK/ha) was applied through urea, super phosphate and muriate of potash to the crop as per treatment. Half quantity of N along with full quantity of P and K fertilizers were applied at the time of sowing, while rest half of N was top dressed at 30 DAS. The data on growth parameters and yield attributes were recorded. Both seed and straw yields were recorded after harvesting of the crops. The crop was harvested in first fortnight of December. Economic indices *viz*., gross monetary returns (GMR), net monetary returns (NMR) and benefit cost ratio (B:C ratio) were computed based on the cost involved in the cultivation and value realized from the produce per unit area under various treatments.

RESULTS AND DISCUSSION

Effect on growth parameters: Significantly the mean maximum plant height (112.2 cm) was recorded with application of recommended dose of fertilizer (RDF) (T_1)

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which was at par with that of T_2, T_3, T_6 and T_7 treatments (Table 1). The variations in total nutrients applied in these treatments were not high which could be able to affect the plant height variably. It could also be said that the nutrient supplied under these treatments might have fulfilled the optimum needs by the crop; hence plant height did not differ due to nutrient management. The mean maximum branches/plant (6.0) were recorded with application of 75% RDF + *Azotobacter* + PSB, 25% RDF + green manure (sunhemp), 25% RDF + green manure (cowpea) and 50% RDF + green manure (cowpea). These treatments synthesized more food materials and photosynthates and due to this fact, these treatments might have resulted in the production of greater number of branches/plant than other treatments. Marked superiority in growth parameters like plant height and branches/plant due to adequate nutrient supply in niger is also reported by Kachapur and Radder (1983 a & b).

Effect on yield attributes: Number of capitulae/plant (50) and seeds/capitulum (28) were maximum with application of 75% RDF + *Azotobacter* + PSB (T_3) as compared to rest of the treatments (Table 1). An increase of 2.5% and 5.2% in number of capitulae/plant and seeds/capitulum respectively were noted with application of 75% RDF + *Azotobacter* + PSB (T_3) over RDF (T_1). This treatment (T_3) produced better plant growth in terms of more branching and slightly taller plant than the treatments receiving other nutrient management. Therefore, T_3 resulted in production superiority in above said yield attributes over others. Similar increase in these yield attributes has also been advocated by the earlier researchers in niger crop (Paikray *et al.,* 1990).

Effect on seed yield: The seed yield of crop is generally governed by various yield attributing characters. Consequence upon the superiority in yield attributes with the treatments receiving applications of 75% RDF + *Azotobacter* + PSB recorded highest seed yield (405 kg/ha) during each year of the three years experimentation as well as pooled yield data (Table 2) closely followed by the treatment with RDF alone (386 kg/ha) and 50% RDF + *Azotobacter* + PSB (370 kg/ha). The differences in T_3, T_2 and T_1 were found to be non significant. The next best treatments for seed yield were T_7, T_6 and T_5 with seed yield of 364, 348 and 334 kg/ha respectively. The higher seed yield with T_3 mainly attributed to superiority in different growth parameters and yield attributes with the efficient utilization of nutrient by the plants. Several workers have emphasized for such improved nutrient use efficiency through integrated nutrient management in niger from their investigations (Deshmukh *et al*., 2007 and Thakur and Umat, 2007).

Economic viability: The input and output prices of commodities prevailed during each year of trial were considered for calculating cost of production, net monetary return and benefit cost ratio (Table 2). Application of 75% RDF + *Azotobacter* + PSB recorded highest net monetary return (₹4083/ha) and B:C ratio (1.50) followed by recommended dose of fertilizer (RDF) alone with net monetary return of ₹ 3650/ha and B:C ratio of 1.45 and application of 50% RDF + *Azotobacter* + PSB with net monetary return of ₹ 3313/ha and B:C ratio of 1.42. The cost of production was minimum (₹ 7787/ha) with application of 50% RDF + *Azotobacter* + PSB than 75% RDF + *Azotobacter* + PSB (₹ 8062/ha) and RDF alone (₹ 7937/ha). It can be inferred that application of 50% RDF + *Azotobacter* + PSB proved to be more remunerative than application of 75% RDF + *Azotobacter* + PSB and RDF alone. It is concluded that 50% RDF + *Azotobacter* + PSB can give more seed yield and monetary returns than application of recommended dose of fertilizer alone in niger.

Table 1 Effect of different nutrient management practices on growth and yield attributing characters of niger
(Pooled mean of 2008, 2009 and 2010)

Treatment	Plant height (cm)	Branches/plant (No.)	Capitulae/plant (No.)	Seeds/capitula (No.)
T_1 : Recommend dose of fertilizer (RDF)	112.2	6.0	49	27
T_2 : 50% RDF + Azotobacter + PSB	109.3	6.0	47	27
T_3 : 75% RDF + Azotobacter + PSB	110.4	6.0	50	28
T_4 : 25% RDF + green manure (sunhemp)	98.7	6.0	45	25
T_5 : 50% RDF + green manure (sunhemp)	101.9	6.0	45	25
T_6 : 25% RDF + green manure (cowpea)	106.5	6.0	46	26
T_7 : 50% RDF + green manure (cowpea)	106.2	6.0	46	26
T_8 : Green manure (sunhemp) alone	95.6	6.0	41	25
T_9 : Green manure (cowpea) alone	97.9	6.0	40	25
T_{10} : FYM @ 5t/ha	98.3	5.0	37	25
SEm±	2.2	0.2	3.3	0.6
CD (P=0.05)	6.7	0.6	9.9	1.8

Table 2 Effect of different nutrient management treatments on seed yield and economics of niger

Treatment	Seed yield (kg/ha)				Economics*		
	2008	2009	2010	Mean	Cost of production (₹/ha)	Net monetary return (₹/ha)	B:C ratio
T_1 : Recommend dose of fertilizer (RDF)	328	382	449	386	7937	3650	1.45
T_2 : 50% RDF + Azotobacter + PSB	302	366	442	370	7787	3313	1.42
T_3 : 75% RDF + Azotobacter + PSB	356	395	464	405	8062	4083	1.50
T_4 : 25% RDF + Green manure (sunhemp)	257	241	432	310	7612	1682	1.22
T_5 : 50% RDF + Green manure (sunhemp)	282	280	440	334	7887	2138	1.27
T_6 : 25% RDF + Green manure (cowpea)	280	343	422	348	7737	2713	1.34
T_7 : 50% RDF + Green manure (cowpea)	291	360	441	364	8012	2905	1.36
T_8 : Green manure (sunhemp) alone	222	234	376	277	7337	986	1.13
T_9 : Green manure (cowpea) alone	240	300	383	308	7462	1772	1.23
T_{10} : FYM @ 5t/ha	252.2	314	419	329	9587	269	1.02
SEm±	13.7	30.0	18.3	13.7	-	-	-
CD (P=0.05)	41	87	53	38.6	-	-	-

*On pooled mean basis for 2008, 2009 and 2010

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Factors affecting groundnut output in Andhra Pradesh: co-integration and error-correction modeling

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ABSTRACT

Groundnut is an important oilseed crop of India. The area under groundnut in India was maximum (8.0 million ha), however the production was less due to the lowest yield (938 kg/ha) among all Asian countries. Thus it becomes more important to identify the factors affecting groundnut productivity which is directly related to the farmer's income, sustainable supply and the price stabilization. Unless until the factors affecting groundnut productivity are known, the corrective measures can not be initiated. In this paper efforts have been made to examine whether producer's price, area cultivated, fertilizer applied and rainfall have an important effect on groundnut production in Andhra Pradesh using co-integration and error correction modeling. Co-integration and error correction modeling tend to solve spurious regression results obtained from the analysis of macro-economic data and also establish an equilibrium long-run relationship which enables one to carry out a valid inference of the explanatory variables that are responsible for affecting the output of the crop. A stationary test was performed which revealed only rainfall series was stationary at level, while other series become stationary at first differencing applying the unit root test. Johansen co-integration and error correction procedure was adopted which indicates the existence of five co-integrating vectors at 1% level of significance, hence rejecting the null hypothesis of no co-integrating vector. Further, a parsimonious error correction model was applied. The statistical significance of error correction model for groundnut validates the existence of an equilibrium relationship among the variables. The results, therefore, indicate the combined effect of area, fertilizer, rainfall and price jointly affect the output of groundnut in Andhra Pradesh. Therefore, a favorable price policy, assured irrigation and timely supply of fertilizers at remunerative price would help the farmers to allocate more area under groundnut. These measures are necessary to enhance the productivity as well as income of the farmers and also supply of groundnut in the benefit of consumers.

Keywords: Error-correction modeling, Groundnut, Johansen co-integration, Stationary, Unit root test

In Asia, major groundnut growing countries are China, India, Indonesia, Myanmar, Pakistan, Thailand and Vietnam with area under groundnut cultivation 5125, 8000, 683, 575, 100, 132 and 240 thousand ha, respectively and their respective yield was 2623, 938, 2016, 1270, 1060, 1517 and 1665 kg/ha in the year 2006-07. Though India has maximum area under groundnut cultivation however the production is less due to the lowest yield among all Asian countries. Thus it becomes more important to identify the factors affecting groundnut productivity which is directly related to the farmer's income, sustainable supply and the price stabilization. Unless until the factors affecting groundnut productivity is known, the corrective measures can not be initiated. In India, groundnut is raised mostly as a rainfed *kharif* crop, being sown from May to June, depending on the monsoon rains. As groundnut yield is extremely sensitive to pattern of rainfall distribution, substantial reduction in acreage was observed in major groundnut growing regions. In India, 70% of the groundnut area and 75% of the production are concentrated in the five states. Gujarat is the leading producer contributing 29.63% of the total production followed by Tamil Nadu (20.78%), Andhra Pradesh (15.23%), Maharashtra (8.23%) and Karnataka (7.82%). Anantapur, Kurnool, Chittoor, Kadapa and Mahabubnagar districts contribute nearly 80% of the groundnut production in Andhra Pradesh with a production of 15.52 lakh tonnes.

Reliable estimates of the determinations of output level are essential for policy decision to foster groundnut production. Due to fluctuation in groundnut output, the regression of its statistical data will be spurious, which invalidate the results and interpretation. During the last decade co-integration and error-correction analysis has become a widely used technique for the analysis of economic time series. In the recent past, several authors have used co-integration analysis technique, Hallam *et al*. (1994) to determine the determinants of land prices, Tambi (1999) applied it to agricultural export supply in Cameroon, Tijani *et al.* (1999) applied co-integration analysis to Nigeria Cocoa export supply. Colin *et al.* (2002) applied error correction model (ECM) of induced innovation, based on the two-stage CES production function applied to US data for 1880-1990. The time series properties of the variables include a structural break in 1920, co-integration is established and an ECM constructed, causality tests showed that the factor-price ratios and R&D are the factor-saving biases of technological change. Christopher and Jau (2002) introduced a new spatial price analysis methodology based on maximum likelihood estimation of a mixture distribution model. This method permits differentiation between market integration and competitive market equilibrium and

derivation of intuitive measures of inter-market tradability, competitive market equilibrium, perfect integration, segmented equilibrium, and segmented disequilibrium. One can also use these estimates to derive semi-parametric measures of time-varying regime probabilities to track changing market conditions. Oyekale (2007) used an ECM to analyze the determinants of agricultural land expansion in Nigeria. Co-integration techniques are applied to agricultural data for the United Kingdom from 1953 to 2000 (Jenifer *et al*., 2011) . The time series properties of the variables are checked, co-integration is established and an Error Correction Model (ECM) constructed, which attempts to separate factor substitution from technological change. The ECM formulation shows that the factor price ratio for chemicals and land is the factor-saving bias of technological change. In this paper efforts have been made to examine whether producer's price, area cultivated, fertilizer applied and rainfall have an important effect on groundnut production in Andhra Pradesh using co-integration and error correction modeling.

MATERIALS AND METHODS

The time series data for variables namely, production, cultivated area, fertilizer consumption, rainfall and farm harvest prices was obtained from CMIE and Indiastat.com on-line data base for the period 1972 to 2008 for which the complete (no missing value) time series data was available.

Co-integration and error-correction representation: By definition, co-integration is an econometric technique for testing the correlation between non-stationary time series variables. If two or more series are themselves non-stationary, but a linear combination of them is stationary, then the series are said to be co-integrated. Co-integration has assumed increased importance in analysis that means to describe long-run or equilibrium relationships. However, most economic series tend to exhibit non-stationary.

Non-stationary series has no error-correction representation (Engle and Granger, 1987). A non-stationary series required differencing to become stationary. Dickey-Fuller (DF) test or Augmented Dickey-Fuller (ADF) tests are appropriate tests for examining the stationary of the series (Dickey and Fuller, 1979).

Once the stationary properties of individual series are established, linear combinations of the integrated series are tested for co-integration. If they do not co-integrate, regression of one 1(1) variables to another become spurious and such regression produce high R^2 and t values that are biased towards rejecting the hypothesis of no relationship even when there is no relationship between the variables. A number of studies have provided exposition of the co-integration methodology along with explicit tests for evaluating the co-integrating properties of a pair of non-stationary series (Hendry 1986; Engle and Granger, 1987; Johansen, 1988; Hallam *et al*., 1994).

The procedure consists of two steps. First OLS is applied to the levels of the variables to establish the order of integration for particular combinations of co-integrating variables. Estimates of the residuals error e_t are obtained as:

$$e_1 = X_t - \alpha - \beta Y_t$$

The null hypothesis that e_t has a unit root and therefore is a random walk, is tested against the alternative that, it is stationary using the DF and ADF tests.

The Johansen (1988) procedure which is the most recent method is based on maximum likelihood estimates of all the co-integrating vectors in a given set of variables and provides two likelihood ratio tests for the number of co-integration vectors. This technique is important when testing for co-integration between more than two variables. The first test is based on the maximal Eigen-value, the null hypothesis is that there are at most r co-integrating vectors against the alternatives of r+1 co-integrating vectors. The second test, is based on the trace of the stochastic matrix, the null hypothesis is that there are at most r co-integrating vectors against the alternative hypothesis that there are r or more co-integrating vectors.

In order to achieve a long-run equilibrium relationship the second step of Engle and Granger (1987) is applied by estimating an error-correcting model in which residual from the equilibrium co-integrating regression are used as an error-correcting regressor in a dynamic model. Error Correction Models (ECMs) are a category of multiple time series models that directly estimate the speed at which a dependent variable (Y) returns to equilibrium after a change in an independent variable (X).

Dynamic error correction model: The general form of the equation specified in the double log form as follows:

$$\Delta Q_t = \alpha_0 + \alpha_1 In\Delta A_{t-j} + \alpha_2 \ln \Delta F_{t-p} + \alpha_3 \ln RF_{t-k} + \alpha_4 \ln \Delta P_{t-m} + ECM_{t-1} + u_t$$

Where
$\ln\Delta Q_t$ = Quantity of groundnut output
$\ln\Delta A_{t-j}$ = Area cultivated under groundnut
$\ln\Delta F_{t-p}$ = Fertilizers consumption
$\ln\Delta RF_{t-k}$ = Rainfall during the season
$\ln\Delta P_{t-m}$ = Farm harvest price of groundnut in the state
ECM_{t-l} = Error correction variable
u_t = Error term
Δ= First Difference

RESULTS AND DISCUSSION

Static model using OLS: On a prior basis all the variables are expected to have a positive effect on output of groundnut. But there could be deviation due to one reason or the other. The data used in the study covered the period 1972 to 2008. The results of the static model for groundnut are presented in Table 1, which show that about 61% movements in the dependent variable.

The priori sign for area cultivated is positive while that of fertilizer, rainfall and price are negative. The negative signs of fertilizer could be attributed to less consumption of fertilizers in groundnut, the negative price attributed to glut in the market and negative sign of rainfall could be due to deficient rainfall.

Table 1 The result of static model estimates using OLS (1972-2008)

Variable	Coefficient
Constant	-1.286 (2.217)
Area cultivated	1.968** (0.294)
Fertilizer consumption	-0.038 (0.248)
Rainfall	-0.392 (0.227)
Farm harvest price	-0.164 (0.211)

R-squared= 0.617; Adjusted R-squared= 0.569; S.E. of regression:0.298
RSS: 2.843; Log likelihood: -5.026; DW=2.746; F-statistic:12.900
**significant at 1% level; Figures in parenthesis indicate S.E.

Unit root test: Augmented Dickey-Fuller test statistics for unit root for the entire variables used in the equation is presented in Table 2. For all variables in their level form except rainfall, the null hypothesis that each variable is 1(1) cannot be rejected as their ADF statistics are above the critical value of |-2.94| at 5% significance level. Thus variables are non-stationary at their level form. All non-stationary variables become stationary at first difference as ADF t statistics are above the critical value |-3.63| at 1% significance level. Thus in the first difference form, however we can reject the null hypothesis for all the variables. After making the series stationary, the Johansen procedure to test for the existence of more than two co-integrating vectors was applied.

The result (Table 3) shows that 'None' denotes rejection of the hypothesis at 1% significance level. Likelihood Ratio test indicates 5 co-integrating equation at 1% significance level. Since the results reveal the existence of co-integration among the variables of the model a parsimonious error correction model (ECM) was set up. The results indicated (going by the value of coefficient of multiple determination) that the model was good fit as the dependent variable jointly explained 99% of the movement in the dependent variables which is a marked improvement on 61% obtained with static model using OLS (Table 4). It can also be seen from Fig. 1 that the estimated and actual values overlapped each other indicate a good fit.

Table 2 Univariate stationary properties of the variable (ADF root test)

Variable	ADF 1(0)	ADF 1(1)	No. of Lags
Quantity	-2.63	-7.02	1(1)
Area	-1.63	-5.80	1(1)
Fertilizer	-1.99	-4.47	1(1)
Price	-0.93	-9.15	1(1)
Rainfall	-4.06	-	1(0)

Table 3 Johnsen test for co-integrating vectors for quantity, price, rainfall, area and fertilizer series

Hypothesis		Likelihood ratio	1% critical value	Eigen value	Hypothesis No. of co-integrating equations
Null	Alternative				
r=0	r=1	186.30	76.07	0.903	None ***
r<=1	r=2	106.78	54.46	0.824	At most 1***
r<=2	r=3	47.54	35.65	0.476	At most 2***
r<=3	r=4	25.55	20.04	0.371	At most 3***
r<=4	r=5	9.77	6.65	0.249	At most 4**

*** denotes rejection of the hypothesis at 1% significance level
L.R. test indicates 5 co-integrating equation(s) at 5% significance level

This indicates that the independent variables used in the model are the major determinants of the output of groundnut in Andhra Pradesh. The results show that all the variables included in the model are significant at various levels or at the level itself. The ECM coefficient and that of its one year lag are both highly significant, which is an indication of its high feed back mechanism, thereby non-less of information and a confirmation of the validity of an equilibrium relationship among the variables in the co-integrating equations. This, therefore confirms that the combine effect of all the variables included in the model jointly affect the output of groundnut in Andhra Pradesh.

To identify the factors affecting groundnut production in Andhra Pradesh, static regression model may show the spurious regression results. Co-integration and error correction modeling tend to solve spurious regression results obtained from the analysis of macroeconomic data and also establish an equilibrium long-run relationship which enables one to carry out a valid inference of the explanatory variables that are responsible for affecting the output of the crop. The results show that all the variables included in the model are significant at various levels or at the level itself. The dynamic model shows that the combine effect of area cultivated, fertilizer, rainfall and producers price jointly affect the production of groundnut in Andhra Pradesh. The ECM coefficient and that of its one year lag are both highly significant, which is an indication of its high feed back mechanism, thereby non-less of information and a confirmation of the validity of an equilibrium relationship among the variables in the co-integrating equations. This, therefore confirms that the combine effect of all the variables included in the model jointly affect the output of groundnut in Andhra Pradesh.

Table 4 Modeling the determinants of output by OLS (Dynamic error correction model)

Variable	Coefficient
Constant	2.575 (0.343)
DLArea	2.447*** (0.128)
DLArea(-1)	-0.515*** (0.120)
DLArea(-2)	0.338*** (0.129)
DLFertilizer	-0.391*** (0.092)
LRainFall	-0.397*** (0.054)
DLPrice	-0.199** (0.086)
DLPrice(-1)	-0.010 (0.088)
DLPrice(-2)	-0.224*** (0.082)
ECM	0.710*** (0.064)
ECM(-1)	-0.909*** (0.059)

R-squared = 0.994; Adjusted R-squared= 0.991; S.E. of regression= 0.060; RSS= 0.083; Log likelihood= 54.021; Durbin-Watson= 1.647; Prob (F-statistic)= 0.000
*** and ** indicate significant at 1 and 5% level, respectively
Figures in parenthesis indicate S.E. of the coefficient

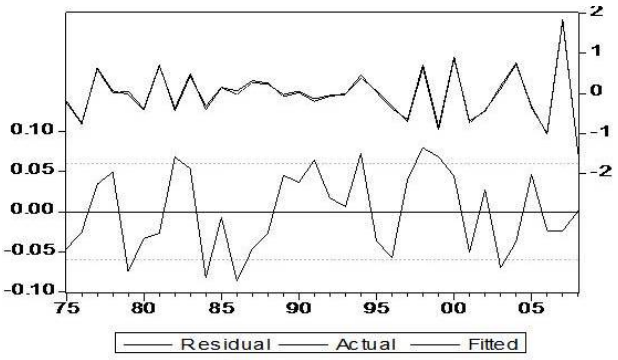

Fig. 1. The graph shows the goodness of fit of the dynamic model

For the policy point of view the study suggests that in order to boost production of groundnut in Andhra Pradesh, a positive price policy along with proper management of available surface and ground water resources (to mitigate the negative effect of uneven distribution of rainfall) must be emphasized with judicial use of fertilizer. Therefore, a favourable price policy, assured irrigation and timely supply of fertilizers at remunerative price would help the farmers to allocate more area under groundnut. These measures are necessary to enhance the productivity as well as income of the farmers and also supply of groundnut in the benefit of consumers.

