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ANNOUNCEMENT

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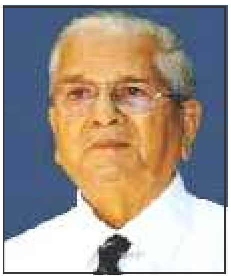


Dr. M.V. Rao

Chairman, Agri-Biotech Foundation, Hyderabad and
Former Special Director General, ICAR, New Delhi

The Indian Society of Oilseeds Research (ISOR) has taken a new initiative to organize **"Dr. M.V. Rao Lecture"** series to honour the doyen of Agriculture for his valuable contributions. Especially, his contributions to the oilseed sector are highly commendable. He is instrumental in bringing "Yellow Revolution" during his tenure as Special Officer, Technology Mission on Oilseeds. ISOR feels proud to announce that the first lecture in the series is delivered by Dr. R.S. Paroda, Chairman, TAAS & Former DG, ICAR on 24th August, 2013 at Hyderabad.

About Dr. M.V. Rao

Born on June 21, 1928 in a farming family in the coastal town of Narsapur in Andhra Pradesh, India, Dr. M.V. Rao had a brilliant academic career. He was awarded the Rockefeller Foundation Fellowship and obtained his Ph.D in Plant Breeding & Genetics and Plant Pathology from Purdue University, USA. Dr. Rao headed the All India Wheat Improvement Project of the Indian Council of Agricultural Research (ICAR) from 1971 to 1981. He is one of the doyens of Indian Agriculture and key architects of the Green Revolution in India whose contributions have spanned over 60 years.

The significant role played by Dr. Rao helped India in increasing wheat production and transforming it from being a net importer for food grains to a nation not only self-sufficient in meeting the food needs of a burgeoning population, but also in having unmanageable food grain buffer stocks. As Deputy Director General (Crop Sciences) of ICAR between 1981 and 1986, he gave a new thrust and impetus at the national level to all researches engaged in food, commercial and horticultural crops. He is an excellent teacher and guided 25 students at Ph.D and M.Sc levels. From 1986 till 1989 he served as the first Director of the Prime Minister's Technology Mission on Oilseeds in the rank of Special Secretary to the Government of India and as a Special Director General of ICAR. He provided leadership and direction for enhancing oilseeds production through multi agency support and coordination which led to the "Yellow Revolution". The second "Revolution" witnessed the almost doubling of the oilseeds production from 12 million tonnes to 22 million tonnes and a dramatic drop in India's import of vegetable oils and saving of critical foreign exchange.

Dr. Rao is the founder President of the Indian Society of Oilseeds Research and served the society for 7 terms. Besides serving on several committees of the Government of India, the Government of Andhra Pradesh and ICAR, he was also the Chairman of the Andhra Pradesh Netherlands Project on Biotechnology, Scientific Advisory Panel on Coastal Ecosystem of the National Agricultural Technology Project (NATP) and President of the Indian Society of Genetics & Plant Breeding. Between 1989 and 1990, Dr. Rao worked as an Agricultural Expert with the World Bank and from 1991 to 1997 as the Vice Chancellor of the Andhra Pradesh Agricultural University, Hyderabad - India's largest Agricultural University. He was on the Wheat Advisory Committee of the Food and Agricultural Organisation (FAO) of the United Nations. He served as the Trustee of the International Rice Research Institute (IRRI), Philippines for 6 years and as an external Panel Expert of the International Maize and Wheat improvement Centre (CIMMYT), Mexico. He successfully led Indian Agricultural delegations to France, USSR, Canada and Bangladesh. He served as a consultant to the World Bank in Uganda (1990) and in Ethiopia (1997), to help in developing agricultural research and higher education. He also served as Chairman of the Committee on the New National Seed Policy of the Government of India. Because of his dynamic leadership and invaluable contributions to agricultural development in India, Dr. Rao was conferred with several prestigious Awards including "PADMA SHRI" of Government of India; Norman Borlaug Award; Doctor of Agriculture, *Honoris Causa*, by Purdue University, USA and Banaras Hindu University; Linker's Award; Peddireddy Thimma Reddy Award; Padma bushan Dr. P. Siva Reddy Foundation Award, and Dr. Srikantia Memorial Award of the Nutrition Society of India, Gold Medal of the Environmental Research Academy, etc.

World renowned agricultural scientist Dr. Norman E. Borlaug acclaimed Dr. Rao's significant contribution to Agriculture and said that *his role in alleviating hunger and misery in the world is praise worthy*. Commending Dr. Rao's contributions, Dr. M.S. Swaminathan, the father of India's Green Revolution said that Dr. Rao can look back with pride and satisfaction on his multi-faceted contributions to agricultural research and development. His contributions to wheat research are monumental. As the first Director of the Oil Technology Mission he laid the foundation for achieving rapid advance in the production of oilseeds and in reduction of imports.

Dr. Rao was a Member of Legislative Council, Government of Andhra Pradesh for 6 years from 2007.

At the age of 86 years, Dr. Rao is still active and energetic. He is successful in motivating and developing good teams and leaders to support the efforts to ensure an "Evergreen and ongoing Green revolution".

Special Article

The Indian oilseeds scenario : Challenges and opportunities*

R S PARODA

Former Director General, ICAR and Secretary, DARE, Government of India

PREAMBLE

It is indeed a great privilege to be the first speaker in the newly instituted Dr. M.V. Rao Lecture Series by the Indian Society of Oilseeds Research (ISOR), Hyderabad. While thanking the office bearers of the Society, let me congratulate ISOR for having taken this initiative to honour one of the most renowned agricultural scientists, with whom I have had a long association since my student days at Post Graduate School, IARI. He has been my role model, from whom I have learnt a great deal. We, the crop scientists, should be proud of the enormous contributions of Dr. M.V. Rao towards food security in India. All through his life, Dr. Rao has been a great crusader aiming to improve the lives of resource poor farmers.

For this lecture, I have chosen the subject "Addressing Emerging Concerns of Indian Agriculture", whereas this paper published for circulation is mainly on the oilseeds production scenario and strategies to improve productivity and long-term self-sufficiency in oilseed sector.

Vegetable oils are critical for the nutrition security of our people in India. Through technological means such as refining, bleaching and deodorisation, newer oils like cotton seed, sunflower, palm oil, soybean and rice bran have become popular in recent times. 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 oilseeds sector has remained vibrant globally with 4.1% growth per annum in the last three decades. In India, oilseeds account for nearly 3% of the gross domestic product and 5.98% of the value of all agricultural products. India 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 m ha), India currently imports about 50% of total oil requirement at a huge cost of ₹ 56,000 crores (2011-12). The proportion of import has increased from a meagre 3% in 1970-71 to almost 56% in 2012-13.

*Delivered as the first Dr. M.V. Rao lecture organised by the Indian Society of Oilseeds Research on 24th August, 2013 at DRR Auditorium, Hyderabad

PRODUCTION SCENARIO

India attained an average productivity of 1087 kg/ha for the triennium ending 2012-13. The average yields of most of the oilseeds are invariably low (Table 1).

Table 1 Oilseeds productivity (kg/ha) in India *vis-a-vis* world (2012)

Crop	India	World	Country with highest average productivity*
Groundnut	1179	1676	4699 (USA)
Rapeseed-Mustard	1140	1873	3690 (Germany)
Soybean	1208	2374	2783 (Paraguay)
Sunflower	706	1482	2494 (China)
Sesame	426	518	1315 (Egypt)
Safflower	654	961	1489 (Mexico)
Castor	1455	1162	1455 (India)
Linseed	260	752	1358 (Canada)
Oil palm fruit	12380	14323	21901 (Malaysia)

Source: FAOSTAT, 2012
* from among the countries with >80% global contribution

The cultivation of oilseeds in the rainfed areas (72%), in varying agro-climatic regions, with uncertain returns on investment, are the major factors for low productivity.

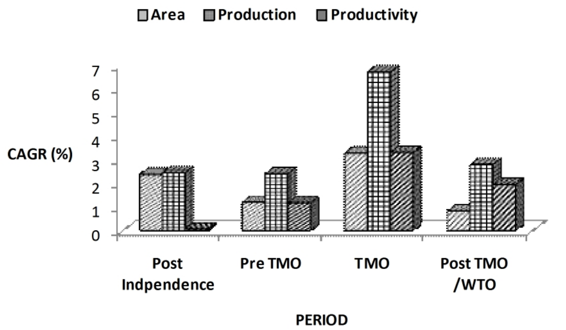
The production scenario of vegetable oilseed sector in the country can be categorized into four periods, *viz*., (i) Post-Independence (1950-1966), (ii) Coordinated Research Program (1967-1985), (iii) Technology Mission (1986-1996) and (iv) Post-Mission (1996-97 to till date) periods.