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Seed-use behaviour of castor growers in Andhra Pradesh

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ABSTRACT

The seed-use behaviour of castor growers in Andhra Pradesh was assessed through the response of 192 randomly selected castor growers in Mahabubnagar district of Andhra Pradesh in 2010. In order to understand the productivity potentials and profitability of castor cultivars as vital information necessary for interpreting the seed-use behaviour, secondary data pertaining to frontline demonstrations (FLDs) in castor for the period from 1997-98 to 2008-09 was analysed. Similarly, to understand the operational cost of castor cultivation (₹ /ha) and output price of castor (₹ /q) in Andhra Pradesh as support information, secondary data of FLDs in castor for the period from 1994-95 to 2007-08 were analysed. These analyses revealed that all the castor growers purchase seeds every year. Better performance of the improved cultivars over the locals was the reason for annual seed-purchase behaviour exhibited by all respondents. Peer group, input dealers, extension personnel of State Department of Agriculture (SDA) and progressive farmers were the information source for seed-purchase. Yield, seed weight and extent of seed filling were the major criteria for choosing the improved castor cultivars. Input dealers and SDA were the major sources of seed purchase. The seed source was selected based on the accessibility of the source, timely availability of seeds, credibility of the source and adequacy of information about the improved cultivars. GCH-4 and Kranthi were the major castor cultivars used by the castor growers. Susceptibility of the improved cultivars to pest and diseases, lack of guarantee about the performance of the cultivars at the time of seed purchase, lack of awareness about the new cultivars and costliness of the seeds of improved cultivars were the major constraints perceived in use of purchased seeds. Implicative strategies were suggested, based on the results of the study to improve the seed-use behaviour of castor growers in Andhra Pradesh.

Keywords: Andhra Pradesh, Castor growers, Seed-use behavior

Seed embodies present and future of Agriculture. Use of quality seeds of improved cultivars has a definite impact on improving productivity and profitability of any crop. Thus, seed becomes a basic and significant input in agriculture. Saving of seeds for the ensuing season through careful selection based on physical purity, appearance and performance was the age old practice followed by the agriculturists. Thus, they themselves provided seed security. However, the modern day's agriculture resulted in development and popularization of high yielding cultivars among the farmers that perform better than the local cultivars under real farm situations through adequate supply of all kinds of inputs. As a result, by and large, the cultivators started depending on the seeds of improved cultivars from external sources. Thus, a huge demand has been created for seed supply and the public sector obviously could not meet such huge demand (Hanchinal *et al*., 2007). As a response to such situation, private sector seed companies, State Agricultural Universities (SAUs), institutes of Indian Council of Agricultural Research (ICAR), Krishi Vigyan Kendras (KVKs), non-governmental organizations (NGOs) and voluntary organizations (VOs) started organizing village level seed production and further multiplication of improved cultivars which are in demand with active participation of the target farmers (Cornwell *et al*., 1992 and Venkattakumar and Padmaiah, 2009). However, these efforts are isolated and need to be integrated appropriately with formal seed sector through formalized institutional mechanisms (FAO, 2007). Since it is imperative to ensure that quality seeds of recommended cultivars are used by the farmers to increase the area under new high yielding cultivars and production, there is a need for increasing awareness and demand for new varieties (Jambhale, 2009) and this situation suits to any crop.

Castor has been one of the major oilseed crops of Andhra Pradesh grown predominantly under rainfed situations. The crop has been grown extensively in Mahabubnagar district which accounts for more than 20% of the total area under castor in India and 90% in Andhra Pradesh (Damodaram and Hegde, 2007). Incidentally, the earlier socio-economic surveys conducted by Directorate of Oilseeds Research (DOR), Hyderabad at Mahabubnagar district revealed that "non-availability of quality seeds of improved cultivars" was the major constraint faced by the castor growers, whereas "information about availability of improved castor cultivars" was the major training/ information need of the castor growers. There are several improved castor cultivars developed at DOR, Hyderabad and the centres of All India Coordinated Research Project (AICRP) on Castor, whose productivity potentials and profitability were already proven under real farm conditions through FLDs. However, the

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earlier socio-economic surveys of DOR implied that these cultivars did not penetrate the major portion of seed-chain in Andhra Pradesh. To improve the castor production scenario in Andhra Pradesh, it is imperative to improve the accessibility of seeds of improved castor cultivars to castor growers. But, assessing the present seed-use behaviour of castor growers obviously will be the pre-requisite. Hence a study was planned with the objectives to assess the productivity potentials and profitability of improved castor cultivars under real farm situations in Andhra Pradesh and seed-use behaviour of castor growers and suggest strategies to improve the seed-use behaviour of castor growers in Andhra Pradesh.

MATERIALS AND METHODS

To assess the productivity potentials and profitability of improved castor cultivars under real farm situations in Andhra Pradesh, secondary data from Annual Reports of FLDs in oilseeds pertaining to the period from 1997-98 to 2008-09 published by Directorate of Oilseeds Research, Rajendranagar, Hyderabad were compiled and subjected to analyses *viz*., percentage seed yield increase of improved technologies (IT) over farmers' practices (FP), additional net returns (net returns of IT - net returns of FP) and benefit: cost ratio (gross returns of IT/ gross returns of FP). Similarly, secondary data pertaining to operational cost of castor cultivation (₹/ha) and output price of castor (₹/q) in Andhra Pradesh were compiled from Annual Reports of FLDs in oilseeds for the period from 1994-95 to 2007-08. To assess the seed-use behaviour of castor growers in Andhra Pradesh, a survey was conducted during February-March 2010 in Mahabubnagar district. A total of 192 randomly selected castor growers were contacted through personal interview and their response was recorded on a structured interview schedule. Information pertaining to the seed-use behaviour of castor growers thus collected was tabulated and subjected to frequency analysis.

RESULTS AND DISCUSSION

Significance of using quality seeds of improved castor cultivars: It was found from the analysis of secondary data that the operational cost of castor cultivation had increased by 4.4 times during the period from 1994-95 to 2007-08 from ₹ 1775/ha to ₹ 7838/ha (Fig. 1). However, the output price of castor had increased only by 1.9 times from ₹ 872/q to ₹ 1720/q during the same period. It implied that irrespective of the change in output price, operational cost of castor cultivation had increased and this might be due to the increase in cost of inputs like seeds, fertilizers, pesticides and labour, etc. The share of investment towards seeds to the total cost of castor cultivation was ranging from 7% (₹ 625/ha) to 27% (₹ 2500/ha) with an average of 11% (₹ 983/ha). This result implies that, on an average, one-tenth of the total cost of castor cultivation is invested on seed and hence, the castor growers need to invest on purchase of quality seeds of improved castor cultivars, so that the investment cost can be compensated by getting higher castor yield levels.

Productivity and profitability of improved castor cultivars under real farm situations in Andhra Pradesh: The seed yield increase of Jyothi over the local castor cultivars was 67% under rainfed situations, while the additional net returns obtained was ₹ 2793/ha (Table 1). Kranti (PCS-4), Haritha and Kiran gave 24, 57 and 54% seed yield increase over the local cultivars with ₹ 2081, 8656 and 7308/ha additional net returns respectively under rainfed situations. Among the castor hybrids, GCH-4 gave seed yield increase of 37% under rainfed situations with additional net returns of ₹ 3995/ha. Another hybrid DCH-32 gave mean seed yield increase of 100% under rainfed conditions over the locals with ₹ 4903/ha additional net returns. The mean seed yield increase of DCH-177 and DCH-519 was 63 and 87% respectively under rainfed conditions with ₹ 5487/ha and ₹ 11412/ha as corresponding additional net returns, respectively. Improved varieties of castor put together gave 48% seed yield increase and ₹ 3646/ha additional net returns, whereas improved hybrids gave 71% seed yield increase and ₹ 5500/ha additional net returns. These results imply that there are improved castor cultivars recommended for castor cultivation in Andhra Pradesh that have the capacity to replace the local cultivars. So, information about these cultivars needs to be popularized among the castor growers.

Seed-use behaviour of castor growers: All the respondents (192) had annual seed-purchase behaviour and none of the farmers used to save the seeds of local cultivars for ensuing seasons (Table 2). Most of the respondents (165) informed that superior performance of the improved cultivars over the locals was the reason for annual seed-purchase behaviour. Peer group (181), input dealers (150), extension personnel of SDA (128) and progressive farmers (53) were the major sources of information towards details about improved castor cultivars, their performance and availability. It implies that castor growers depend mostly on the neighboring information sources. At the same time, research institutions like DOR, Hyderabad (46), All India Radio (AIR) (27) and television (15) were also the information sources for getting details about improved castor cultivars. Progressive and innovative castor growers might have sought information about improved castor cultivars from such sources. All the castor growers (192) opined that 'high yield' was the major criteria for selecting a cultivar. Suitability to local conditions (18), tolerance to pest and diseases (15) and drought tolerance (11) were the other criteria for selecting a cultivar.

Table 1 Impact of improved castor cultivars under rainfed situations in Andhra Pradesh (1997-98 to 2008-09)

Improved castor cultivars	No. of FLDs	Mean seed yield (kg/ha)		% increase in yield	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Additional net returns (₹/ha)	B: C Ratio	
		IT	FP		IT	FP	IT	FP		IT	FP
Improved Varieties											
Jyothi	31	755	453	67	5887	5726	10351	6269	2793	1.7	1.3
Kranti	4	1122	904	24	7387	6594	14987	12113	2081	2.0	1.8
Haritha	5	1675	1065	57	5871	5779	24093	15345	8656	4.1	2.6
Kiran	8	1450	937	54	6434	6179	21519	13956	7308	3.3	2.2
Improved Hybrids											
GCH-4	5	986	715	37	6925	5647	19945	14671	3995	2.8	2.5
DCH-32	26	1160	579	100	5825	4223	13121	6616	4903	2.5	1.6
DCH-177	51	1168	716	63	7091	5882	18202	11506	5487	2.4	1.9
DCH-519	2	1875	1000	87	7288	7050	28250	16600	11412	3.8	2.3
Overall Impact											
Varieties	48	1117	754	48	5560	4740	15139	10672	3646	2.9	2.4
Hybrids	84	1207	721	71	6955	5753	17718	11015	5500	2.5	1.9

IT=Improved technology; FP=Farmers' practice

Table 2 Seed-use behaviour of castor growers in Andhra Pradesh

Seed-use behaviour	Frequency*
Why did you purchase seeds?	
Superior performance of the improved cultivars than the locals	165
Distribution of seeds of improved cultivars through subsidy by SDA	33
Improved cultivars might withstand biotic stress	14
Improved cultivars might withstand drought	10
To repay the credit from input dealers	8
Lack of knowledge on proper selection and saving of seeds of local cultivars	3
Who was the information source for purchase of seeds?	
Peer group	181
Input dealers	150
SDA	128
Progressive farmers	53
Research organizations	46
AIR	27
Television	15
What were the criteria for selecting a cultivar?	
High yielding nature	192
Whatever cultivar distributed under subsidy	29
Suitability of the cultivars to local conditions	18
Tolerance to pest and diseases	15
Tolerance to drought	11
Whatever cultivar that was available with the dealers at the time of purchase	7
What were the seed related characteristics you considered during purchase of seeds?	
High yield	189
Extent of seed filling	38
Seed weight	22
Seed size	12
Price	12
Maturity period	5
Germination %	4
Oil content	1
What were the criteria for selecting source of seed purchase?	
Nearness/accessibility	97
Timely availability of seeds of improved cultivars	96
Credibility of seed source	65
Adequacy of information about the performance of improved cultivar	32
Adequacy of quantity	21
Price	10
What was the source of seed purchase?	
Input dealer	144
SDA	85
Research organizations	21
APSSDC	6

Contd...

Table 2 (contd...)

What did you check at the time of seed purchase?	
Price	85
Quantity	66
Oral guarantee	16
Germination percentage	13
Expiry date	3
What was the castor cultivar purchased?	
GCH-4	121
Kranti	83
MAHYCO-409	23
Jyothi	11
DCH-177	7
DCH-519	6
Nuziveedu Seeds	5
How often did you change the castor cultivars?	
Whenever you came to know about new cultivar	116
Whenever new cultivars were introduced	40
When the yield of the cultivar being cultivated started declining	18
Every year	15
Every second year	3
What were the constraints faced by you in using seeds of improved cultivars?	
Susceptibility of the improved cultivars to pests and diseases	38
No guarantee about the performance	36
Seeds of improved cultivars are costly to buy	33
Lack of awareness about improved cultivars	31
Spuriousness of purchased seeds	19
No compensation during crop failure	13
Lack of accessibility	9
Lack of drought tolerance	8
Untimely supply	5

* : Multiple response

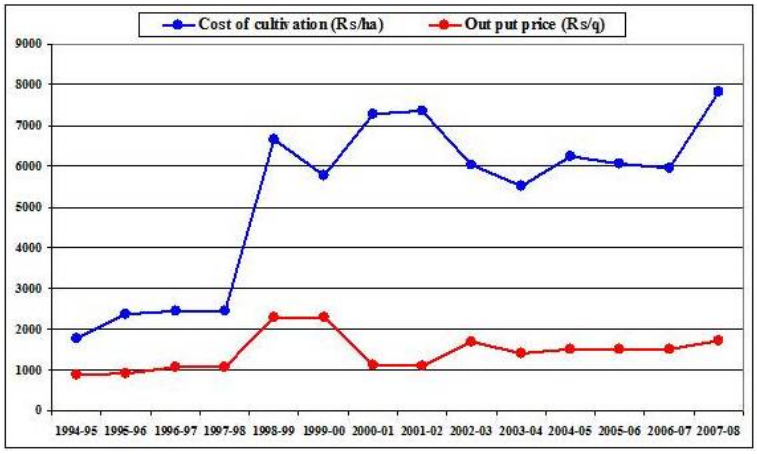

Fig. 1. Operational cost of castor cultivation (₹/ha) and output price (₹/q)

Among the seed related characteristics of seed-purchase behaviour, most of the farmers (189) opined that the seeds of the cultivar that yields better would be the first choice. However, extent of seed filling (38), seed weight (22), seed size (12), price (12), period of maturity (5), germination percentage (4) and oil content (1) were also the criteria while selecting the seeds of improved cultivars. Most of the farmers opined that nearness (97) and timely availability (96) were the criteria for selecting a seed source, whereas creditability of source (65), getting adequate information about the cultivars (32), availability of adequate quantity of seeds (21) and affordability (10) were the other criteria for selecting source of seed-purchase. Most of the farmers purchased seeds from input dealers (144) and SDA (85), both being the neighboring sources. Some of the farmers purchased directly from research organizations (21) and Andhra Pradesh State Seeds Development Corporation (APSSDC) (6) as well. At the time of purchase, price (85), correct quantity (66), oral guarantee by the seed-source about the performance of the cultivar (16), germination

percentage (13) and expiry date (3) were ensured by the castor growers. Most of the farmers (121) used seeds of GCH-4 castor cultivar, followed by Kranthi (83). It implies that many of the improved castor cultivars still to penetrate into the castor seed-chain.

Most of the castor growers changed the castor cultivars, whenever they became aware about new cultivars (116) and hence creating awareness about the new cultivars is very much significant in improving the seed-use behaviour of castor growers. Some farmers opined that they changed the cultivars, whenever new cultivars were introduced (40), who could be categorized as innovators and early adopters. Some of them opined that they changed the cultivars whenever the seed yield of the cultivar being cultivated started declining (18), who might be the late adopters and laggards. Susceptibility of the improved cultivar to pests and diseases (38), no guarantee about the performance of improved cultivars under real farm conditions (36), high cost of the cultivars (33) and lack of awareness about improved cultivars (31) were the major constraints in seed-purchase behaviour of castor growers. Spuriousness of seeds (19), no compensation during poor performance (13), lack of accessibility to seed source (9), lack of cultivars with drought tolerance (8) and untimely supply of castor seeds of SDA (5) were the other constraints in castor seed-purchase opined by the respondents. These constraints reserve a lot of meaningful pointers for castor researchers, development departments and policy makers.

All the castor growers purchased seeds every year and there are improved castor cultivars with capacity to replace the local cultivars in Andhra Pradesh, whose impact were already proven under real farm conditions through FLDs. Hence, penetration of seed of improved castor cultivars into the seed-chain would bring tremendous increase in area and production in Andhra Pradesh. Castor growers expect cultivars to be high yielding with tolerance to major pests and diseases and drought. Seed filling and seed weight were also found as the criteria to select cultivars apart from yield. So, varietal development programmes must concentrate much on these traits. Since localite sources (peer group, input dealers, local extension personnel and progressive farmers) were the major information sources towards purchase of castor seeds, such information need to be intensively disseminated through specialized transfer of technology programmes like awareness campaigns, field days, FLDs and training programmes targeting or in collaboration with progressive farmers, KVK functionaries, extension personnel and input dealers. Accessibility and timely availability of seeds of improved castor cultivars to needy farmers must be ensured by making such cultivars available in seed-chain well in advance through appropriate seed multiplication strategies. Price and quantity were the major factors that affected the seed-purchase behaviour. Hence, village level seed production activities must be tried at larger scales by research organizations, SAUs, KVKs and private seed industries in collaboration with NGOs, so that quality seeds can be produced at village level at required quantity and distributed at cheaper prices in time. Awareness creation about the availability of improved cultivars should be the foremost responsibility of the stakeholders around research and development of castor.

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Development and utility of online knowledge repository of safflower (*Carthamus tinctorius* L.) in Agropedia platform

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ABSTRACT

The development of safflower (*Carthamus tinctorius*) knowledge repository in the larger platform of Agropedia is discussed in this paper. Agropedia is an open platform which facilitates exchange and delivery of information between the agricultural community through a web portal and mobile phone networks accessible to phones with limited data capability. The reasons and requirements for development of such web portal in general and safflower in particular and the requirement of semantic search in Agropedia were discussed. Safflower knowledge model is one among different knowledge models of cereals, pulses and horticultural crops. The need for development of safflower knowledge model and different steps involved in development, different methods of searching the content were discussed. Extension workers can access the content available in Agropedia web portal to advise the farmers with respect to improved technologies in safflower cultivation for obtaining higher crop productivity.

Keywords: Agricultural extension, Agropedia, Knowledge modeling, Safflower

With 60% of the country's total land area contributing around 14% of Gross Domestic Product (GDP), the agriculture sector remains a cornerstone of the Indian economy. Yet the 14% that agriculture contributes to GDP is steadily declining, having comprised 30% of GDP in 1990-91, despite around 52% of India's workforce still engaged in the agriculture sector. A study by the Confederation of Indian Industry indicates that a growth in agriculture by one percentage point is two to three times more effective in reducing poverty than the same increase in other sectors. In this context, the demand for addressing the needs of the agriculture sector becomes even more critical for the nation's development. Many social enterprises are currently addressing the agriculture space, attempting to bring new technologies to rural areas to improve the efficiency and profitability of farmers. One such example is agropedia, an online platform developed by the Indian Institute of Technology, Kanpur, which serves as a one-stop hub for information on the agriculture ecosystem. This platform provides, among other things, a space for stakeholder interaction, best practice sharing, news updates, and an online library certified by the Indian Council of Agricultural Research (ICAR). Agropedia has also collaborated with Krishi Vigyan Kendra (KVK), a training and education center for farmer and rural entrepreneurs, to develop "Voice Krishi Vigyan Kendra" (vKVK), a mobile-based advisory system that sends SMS and voice-based messages to field officers and farmers around the country.

Agropedia platform: One of the major aims of agropedia is knowledge management. Knowledge management refers to managing a repository of knowledge that needs to be identified, captured, stored and processed via Information Technology (IT) tools so that it can be applied further in a new context. The knowledge is disseminated in multiple languages such as English, Hindi and other regional languages through appropriate interfaces to users categorized as anonymous, authentic users and editors. The key elements of the system are knowledge objects and knowledge models (Sini *et al*., 2009 and Sini and Yadav, 2009). Knowledge objects describe agricultural resources such as documents/information in the form of text, image, audio, video, etc. Knowledge models are used to organize, search and navigate agricultural content. Knowledge models are visual representations of important concepts in agriculture with appropriate relationships defined between them. Models can be prepared using several tools but for its easier integration with other models and incorporation in the agropedia portal, these tools need to save or export to Web Ontology Language.

The content in agropedia is aggregated and organized through the use of knowledge models. To enable any specialist to easily develop a knowledge model and connect it to the knowledge base in agropedia, standardization of processes and coding has been done for nine crops i.e., rice, wheat, chickpea, pigeonpea, vegetable pea, sorghum, groundnut, sugarcane and litchi.

The website allows creation of knowledge models with the help of Concept Maps (C-maps). A C-map is a diagrammatic representation of the concept using nodes and arrows, which show relationships between them. The C-map software allows users to easily construct C-maps and link them with the associated resources which can be in form of text, image and sound clips (Tripathi *et al*., 2008). An example is the knowledge model that has been developed for safflower using C-map (Fig. 1). Concepts are designated as nodes and the relation between nodes is depicted through arrows.

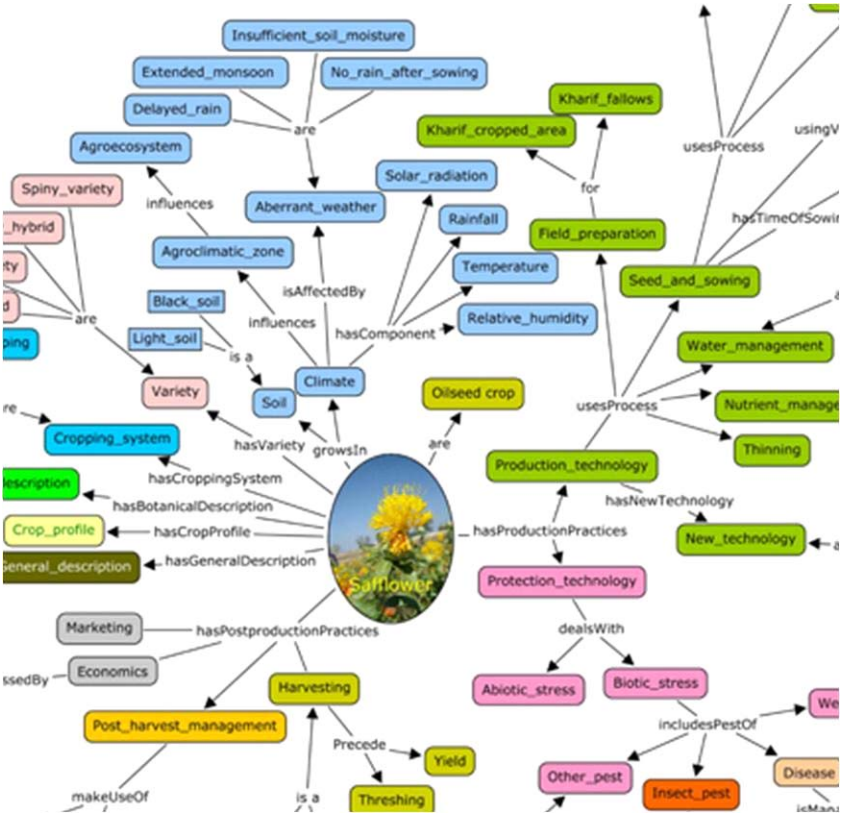


Fig. 1. Snapshot of the knowledge model of safflower

Need for safflower knowledge sharing: Safflower (*Carthamus tinctorius* L.) is one of the important *rabi* oilseed crops of India. It is grown during post-rainy season under residual soil moisture conditions in Vertisols. Although safflower is grown mainly for its seed oil, it has many other uses in preparation of edible dyes, textile dyes, medicines from petals, and all plant parts find place in herbal medicines. Apart from its superior adaptability to scanty moisture conditions, safflower produces oil rich in polyunsaturated fatty acids (linoleic acid 78%) which play an important role in reducing the blood cholesterol level.

India ranks second both in area (30%) and production (23%) in the world. The safflower production in the country was 1.52 lakh tonnes from 2.32 lakh ha with a productivity of 655 kg/ha. Maharashtra and Karnataka are the major safflower growing states accounting for 49, 22% of area and 46, 24% of production, respectively. It is also grown to a limited extent in Gujarat, Andhra Pradesh, Madhya Pradesh, Orissa and Bihar, etc., which altogether account for about 29 and 30% of the safflower area and production in the country (2011-12). There is tremendous scope for expansion of area particularly in drought prone and salinity areas.

The crop productivity is only 50% of the crop yield demonstrated in farmers field (2012-13) with improved methods of crop cultivation (1260 kg/ha). Poor crop management under input starved conditions is one of the major constraints for low crop productivity. The research and development efforts through eight centres of All India Coordinated Research Project (AICRP) on safflower spread in different agro-ecologies and Directorate of Oilseeds Research have yielded promising technologies for realizing higher yields and profits from the crop. The information related to improved technologies available on online availability to extension workers or field level workers is very important. In this context, the content available under the broad headings of climate, soil, cultivars, cropping systems, production technology, protection technology, crop profile, harvesting and post-harvest management were uploaded in Agropedia platform.

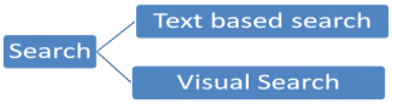
MATERIALS AND METHODS

Methodology followed in development of knowledge model of safflower are detailed below. Knowledge model is the structural representation of knowledge developed by using pieces of knowledge and relationships between them. It was created by using the Concept Map (C-map) tool. In other words, a collection of C-maps associated with

resources (like text, image, audio, and video clips) known as knowledge models. Concept map is a diagrammatically presentation of a concept with arrows and nodes; where nodes present the related terms of the focused concept and the arrow shows the relations of that concept with the other nodes. Concept maps for each topic *viz.*, crop production, crop protection, alternate uses of the crop, contingency planning etc were created and brought together to create knowledge model. Concept maps specific to safflower were created. Safflower knowledge model was created by domain expert using concept ontology editor tools. These models are then used as the essential element to organize the data pool. Indexing is performed by the user after uploading a document. The user is presented with a list of concepts from the Knowledge Models from where he or she can select one or more concepts to associate to the uploaded resource. The system will relate the URI of the selected concept(s) to the document. Similarly when the user search for information, can select concepts from the model, and the system will retrieve all resources which have been previously associated to these concepts. The content was added by crop expert after creating username and password. Content was visible in the platform once the content is certified.

RESULTS AND DISCUSSION

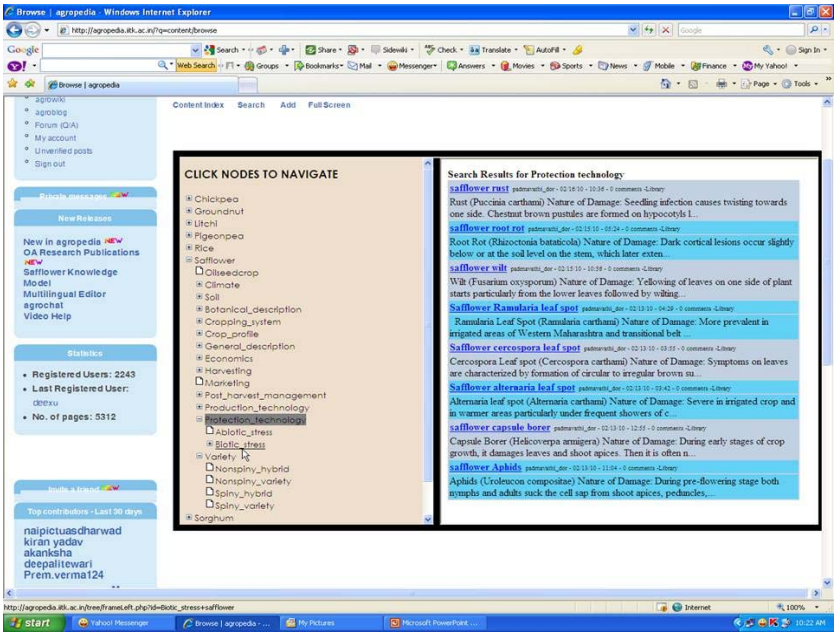
Result of safflower knowledge model and different methods of searching the content are as follows. There are two types of searches in agropedia.



(1) Keyword search: This is google like search, provided on the top right corner. User has to enter the keyword safflower. User has the option either to search from all the spaces in agropedia (Searchall) or search from a particular content type (library, agrowiki, agroblog, agroforum).

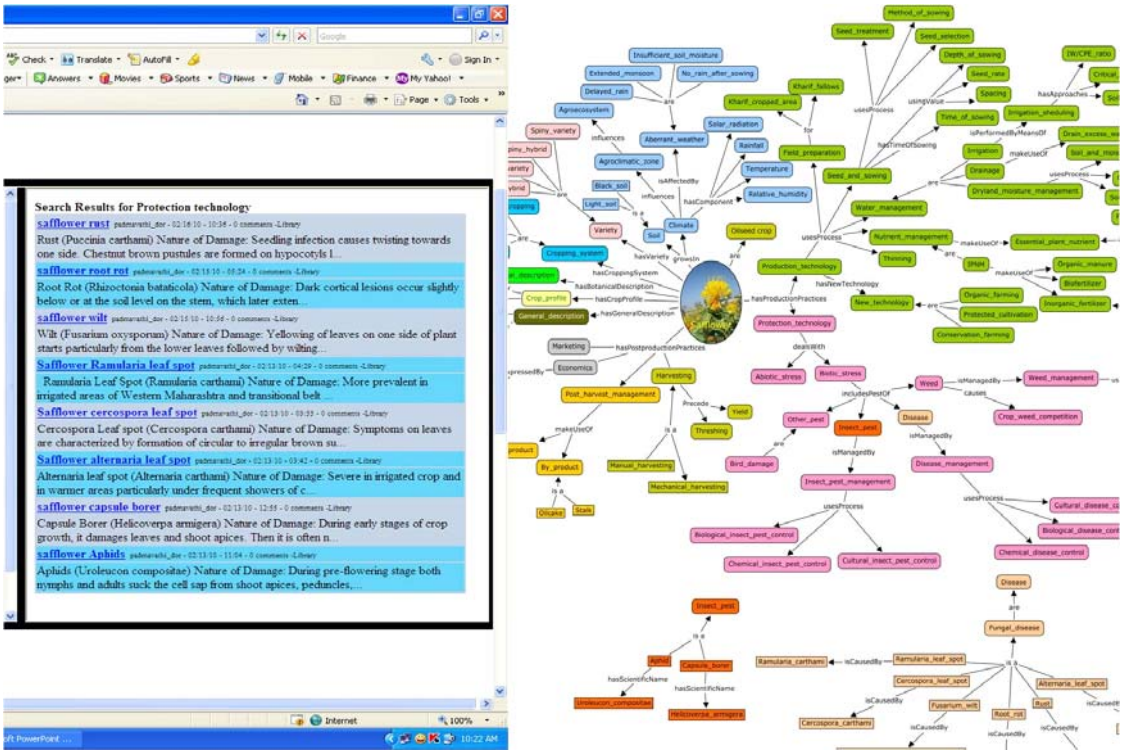
(2) Semantic search: This is a tagged based search. This search is provided in the library section of the extension section. The distinguishing feature of this search is that it does not search the keyword in the document itself, it searches the document tagged with that keyword. This increase the relevancy of the content with the information a user is searching for. Three different interfaces are provided for this search.

(a) Content index: Crop taxonomy of nine crops is represented in a hierarchical structure in left pane and when the user clicks on safflower, results tagged with that taxonomy are displayed in the right pane.



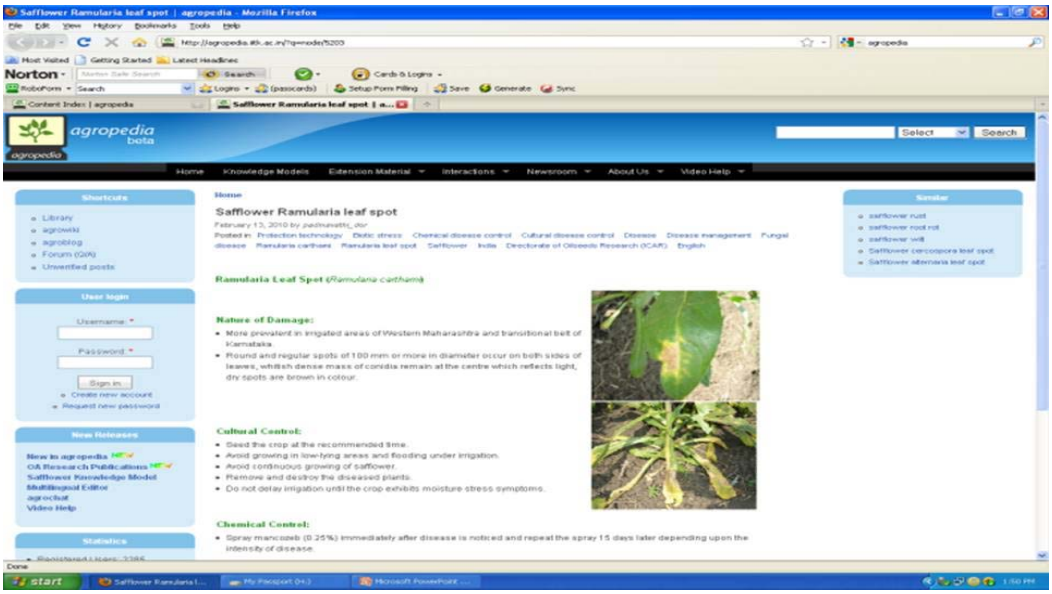
Searching through content index

(b) Browse content: This interface provides the user with a concept map like interface of safflower crop. The map is rendered in the right pane. When a user clicks a concept, results tagged with that concept is displayed in the left pane.



Searching through browse content

(c) Search: This interface provides user with a drop down list of nine crops already present in the knowledge base of the platform and a text box. User has to select safflower and enter a taxonomy term. On clicking the search button, results tagged with that concept is displayed below the text box.



Low productivity of the crop is because of poor crop management under input starved conditions. The online availability of information facilitates the easy accessibility of the content by extension workers become easy. Therefore the extension workers can advise the farmers in time which is very important in crop cultivation in general and in pest and disease management in particular. Involvement of other stakeholders from production to marketing, seed production, processing of safflower and their regular interaction in the platform shall go a long way in improving the productivity, sustenance and profitability of the crop and its growers.

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Genetic divergence analysis for qualitative and quantitative traits in groundnut (*Arachis hypogaea* L.)

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ABSTRACT

In the present investigation, 60 genotypes of groundnut were grouped into 12 different clusters. D^2 analysis indicated existence of wider genetic variability in the population of sixty genotypes which were grouped in twelve clusters, based on their inter clusters distance. The maximum inter-cluster distance was found between cluster III and X carrying one and two genotypes from each cluster respectively followed by that between V and X and cluster III and XII. The minimum inter-cluster distance was observed between cluster VII and XI. The minimum intra-cluster distance (D) was found in cluster II which includes eight genotypes. Cluster III showed high genetic divergence with cluster X followed by cluster V. Therefore it is advisable to make crossing between the genotypes from cluster I with cluster X, cluster III, cluster V and cluster VIII for the generation of wide spectrum genetic variability and isolation of transgressive segregants for enhancement of pod yield in groundnut.

Keywords: Genetic distance, Groundnut, Yield components

Knowledge on genetic distance is very important in the selection of parents in hybridization programmes for identifying heterotic crosses and obtaining desirable segregants. Among the several multivariate analyses, the Mahalanobis D^2 technique is a unique tool for identifying the degree of genetic divergence in a biological population. The objective of this research was to study the magnitude of genetic divergence and characters contributing to it, among 60 groundnut genotypes using the D^2 statistics. Sixty groundnut genotypes were taken for the study at the Centre for Crop Improvement, S.D. Agricultural University, Sardarkrushinagar during summer 2010-11 in a Randomized Block Design with three replications. Each entry was raised in a single row of 3.0 m length with a spacing of 45 x 15 cm. Normal recommended cultural practices and plant protection measures were followed. Five competitive plants were randomly selected for recording biometrical measurements on fourteen traits *viz*., pod yield/plant, days to 50% flowering, days to maturity, number of branches, plant height, number of kernels/pod, 100-seed weight, harvest index, shelling per cent, oil, protein, total carbohydrate which was determined by using Anthrone reagent method, reducing sugar by Nelson-Somogyi method and sucrose percentage calculated by extracting reducing sugar from total carbohydrate.

The data were subjected to multivariate analysis (Rao, 1952). The original mean values were transformed to normalized variables and all possible D^2 values were calculated. For determining clusters, the criterion suggested by Rao (1952) was followed. After establishing the clusters, the inter-cluster distances were worked out by taking the average of the component genotypes in that cluster. The average of inter-cluster distance was computed taking into consideration all the component D^2 values among the members of the two clusters considered. The square root of D^2 values gave the genetic distance (D) between clusters.

The analysis of variance revealed significant differences between the 60 genotypes for all the fourteen characters studied. The aggregate effects of all the fourteen characters were tested by the Wilk's criterion, indicating significant differences between the genotypes. Hence, the analysis of genetic divergence based on D^2 values was considered relevant. The constituents of different clusters with their source are presented in Table 1. Based on D^2 analysis, 60 genotypes were grouped into 12 clusters. Grouping of the genotypes was carried out by following the Tocher's method (Rao, 1952) with the assumption that the genotypes within the cluster have smaller D^2 values among themselves than those from groups belonging to different clusters. The composition of clusters is given in Table 1 and clustering pattern is shown in Table 2. The cluster III was the smallest having one genotype of ICRISAT-Hyderabad. Cluster II, V, VI, XI contained eight genotypes of ICRISAT-Hyderabad and cluster V also contains two genotypes from Junagadh with cluster VI also contains one genotype from USA. The cluster I and VII has six genotypes of ICRISAT, Hyderabad. The cluster IX and XII contain three genotypes of ICRISAT, Hyderabad. The cluster VIII has five genotypes from ICRISAT, Hyderabad whereas cluster IV and X has two genotypes from ICRISAT, Hyderabad. Thus the observed clustering pattern of genotypes was independent of their origin.

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Table 1 Composition of cluster based on D^2 values of sixty genotypes of groundnut

Cluster	No. of genotypes	Name of genotypes	Origin/Source
I	6	ICGV-93289, ICGV-95440, ICGV-95446, ICGV-95469, ICGV-95492, ICGV-02286	ICRISAT, Hyderabad
II	8	ICGV-02271, ICGV-03157, ICGV-03184, ICGV-01379, ICGV-01433, ICGV-02234, ICGV-02242, ICGV-01258	ICRISAT, Hyderabad
III	1	ICGV-97281	ICRISAT, Hyderabad
IV	2	ICGV-02313, ICGV-02240	ICRISAT, Hyderabad
V	8	ICGV-97328, ICGV-01005, ICGV-01015, ICGV-01043, ICGV-1080, ICGV-01105, GG2, J-11	ICRISAT, Hyderabad Junagadh, Gujarat
VI	8	ICGV-02144, ICGV-03178, ICGV-03179, ICGV-03181, ICGV-01376, ICGV-01395, ICGV-03137 CHICO	ICRISAT, Hyderabad USA
VII	6	ICGV-01014, ICGV-03056, ICGV-03057, ICGV-02022, ICGV-03169, ICGV-02229	ICRISAT, Hyderabad
VIII	5	ICGV-01432, ICGV-01434, ICGV-01447, ICGV-02227, ICGV-03166	ICRISAT, Hyderabad
IX	3	ICGV-03194, ICGV-03196, ICGV-03206	ICRISAT, Hyderabad
X	2	ICGV-00371, ICGV-03207	ICRISAT, Hyderabad
XI	8	ICGV-01124, ICGV-99240, ICGV-99241, ICGV-99247, ICGV-99249, ICGV- 00346, ICGV-00362, ICGV-00360	ICRISAT, Hyderabad
XII	3	ICGV-03187, ICGV-01369, ICGV-01393	ICRISAT, Hyderabad

The maximum inter-cluster distance (D = 7.044) was found between cluster III and X carrying one and two genotypes from each cluster respectively followed by that between V and X (D = 6.447) and cluster III and XII (D= 5.943). The minimum inter-cluster distance was observed between cluster VII and XI (D = 2.770). The intra-cluster distance (D ranged from 1.909 to 2.863), the maximum being in cluster V (2.863) (Table 3). The minimum intra-cluster distance (D) was found in cluster II (1.909) which includes eight genotypes. The cluster I have the highest mean values for number of seeds per pod (2.75). The cluster II was better for shelling per cent (68.41). The cluster III got desirable rating in respect of 100-seed weight (102.33) whereas, sucrose per cent (10.17) was higher in cluster IV. The cluster V has highest mean values for pod yield/plant (24.77) and higher oil per cent (47.49) for cluster VI. Protein per cent (34.86) was found to be highest in cluster VII where as in cluster VIII days to 50% flowering (45.27) was desirable. Number of branches/plant (6.98) has better value for cluster XI. Total carbohydrate (12.71) was found to be superior in cluster X and plant height (51.97) for cluster XI. The cluster XII has highest mean values for harvest index (27.35). The absence of parallelism between geographic distribution and genetic diversity in the present study is in accordance to the findings of Nadaf *et al.* (1986), Golakia and Makne (1992), Yadav *et al.* (1991), Katule *et al*. (1992) and Reddy and Reddy (1993) in groundnut.

Table 2 Source and clustering pattern of sixty genotypes of groundnut

Cluster	Gujarat Junagadh	Hyderabad ICRISAT	USA	Total
I	0	6	0	6
II	0	8	0	8
III	0	1	0	1
IV	0	2	0	2
V	2	6	0	8
VI	0	7	1	8
VII	0	6	0	6
VIII	0	5	0	5
IX	0	3	0	3
X	0	2	0	2
XI	0	8	0	8
XII	0	3	0	3
Total	2	57	1	60

Table 3 Average inter and intra-cluster distance ($D = \sqrt{D^2}$) values in groundnut

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	**2.559**	5.096	3.823	4.829	3.427	5.071	4.447	5.404	4.856	6.152	3.957	5.778
II		**1.909**	4.873	3.842	4.971	2.484	4.028	2.957	4.168	3.691	3.423	3.667
III			**0.000**	5.010	4.089	5.624	5.409	5.772	5.907	7.044	4.395	5.943
IV				**2.390**	5.766	4.574	4.863	4.131	5.228	4.930	3.852	5.407
V					**2.863**	4.617	3.736	5.099	4.691	6.447	4.117	5.968
VI						**2.282**	3.155	2.851	3.798	3.663	3.103	3.463
VII							**2.089**	3.412	4.649	4.920	2.770	4.160
VIII								**1.984**	5.331	4.759	3.505	5.016
IX									**1.926**	4.378	4.475	5.631
X										**2.275**	4.537	3.860
XI											**2.016**	4.011
XII												**2.148**

Bold values denote inter cluster distances

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GJG-9: A high yielding and stem rot tolerant Spanish bunch groundnut (*Arachis hypogaea* L.) variety for Gujarat state

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ABSTRACT

A Spanish bunch groundnut genotype GJG-9 was identified based on the mean pod yield from the state level trials. It has recorded higher pod yield of 1632 kg/ha as compared to the checks *viz*., GG-2 (1255 kg/ha), GG-5 (1355 kg/ha) and GG-7 (1413 kg/ha). The genotype was also tested in Spanish bunch trials of AICRPG and performed better than GG-2 by 9.95% and 12.20% during *kharif*, 2007 and 2008, respectively with a mean increase of 11.00%. But, it was comparable with GG-7 and TG-37A. Average kernel yield of GJG-9 was 1183 kg/ha as against the checks *viz*., GG-2 (935 kg/ha), GG-5 (997 kg/ha) and GG-7 (1026 kg/ha). GJG-9 had recorded an average 100 kernel weight of 36.89 g, average 100 pod weight of 96.70 g and average shelling out-turn of 72.49%. The reaction against tikka, rust and collar rot, the variety was comparable to the check varieties under field conditions. However, GJG-9 was found tolerant to the stem rot as compared to the check varieties. Whereas, the damage due to thrips and jassids of GJG-9 was comparable to the check varieties. Based on the superior performance, GJG-9 has been released in 2010 for general cultivation in the *kharif* bunch groundnut growing areas of Gujarat State.