Post-independence Period

This period witnessed mainly an area expansion by five million ha from 10.73 million ha in 1950-51 to 15.25 million ha in 1965-66 with production of 5.16 and 6.40 million tonnes, respectively for the aforesaid periods. The area increased by 32% while the production increased by 34% with negligible gain in productivity levels, although this period witnessed the release of 40 improved cultivars. The compound growth rate for the period from 1950-51 to 1965-66 indicated that area increased by 2.38%, whereas the production increased by 2.46%. The growth rate of productivity was a meagre 0.07% (Fig. 1).

Coordinated Research Programme Period (Pre-TMO)

Research on oilseeds got an impetus after the establishment of the All India Coordinated Research Project on Oilseeds (AICORPO) in 1967. This project strengthened the base for the development, verification and adoption of location specific technologies for increased productivity, especially the new varieties and hybrids. This period witnessed massive structural reforms in the national network in oilseeds. The Directorate of Oilseeds Research (DOR) came into being on August 1, 1977. The area, production and productivity increased by 18, 41 and 19%, respectively for the quinquennium ending 1971-72 as against 1985-86. The annual growth rates registered during the period 1967-68 to 1986-87 was 1.21, 2.41 and 1.19% for area, production and productivity, respectively (Fig. 1). The period also witnessed release of 153 varieties of oilseeds.



Post independence = 1950-51 to 1965-66; Pre TMO = 1966-67 to 1985-86; TMO = 1986-87 to 1995-96; Post TMO = 1996-97 to 2012-13

Fig. 1. Compound Annual Growth Rates (CAGR) of annual oilseeds in India

Technology Mission Period

Technology Mission on Oilseeds was initiated by the Late Prime Minister Shri Rajiv Gandhi in May, 1986 with very ambitious objectives of (a) self-reliance in edible oils by 1990 (b) reduction in imports to almost zero by 1990, and (c) raise oilseed production to 18.0 million tonnes by 1989-90 and 26.0 million tonnes of oilseeds and 8.0 million tonnes of vegetable oil by 2000 AD. Thrust was given on the main oilseed crops in selected 180 districts in 17 states which contribute the maximum quantity of oilseeds to the nation. The scope of the Mission and strategies to be adopted to achieve the objective were set well before the onset of the Mission in February 1986, which is elaborated in the excerpts from the then Prime Minister's speech quoted below:

"One of our biggest problems today in the agricultural sector is oilseeds. We are setting up a thrust Mission for oilseeds production. When we talk of a Mission, we mean an exercise starting from the engineering of the seeds and finishing with the finished products of the vegetable oil (and the by-products like oil meal) which could be delivered to the consumer. We would like to put one person in-charge of such a Mission with full funding, with no restrictions on him, whether bureaucratic or otherwise. The only limits will be certain achievements which must come within a certain time frame. This will cut across a number of ministries…"

This one person in-charge at that time was none other than Dr M.V. Rao

The mission started functioning as a consortium of concerned Govt. departments, *viz.*, Agricultural Research and Education (DARE), Agriculture and Cooperation (DoAC), Civil Supplies (DoCS), Commerce (DoC), Science and Technology (DST), Biotechnology (DBT), Planning, Health, Irrigation and Economic Affairs. The Mission adopted a four-pronged strategy under the following Mini-Missions.

Mini-Mission-I: Improvement of crop production and protection technologies for realizing higher yields and profit to farmers.

Mini-Mission-II: Improvement of processing and post-harvest technology to minimize the losses and increase the oil yield from both traditional and non-traditional sources of oil.

Mini-Mission-III: Strengthening the input support system to ensure availability of right kind of seeds, fertilizers, pesticides, irrigation, credit, etc. and to bring awareness among farmers about the potential of the farm worthy technology through massive transfer of technology programmes.

Mini-Mission-IV: Improvement of post-harvest operations for effective procurement, handling, disposal including price support system to farmers, financial and other supports to processing.

The constitution of Technology Mission on Oilseeds (TMO) in 1986, spearheaded by Dr. M.V. Rao, resulted in the country's oilseed production surpassing the target of 18 million tonnes, fixed for the VII Five-Year Plan with an impressive annual growth rate of nearly 6% in the short-run. Thanks to TMO, the import got reduced to almost negligible. Hence, India achieved near self-sufficiency in edible oils during early 1990s, which was popularly referred to as 'Yellow Revolution". The growth rate in the *per capita* edible oil consumption during this period was 3.66% with an average *per capita* consumption of 6 kg/annum. The increase in the *per capita* consumption *vis-à-vis* the previous period was 54%.

As a result of concerted efforts under TMO, a quantum jump in oilseeds production from 108.3 lakh tonnes (1985-86) to 247.5 lakh tonnes (1998-99) was made possible through effective coordination among different Ministries, Departments and Organizations like ICAR and SAUs under the able leadership of Dr. M.V. Rao. The latter developed high yielding varieties with disease and insect resistance suited to various agro-climatic conditions. Ministry of Agriculture provided needed support for timely supply of inputs like seed and propagation of production technology through State Extension Services, arranging credit facilities, marketing and processing, storage and price support, etc. It is overwhelming to record that the area under oilseed cultivation increased from 190 lakh ha (1985-86) to 260 lakh ha (1996-97) and production increased from 108.3 to 243.8 lakh tonnes during just one decade, registering an increase of 36% in area and 125% in production. Similarly, productivity of all annual oilseed crops, on an average, increased from 570 to 926 kg/ha, being an increase of 62% during this period. This golden era witnessed the release of 200 varieties and hybrids and performance of improved crop technologies under real farm situations, leading to significant improvements both in yield and profits to the farmers. As a result, India achieved a status of 'self sufficient and net exporter' during early nineties, rising from the 'net importer' state. At the same time, the imports declined from ₹ 700 crore in 1985-86 to ₹ 300 crore in 1995-96.

Post-Mission Period

The other dominant feature which has had significant impact on the present status of edible oilseeds/oil industry has been the program of liberalisation under which the Government's economic policy allowed greater freedom to the open market through open general licencing (OGL) and encouraged healthy competition and self regulation rather than protection and control. Controls and regulations thus got relaxed resulting in a highly competitive market dominated by both domestic and multinational players. At the same time, 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. This completely eroded the gains that the country had achieved during the TMO period (Fig.1). In addition, the increasing biotic and abiotic stresses, strong intervention of market and non-market forces led to a sticky domestic oilseeds production and profitability.

Despite the above developments, the performance of oilseeds on the domestic front during the last two decades has been commendable considering the adverse weather conditions, the global price aberrations and the ever increasing domestic demand. The growth rate of nine annual oilseeds during 2000-01 to 2011-12 *vis-a-vis* 1990-91 to 1999-2000 did provide a fillip for consolidation and revitalization of oilseed economy (Fig. 2). Although enhanced growth rates of 5.94% were evidenced on the domestic availability of edible oils for the period ending 2011-12, it could not match the rate of growth of imports of edible oils which was 6.99%. The *per capita* consumption of edible oils grew at a rate of 5.65%. Growth analysis of individual oilseed crops during the decade 2000-01 to 2010-11 suggests that there has been acceleration in area under soybean, rapeseed-mustard and sesame while stagnation/deceleration has been observed in groundnut, sunflower, niger, safflower and linseed. The growth in area under castor crop, although marginal, resulted in production enhancement through considerable productivity improvement.