Keywords: GJG-9, Groundnut, Spanish bunch, Yield

Groundnut (*Arachis hypogaea* L.) is one of the most protein rich vegetable oilseed crops of India. Gujarat is the leading groundnut growing state. The area under groundnut in Gujarat during 2010 was 16.91 lakh ha. having 31.59 lakh tonnes of production and average productivity of 1868 kg/ha (Anonymous, 2010a). Presently cultivated *kharif* Spanish bunch groundnut varieties *viz*., GG-2, GG-5 and GG-7 are obsolete and need to be replaced with new high yielding varieties. Hence, with an objective to replace the old varieties, an attempt was made to develop a new varieties with desired agronomic features. There is a great demand for medium to bold seeded variety in India and especially in Gujarat for the export of HPS type of groundnut. In addition, during *kharif* season, stem rot disease is one of the most important biotic stresses in groundnut. Therefore, a variety having stem rot tolerance is highly essential to stabilize the pod yield.

The Spanish bunch groundnut genotype GJG-9 was developed by hybridization followed by pedigree method of selection. It is a derivative of GG-5 x ICGV-90116. The material was advanced up to F6 generation and from the segregating populations, a Spanish bunch type was isolated and evaluated for its yield performance. It derived from a cross of drought tolerant Spanish bunch variety GG-5 and large seeded Virginia bunch genotype ICGV-90116. The genotype was tested in station trial at Junagadh during *kharif*, 2004. Later, it was evaluated under multilocation trials at eleven locations across Gujarat State during *kharif*, 2005 to 2009 (Anonymous, 2010b). The genotype was also nominated for evaluation under AICRPG trials during *kharif*, 2007 and 2008 for Zone II (Southern Rajasthan and Gujarat) (Anonymous, 2010c). It was screened for reaction to pests (thrips and jassids) and diseases (tikka, rust, stem rot and collar rot) under field and sick plot conditions. The recommended packages of practices were followed for conducting the trials to raise the healthy crop. The station, state and AICRPG trials were conducted in Randomized Block Design and the yield data were analyzed following the statistical procedure given by Panse and Sukhatme (1985). The analysis of variance revealed that the pod yield differences were significant in the station trial as well as all 37 state trials except at Derol station where the differences were non-significant during *kharif*, 2009. On the basis of pod yield data from the station and state trials, GJG-9 had proven its superiority in all the six years. The mean pod yield over six years of GJG-9 was 1632 kg/ha as compared to the checks *viz*., GG-2 (1255 kg/ha), GG-5 (1355 kg/ha) and GG-7 (1413 kg/ha), which was 15.5 to 30.0 % higher than the checks (Table 1). The mean pod yield in the AICRPG trials revealed that the testing genotype had recorded the highest pod yield of 1483 kg/ha as compared to the check varieties; GG-2 (1336 kg/ha), GG-7 (1434 kg/ha) and TG-37A (1434 kg/ha). GJG-9 has performed better than GG-2 with 11.00% higher mean pod yield, but it was comparable with other two check varieties, GG-7 and TG-37A with 3.42% higher pod yield (Table 2).

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Fig. 1. Plant, pods and kernels of groundnut variety, GJG-9

Ancillary observations of economic attributes of GJG-9 along with the checks are presented in Table 3. Average kernel yield of GJG-9 was 1183 kg/ha, which was 26.5%, 18.7% and 15.3% higher over the check varieties *viz.*, GG-2 (935 kg/ha), GG-5 (997 kg/ha) and TG-37A (1026 kg/ha), respectively (Table 3). GJG-9 recorded higher mean 100-kernel weight (36.89 g) over the GG-2 (28.98 g) and GG-5 (33.58 g), but it was comparable with GG-7 (36.38 g). The average 100-pod weight of GJG-9 was also higher (96.70 g) as compared to the check varieties *viz.*, GG-2 (68.29 g), GG-5 (85.66 g) and GG-7 (88.44 g). The average shelling out-turn of the testing genotype was at par with all the check varieties.

The testing variety GJG-9 was screened for pests and diseases during *kharif*, 2004 to *kharif*, 2009 in Gujarat (Subrahmanyam *et al.*, 1995). The testing genotype showed lower incidences of thrips and jassids as compared to all the check varieties. For the reaction against tikka, rust and collar rot, the genotype was comparable to the check varieties under field conditions. However, GJG-9 was found tolerant to stem rot as compared to the check varieties (Table 4).

By virtue of all the superior performance for high pod yield, kernel yield, oil yield, haulm yield with better quality characteristics, the newly developed variety GJG-9 has been released by 6th Combined Joint AGRESCO (Agricultural Research Council) meeting of plant breeding and genetics sub-committee held at Junagadh (Gujarat) during 20-22 April, 2010 (Anonymous, 2010d) for rainfed groundnut growing areas of Gujarat state. It has been notified for *kharif* rainfed cultivation in the Gujarat state (Anonymous, 2012).

In the station and state evaluation trials conducted in Gujarat over six seasons during 2004-09, the released variety, GJG-9 was found to mature in about 103 days and recorded up to 30% increased pod yield, 27% higher kernel yield and 25% higher oil yield as compared to check GG-2. However, the shelling out-turn and oil content of GJG-9 were at par with all the check varieties.

Table 1 Yield performance of groundnut variety GJG-9 in the station and state trials conducted during 2004-2009 in Gujarat state

Season/Year	Name of Trial	No. of Locations	Mean pod yield (kg/ha)*			
			GJG-9	GG-2(C)	GG-5(C)	GG-7(C)
Kharif, 2004	PET-SB#	1	1778	776	1296	1280
Kharif, 2005	SSVT- SB	4	1476	1073	1213	1273
			(891-1811)	(860-1317)	(666-1687)	(643-1670)
Kharif, 2006	LSVT- SB	5	1144	789	853	944
			(1027-1302)	(602-1160)	(710-1177)	(798-1269)
Kharif, 2007	LSVT- SB	11	1691	1346	1384	1509
			(1183-3259)	(951-2790)	(880-2235)	(971-2975)
Kharif, 2008	LSVT- SB	7	1549	1209	1442	1449
			(1141-2029)	(624-1632)	(1008-1993)	(1035-2005)
Kharif, 2009	LSVT- SB	10	1909	1542	1574	1585
			(896-3102)	(1014-2164)	(1009-2378)	(938-2199)
Overall Mean		(38)	1632	1255	1355	1413
Overall % increase over the checks			-	30.03	20.44	15.50

Station trial; *Mean over locations; C=Check; Figures in parentheses indicated the range of pod yield (kg/ha)

Table 2 Yield performance of groundnut variety GJG-9 in the AICRPG trials in Zone II, India

Season/Year	Name of Trial	No. of Locations	Mean pod yield (kg/ha) over locations			
			GJG-9	GG-2 (L.C.)	GG-7 (Z.C.)	TG-37A (N.C.)
Kharif, 2007	IVT-SB-I	5	1524	1386	1585	1565
			(1315-1952)	(740-2178)	(1152-2078)	(987-1959)
Kharif, 2008	IVT-SB-II	5	1443	1286	1283	1303
			(1068-2017)	(557-2033)	(882-1505)	(685-1917)
Overall Mean		(10)	1483	1336	1434	1434
Overall % increase over the check			-	11.00	3.42	3.42

Figures in parentheses indicated the range of pod yield (kg/ha)

Table 3 Mean ancillary observations of economic attributes of variety GJG-9 along with checks from the state trials at Junagadh centre during *kharif*, 2004 to *kharif*, 2009

Character	Variety			
	GJG-9	GG-2(C)	GG-5(C)	GG-7(C)
Pod yield (kg/ha)	1632	1255	1355	1413
Kernel yield (kg/ha)	1183	935	997	1026
Oil yield (kg/ha)	570	455	487	503
Haulm yield (kg/ha)	2590	2332	2408	2387
Shelling out-turn (%)	72.49	74.48	73.57	72.60
Oil content (%)	48.17	48.68	48.81	49.08
100-pod wt. (g)	96.70	68.29	85.66	88.44
100-kernel wt. (g)	36.89	28.98	33.58	36.38
Maturity days	103	103	103	105
Count (No. of kernels/30 g wt.)	76.0	93.5	80.0	68.8

Table 4 Mean rating of incidence of insect-pests and diseases at Junagadh centre (*kharif*, 2004 to *kharif*, 2009)

Diseases/Insect Pests	Variety			
	GJG-9	GG-2 (C)	GG-5 (C)	GG-7 (C)
I. Diseases				
Tikka score (1-9 scale)	6.3	6.3	7.2	7.0
	(2.0-9.0)	(3.0-8.0)	(4.0-9.0)	(4.0-9.0)
Rust score (1-9 scale)	3.0	3.0	3.0	3.1
	(0.0-6.0)	(0.0-6.0)	(0.0-6.0)	(0.0-6.0)
Stem rot incidence (%)	7.96	18.87	25.67	41.44
(in sick plot)	(1.9-18.2)	(3.7-30.2)	(6.3-47.8)	(3.6-75.0)
Stem rot incidence (%)	0.69	0.78	1.33	1.80
(in field conditions)	(0.0-2.1)	(0.0-2.3)	(0.0-4.0)	(0.0-2.9)
Collar rot incidence (%)	8.88	6.52	6.03	8.47
(in sick plot)	(0.0-19.2)	(3.8-9.3)	(0.0-14.6)	(0.0-14.3)
Collar rot incidence (%)	0.54	1.17	1.78	3.16
(in field conditions)	(0.0-1.1)	(0.0-2.3)	(1.0-2.6)	(2.0-4.3)
II. Insect Pests				
% leaf damage by thrips	53.43	63.90	62.07	57.68
	(20.0-74.2)	(48.6-90.3)	(38.0-76.4)	(38.0-72.2)
Average number of	2.25	3.95	2.32	2.29
jassids/3 leaves/plant	(1.7-2.5)	(2.5-2.7)	(2.3-2.3)	(1.9-2.7)

Figures in parentheses indicated the range

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Combining ability analysis for seed yield and its attributes in Indian mustard [*Brassica juncea* (L.) Czern and Coss]

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ABSTRACT

The hybrids were developed by adopting diallel mating design excluding reciprocals involving ten diverse Indian mustard genotypes during *rabi* 2007-08. The resultant 45 hybrids along with their parents were evaluated in a Randomized Block Design with three replications under four environments *viz.*, timely sown at Sardarkrushinagar (E_1) and Ladol (E_2), and late sown at Sardarkrushinagar (E_3) and Ladol (E_4), during *rabi* 2008-09. Combining ability analysis on pooled basis, revealed importance of both additive and non-additive genetic variances for the control of various traits. However, the ratio $\sigma^2 gca/\sigma^2 sca$ indicated preponderance of non-additive gene action for days to 50% flowering, days to maturity, seed yield/plant and oil content, while additive gene action was preponderant for rest of the traits. The parents RK 9501, GM 1 and GM 2 were good general combiners, whereas, the crosses 'RK 9501 x GM 2', 'GM 1 x GM 3' and 'GM 3 x SKM 139' were found to be the best specific combinations for seed yield/plant and some of the important yield contributing traits. However, on the basis of *per se* performance, exploitable heterosis and significant *sca* effects for seed yield/plant and some of its important components, the above hybrids were considered to be the most promising for exploitation of heterosis.

Keywords: *Brassica juncea*, Combining ability, Diallel, Mustard

Mustard is one of the most important edible *rabi* oilseed crops. The genus *Brassica* belongs to *Brassicaceae* family and includes many crop species. Exploitation of heterosis in mustard has been recognized as a practical tool in providing plant breeders a means of improving yield and other important traits. The phenomenon of heterosis of F_1 hybrids can also reflect special combining ability (SCA) and general combining ability (GCA) of parental lines. Combining ability concepts are the basic tools for improved production of crops in the form of F_1 hybrids. Identifying parental combinations with strong heterosis for yield and obtain genetic parameters are the most important steps in the development of new cultivars. Among different mating designs, diallel analysis is a systematic approach which has been widely used in crop plants for testing the performance of genotypes in hybrid combinations and also for characterizing the magnitude and nature of gene action involved in controlling quantitative characters (Griffing, 1956).The present investigation was undertaken with a view to estimate general and specific combining ability variances and effects in Indian mustard.

The experimental material consisted of 10 parents and their 45 F_1s produced utilizing diallel mating design suggested by Griffing, 1956 method II and model I and were developed at the Seed Technology Department, S.D. Agricultural University, Sardarkrushinagar during *rabi* 2007-08. The field experiments were conducted in a Randomized Block Design with three replications at the Seed Technology Department, S.D. Agricultural University, Sardarkrushinagar and the Agricultural Research Station, S.D. Agricultural University, Ladol during *rabi* 2008-09 over four environments created by two staggered dates of sowing *viz.*, timely sown (16th October) at Sardarkrushinagar (E_1) and Ladol (E_2) and late sown (3rd November) at Sardarkrushinagar (E_3) and Ladol (E_4). All agronomic practices and plant protection measures were adopted in order to obtain a healthy crop growth. A sample of five representative plants were taken from each plot for recording data on plant height, number of branches/plant, number of siliquae on main raceme, number of siliquae/plant, seed yield, 1000-seed weight and oil content in each replication, while data on days to 50% flowering, days to maturity were recorded on plot basis. Mean values of sample for various traits were subjected to combining ability analysis.

Analysis of variance for combining ability for all the traits studied under four environments (Table 1) revealed that the mean squares due to general combining ability were significant for all the traits in all the environments. The mean squares due to specific combining ability were found to be significant for all the traits studied in all the environments except for number of branches/plant in all environments and number of siliquae/plant in E_2.

On pooled basis, the ratio of *gca* and *sca* variance components ($\sigma^2 gca/\sigma^2 sca$) was less than unity for days to 50% flowering, days to maturity, seed yield/plant and oil

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content. This indicated that non-additive type of gene action played greater role in the inheritance of these characters. The presence of predominantly large amount of non-additive gene action would necessitate the maintenance of heterozygosity in the population. Breeding methods such as biparental mating and *inter se* crossing between suitable lines followed by reciprocal recurrent selection may increase frequency of genetic recombinations and hasten the rate of genetic improvement. Whereas, the ratio of *gca* and *sca* variance components ($\sigma^2 gca/\sigma^2 sca$) was more than unity for plant height, number of branches/plant, number of siliquae/main branch, number of siliquae/plant and 1000-seed weight. This indicated that additive type of gene action played greater role in the inheritance of these characters. Breeding methods such as recurrent selection may increase frequency of genetic recombination and hasten the rate of genetic improvement. The predominant role of additive gene action in the inheritance of plant height was observed by Singh (2005) and Shrivastava *et al*. (2009) for number of siliquae/main branch; Ramesh and Thakral (2003) and Singh (2005) for number of siliquae/plant; Singh *et al*. (2001) and Shrivastava *et al*. (2009) and for 1000-seed weight (Bhatt, 2007).

Combining ability analysis pooled over environments revealed that mean squares due to GCA variance, SCA variance, GCA x environments and SCA x environments were significant for most of the characters (Table 1). The results on general combining ability effects on pooled basis (Table 2) revealed that the parents, RK 9501, GM 2, GM 3, GM 1 and SKM 139 were found to be good combiners for seed yield/plant as well as for some of its important component traits. SKM 149 was average general combiner for seed yield/plant but was good general combiner for days to 50% flowering, days to maturity, plant height and number of siliquae/plant. On pooled basis, parent GM 2 was good general combiner for earliness; Rai Kutch for dwarf ness; RK 9501 for number of branches/plant, number of siliquae/main branch, number of siliquae/plant and 1000-seed weight and GM 1 for oil content.

The crosses, RK 9501 x GM 2, GM 1 x GM 3 and GM 3 x SKM 139 had significant positive *sca* effects on the basis of pooled over environments for seed yield/plant. Significant positive *sca* effects for seed yield have also been reported by Ghosh *et al*. (2002); Gupta and Narayan (2005) and Patel *et al*. (2005). Out of these, RK 9501 x GM 2 exhibited significant desirable *sca* effects for number of branches/ plant, number of siliquae/main branch and number of siliquae/plant. The hybrid, GM 1 x GM 3 exhibited significant desirable *sca* effects for days to 50% flowering, days to maturity, plant height, number of siliquae/main branch, number of siliquae/plant and oil content. The hybrid, GM 3 x SKM 139 exhibited significant desirable *sca* effects for number of siliquae/main branch and number of siliquae/plant. The crosses showing significant *sca* effects are expected to throw-off transgressive segregants in segregating generations and thus, such crosses can be exploited for the improvement of yield and specific yield attributing traits (Table 3).

The estimates of *sca* effects revealed that none of the hybrids was superior for all the characters. However, best three hybrids on the basis of *sca* effects for seed yield/plant over the environments were RK 9501 x GM 2, GM-1 x GM 3 and GM 3 x SKM 139. The highest *sca* effects in desired direction for different characters were exhibited by different hybrids *viz.*, PM 67 x GM 2 for days to 50% flowering, PM 67 x RK 9501 for days to maturity, SKM 149 x GM 2 for plant height, GM 1 x RK 9501 for number of branches/plant, for number of siliquae/plant and for seed yield/plant. RK 9501 x GM 2 for number of siliquae/plant and for seed yield/plant, SKM 149 x SKM 139 for 1000 seed weight and GM 1 x PM 67 for oil content (Table 3).

Table 1 Analysis of variance for combining ability for different traits pooled over environments in mustard

Source of variation	d.f.	Characters								
		Days to 50 % flowering	Days to maturity	Plant height	Number of branches/ plant	Number of siliquae/ main branch	Number of siliqua/ plant	1000 seed weight	Seed yield / plant	Oil content
GCA	9	55.202**	147.921**	993.195**	130.138**	430.977**	14110.176**	13.447**	283.605**	12.606**
SCA	45	8.098**	18.481**	30.010**	0.651	10.287**	275.602**	0.246**	36.193**	2.017**
Environments	3	102.022**	254.617**	521.095**	73.193**	401.481**	5418.926**	0.539**	401.933**	7.935**
GCA x E	27	2.619**	6.624**	13.359**	1.074**	1.577**	21.309	0.214**	9.614**	0.553**
SCA x E	135	1.174**	2.032**	6.024**	0.206	0.728	21.355	0.097**	4.472**	0.211**
Error	432	0.447	0.680	3.713	0.537	0.832	23.179	0.022	2.776	0.066
$\sigma^2 gca$	-	1.141	3.068	20.614	2.700	8.961	293.479	0.280	5.851	0.261
$\sigma^2 sca$	-	1.913	4.450	6.574	0.029	2.364	63.106	0.056	8.354	0.488
$\sigma^2 gca/\sigma^2 sca$	-	0.596	0.689	3.136	94.720	3.791	4.651	4.991	0.700	0.535

*,** = Significant at P=0.05 and P=0.01 levels, respectively

Table 2 Estimates of general combining ability effects of parents for various traits of mustard in pooled environments

Parent	Days to 50% flowering	Days to maturity	Plant height	Number of branches/ plant	Number of siliquae/ main branch	Number of siliquae/plant	1000-seed weight	Seed yield/ plant	Oil content
GM 1	-0.57**	0.33**	-2.79**	1.53**	3.56**	20.83**	0.09**	2.70**	0.61**
GM 3	-0.57**	-0.16	0.48	0.75**	1.54**	9.81**	0.11**	1.49**	0.02
SKM 149	-0.64**	-1.97**	-2.30**	0.17	0.59**	1.50**	-0.06**	-0.00	-0.49**
SKM 139	-0.82**	-2.23**	-2.59**	-0.53**	-0.18	-2.80**	-0.09**	0.49*	0.05
PM 67	0.72**	1.79**	3.04**	0.88**	-0.98**	-5.90**	-0.39**	-1.21**	-0.99**
PCR 7	1.31**	0.17	3.37**	-1.15**	-2.07**	-12.77**	0.02	-1.65**	0.36**
CS 52	1.90**	1.73**	-1.16**	-2.21**	-3.43**	-20.62**	-0.19	-2.91**	0.49**
Rai Kutch	-1.04**	-2.77**	-9.09**	-2.84**	-5.24**	-26.25**	-1.04**	-4.01**	-0.46**
RK 9501	0.77**	1.48**	4.97**	2.13**	4.02**	26.45**	0.90**	3.48**	0.49**
GM 2	-1.06**	1.63**	6.08**	1.27**	2.18**	9.72 **	0.65**	1.63**	-0.12**
S.E. gi ±	0.09	0.11	0.26	0.10	0.12	0.66	0.02	0.23	0.04

*, ** Indicate significance at P = 0.05 and P = 0.01 levels, respectively

Table 3 Specific combining ability effects of some selected crosses for important characters

Cross	Days to 50% flowering	Plant height	Number of siliquae/Plant	1000-seed weight	Seed yield/ plant	Oil content
PM 67 x GM 2	-3.10**	0.03	-3.01	0.34**	-2.659**	-0.13
SKM 149 x GM 2	0.00	-4.80**	2.97	0.16*	-0.910	-1.18**
GM 1 x RK 9501	-098**	3.77**	25.10**	-0.03	5.848**	-0.18
RK 9501 x GM 2	0.73*	1.50**	25.36**	-0.20**	8.928**	0.00
GM 1 x PM 67	1.07**	0.14	-2.32	0.05	-1.692*	1.42**
SKM 149 x SKM 139	-0.49	1.35**	3.12	0.56**	-1.160	-0.17
GM 3 x SKM 139	0.28	1.47**	15.36**	0.07	6.884**	-0.08
S.E. (sij) ±	0.31	0.26	2.21	0.07	0.77	0.12

*, ** Indicate significance at P = 0.05 and P = 0.01 levels, respectively

In view of preponderance of non-additive gene action for seed yield/plant, hybrid breeding would be the most appropriate breeding methodology. However, to exploit both additive and non-additive gene actions as observed under the present investigation, biparental mating and *inter se* crossing between suitable lines following reciprocal recurrent selection may be employed.