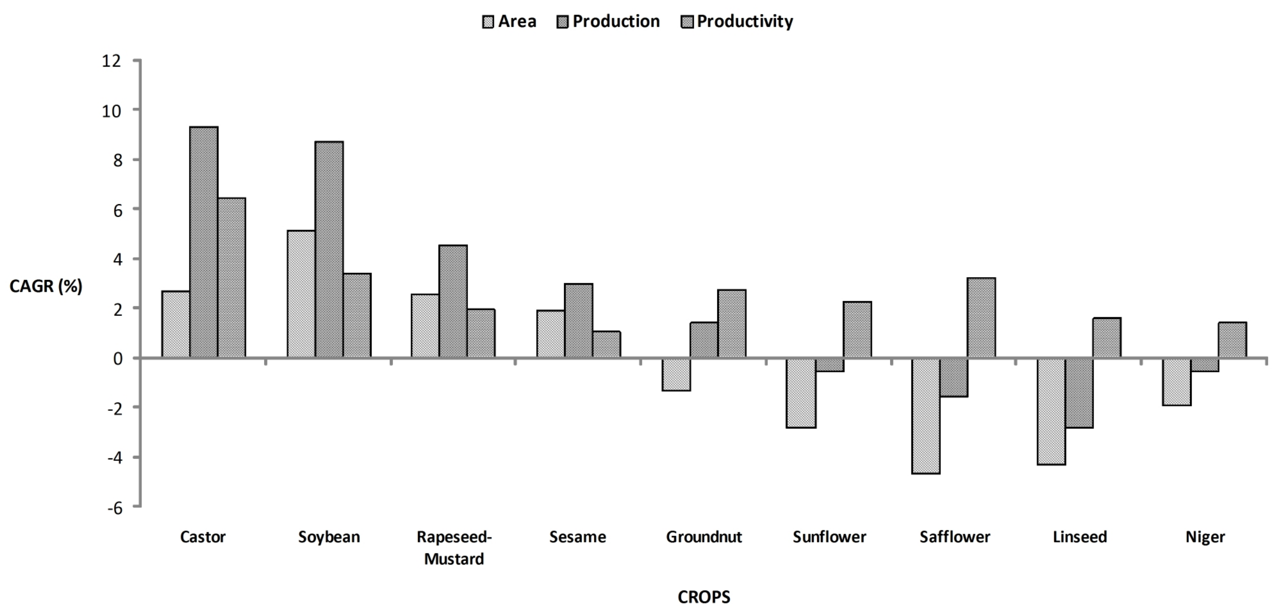


Fig. 2. Compound Annual Growth Rates of annual oilseed crops in India (2000-01 to 2011-12)

The trend of vegetable oils production over the years did help to a considerable extent in reducing imports (Table 2). On the contrary, the Government policy allowed greater freedom to open market and encouraged healthy competition rather than protection or control.

Table 2. Domestic production, imports, *per capita* consumption and self-sufficiency in edible oils in India

Year	Edible oil (lakh tonnes)	Imports (lakh tonnes)	*Per capita* consumption (kg/annum)	Self-sufficiency (%)
1986-87	38.7	14.7	6.2	72
1990-91	63.7	5.3	6.5	92
1994-95	71.9	3.5	7.3	95
1998-99	70.0	26.2	9.8	73
2002-03	51.5	43.6	8.8	53
2006-07	80.0	42.7	11.2	65
2007-08	91.4	49.0	12.2	65
2008-09	89.9	67.2	13.5	57
2009-10	82.3	81.2	14.1	51
2010-11	97.8	72.4	13.6	57
2011-12	90.2	99.4	13.8	48

Source: Various reports from DGCIS, Kolkata and DES, Govt. of India

DEMAND, IMPORT AND EXPORT SCENARIO

Demand Projections

The domestic demand for vegetable oils and fats has also been rising rapidly at an increasing rate due to increase in per capita income and increase in standard of living. Thus, annual demand is increasing at the rate of 6% while our domestic output has been increasing at just about 2%.

The average *per capita* consumption of edible oils was 3.66 kg/annum which was much less than the norms prescribed by ICMR/WHO, with a growth rate of 5.01%. The Import bill began to increase at an alarming rate of almost 25% from ₹31.3 crores to ₹ 692 crores for the triennium ending 1985-86. On the export scenario of edible oilseeds and the products, the rate of growth was a meagre 4% from 1970-71 to 1985-86 with the export earnings being ₹ 101 and ₹138 crores for the trienniums ending 1973-74 and 1985-86, respectively. Systematic efforts were made to increase the domestic production of oilseeds, reduce the import bill, and to make the country self-reliant as early as possible in vegetable oils during early eighties through the National Oilseeds Development Project (NODP). There was a visible effect of the measures taken but it was not enough to curtail the import bill. Need for a special purpose vehicle to increase the domestic production of edible oilseeds production to combat the swelling imports of edible oils was felt. This paved the way for the genesis of the Technology Mission on Oilseeds in the year 1986.

Vegetable oils do provide much needed food security measured in terms of calorie requirements for our poverty assessment. Rapid growth of food demand in the developing countries, in conjunction with the high calorie content of oil products, has contributed to the increased calorie consumption in developing countries. One out of every four calories added to the consumption in developing countries originated in this group of products. In future, vegetable oils are likely to retain, and indeed strengthen, their primacy as major contributors to further increases in food consumption of the developing countries. Three decades ago, 136 kcal/person/day or 6.5% of the total availability of 2110 calories were contributed by oil products in the developing countries. Oil consumption *per capita* had grown to 10.4 kg by the year 2000, contributing 272 kcal to total food supplies, or 10% of the total 2650 kcal consumed. Average *per capita* consumption of edible oils for the period 2002 to 2012 rose to 29.4 g/day (10.7 kg from edible oils and 1.2 kg from vanaspati). The increase in average *per capita* consumption of the edible oils was 5.25% during the period. 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 suffice to 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, cosmetics purposes (Fig. 3).

Thus, the vegetable oil consumption trends for vegetable oils continuously increased at an increasing rate (Fig. 4).

Taking into consideration a host of factors *viz*., domestic production, the import dependency, the trade buoyancy, the pattern of *per capita* consumption, the changes in dietary standards, the growing trend of out-of-house consumption, the rising demand for vegetable oils for non industrial uses and the production of biofuel; the projections have been made for the Indian vegetable oilseeds. The projections are based on the assumptions that the *per capita* consumption would be increasing annually at 3% till 2015, followed by an increase at a declining rate of 2.5% from 2015 to 1.75% in 2020, with a further decline in the incremental consumption to negligible levels by the year 2050. The estimated *per capita* consumption is accordingly placed at 16.43, 17.52, 18.62 and 19.16 kg/annum for the year 2020, 2030, 2040 and 2050, respectively.

A newer dimension of vegetable oil requirement for industrial use is estimated to grow by 15% in 2020, 20% in 2030 and 25% post 2040, thus requiring around 3.57, 6.34, 9.69 and 10.61 million tonnes in 2020, 2030, 2040 and 2050, respectively (Table 3). 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. The contribution of vegetable oil availability from secondary sources including arboreal tree species (20%) is estimated at 5.05, 5.89, 6.85 and 7.18 million tonnes during 2020, 2030, 2040 and 2050, respectively. Thus, the total domestic vegetable oilseeds requirement from nine annual oilseed crops is estimated at 67.37, 71.45, 80.65 and 82.06 million tonnes by 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. Further, the urban population in the country is increasing by more than 3% annually. The report by McKinsey Global Institute predicts that 590 million people or 40% of India's population will live in cities by 2030, up from 340 million today. This would have tremendous effect on increased consumption of edible oils looking down to the social status and the size of the strata to the total population in the country. Higher economic growth and concomitant rise in incomes, coupled with change in tastes and preferences in both urban and rural areas are expected to increase the demand for high-value commodities, especially the edible oils.

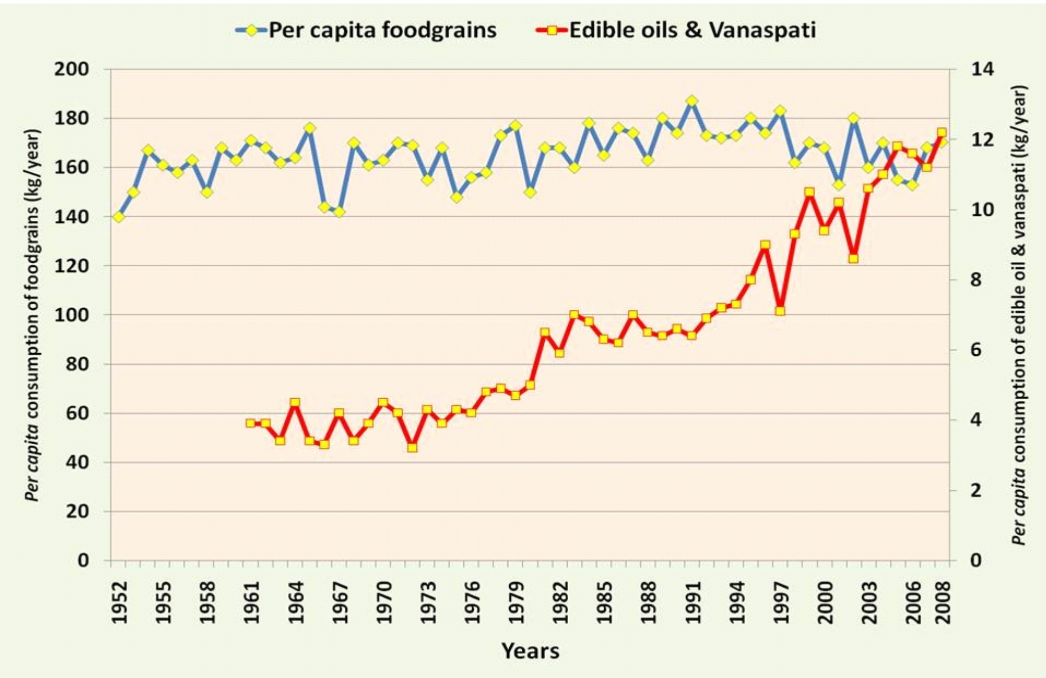


Fig. 3. *Per capita* consumption of food grains and edible oils

(Source: Various issues of Five Year Plan Documents, Min. of Finance, DGCIS and Economic Survey, GOI)