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Genetic architecture for yield and its components in castor (*Ricinus communis* L.)

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ABSTRACT

The genetic analysis was done through line x tester design involving five pistillate lines and 13 pollen parents for the development of a set of 65 hybrids in castor, *Ricinus communis*. The combining ability analysis for yield and its components revealed that both the components, additive and non-additive of genetic variances were significantly influenced by environment. The preponderance of additive gene action was observed for the control of days to 50% flowering and days to 50% maturity of main raceme as well as number of nodes up to main raceme. For the characters plant height and oil content, non-additive gene effect was propounded. The parents SKP-8, 103745, 1379, SKP-93, TMV-5, Aruna, SH-72 and SK2-8A were good general combiners for imparting earliness, former three as well as VP-1 were good general combiner for short plant stature, whereas later two and SKP-82, JH-128, SH-41 and 48-1 were good general combiners for oil content. The estimates of *gca* effects suggested that parents SKP-93, SKP-82, 48-1, Aruna, SPS-35-9B, JI-77 and JH-128 were good general combiners for seed yield and at least for two important yield attributes *viz.*, 100-seed weight, effective branches/plant, number of capsules in main raceme and length of main raceme. The good specific cross combinations for yield were SKP-8 x TMV-5, VP-l x SKI-41 and SKP 25 x 1379, also identified as superior hybrid for earliness, high oil content and short plant stature, respectively. Hence, these may be exploited for commercial cultivation. The hybrids SKP-8 x TMV-5, SKP-25 x JH-128 and SKP-82 x 48-1 depicted significant positive *sca* effect for seed yield, these hybrids could be exploited for development of hybrids and new inbred as well as pistilate lines in castor. The potence ratio of genetic variance suggested preponderance of non-additive gene effect for inheritance of the seed yield/plant, number of capsules in main raceme and number of effective branches.

Keywords: Castor, Combining ability, Oil content, Seed yield

Castor (*Ricinus communis* L.) is an important oilseed crop known for its numerous industrial applications. It is cultivated in an area of 9.9 lakh ha in the country, with a production of 12.7 lakh tonnes and productivity of 1419 kg/ha. Heterosis breeding is the major breeding approach for castor crop in present era. However, the extent of success in improving one or more economic characters depends on the judicious selection of parents and subsequent handling of segregating generations. The availability of pistillate lines has permitted large scale exploitation of heterosis in castor. The choice of appropriate parents to be incorporated in hybridization programme is a crucial step for the breeders. Use of known superior genetical worth parents ensures much better success. Information of combining ability of pistillate lines and staminate lines would be useful to formulate breeding programme for development of new hybrids. Hence, a Line x Tester analysis was under taken to obtain information on combining ability for yield and its attributes.

Five pistillate lines (SKP-8, SKP-25, SKP-82, SKP-93 and VP-l) and 13 pollen parents (Table 2) were crossed in Line x Tester mating design during 2009-10 in experimental field of Department of Agricultural Botany, B. A. College of Agriculture, Anand, Gujarat. Sixty five hybrids along with their 19 parents were evaluated in Randomized Block Design with four replications. Each entry was represented by a single row of 9.60 m length with 90 x 60 cm spacing. Ten competitive plants/plot were randomly selected for recording observations of eleven quantitative traits. The combining ability analysis was done as suggested by Kempthrone (1957).

The analysis of variance for combining ability (Table 1) revealed that the variance due to females, males and hybrids were significant for all the characters except variance due to female for the trait oil content, which suggest that the females, males and hybrids differed statistically among themselves. The contrast comparisons due to parent vs. hybrid were also significant for all the attributes indicating for the presence of heterotic effects.

Both the components of genetic variance were significant for all the characters revealing importance of both additive and non-additive genetic variances. However, the large estimates of variance due to general combining ability for the days to 50% flowering of main raceme, days to 50% maturity of main raceme and number of nodes up to the main raceme suggested preponderance of additive genetic variance. However, for the plant height, both the components were of equal importance. For oil content and seed yield, the

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variance due to specific combining ability was of larger magnitude indicating greater influence of non-additive genetic variance for the inheritance of these traits. The results are in conformity with reports of Singh and Yadava (1981), Ramu *et al.* (2002), Lavanya and Mohan (2003) and Patel *el at.* (2003).

The lines and testers also differed statistically among themselves for all the characters except lines for the trait seed yield/main raceme. The variance component due to hybrids was significant for all the characters suggesting existence of differences among the hybrids. The contrast comparisons of parents and hybrids were also significant for all the characters except effective branches/plant indicating the possibility for expression of the heterosis for these traits. The variance components due to male (σ^2m) were higher than those due to females (σ^2f) for number of capsules in main raceme, effective branches/plant and seed yield/main raceme. However, females contributed largely in comparison to males for total genetic variance for the traits, length of main raceme, hundred seed weight and seed yield/plant. However, the estimates of *sca* variances were considerably higher than those of *GCA* variances for number of capsules in main raceme, effective branches/plant, 100-seed weight and seed yield/plant, indicating preponderance of non-additive genetic variance for the inheritance of these traits. However, for length of main raceme and seed yield/main raceme additive genetic variance influenced predominantly. Thus, both additive and non-additive genetic variances were important for yield contributing characters. The results confirm the findings of Thatikunta *et al.* (2000), Gondalia *et al.* (2001), Ramu *et al.* (2002) and Solanki *et al.* (2003).

Table 1 Analysis of variance for combing ability in castor

Source	d.f.	Days to 50% flowering of main raceme	Days to 50% maturity of main raceme	Number of nodes up to primary spike	Plant height (cm)	Length of main raceme (cm)	Number of capsules in main raceme	Effective branches/ plant	100-seed weight (g)	Seed yield/ main raceme (g)	Oil content (%)	Seed yield/ plant (g)
Replication/season	3	7.10	31.64	15.34	22.8	8.64	14.35	2.18	1.57	20.10	0.54	149.09
Parents	18	368.20 **	3094.96**	40.94	150.9**	501.13**	380.99**	50.80 **	86.15**	227.84 **	4.67**	11018.40**
Females	4	210.78 **	1631.53**	7.62**	58.59**	795.90 **	282.72**	34.91*	105.93**	97.84	6.04	12693.34**
Males	13	423.54 **	3678.59**	48.80**	158.9**	385.72 **	407.99**	59.45**	86.34**	246.52*	4.04*	5590.32**
Females Vs Males	1	278.37**	1361.50**	72.01**	511.19**	822.40 **	423.08**	2.00	0.50	506.45**	7.42**	74883.75**
Hybrids	69	248.72**	1227.19**	37.48**	544.2**	299.23 **	558.70**	17.04*	26.73**	417.91**	5.03**	8749.33**
Parents Vs Hybrids	1	50.88 **	2277.75**	7.87**	277.2**	1149.53**	4770.32**	3.17	259.87**	8873.67**	52.8**	72987.75**
Error	528	2.78	5.13	1.77	15.94	10.492	14.953	1.350	1.562	14.47	0.16	67.86
Variance components												
σ^2 *gca*	--	9.15	37.77	1.74	17.81	18.26	10.17	0.26	1.18	17.13	0.10	321.86
σ^2 *sca*	--	1.99	28.05	0.55	17.90	11.07	46.62	0.66	1.25	12.72	0.90	540.99
$2\sigma^2$ *gca*/ $2\sigma^2$ *sca*	--	0.22	0.74	0.32	1.01	0.61	4.58	2.62	1.06	0.75	3.03	1.68

* = 5% level of probability and ** = 1% level of probability

Table 2 General combining ability (*gca*) effects of the parents for different characters in castor

Parents	Days to 50% flowering of main raceme	Days to 50% maturity of main raceme	Number of nodes up to main raceme	Plant height (cm)	Length of main raceme (cm)	Number of capsules in main raceme	Effective branches/ plant	100-seed weight (g)	Seed yield/ main raceme (g)	Oil content (%)	Seed yield/ plant (g)
Females											
SKP-8	-1.30**	-2.48**	-1.85**	-0.97	-5.05**	-3.45**	0.19*	-1.60**	-5.74**	-0.37**	-14.85**
SKP-25	-1.26**	1.34**	-0.50**	0.47	-4.98**	-1.70**	0.33**	-0.46**	-2.80**	0.42**	-16.93**
SKP-82	3.08**	6.30**	1.32**	-5.31**	5.74**	7.47**	-0.66**	0.89**	8.02**	0.62**	16.04**
SKP-93	-1.12 **	-5.72**	0.58**	0.52	0.55 **	0.48	0.02	1.57**	2.22	0.08**	30.73**
VP-1	0.61**	0.57**	0.45**	5.33**	3.74**	-2.80**	0.11	-0.40**	-1.63**	0.39**	-15.00**
SE (gi) ±	0.12	0.17	0.10	0.55	0.24	0.28	0.09	0.09	0.28	0.03	0.62
Males											
JH-128	2.51**	1.34**	0.15	-0.79**	1.46 **	-1.15*	-0.13	-0.08	1.69**	0.19**	5.61**
JI-77	7.06**	15.19**	1.08**	2.23**	-0.26	-0.14	0.72**	0.91	0.39	-0.50**	24.33**
SH-66	-0.16**	3.43**	0.72**	10.55**	-0.53	3.50**	-1.12**	0.26	2.81**	0.46**	1.81
SH-72	2.56**	-2.39**	0.10	-1.91**	1.10**	2.05**	-0.71**	1.58**	2.97**	-0.19**	-16.57**
SK2-8A	-2.09**	-6.33**	0.14	5.13**	2.54**	-1.99**	-0.59**	-0.39*	-1.57**	0.42**	-12.99**
SK2-41	-0.51**	0.89**	1.27**	-4.22**	-1.99**	1.26*	0.48**	0.32	1.23*	0.11*	-17.32**
SA-2	-2.24**	-4.78	0.24	4.54**	0.17	1.05*	0.61**	-0.95**	0.60	0.35**	-12.17**
48-1	-1.71 **	-0.61*	0.66**	-2.02**	3.85 **	1.49**	1.26**	0.58**	5.16**	-0.09*	16.98**
TMV-5	7.56 **	-9.29**	1.16**	5.29**	-0.19	0.71	-0.26	-1.35**	-0.59	0.13**	-23.89**
SPS-35-9B	-0.74**	-3.38**	0.58**	0.12	2.69**	-2.41**	0.24	0.61**	-3.74**	0.07	12.13**
103745	-8.31**	-14.33**	-3.73**	-12.86**	1.09*	0.14	0.22	0.60**	0.41	-0.30**	-5.74**
1379	-9.14**	-17.36**	-4.14**	-11.13**	4.15**	1.50**	-1.35**	-0.68	-0.77	-0.37**	2.68
Aruna	-2.34**	-4.36**	1.06**	3.43**	0.39	6.83**	2.86**	-2.41**	2.19**	-0.08	15.46**
SH-41	-1.44**	-3.42**	0.36	0.43	0.08	1.33*	1.76*	-2.41**	1.19	0.48**	12.28**
S.E. (gi) ±	0.22	0.31	0.18	0.31	0.43	0.51	0.15	0.17	0.51	0.05	1.12

* = 5% level of probability and ** = 1% level of probability

Table 3 Estimates of specific combining ability (*sca*) effects of some selected crosses for selective characters

Selected Crosses	Days to 50 % flowering of main raceme	Days to 50 % maturity of main raceme	Number of nodes up to main raceme	Plant height (cm)	Oil content (%)	Seed yield/ plant (g)
SKP-8 x JH-128	-1.45**	-10.19**	4.62**	0.25	-1.77**	9.97**
SKP-8 x TMV-5	-2.73**	-5.69**	2.09	0.17	0.21*	7.95**
SKP-25 x SH-41	-1.94**	-4.61**	-5.86**	-0.44	-0.24*	0.55
SKP-25 x SH-72	-1.14**	-8.59**	-0.21	0.44	0.51*	18.52**
SKP-25 x 1379	-1.59**	-3.69**	-2.79*	0.58	-0.70**	33.48**
SKP-82 x JI-77	-1.62**	-2.45**	7.94**	0.55	0.07	50.78**
SKP-82 x 1379	-2.42**	-4.05**	-1.49	-1.70*	0.91**	2.26
VP-1 x SKI-41	-1.99**	-6.37**	-2.14	-0.62	0.68**	29.30**
S.E. (gi) ±	0.44	0.63	1.11	0.37	0.05	1.12

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

The estimates of *gca* effects (Table 2) revealed that the females parent SKP-93 and SKP-8 were good general combiner for days to 50% flowering as well as days to 50% maturity of main raceme and seed yield. Likewise lines SKP-25 and SKP-82 were good general combiners for oil content and VP-1 for plant height. In case of pollen parents, SH-41, SH-72, SKI-41, Aruna, 103745 and 1379 were good general combiners for imparting earliness. Out of these, former three were good combiners for oil content, while, later two were good general combiners for short plant stature.

The female lines SKP-82 and SKP-93 were identified as good general combiners for seed yield/plant, seed yield/main raceme, 100-seed weight, number of capsules in main raceme and length of main raceme (Table 2). Among male parents, JH-128, JI-77, 48-1, SPS-35-9B, 1379 and Aruna were good general combiners for seed yield/plant and at least for two important yield attributes *viz.*, 100-seed weight, effective branches/plant, number of capsules in main raceme and length of main raceme. For effective branches/plant the male parents 48-1 and Aruna were good general combiners. Whereas, pollen parents SH-72, 48-1 and 1379 were good general combiners for length of main raceme and number of capsules in main raceme. For test weight the male parents SH-72 and 48-1 showed significant desirable *gca* effects.

About 33% of the total number of hybrids depicted significant *sca* effects for seed yield of which, the hybrids SKP-8 x TMV-5 and VP-l x SKI-41 were good specific combiners for seed yield/plant in addition to high oil contents and for imparting earliness (Table 3). The cross SKP-25 x 1379 had significant *sca* effect in desired direction for earliness, short plant stature and seed yield/plant. These hybrids involved both or one poor general combining parents; hence these may be directly exploited for commercial cultivation. The hybrid SKP-82 x JI-77 had significant *sca* effects for seed yield and also involved both good general combining parents. This hybrid may be advanced in addition to commercial exploitation for production of desirable transgressive segregants for development of improved male inbred and female lines. The results confirm the findings of Patel and Patil (2013).

The *sca* effects revealed that hybrids SKP-25 x JH-128, SKP-82 x 48-1, SKP-82 x JI-77, SPK-93 x SPS 35-9B, SPK-8 x TMV-5 and VP-l x SH-72 for grain yield/plant; SKP-8 x 103745, SKP-82 x SH-66, SKP-82 x JI-77 and SKP-8 x SA-2 for length of main raceme; SKP-82 x SH-66, SKP-93 x Aruna; SKP-8 x 103745 and SKP-82 x SH-41 for number of capsules in main raceme; VP-1 x 48-1, SKP-93 x 103745, SKP-93 x Aruna and SKP-25 x JH-128 for effective branches/plant; SKP-8 x SA-2, SKP-25 x TMV-5, SKP-82 x 103745 and SKP-82 x SH-72 for hundred seed weight; SKP 82 x SH-41, SKP-8 x 103745; SKP-82 x JH-77 and VP-l x SH-72 for seed yield/main raceme were good specific combiners. The hybrids SKP-93 x Aruna, SKP-82 x JH-77 and SKP-93 x TMV-5 were good specific combiners for seed yield and other most of the yield contributing characters.

The hybrids which had high *sca* effects and involved both good general combiner parents suggest the involvement of additive x additive and additive x dominance type of interallelic interactions. However, hybrids involved poorer general combiner parents and higher estimates of *sca* effects suggest the presence of dominance and pseudo dominance gene effects. The crosses, which had both the good general combiner parents, may be advanced for development of improved female and male lines, in addition to commercial exploitation of hybrids. Thus, the hybrids which involved both the parents as poor general combiners may be exploited for commercial cultivation.

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Seed rate and row spacing effect on yellow *sarson* (*Brassica rapa* var. *trilocularis*) under rainfed conditions

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ABSTRACT

A field experiment was conducted during *rabi* season of 2010-11 at Assam Agricultural University, Jorhat to study the effect of four seed rates (4, 6, 8 and 10 kg/ha) and two row spacings (30 and 40 cm) on the productivity of yellow *sarson*. Increasing the seed rate from 4 to 10 kg/ha increased the growth, yield attributes and yield of yellow *sarson*, however, the differences among the seed rates 6, 8 and 10 kg/ha were not significant. Out of the two row spacings, the closer row spacing of 30 cm recorded significantly higher seed yield and harvest index over the wider row spacing of 40 cm. The oil content was not affected significantly due to different seed rates and row spacings.

Keywords: *Brassica rapa*, Row spacing, Seed rate, Yellow *sarson*

Yellow *sarson* (*Brassica rapa* var. *trilocularis*) under the group of rapeseed is an important edible *rabi* oilseed crop of Assam which plays an important role in rural economy. The productivity of rapeseed in Assam is low (528 kg/ha) as against the national average of 1151 kg/ha. Among various factors to improve productivity, optimum plant population and other agronomic manipulations are important. Spacing plays a vital role by changing the magnitude of competition. Plant density/unit area and the yield/plant are two most important and inter dependent factors responsible for yield of mustard (Kumar *et al*., 2004). There is meager information on these aspects on yellow *sarson* in Assam for which the present investigation was carried out to study the effects of different seed rates and row spacings on yellow *sarson*.

A field experiment was conducted with yellow *sarson* under rainfed condition at the Instructional cum Research Farm of Assam Agricultural University, Jorhat during *rabi* season of 2010-11. Geographically, Jorhat is situated at 26°47 N latitude and 94°12 E longitude and at an altitude of 86.6 m above mean sea level. The treatments consisted of 4 seed rates (4, 6, 8 and 10 kg/ha) and 2 row spacings (30 and 40 cm) were replicated four times in a Randomized Block Design. The soil of the experimental site was sandy loam in texture with pH 5.4, medium in organic carbon (0.53%), available N (290.3 kg/ha) and available P (12.9 kg/ha) but low in available K (80.6 kg/ha). A uniform dose of 30 kg/ha each of N, P_2O_5 and K_2O was applied one day before sowing. An additional dose of 30 kg N/ha was top dressed after weeding and interculture operation done at 21 days of sowing. The seeds of 'Binoy' variety were sown on 19 November, 2010 and harvested on 16 February, 2011. The rainfall received during the crop season was 52.4 mm distributed in 10 days.

Increasing the seed rates from 4 to 10 kg/ha increased the growth, yield attributes and yield of yellow *sarson*, however, the effect was significant only in case of plant population, 1000-seed weight, seed and stover yields (Table 1).

Table 1 Effect of seed rate and row spacing on growth, yield attributes and yield of yellow sarson

Treatment	No. of plants/m^2	Plant height (cm)	No. of branches/ plant	No. of siliquae/ plant	No. of seeds/ siliqua	1000-seed weight (g)	Oil content (%)	Seed yield (q/ha)	Stover yield (q/ha)	Harvest index (%)
Seed rate (kg/ha)										
4	92	103.1	4.0	56	20	3.2	36.2	6.66	22.3	23.0
6	97	101.5	3.9	56	21	3.3	35.9	7.53	25.2	22.9
8	115	101.4	3.7	52	21	3.4	36.3	8.17	26.6	23.5
10	116	104.2	3.9	54	20	3.5	36.1	8.49	27.2	23.8
S.Em±	6.0	1.26	0.18	2.87	0.97	0.06	0.14	0.42	1.35	0.62
CD (P=0.05)	18	NS	NS	NS	NS	0.2	NS	1.27	4.1	NS
Row spacing (cm)										
30	115	101.3	3.9	56	20	3.3	36.2	8.18	25.3	24.4
40	95	103.8	3.8	53	21	3.4	36.0	7.24	24.3	22.9
S.Em±	4.3	0.89	0.13	2.03	0.69	0.04	0.12	0.28	0.95	0.21
CD (P=0.05)	13	NS	NS	NS	NS	0.1	NS	0.84	NS	0.7

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The effect of variations of seed rates among 6, 8 and 10 kg/ha was not significant in respect of seed yield. The increase in seed yield with successive higher seed rates over the lower from 4 to 10 kg/ha was 13.1, 8.5 and 3.9%. The corresponding increase in stover yield was 13.2, 5.3 and 2.3%. Similarly, non-significant effects of seed rates beyond 5 kg/ha on *toria* crop were also reported by Kharwara and Singh (1989) and Khanday *et al.* (1991).

Out of the two row spacings, rows spaced at 30 cm recorded significantly higher seed yield and harvest index over 45 cm row spacing. Higher plant population/unit area and number of siliquae/plant resulted in higher seed yield in 30 cm row spacing. The increase in seed yield with closer row spacing of 30 cm over the wider row spacing of 45 cm was 12.9%. Similar results were also reported by Singh and Dhillon (1991), Misra and Rana (1992), Sharma (1992), Brar *et al.* (1998) and Kumar *et al.* (2004). Different seed rates and row spacings had no any significant effect on oil content. It is concluded that a seed rate of 8 or 10 kg/ha can be sown at a row spacing of 30 cm for higher productivity of yellow *sarson*.

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A modified medium for improved sporulation of gray mold pathogen, *Botryotinia ricini* (Godfrey) Whetzel in castor (*Ricinus communis* L.)