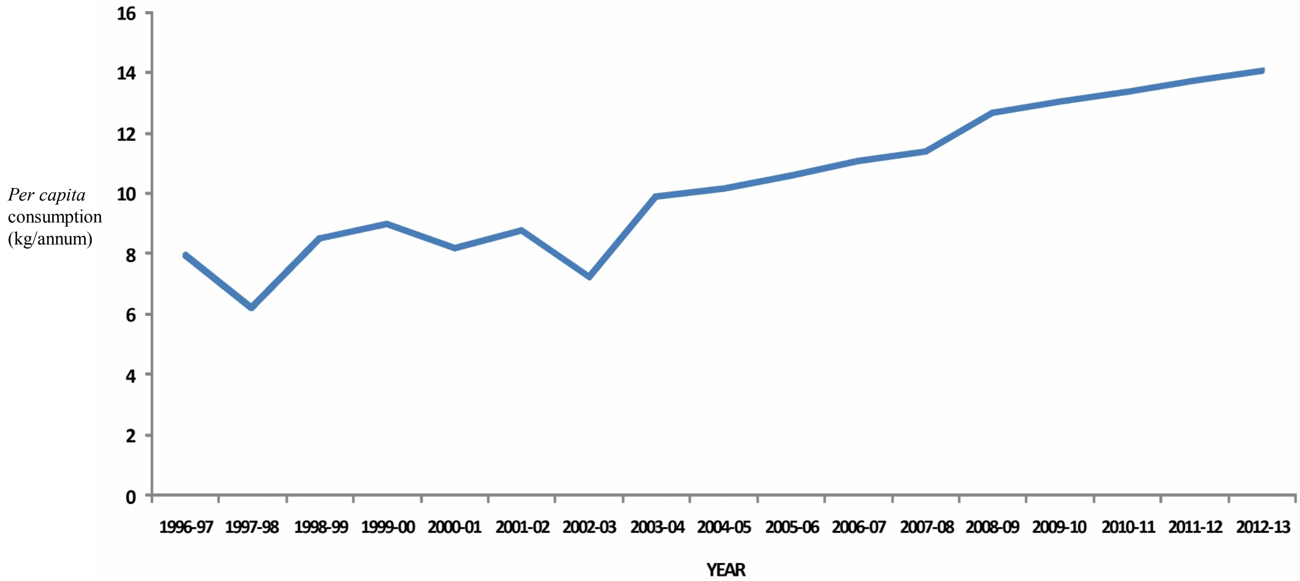


Fig. 4. Trends in *per capita* consumption of edible oils in India
(Source: Various issues of Five Year Plan documents, Ministry of Finance, DGCIS and Economic Survey, GOI)

Table 3 Demand projections of vegetable oils in India

	2020	2030	2040	2050
Projected population (billion)	1.32	1.43	1.55	1.68
Per capita consumption considering 50, 60, 70 and 75% above the prescribed consumption levels during 2020, 2030, 2040 and 2050, respectively				
Per capita consumption (kg/annum)	16.43	17.52	18.62	19.16
Vegetable oil requirement for direct consumption (million tonnes)	21.69	23.13	24.58	25.29
Vegetable oil requirement for non industrial use (million tonnes)	3.57	6.34	9.69	10.61
Total vegetable oil requirement (million tonnes)	25.26	29.47	34.27	35.90
Vegetable oil availability from secondary sources (million tonnes)	5.05	5.89	6.85	7.18
Total vegetable oil requirement from annual oilseed crops (million tonnes)	20.21	23.58	27.42	28.72
Total vegetable oilseeds requirement from nine annual oilseed crops (million tonnes)	67.37	71.45	80.65	82.06