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ABSTRACT

Oat meal agar medium enriched with gallic acid, L-asparagine and castor pericarp extract was developed to enhance sporulation of castor gray mold pathogen, *Botryotinia ricini.* The enriched oat meal agar medium supported higher sporulation compared to oat meal agar medium and corn meal agar medium which are commonly used for growing *B. ricini*.

Keywords: *Botryotinia ricini*, Castor, Conidia, Gray mold, Oat meal agar

Castor is an important non-edible oilseed crop in India. The gray mold disease in castor caused by the pathogen, *Botryotinia ricini* (Godfrey) Whetzel is very destructive in the states of Andhra Pradesh and Tamil Nadu in South India where the weather conditions are more favourable for disease development. The disease affects the seed yielding spikes/racemes leading to total yield loss. It is very important to have a suitable medium for culturing of the pathogen and also to have conidial inoculum for use in artificial screening tests aiming at identification of resistance sources to the pathogen. Corn meal agar (CMA), oat meal agar (OMA) and potato dextrose agar (PDA) are used for the isolation of castor gray mold pathogen. Among these media, CMA is known to support easy sporulation of the fungus and potato agar supported sclerotia production (Hong *et al.,* 2001). Castor leaf extract medium (CLEM), V_8 juice agar medium, gallic acid synthetic medium and potato dextrose agar medium supported fast growth and good sporulation (Yasmeen, 2004). Addition of 0.4% gallic acid to the basal medium considerably enhanced sporulation of *Botryotinia ricini* (Orellana and Thomas, 1964). In our studies, CLEM, CMA and OMA did not support good sporulation. Further attempts were made to improve these media for enhancing the sporulation by amending CMA, OMA, V_8J agar and potato carrot agar (PCA) media with a nitrogen, amino acid source and castor pericarp extract.

CMA, OMA, V_8J agar and PCA were used as basal medium. To this basal media, ammonium nitrate (1g/lit), yeast (1.5g/lit) and gallic acid (1g/lit) were added to prepare CMA1, OMA1, V_8J1 and PCA1. In another combination along with the above nitrogen and amino acid sources, 20% castor pericarp extract/lit also added to the each basal medium and designated as CMA2, OMA2, V_8J2 and PCA2. The final pH of all the media were adjusted to 6.5 with 2N NaOH or 2N HCl before autoclaving at 121°C for 15 min.

Table 1 Growth of *Botryotinia ricini* on different agar media

Medium	Colony growth (mm)*	Log_{10} conidia/ml*
CMA	35.4^{b}	5.14^{b}
CMA1	32.6^{bcd}	5.15^{b}
CMA2	34.2^{bc}	5.17^{b}
OMA	42.6^{a}	5.16^{b}
OMA1	43.4^{a}	5.32^{a}
OMA2	45.2^{a}	5.42^{a}
V8J	24.6^{e}	4.94^{c}
V8J 1	34.4^{bc}	4.78^{d}
V8J 2	29.0^{d}	4.96^{c}
PCA	22.6^{e}	-
PCA1	31.0^{cd}	-
PCA2	32.2^{bcd}	-

* Significant at P=0.01; In a column, means superscripted by a common letter are not significantly different by DMRT

The plates having media described above were inoculated with 5 mm agar discs obtained from 6-day-old culture plates of *B. ricini*. The experiment was conducted in Completely Randomized Design with five replications. Inoculated plates were incubated at 20°C temperature in an incubator. The growth of *B. ricini* was recorded 5-days after incubation. Conidial suspension was prepared by transferring 2mm media plugs taken from three different places of Petri-plate to 3ml sterile water and conidial suspensions filtered through three layers of muslin cloth. Conidial concentration was determined by using Neubauer counting chamber.

The growth of *B. ricini* on modified media (CMA1, CMA2, OMA1, OMA2, V_8J1, V_8J2, PCA1 and PCA2) was compared with the growth on respective basal media (CMA, OMA, V_8J and PCA). The media OMA, OMA1 and OMA2 have supported significantly high mycelial growth compared to other media but sporulation was significantly high in OMA1 and OMA2 only (Table 1). The numbers of conidia

produced/ml of OMA1, OMA2 are log 5.32 and 5.42, respectively, which is significantly higher compared to OMA (log 5.16), CMA (log 5.14) and V_8J (log 4.94) agar media. Among the all media, PCA based media supported very sparse mycelial growth and did not yield any conidia.

Among the media combinations, OMA2 medium was found to support good mycelial growth and sporulation and was further improved by adding different concentrations of the amino acid L-asparagine. The OMA and OMA2 which were found to support good mycelial growth and sporulation in previous experiment served as controls. The two modified combinations of OMA2 have a composition of oat meal agar, yeast (1.5g/lit), L-asparagine (1g/lit), gallic acid (1g/lit), castor pericarp extract 20% in OMA2a and oat meal agar, yeast (1.5g/lit), L-asparagines (2g/lit), gallic acid (1g/lit), castor pericarp extract 20% in OMA2b. For each medium combination (OMA, OMA2, OMA2a, OMA2b) fifteen plates were used for growing *B. ricini.* Five plates of each medium combination were kept under light, dark and 12h cycle of dark and light respectively (Table 2). The plates were incubated at 20°C temperature in an incubator. Colony growth was measured after 5 days of inoculation. Conidial concentration was determined by using Neubauer counting chamber.

Table 2 Growth of *Botryotinia ricini* on modified oat meal agar media

Medium	Colony growth (mm)*			Log_{10} conidia/ml*		
	Light	Dark	12h cycle of dark & light	Light	Dark	12h cycle of dark & light
OMA	28.4[b]	26.6[c]	28.8[c]	5.36[c]	5.29[c]	5.48[c]
OMA2	39.2[b]	30.2[b]	31.0[b]	5.39[c]	5.29[c]	5.56[b]
OMA2a	45.0[a]	45.0[a]	45.0[a]	5.94[a]	5.51[a]	5.99[a]
OMA2b	45.0[a]	45.0[a]	45.0[a]	5.61[b]	5.38[b]	5.98[a]

* Significant at P=0.01; Values given are mean of 5 replications; In a column, means superscripted by a common letter are not significantly different by DMRT

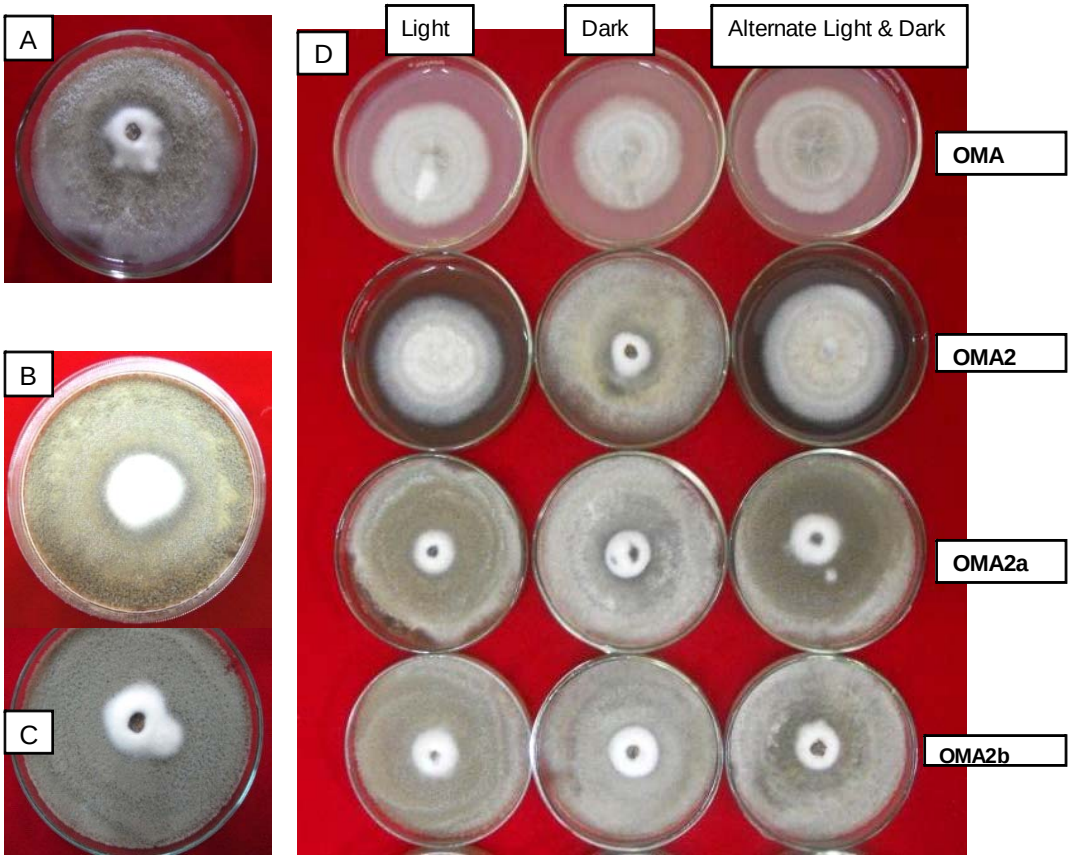

Fig.1. Effect of different medium on the growth of castor gray mold pathogen, *Botryotinia ricini*

(A). OMA-Oat meal agar medium with sporulation, (B). OMA2 medium (Oat meal agar, yeast (1.5g/lit), gallic acid (1g/lit), castor pericarp extract 20%) with sporulation. (C). OMA2a [Oat meal agar, yeast (1.5g/lit), L-asparagines (1g/lit), gallic acid (1g/lit), castor pericarp extract 20%] (D). OMA based formulations exposed to Light, Dark and 12h Cycle of Dark & Light: OMA - Oat meal agar, OMA2-Oat meal agar, yeast (1.5g/lit), gallic acid (1g/lit), castor pericarp extract 20% OMA2a-Oat meal agar, yeast (1.5g/lit), L-asparagines (1g/lit), gallic acid (1g/lit), castor pericarp extract 20%, OMA2b-Oat meal agar, yeast (1.5g/lit), L-asparagines(2g/lit), gallic acid (1g/lit), castor pericarp extract 20%.

The mycelial growth of *B. ricini* in OMA2a and OMA2b (45.0 mm) is significantly higher than OMA, OMA2 under dark, light and 12h cycle of dark and light (Table 2 and Fig.1). The conidial concentration of OMA2a (log 5.99) and OMA2b (log 5.98) was high in 12h cycle of dark and light. The OMA2b plates incubated under light (log 5.61) and dark (log 5.38) supported less spore production when compared to sporulation under 12h cycle of dark and light (log 5.98). There have been many studies on the effect of light on the *Botrytis* sp. sporulation. A snow mold type *Botrytis* sp. grew better in the dark than in the light (Sato *et al*., 1959). A 12h dark cycle or continuous light promoted sporulation and suppressed sclerotial formation in *B. cinerea* (Harada *et al*., 1972). It is concluded based on the present findings that the OMA medium enriched with yeast (1.5g/lit), L-asparagine (1g/lit), gallic acid (1g/lit) and castor pericarp extract 20% can be used for better mycelia growth and sporulation of *B. ricini.*

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Molecular variability of *Fusarium oxysporum* f. sp. *lini* isolates by RAPD analysis

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ABSTRACT

Seven isolates of *Fusarium oxysporum* f. sp. *lini* collected from different linseed growing areas in India were analyzed by random amplified polymorphic DNA-polymerase chain reaction. Two isolates (FOL 1 and FOL 2) found non-pathogenic to linseed crop. Twenty random decamer primers were used for amplification. All the primers revealed scorable polymorphism among the isolates and a total of 156 bands were recorded. Amplification patterns of non-pathogenic *Fusarium* isolates were entirely distinct from those of pathogenic isolates. Seventeen primers generated isolate specific bands which would be highly useful in the identification and characterization of *Fusarium* isolates. RAPD markers showed substantial genetic diversity among the different isolates with maximum of 0.89 between FOL1 and FOL6. UPGMA cluster analysis was used to generate a dendogram showing relationship between them. Isolates were clustered in to three groups corresponding to their genetic similarity and physiological reactions. RAPD markers can be quick and reliable alternative for differentiating isolates of *Fusarium oxysporum* f. sp. *lini* in to different groups.

Keywords: *Fusarium oxysporum* f. sp. *lini,* Genetic diversity, Linseed, RAPD

Occurrence of *Fusarium* wilt of flax was first reported by Lugger (1890) from Minnesota, USA and Butler (1918) from India. It has world-wide distribution and is common in wide range of soils. *Fusarium oxysporum* f. sp. *lini,* causal organism of wilt is known to persist in soil for about 25 years even in the absence of host, simply because of its strong competitive saprophytic ability. The identification of *Fusarium* species is mostly based on morphological characteristics such as the size and shape of macro conidia, the presence or absence of micro conidia, chlamydospores and the structure of conidiophores. Variation in spore morphology of isolates collected from Gurdaspur, Kangra and Nagpur areas has been already indicated (AICRP on Linseed, 2008). Infested soil from different areas may contain different physiological races. The susceptibility of the released resistant varieties is due to the shift in the physiological race population of the pathogens.

Ecological divergence within and between fungal pathogens can give rise to pathogenic variants referred as special forms (f. sp.). Sometimes those variants also consist of variants termed races based upon cultivar-host pathogenecity. Verification of morphological characteristics by microscopic observations is time consuming and demands some practice. Furthermore, differentiation of some species relies only on minor differences in conidial or conidiophores shapes or on the absence of any character. Consequently, species like *Fusarium subglutinans* and *F. redolenes* can be easily misunderstood as *F. oxysporum.*

Molecular approaches have considerable potential for the identification of micro-organisms and have been used to differentiate and assess the genetic relationships of *Fusarium* species (Donaldson *et al.,* 1995; Bateman *et al.,* 1996; Edel *et al.,* 1997). Development of species specific tool or PCR primers would greatly facilitate both the identification of *F. oxysporum* species collected from different locations and their ecological variations. The objective of the present study is to know the genetic diversity based on RAPD analysis in *Fusarium oxysporum* f.sp. *lini* isolates of different locations.

Diseased samples of linseed crop were collected from different locations *viz*., Berhampore, Jashipur, Kanpur, Kangra, Kanke, Nagpur and Raipur during 2007-08. *Fusarium* species were isolated and purified using single spore culture method on PDA medium. Based on morphological characteristics the associated pathogen was identified as *Fusarium oxysporum.* Out of several isolations only seven isolates of *Fusarium oxysporum* were used for further studies.

Pathogenecity assay was conducted to determine the pathogenecity of all *F. oxysporum* isolates. Each isolate was grown in a 250 ml flask containing 100 ml of PDB (potato dextrose broth) for 10 days at room temperature. The spores/ mycelium suspension (about 10^5-10^6 spore or mycelium/ml) was inoculated by pouring it to the root zone of 20 days old seedlings of linseed grown in pots.

Mycelial mat of 100mg dried on sterilized blotter paper used for DNA isolation. It was ground in pre-cooled mortar and pestle with liquid nitrogen. Powder was transferred into 1.5 ml tubes of each isolate separately having 0.5 ml of CTAB extraction buffer [(10 ml of 1 mol/L Tris-HCl (pH 7.6), 14 ml of 5 mol/L NaCl and 4 ml of 0.5 mol/L EDTA (pH 8.0) mixed together and dissolved 1 g DDT and 1 g CTAB in the solution and final volume was made upto 100

ml by adding ultra pure water] pre-warmed at 65°C. Then the tubes were incubated at 65°C for 15 minutes. The sample was centrifuged at 13,000 rpm at 20°C for 2 minutes. The supernatant was transferred in a fresh tube and rest of the protocol was followed according to the manufacturer of SiMax Genomic DNA Extraction (SBS Genetech Co., Ltd, China). The isolated DNA was electrophoresed in 1% agarose gel, stained with ethidium bromide and visualized by gel documentation system (Uvitec, UK) for knowing the quality and quantity.

Table 1 List of the decamer primers and the polymorphism observed in the study

Primer	Primers sequences (5' - 3')	Total no of bands	No. of polymorphic bands	Per cent polymorphism	Isolate distinguished
SBSB-01	GTT TCG CTC C	11	11	100	FOL 1, 2, 7
SBSB-02	TGA TCC CTG G	8	8	100	FOL 1
SBSB-03	CAT CCC CCT G	5	5	100	-
SBSB-04	GGA CTG GAG T	1	1	100	-
SBSB-05	TGC GCC CTT C	6	6	100	FOL 1, 2, 7
SBSB-06	TGC TCT GCC C	9	9	100	FOL 1, 2, 7
SBSB-07	GGT GAC GCA G	8	8	100	FOL 1, 2
SBSB-08	GTC CAC ACG G	10	10	100	FOL 1, 2
SBSB-09	TGG GGG ACT C	5	5	100	-
SBSB-10	CTG CTG GGA C	12	12	100	FOL 1, 2
SBSB-11	GTA GAC CCG T	10	10	100	FOL 1, 2
SBSB-12	CCT TGA CGC A	11	11	100	FOL 1, 2
SBSB-13	TTC CCC CGC T	11	11	100	FOL 1, 6
SBSB-14	TCC GCT CTG G	4	4	100	FOL 3
SBSB-15	GGA GGG TGT T	2	2	100	FOL 2, 3
SBSB-16	TTT GCC CGG A	7	6	86	FOL 1, 2
SBSB-17	AGG GAA CGA G	11	10	91	FOL 1, 2
SBSB-18	CCA CAG CAG T	11	9	82	FOL 1, 2, 7
SBSB-19	ACC CCC GAA G	6	6	100	FOL 7
SBSB-20	GGA CCC TTA C	6	8	100	FOL 7
	Total	156	152		
	Average	7.80	7.60	97.44	

Table 2 Genetic similarity coefficients based on 20 RAPD primers among seven *Fusarium oxysporum* f. sp. *lini* isolates collected from different locations

Fusarium isolates	Non-pathogenic to linseed crops			Pathogenic to linseed crops			
	FOL1	FOL2	FOL3	FOL4	FOL5	FOL6	FOL7
FOL1	1.000						
FOL2	0.165	1.000					
FOL3	0.129	0.155	1.000				
FOL4	0.133	0.149	0.859	1.000			
FOL5	0.120	0.137	0.806	0.879	1.000		
FOL6	0.115	0.159	0.826	0.835	0.784	1.000	
FOL7	0.138	0.153	0.640	0.666	0.661	0.649	1.000

The random primer kit (SBS-B) used for amplification were procured from SBS Genetech Co., Ltd, China (Table 2). The PCR mix was setup by using Easy-Do PCR Premix Kit (SBS Genetech, China) supplied in lyophilized format. The mix contained Taq DNA polymerase-2 units, 10 x PCR reaction buffer-5 µl, dNTPs (10 mM each)-200 µM each, loading dye-5 µl, stabilizer- 5 µl. In this pre-mix about 50 ng DNA template and 50 pmol of RAPD primer was added and the final volume of 50 µl was made up by adding nuclease free water. The DNA amplification was performed in an Eppendorf Master Cycler Gradient (Eppendorf, Hamburg) by using the following programme: 1 cycle of 94°C for 5 minutes, 45 cycles of "94°C for 1 minute, 36°C for 1 minute, 72°C for 2 minutes" followed by a final 5 minutes cycle at 72°C.

The amplified DNA was analyzed on 1% Agarose gel in 1 x TAE (40 mM Tris-acetate and 1 mM EDTA, pH 8.0) by electrophoresis at 60 V for 2 hrs. The bands were visualized by adding ethidium bromide stain (0.5 µg/ml) in the gel. The gels were photographed using Gel Doc System (Uvitec, UK). Bands were scored as 1 (present) or 0 (absent) for all *Fusarium* isolates. Reproducibility of the bands was confirmed by repeating the experiment twice (extraction and amplification).

Each band was assumed to represent a unique genetic locus. Its presence was interpreted as either a heterozygote

or dominant homozygote and absence of the band as a recessive homozygote. The pattern and extent of RAPD variation were analyzed with respect to primer, polymorphic locus and isolate. Data entry was done in to binary data matrix and statistical analysis was carried out using NTSYS-pc, 2.01 versions (Rolf, 1993). Pair wise comparisons of samples were used to estimate Jaccard's similarity coefficient and dendrogram was generated using unweighted pair group method with arithmetic mean-UPGMA (Sneath and Sokal, 1973).

Based on the cultural and morphological characters seven distinct *Fusarium oxysporum* isolates were selected and tested for their pathogenicity. Among them isolates FOL1 and FOL2 found non pathogenic and rest of the isolates were found pathogenic to linseed crop. RAPD patterns were established for all the seven isolates of *Fusarium oxysporum* with 20 decamer primers listed in Table 2. The size of amplified DNA bands generated with the 20 primers ranged from 200 bases to 2000 bases. All the primers except SBSB-16, 17 and 18 revealed 100% polymorphisms useful for classifying the isolates (Table 1). Amplification patterns of non-pathogenic *Fusarium* strains FOL 1 and FOL 2 were entirely distinct from those of pathogenic isolates FOL 3-FOL 7. Total number of amplified fragments and polymorphic fragments produced were 156 and 152, respectively. The number of amplified fragments per primer varied from 1 (SBSB-04) to 12 (SBSB-12). Seventeen primers produced isolate specific DNA fragments which would be highly useful in the identification of *Fusarium* isolates/races. Primer SBSB-14 generated a unique DNA fragment of 1100 bp in FOL 2 whereas SBSB-19 in FOL 7 (1500 bp) that will be useful for race characterization (Fig. 1). Most isolates used in this study could be fingerprinted with the use of primers that differentiate the banding pattern of particular isolate from other isolates (Table 1). This may be of interest for culture storage and might be useful in evolutionary studies of new races.

RAPD markers revealed substantial genetic diversity among different isolates with genetic similarity ranging from 0.115 to 0.879 (Table 2). Maximum diversity was observed between FOL 1 and FOL 6, whereas minimum was found between FOL 4 and FOL 5. Based on UPGMA cluster analysis, three distinct groups were differentiated among the seven *Fusarium* isolates at a genetic distance of 0.65 (Fig. 2). Cluster I included both non-pathogenic isolates (FOL 1 and FOL 2), cluster II comprised of four isolates (FOL 3, FOL 4, FOL 5 and FOL 6) whereas, cluster III was having only one isolate FOL 7, which displayed significant differences in the DNA profile.

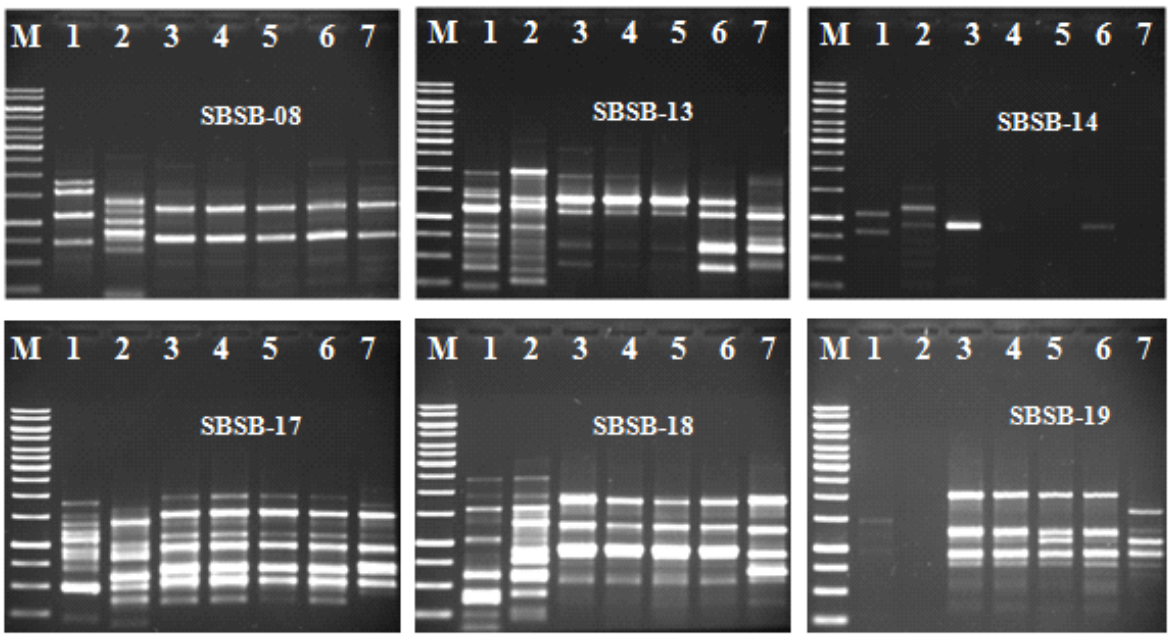

Fig. 1. RAPD patterns of seven *Fusarium oxysporum* f.sp. *lini* isolates observed with primers SBSB-08, 13, 14, 17, 18 and 19
(Lane 1=M; Lane 2=FOL1; Lane 3=FOL2; Lane 4=FOL3; Lane 5=FOL4; Lane 6=FOL5; Lane 7=FOL6; Lane 8=FOL7)

Pathogenecity tests are the only means of determining the pathological classification of fungal strains. RAPD markers used in the present study would be useful for identification purposes. Reproductive habits and mechanisms available for genetic change greatly affect the structure of populations in nature. However, mechanisms available for genetic change in *Fusarium oxysporum* are still largely unknown, but numerous possibilities exist beyond simple sexual or clonal reproduction (Kislter, 1997). Future work, therefore, should concentrate on how populations of *Fusarium oxysporum* change over time and the factors that influence the change. Undoubtedly, the presence or absence of hosts plants and the effect of the genotype of host plants shall be important factors to consider.

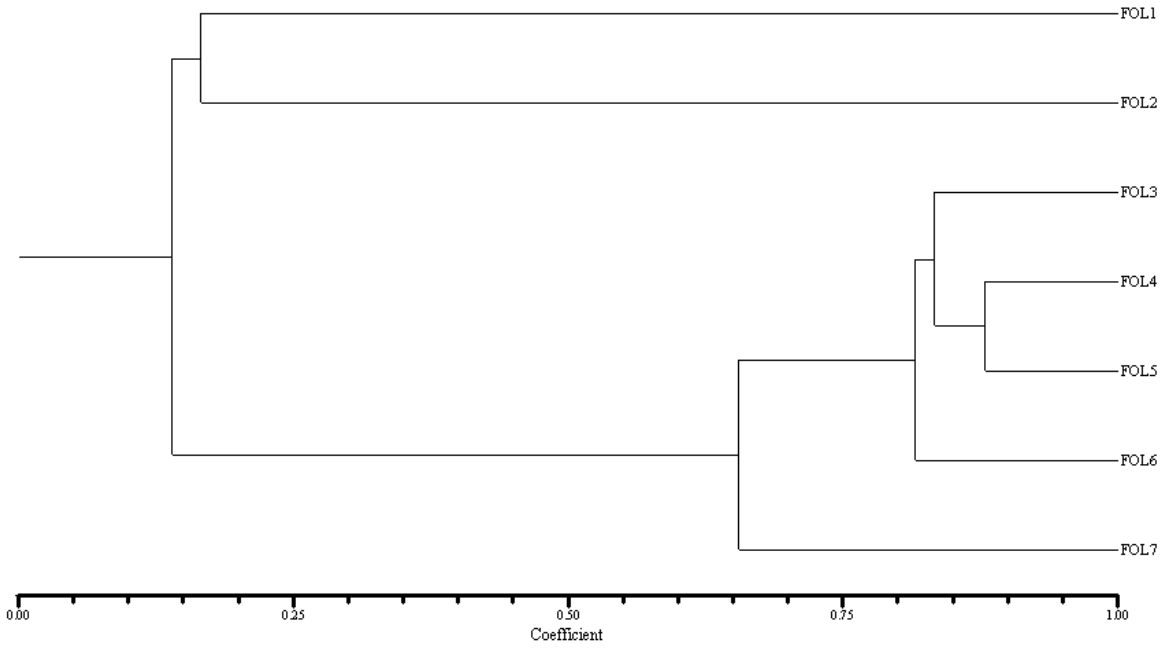

Fig. 2. UPGMA dendogram depicting relationships among seven *Fusarium oxysporum* f. sp. *lini* isolates (FOL1 and FOL2 Non -pathogenic and FOL3-FOL7 pathogenic to linseed crop) collected from different locations

Our results provide evidence to summarize that RAPD analysis can be used for differentiating and identifying *F. oxysporum* isolates in linseed.

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Extent of awareness, knowledge and adoption of different farm machinery by the groundnut farmers in Chittoor district of Andhra Pradesh

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ABSTRACT

Andhra Pradesh shares about one-third of groundnut area of the country and occupies third place in production contributing 18.8% of production in the country. In Andhra Pradesh, Chittoor district ranks second in the area and production under groundnut. Keeping this in consideration present study was conducted among groundnut farmers with a view to study extent of awareness, knowledge and adoption of different farm machinery used in groundnut cultivation in Chittoor district of Andhra Pradesh with a sample of 120 farmers. Results unveiled that nearly half of the groundnut farmers were having medium extent of awareness, slightly more than half of the farmers having medium extent of knowledge and with respect to extent of adoption nearly forty three per cent of the farmers were having medium level of adoption. Depending upon the extent of awareness, knowledge and adoption of different farm machinery used by the groundnut farmers were ranked in terms of their awareness, knowledge and adoption.

Keywords: Farm machinery, Extent of adoption, Extent of awareness, Groundnut Farmers

Groundnut is the major oilseed crop grown in India in an area of 67 lakh ha with a production of 70 lakh tonnes annually. Out of total cultivated area for groundnut, 58 lakh ha (85% of total area) is under dry land agriculture or rainfed conditions with an average productivity of 0.8 tonnes/ha. In Andhra Pradesh, Chittoor district ranks second in the area and production of groundnut with 1.89 lakh ha and 1.31 lakh tonnes, respectively. The productivity of groundnut in the district was 2696 kg/ha under irrigated conditions, while it was 611 kg/ha under rainfed conditions (FAO, 2010). One of the major areas for improving the farming condition of groundnut farmers is to reduce the drudgery in the field and to make the cultivation cost effective. By using various recommended farm machinery in the field, the human labour usage can be brought down to a maximum extent. Therefore there is a greater need to adopt new farm machinery. But, it is observed from the present field condition that there is still wide gap between existing implements used by the farmers and the implements recommended by the agricultural universities. In this context, the present investigation was undertaken to study the extent of awareness on farm implements among the groundnut farmers, the level of knowledge about the farm implements and their adoption by the groundnut farmers.

The present study was conducted in Chittoor district of Andhra Pradesh. Four mandals from Chittoor district were selected based on the highest area under groundnut. From each of the selected mandal, 3 villages were selected based on the highest area under groundnut thus making a total of 12 villages for the study. From each of the selected village, 10 groundnut farmers were selected by following random sampling technique, thus making a total 120 respondents. The respondents were interviewed though a well-structured interview schedule. Different farm implements used in groundnut cultivation were given suitable ranks in terms of their extent of awareness, knowledge and adoption.

For measuring the awareness of the farmers regarding farm mechanization in groundnut, all the farm implements used in the groundnut cultivation were enlisted in the schedule. The extent of awareness on each implement by the farmers was recorded by 'yes' and 'no' response. For every 'yes' response a score of one and for every 'no' response a score of zero was given. Thus, the minimum and maximum possible scores of each implement could be 0 and 120 and the minimum and maximum possible scores of a respondent could be 0 and 33.

With regard to extent of knowledge for each farm implement recommended in groundnut cultivation, questions were framed in the form of both multiple choice and fill in the blanks. To have uniformity in evaluation, four questions were finalized for each implement duly considering the practical relevancy of the implement. A schedule consisting of four practically relevant questions for each implement were selected. For every 'correct' response a score of 'one' and for every 'wrong' response a score of 'zero' was given. Thus the minimum and maximum possible scores of each implement could be 0 and 480 and the minimum and maximum possible scores of a respondent could be 0 and 132.

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Relating to extent of adoption under each implement, the responses were elicited from farmers on a three point continuum *viz.*, 'full adoption', 'partial adoption' and 'non-adoption' and scores were given as 2, 1, 0 respectively. Thus the minimum and maximum possible scores of each implement could be 0 and 240 and the minimum and maximum possible scores of a respondent could be 0 and 66. Percentage of awareness, knowledge and adoption was used in ranking of different implements. The percentages were calculated using following formulae:

Percentage of awareness of each implement:

$$= \frac{\text{Sum of obtained awareness score from 120 respondents}}{\text{Sum of maximum possible score of 120 respondents}} \times 100$$

Percentage of knowledge of each implement:

$$= \frac{\text{Sum of obtained knowledge score from 120 respondents}}{\text{Sum of maximum possible score of 120 respondents}} \times 100$$

Percentage of adoption of each implement:

$$= \frac{\text{Sum of obtained adoption score from 120 respondents}}{\text{Sum of maximum possible score of 120 respondents}} \times 100$$

It is evident from the Table 1 that 47.5% of the groundnut farmers were having medium extent of awareness followed by low (30.84%) and high (21.66%) extent of awareness about different farm machinery. As the farmers are taking up groundnut cultivation, they might have come across the day to day developments in terms of the invention of latest production technologies through different information sources. Hence, about seventy per cent of the farmers had medium to high awareness about different farm machinery in groundnut. Still thirty per cent of the farmers were not aware of the farm machinery in groundnut might be due to their poor education system, lack of exposure to mass media, poor extension contact and also lack of zeal towards innovation.

More than 51% of the groundnut farmers were having medium extent of knowledge followed by low (33.34%) and high (15.00%) of extent of knowledge on different farm machinery. Acquisition of knowledge is a complex process. Farmers with good education and passion towards innovation might have been keen to learn in detail about the technologies. On the other side, the farmers with illiteracy coupled with traditional approach might have obstructed the farmers to learn about new technology. Similar findings were reported by Sajithkumar (2004) and Gopinath (2005).

Table 1 Distribution of respondents according to their extent of awareness, knowledge and adoption of different farm machinery in groundnut (n=120)

Category	Frequency and (Percentage)		
	Awareness	Knowledge	Adoption
Low	37 (30.84)	40 (33.34)	39 (32.51)
Medium	57 (47.50)	62 (51.66)	52 (43.33)
High	26 (21.66)	18 (15.00)	29 (24.16)
Total	120 (100.00)	120 (100.00)	120 (100.00)
	Mean: 18.05 S.D.: 3.957	Mean: 42.825 S.D.:10.830	Mean:9.916 S.D.:2.594

More than 43% of the groundnut farmers were having medium extent of adoption followed by low (32.51%) and high (24.16%) of extent of adoption of different farm machinery. Due to intensification in agriculture and also changing scenario of farming community, the farm mechanization is becoming inevitable. Even though the farmers were aware of the technology and also acquired enough knowledge of the farm machinery, due to complexity, compatibility of the implement to the field conditions followed by high cost of the farm machinery and poor economic status of the farmers, they could not be able to use the implement in their fields. Hence 75% of the farmers were under low to medium adoption category. This finding is in conformity with the findings of Gopinath (2005).

It is clear from the Table 2 that the implements like mould board plough, cultivator, disc plough, rotovator, sprinkler, drip, plank, knapsack sprayer, motorized knapsack sprayer, power sprayer stood first (100.00%) position in terms of awareness among the farming community. The above implements might have been more popular among the farming community and some of the farmers might be using these implements in their fields.

Leveler (95.83%), seed treatment drum (92.50%), seed cum ferti drill (90.83%), star weeder (90.00%), power operated groundnut decorticator (72.5%), four row bullock drawn groundnut planter (58.33%) and bullock drawn inter cultivation implement (54.16%) ranked 11^{th} to 17^{th} respectively in terms of awareness among groundnut farmers. More than fifty percent of farmers were aware of these implements.

The implements such as tractor drawn inter cultivation implement (47.50%), tractor drawn groundnut planter (21.87%), hand operated groundnut decorticator (20.41%), power tiller (20.00%), dry pod thresher (20.00%), TNAU groundnut harvester (12.50%), groundnut kernel grader (11.66%) and ANGRAU blade guntaka (10.00%) were in ranked 18^{th} to 25^{th} positions respectively in terms of awareness amid of farming community.

Very meager per cent of the farmers were aware of the implements such as sub soiler (8.33%), portable sprayer (7.50%), fresh pod stripper (7.50%), groundnut fresh pod thresher (7.50%), asha guntaka (5.00%), boom sprayer (4.16%), laser leveler (3.33%) and groundnut digger shaker cum windrower (2.50%). This epitomizes the need for efforts to concentrate on these implements to bring them into the groundnut cultivation.

Table 2 Ranking of different farm machinery in terms of their extent of awareness, knowledge and adoption by the groundnut farmers

Technology	Extent of awareness			Extent of knowledge			Extent of adoption		
	Score (for 120)	%	Rank	Score (for 480)	%	Rank	Score (for 240)	%	Rank
Hand Operated Groundnut Decorticator	47	9.16	0	98	0.41	9	0	0	18
Power Operated Groundnut Decorticator	87	2.50	5	166	4.58	15	27	11.25	10
Groundnut Kernel Grader	14	11.66	24	32	6.66	24	0	0	18
Mould Board Plough	120	100	1	200	41.66	14	25	10.41	12
Cultivator	120	100	1	313	85.62	2	190	92.92	1
Disc Plough	120	100	1	275	57.29	8	21	8.75	13
Rotovator	120	100	1	243	50.62	10	134	55.83	4
Sub Soiler	10	8.33	26	13	2.70	28	0	0	18
Leveler	108	95.83	11	381	76.87	4	49	20.42	8
Plank	120	100	1	411	79.37	3	157	65.42	3
Laser Leveler	4	3.33	32	56	11.66	21	0	0	18
Seed Treatment Drum	111	92.50	12	295	61.45	7	101	42.08	6
4 Row Bullock Drawn Groundnut Planter	70	58.33	16	154	32.08	16	4	1.66	16
Tractor Drawn Groundnut Planter	50	41.66	19	105	21.87	18	30	12.5	9
Seed Cum Ferti Drill	109	90.83	13	298	62.08	6	27	11.25	10
Sprinkler Method	120	100	1	417	86.87	1	9	3.75	15
Drip Method	120	100	1	369	65.20	5	0	0	18
Bullock Drawn Inter cultivation Implement	65	54.16	17	107	22.29	17	1	0.41	17
Tractor Drawn Inter cultivation Implement	57	47.50	18	86	17.91	20	0	0	18
Star Weeder	120	90	14	210	43.75	13	0	0	18
Power Tiller	24	20	21	51	10.62	22	0	0	18
Knapsack Sprayer	120	100	1	243	50.62	10	53	22.08	7
Motorized Knapsack Sprayer	120	100	1	217	45.20	12	119	49.58	5
Power Sprayer	120	100	1	261	54.37	9	223	79.17	2
Boom Sprayer	5	4.17	31	6	1.25	31	0	0	18
Portable Sprayer	9	7.50	27	9	1.87	29	0	0	18
ANGRAU Blade Guntaka	12	10.00	25	28	5.83	25	0	0	18
Asha Guntaka	6	5.00	30	3	0.62	32	0	0	18
TNAU Groundnut Harvester	15	12.50	23	16	3.33	27	0	0	18
Groundnut Digger Shaker Cum Windrower	3	2.50	33	3	0.62	32	0	0	18
Groundnut Fresh Pod Thresher	8	6.67	29	23	4.79	26	0	0	18
Dry Pod Thresher	24	20	21	42	8.75	23	20	8.33	14
Fresh Pod Stripper	9	7.50	27	8	1.66	30	0	0	18
Average percentage of farm mechanization in groundnut		54.59			32.43			15.02	

The implements such as sprinkler (86.87%), cultivator (85.62%), plank (79.37%) and leveler (76.87%) ranked first to fourth respectively in terms of extent of knowledge among the groundnut farmers. More than 75% of the farmers had knowledge about these four implements.

Implements such as drip method (65.20%), seed Cum ferti drill (62.08%), seed treatment drum (61.45%), disc plough (57.29%), knapsack sprayer (57.29%) and rotovator (50.29%) were ranked from 5th to 10th, respectively. Motorized knapsack sprayer (45.20%), star weeder (43.75%), mould board plough (41.66%), power operated groundnut decorticator (34.58%), 4 row bullock drawn groundnut planter (32.08%), bullock drawn inter cultivation implement (22.29%), tractor drawn groundnut planter (21.87%), hand operated groundnut decorticator (20.41%), tractor drawn inter cultivation implement (17.91%), laser

leveler (11.66%) and power tiller (10.62%) were ranked from 12th to 22nd respectively according to the knowledge possessed by farmers with regard to these implements.

Rest of the implements such as dry pod thresher (8.75%), groundnut kernel grader (6.66%), ANGRAU blade guntaka (5.83%), fresh pod thresher (4.79%), TNAU groundnut harvester (3.33%), sub soiler (2.70%), portable sprayer (1.87%), fresh pod stripper (1.66%), boom sprayer (1.25%), asha guntaka (0.62%) and groundnut digger shaker and windrower (0.62%) were under very meager knowledge category.

Cultivator stood first (92.92%) in terms of adoption by groundnut farmers. Being most popular implement among farming community which is replacing traditional implement like country plough, the cultivator occupied major role in preparatory cultivation. Power sprayer (79.17%) stood in second place in terms of adoption by groundnut farmers. This signifies the importance of power sprayer for easy pesticidal sprayings in groundnut. Plank is another important implement ranked 3rd with 65.42% of adoption used mainly for land leveling. It is the basic implement which is popularly known as 'Manu' among farmers required for proper leveling. Rotovator is a new innovation in the recent past but it occupied major place in farming. It was ranked 4th with 55.83% of adoption by groundnut farmers. The utility of the rotovator is been perceived high by the farming community. Hence, it attracted the farmers for adoption.

The implements such as motorized knapsack sprayer (49.58%), seed treatment drum (42.08%), knapsack sprayer (22.08%), leveler (20.42%), tractor drawn groundnut planter (12.50%), seed cum ferti drill (11.25%) and power operated groundnut decorticator (11.25%) ranked 5th to 12th were recorded less than 50% of adoption. The implements like disc plough (8.75%), dry pod thresher (8.33%), sprinkler method (3.75%), 4 row bullock drawn groundnut planter (1.66%) and bullock drawn inter cultivation implement (0.41%) were ranked 13th to 17th positions respectively in terms of adoption. Remaining implements namely hand operated groundnut decorticator, groundnut kernel grader, sub soiler, laser leveler, drip method, tractor drawn inter cultivation implement, star weeder, power tiller, boom sprayer, portable sprayer, ANGRAU blade guntaka, asha guntaka, TNAU groundnut harvester, groundnut digger shaker cum windrower, fresh pod thresher and fresh pod stripper were not at all being adopted by groundnut farmers. Hence extension functionaries and State Department personnel should look forward in bringing these implements into higher adoption stratum.

Groundnut farmers have medium awareness on farm machinery, medium level of knowledge and extent of adoption. Most popular farm machinery among the farmers were cultivator, power sprayer and plank, which were the low cost and maintenance free implements. Farm machinery such as threshers (wet and dry pod), tractor drawn inter cultivation implements and groundnut decorticator are very useful implements for timely field operations. Hence, awareness has to be created on these implements. The State Agricultural Department has to provide required subsidies for the purchase of these implements as they involve a sizeable investment to the farmers. Necessary partnerships are to be formed with the stakeholders in creating required awareness and improving the knowledge about the farm implements in turn leading to enhanced adoption level. This facilitates in reducing the drudgery of farmers and to take up timely operations.

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Evaluation of personal, socioeconomic and psychological characteristics of FFS and non-FFS groundnut growers

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ABSTRACT

The personal, socioeconomic and psychological characteristics play a vital role in planning any capacity building programmes to farmers. A study was conducted during 2012-13 to know the personal, socioeconomic and psychological characteristics of Farmer Field School (FFS) and non-FFS farmers of groundnut in Chittoor district of Andhra Pradesh. There was no significant difference in farming experience and socioeconomic status was observed between FFS and non-FFS farmers of groundnut. Significant differences in extension participation, mass media exposure, innovativeness, achievement motivation, management orientation, economic orientation, information input behavior, information process behaviour and information output behaviour were observed between FFS and non-FFS farmers of groundnut

Keywords: Farmer Field School, Groundnut, Impact assessment

Farmer Field School (FFS) is a capacity building method based on adult education principles for group of farmers, usually comprises of 25-30. It is best described as a 'school without walls', where farmers learn through observation and experimentation in their own fields. It aims to increase the capacity of farmers to test new technologies in their own fields, assess results and their relevance to particular circumstances. This allows them to improve their management skills and become knowledge experts on their own farms. FFS is being implemented to inculcate use of eco-friendly measures (bio-agents and bio-pesticides) to manage crop pests which in turn reduce cost of cultivation and improve the quality of produce, resulting in high market price and good returns. The personal, socioeconomic and psychological characteristics play a vital role in planning any capacity building programmes to farmers. The present study was conducted with the objectives to assess the personal, socioeconomic and psychological characteristics of FFS and non-FFS farmers of groundnut in Chittoor district of Andhra Pradesh.

The study was conducted in the year 2012 - 2013 in Chittoor district of Andhra Pradesh. An *ex-post-facto* research design was used in the present study. Four mandals each from three revenue divisions of the district *viz.*, Chittoor, Tirupathi and Madanapalli were selected randomly for the study. From each of the selected mandal, one village, where FFS was organized was selected randomly for the study making a total of 12 villages. Ten each of FFS and non-FFS farmers were selected from each selected village by random sampling method. Thus, making a sample size of 240 i.e., 120 FFS and 120 non-FFS farmers. Personal, socioeconomic and psychological characteristics *viz*., farming experience, socioeconomic status, extension participation, mass media exposure, innovativeness, achievement motivation, management orientation, economic orientation, information input behavior, information process behaviour and information output behaviour were selected for the study based on the literature and the expert's consultation in the field. The relevant information was collected from the farmers with the help of suitable tests and schedules through personal interview method. The data were tabulated and analyzed, using mean, percentages, standard deviation and t-test.

It was evident from the Table 1 that majority of FFS (68.33%) and non-FFS farmers (65.00%) of groundnut were in medium category with respect to farming experience. Similar results were reported by Deshmukh *et al.* (2013), Naik (2008) and Obaiah (2004). With regard to socioeconomic status, majority of FFS (64.17%) and non-FFS farmers (65.00%) of groundnut were in medium socioeconomic category. These findings were in accordance with those of Lakshminarayan *et al.* (2013) and Obaiah (2004). It was observed that majority of FFS (80.00%) and non-FFS farmers (64.17%) were in medium extension participation category. These findings were in concurrence with Sreenivasulu (2011) and Patil (2008). The results revealed that majority of FFS (63.33%) and non-FFS farmers (53.34%) belonged to medium mass media exposure category. Deshmukh *et al.* (2013), Sreenivasulu (2011) and Obaiah (2004) reported similar findings.

With regard to innovativeness, majority of FFS (68.33%) and non-FFS (62.50%) farmers belonged to medium category

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and these results are in confirmation with the findings of Sreenivasulu (2011), Naik (2008) and Obaiah (2004). It was observed that majority of FFS (72.50%) and non-FFS (55.00%) farmers of groundnut were in medium achievement motivation category. The findings are in accordance with the studies conducted by Reddy (2006) and Obaiah (2004). Majority of FFS (44.17%) and non-FFS farmers (43.33%) of groundnut were in medium category with respect to management orientation. The results are in congruence with the findings of Devi *et al.* (2013), Sreenivasulu (2011) and Obaiah (2004). It is evident that majority of FFS (46.67%) and non-FFS farmers (42.50%) of groundnut were under medium economic orientation category. Similar results were reported by Obaiah (2004).

With respect to information input behavior, majority of FFS (64.17%) and non-FFS farmers (56.67%) of groundnut were distributed in medium category. These findings were in accordance with the results of Dhayal *et al.* (2013), Ravindrakumar (2006) and Obaiah (2004). Majority of FFS (64.17%) and non-FFS farmers (54.17%) of groundnut were in medium category with respect to information process behavior. These findings were in the line with those of Ravindrakumar (2006) and Obaiah (2004). With regard to information output behavior, majority of FFS (60.00%) and non-FFS farmers (53.33%) of groundnut were in medium category. These results were in conformity with the findings of Ravindrakumar (2006) and Obaiah (2004).

It was observed from Table 2, that there was no significant difference between FFS and non-FFS farmers of groundnut with respect to farming experience. The reason might be that FFS organizers purposefully selected middle aged farmers for FFS programme. With regard to socioeconomic status, there was no significant difference between FFS and non-FFS farmers of groundnut. It shows that age, education, land holding and material possession were not influencing the process of selection of farmers for FFS activity.

Significant differences were observed between FFS and non-FFS farmers of groundnut with respect to extension participation. Season long FFS activity might have influenced the FFS farmers of groundnut to participate in more number of programmes organized by Department of Agriculture, Research Stations and Krishi Vigyan Kendra etc. There is still scope to shift medium extension participation category to high by mobilizing them to participate in more number of agricultural programmes. There was significant difference between FFS and non-FFS farmers of groundnut with respect to mass media exposure. This may be due to the fact that FFS farmers were in regular touch with department officials and the intrinsic motivation spurred by these officials might have made them exposed to different mass media sources like radio, television, newspapers, agricultural magazines etc., to get updated on latest technologies.

With regard to innovativeness, there was significant difference between FFS and non-FFS farmers of groundnut. It was due to the fact that the farmers who were having innovative thinking or ideas to adopt modern agricultural activities were selected by the FFS organizers. It was observed that there was significant difference in achievement motivation of FFS and non-FFS farmers of groundnut. Achievement motivation mentally motivates human beings to act upon based on their active needs and compel them to move forward and achieve their goals. Due to the participation in FFS programme, the inner drive of participants might have gained momentum to achieve their targets and reaching the goals.

Regarding management orientation, there was significant difference between FFS and non-FFS farmers of groundnut. Majority of groundnut FFS farmers had good orientation towards planning, marketing and production aspects and it is due to season long FFS programme, which enabled them to learn about decision making and management aspects. It was evident that there was significant difference in economic orientation between FFS and non-FFS farmers. It was due to the fact that the farmers who were having interest in cultivation of commercial crops, adopt modern techniques and take up agricultural based enterprises in addition to agriculture were selected for FFS programme by the organizers.

It was observed that there was significant difference in information input behaviour of FFS and non-FFS farmers of groundnut. FFS created an opportunity to farmers to meet extension workers and subject matter specialists, which helped them to get necessary information for their agricultural production. Season long field study also motivated the FFS farmers to participate in different extension activities organized by KVKs, Research Stations and Department of Agriculture, which were important information input sources for them. The results reveal that there was significant difference in information process behaviour of FFS and non-FFS farmers of groundnut. Majority of the FFS farmers had high school and college level education and so they were able to evaluate process and store the information by consulting different experts. There was significant difference between FFS non-FFS farmers of groundnut with regard to information output behavior. FFS farmers effectively utilized the information dissemination methods like farm and home visits, group discussion with fellow farmers, participation in trainings and demonstrations, agricultural exhibitions and kisanmelas etc. It was due to FFS activity which enhanced the dissemination capacity of FFS farmers.

The results of the present investigation inferred that there were no significant differences in farming experience and socioeconomic status of FFS and non-FFS farmers cultivating groundnut. Significant differences were observed between FFS and non-FFS farmers of groundnut in extension

participation, mass media exposure, innovativeness, achievement motivation, management orientation, economic orientation, information input behavior, information process behaviour and information output behavior. This indicates that personal, socioeconomic and psychological variables would be improved by participation in FFS. Hence, farmers need to be encouraged to participate in FFS programmes.

Table 1 Distribution of FFS and non-FFS farmers according to their personal, socioeconomic and psychological characteristics

Variable	FFS (N=120)						Non-FFS (N=120)					
	Low		Medium		High		Low		Medium		High	
	F	%	F	%	F	%	F	%	F	%	F	%
Farming experience	20	16.67	82	68.33	18	15.00	21	17.50	78	65.00	21	17.50
Socioeconomic status	23	19.17	77	64.17	20	16.67	24	20.00	78	65.00	18	15.00
Extension participation	5	4.17	96	80.00	19	15.83	31	25.83	77	64.17	12	10.00
Mass media exposure	17	14.17	76	63.33	27	22.50	37	30.83	64	53.34	19	15.83
Innovativeness	22	18.33	82	68.33	16	13.33	30	25.00	75	62.50	15	12.50
Achievement motivation	16	13.33	87	72.50	17	14.17	39	32.50	66	55.00	15	12.50
Management orientation	31	25.83	53	44.17	36	30.00	45	37.50	52	43.33	23	19.17
Economic orientation	23	19.17	56	46.67	41	34.17	48	40.00	51	42.50	21	17.50
Information input behaviour	20	16.67	77	64.17	23	19.17	36	30.00	68	56.67	17	14.17
Information process behaviour	18	15.00	77	64.17	25	20.83	34	28.33	65	54.17	21	17.50
Information output behaviour	21	17.50	72	60.00	27	22.50	36	30.00	64	53.33	20	16.67

FFS: Farmer Field School farmers

Table 2 Differences in personal, socioeconomic and psychological characteristics of FFS and non-FFS farmers

Variable	FFS		Non-FFS		t-value	p-value
	Mean	SD	Mean	SD		
Farming experience	18.78	6.89	19.20	7.30	0.464	0.643
Socioeconomic status	14.58	7.22	13.00	6.46	0.684	0.495
Extension participation	4.77	2.29	2.33	1.77	9.236**	0.000
Mass media exposure	10.12	4.61	5.33	5.00	7.719**	0.000
Innovativeness	13.66	4.35	7.20	3.09	13.251**	0.000
Achievement motivation	19.59	2.88	15.89	4.54	7.544**	0.000
Management orientation	38.73	12.74	32.54	11.48	3.954**	0.000
Economic orientation	14.39	3.57	13.47	3.36	3.561**	0.000
Information input behaviour	20.53	5.17	15.97	5.38	6.691**	0.000
Information process behaviour	37.16	7.84	30.53	9.78	5.799**	0.000
Information output behaviour	16.38	3.95	14.04	3.83	4.660**	0.000

FFS: Farmer Field School farmers; ** Significant at 0.01 probability level

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Evaluation of benefits of optimum sowing time on yield and economics of spring sunflower under frontline demonstrations

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ABSTRACT

A total of 76 frontline demonstrations were conducted to evaluate the effect of sowing time on productivity and economics of spring sunflower at farmers' fields during the years 2008 to 2012 in Kurukshetra district, Haryana. The crop sown in first fortnight of February produced 11.3 and 34.8% more seed yield than the crop sown in second fortnight of February and first fortnight of March, respectively on an average basis of five years study. Sowing the seed in second fortnight of February also recorded 21.1% higher yield over March sowing. Fluctuating price of produce could not compensate the consistently increased cost of cultivation (8.7-11.0% hike every year) during the years 2008 to 2012. Early sowing in first fortnight of February gave 20.3 and 73.9% more net returns than the crop sown in second fortnight of February and first fortnight of March, respectively. Sowing the crop in second fortnight of February also enhanced the net returns by 44.5% over the sowing in first fortnight of March.

Keywords: Demonstrations, Economics, Sowing time, Spring sunflower

Sunflower a wonderful non-traditional oilseed crop offered the opportunity in early nineties in north-western parts of the country. The co-incidence of herbicide resistance in wheat and availability of high yielding sunflower hybrids triggered the sunflower cultivation in some parts of Punjab and Haryana. The short duration spring sunflower became the part of potato, *toria,* vegetable pea and sugarcane based cropping systems to diversify some of the wheat area. The sowing time of spring sunflower varied depending upon the harvesting of previous crops. Farmers started planting of sunflower upto middle of March resulting in yield reduction and decreased profits. Time of sowing is most crucial factor in attaining the yield potentials of any cultivated crop. Therefore, present study was undertaken to assess the effect of sowing time on productivity of sunflower through FLDs in farmers' fields. Krishi Vigyan Kendra, Kurukshetra conducted FLDs on spring sunflower during the years 2008-2012 in Kurukshetra district, Haryana. The soil of the district is clay loam with slightly alkaline reaction and possesses medium fertility status. A total of 76 FLDs on spring sunflower were undertaken across the district randomly. Most of the demonstrations were laid out in the fields after harvest of potato and vegetable pea crops. The sowing time varied from beginning of February to middle of March depending upon the harvesting of previous crops. The demonstrations were divided into three categories based on the sowing time (February 1-15, February 16-28 and March 1-15) of the crop. The number of demonstrations under different periods of sowing varied during different years of study. Thus the sowing of 38, 39 and 23% demonstrations was done during February 1-15, February 16-28 and March 1-15, respectively over the years from 2008 to 2012. Almost all the farmers adopted recommended package of practices like seed rate (5 kg/ha), nutrients dose (nitrogen and phosphorus @ 100 and 50 kg/ha, respectively) and planting geometry (60 x 30 cm) under different periods of sowing. The harvesting time of different FLDs differed depending upon the maturity of the crop. The details of FLDs under varying sowing time during different years of investigation are given in Table 1. The FLDs were monitored at regular intervals and data on seed yield were recorded. The data were analyzed using descriptive statistics such as mean. The economic analysis was carried out by taking into account the variable costs involved in cultivation and market price of the produce (seed yield) prevailed during different years of study.

Table 1 Details of frontline demonstrations conducted during 2008-2012

Year	Number of FLDs	Area (ha)	Number of FLDs under different sowing time		
			February 1-15	February 16-28	March 1-15
2008	17	6.8	5	9	3
2009	9	4.0	5	2	2
2010	17	8.0	4	9	4
2011	15	10.0	7	4	4
2012	18	10.0	8	6	4
Total	76	38.8	29	30	17

Variations in seed yield were noticed over a span of five years (2008-2012) study. The average seed yield ranged between 1890 and 2440 kg/ha irrespective of the differences recorded under different sowing times (Table 2). Farmers harvested highest seed yield during the year 2008 and lowest seed yield during the year 2010 attributing to corresponding

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weather conditions and sowing of various hybrids (hybrid selection by farmers' own choice) coupled with quality of seed sown during different years of investigation.

Sowing time influenced the seed yield of spring sunflower during all the years under study. Early sowing done in the first fortnight of February resulted in 11.3 and 34.8% higher productivity than the sowing in second fortnight of February and first fortnight of March, respectively. Sowing in second fortnight of February also recorded 21.0% higher seed yield over sowing in first fortnight of March. The yield advantage with sowing time of February 1-15 were to the tune of 10.2, 4.8, 11.5, 12.2 and 18.9% over the February 16-28 sowing during the years 2008, 2009, 2010, 2011 and 2012, respectively. Similarly, sowing the seed in second fortnight of February produced more seed yield (16.0-22.9%) than the crop sown in first fortnight of March during different years. Early sowing in first fortnight of February during which period low temperatures prevailed increased the crop growth period, this provided more time for flowering, seed development and proper ripening of grains/seeds in comparison to planting in second fortnight of February and first fortnight of March under the irrigated agro-ecological conditions of north-western parts of India. For this reason, spring sunflower performs better than *kharif* season in Haryana and Punjab states. Delayed sowing after first fortnight of February showed yield decline due to decreased duration of crop growth. The coincidence of grain development with early monsoon rains created hindrances in seed maturity and even the process of harvesting. Similar observations have been reported by Sidhu and Kolar (1996) in Punjab in spring sunflower. Yield differences among different sowing dates have been reported by Saleem *et al*. (2007) also in autumn planted sunflower in Pakistan.

On one side, cultivation cost of sunflower increased over the years of investigation to the tune of 12.8, 8.7, 12.5 and 11.0% from the year 2008 to 2009, 2010, 2011 and 2012, respectively. On the other side, the price of produce fluctuated between ₹1900 and 2800/100 kg showing inconsistent rise and falls during different years, these indefinite trends affected the economics (Table 3). Maximum returns were obtained during the year 2008 followed by 2012, 2011, 2009 and minimum during the year 2010 which were in accordance with the seed yield and price of the produce prevailed during different years.

Table 1 Effect of sowing time on seed yield of spring sunflower

Year	Average seed yield (kg/ha)			
	February 1-15	February 16-28	March 1-15	Average
2208	2700	2450	2000	2440
2009	2420	2310	1880	2280
2010	2130	1910	1590	1890
2011	2200	1960	1580	1970
2012	2330	1960	1690	2060
Average	2360	2120	1750	-

Table 3 Effect of sowing time on economics of spring sunflower

Year	Rate of produce (₹/100kg)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)			Net returns (₹/ha)		
			February 1-15	February 16-28	March 1-15	February 1-15	February 16-28	March 1-15
2008	2500	17072	67500	61250	50000	50428	44178	32928
2009	2000	19253	48400	46200	37600	29147	26947	18347
2010	1900	20925	40470	36290	30210	19545	15365	9285
2011	2800	23550	61600	54880	44240	38050	31330	20690
2012	2500	26147	58250	49000	42250	32103	22853	16103
Average	2340	21389	55244	49254	40860	33855	28135	19471

Sunflower sown in the first fortnight of February resulted in maximum net returns which were 20.3 and 73.9% more than the returns obtained under the sowing times of second fortnight of February and first fortnight of March, respectively. Maximum reduction in net returns (40.5%) due to change in sowing time from February 1-15 to February 16-28 were observed during the year 2012 and the corresponding minimum reduction was 8.2% in the year 2009 for obvious reason of decreased seed yield. Further delayed sowing in first fortnight of March 1-15 registered 53.1 to 110.5% reduction in net returns in comparison to sowing done in first fortnight of February during different years. There was significant decrease (44.5%) in net returns under sowing time of March 1-15 when compared with sowing time of February 16-28 on an average basis of five years associated with the corresponding seed yield reductions. The incremental decrease in gross as well as net returns showed increasing trend with the delayed sowing from February 1-15 to February 16-28 and March 1-15 for spring sunflower. Hence, sowing of spring sunflower during first fortnight of February in Kurukshetra district of Haryana is beneficial in terms of yield and economics. It is suggested that appropriate partnerships with stakeholders are to be built to popularize the technology.

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OBITUARY

Dr. Gummadi Ankineedu

(1935-2014)

Dr. G. Ankineedu born on 12th December 1935. He obtained his M. Sc. and Ph. D. in Botany from the Osmania University, Hyderabad. He served as Scientist at IARI Regional Station, Hyderabad where he has done extensive work on genetic improvement of castor through traditional breeding and mutagenesis. Major milestones include the isolation of 240 pistillate lines and useful variants for yield, oil content, plant height and variations in sex tendencies through fast-neutrons and gamma rays. Particularly noteworthy is the development of the early-maturing cultivar "Aruna" through fast-neutron mutagenesis which was of significant relevance to the drought prone areas of Andhra Pradesh as it not only helped in stabilization of castor yields in the region but also in facilitating two crops in years with favourable winter conditions. On 31st December 1976, he joined the Directorate of Oilseeds Research, Hyderabad as Project Coordinator (Castor) where he has continued his work on castor improvement. He also served as Project Director for a very short period. Due to ill-health, he has taken voluntary retirement and retired from service on 4th April 1988. The services of Dr. Ankineedu, as Project Coordinator particularly for the research and development of castor varieties and hybrids were most commendable and paved a path for great strides which will be remembered for ever. His contributions for the two decades at DOR led to the development of promising castor breeding lines.

Dr. Ankineedu was a very simple, honest and kind personality with highest dedication towards the oilseeds research. During his stay at DOR, his dedication and selfless nature was always something that many others should try to follow and all who knew him regarded him with great respect and admiration.

Tragically, Dr. Ankineedu expired on 24th March 2014 on account of paralysis. He is a very valuable and respected member of DOR and ISOR family. On behalf of DOR and ISOR, we express our deep sense of sympathies on the sudden demise of the most dedicated and richly contributed oilseed researcher.

Dr. Morapalli Venkata Ramana Reddy

(1929-2014)

Dr. Morapalli Venkata Ramana Reddy popularly known as Dr. M.V. Reddy born on 3rd October 1929 in a farming community in a village Pedda Yeddulavaripalli, Tanakallu mandal, Ananthapur District, Andhra Pradesh. He did B. Sc. (Agri) in 1954 and M. Sc (Agri) in 1958 from Agriculture College, Bapatla. He obtained Ph.D. in 1967 from Kansas State University, USA. He was Professor and Head of Genetics & Plant Breeding for more than 10 years and during 1980-83 he was Principal of the Agriculture College, Bapatla. He and his associates at Bapatla developed a fine grain rice variety BPT 5204 called as Samba masoori/ Sona masoori/ Kurnool sona which became very popular and still cultivated in larger areas in many parts of the country. He also worked as Associated Director of Research at Tirupati till his retirement in 1989. From Tirupati he released a groundnut variety, TPT-1.

Dr. Reddy was the first Project Director, In- charge of the newly established Directorate of Oilseeds Research (DOR) for the period from 1st August 1977 to 30th June 1978. During his period, he paved the way for overall development of DOR and release of Sunflower Hybrid APSH-11. He received several awards including Best Teacher Award in 1983 and Outstanding Agricultural Scientist Award from Govt. of Andhra Pradesh in 2009. Dr. Reddy at the age of 85 passed away on 23rd April 2014. The staff of DOR and members of Oilseeds Society deeply mourn and pray the God for rest of his soul in peace and courage to his family members.

JOURNAL OF OILSEEDS RESEARCH

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