Import Situation

The success of Technology Mission on Oilseeds was evident from the doubling of the oilseeds production and reduction in imports during the triennium ending 1993-94. Except for this period, there has always been a large gap between the domestic demand and production. After China, India is the world's largest importer of vegetable oil. Besides meeting the shortfall in production, to check the inflation, state owned trading companies started increasing their overseas purchases. To aid the process and for consumer protection against price rise, in the year 2005, import duty was raised on crude palm oil/crude palmolein from 65% to 80% and on refined palm oil/RBD palmolein from 75% to 90%. Subsequently, in August 2006, the import duty was reduced on crude palm oil/crude palmolein from 80% to 70% and on refined palm oil/RBD palmolein from 90% to 80%. In the year 2007, the custom duty on crude and refined palm oil/palmolein was further reduced to 45% and 52.5%, respectively. The custom duty on crude as well as refined sunflower oil was further reduced to 40% and 50%, respectively. In 2008, the custom duty on all major crude and refined oils was reduced to 'Nil' and 7.5%, respectively.

In 2008-09, the Government of India introduced a scheme of distribution of up to 10 lakh tonnes of imported edible oils. Four Public Sector Undertakings (PSUs), namely, Projects Equipment Corporation (PEC), Minerals & Metals Trading Corporation (MMTC), State Trading Corporation (STC) and National Agricultural Corporation Marketing Federation (NAFED) were entrusted the job of import, refining, packing and distribution of subsidized edible oils to the states. The scheme continued from August

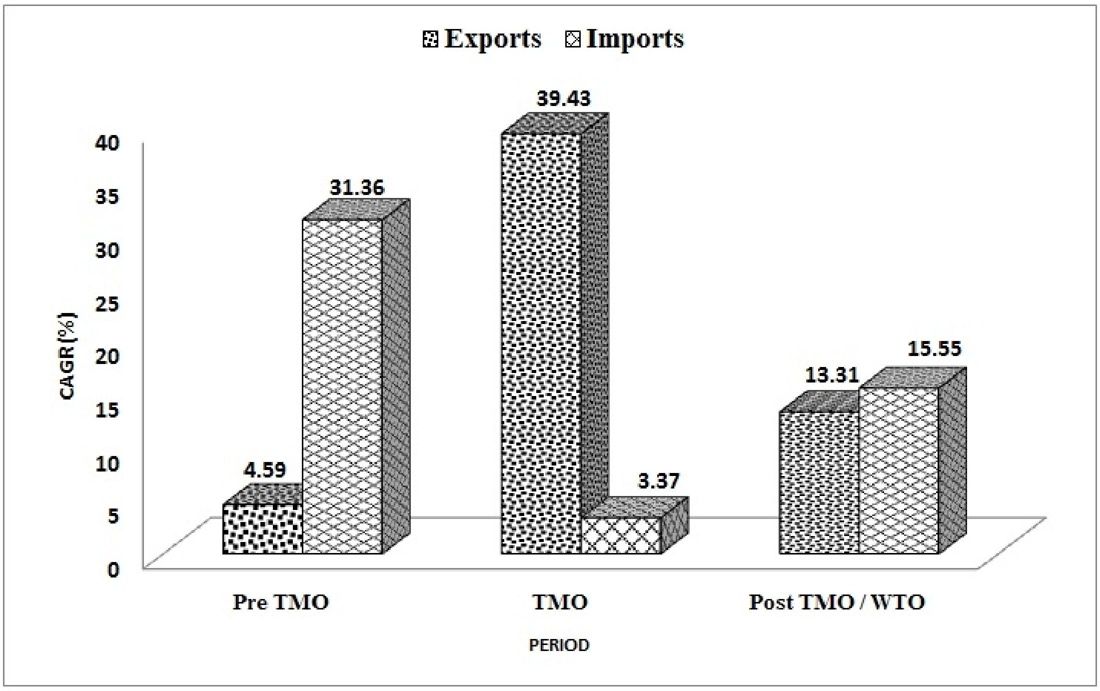
2009 to October 2010 for import of 10 lakh tonnes of edible oils with a subsidy of ₹ 15/kg. The scheme is believed to have helped to soften the prices of edible oils in the domestic market, but on the contrary, raised import bill significantly, which now touches almost ₹ 56,000 crores annually.

The cascading effect of the "Yellow Revolution" was also evident in the balance of payments scenario. There was a complete reversal in the dependency on imports and the country was close to reaching self sufficiency in oilseeds. The globalization/WTO era failed to consolidate the gains achieved during the TMO period (Fig. 5) due to operationalization of market/non market forces in addition to biotic/abiotic problems.

As stated above, the country is meeting now more than 50% of its oil requirement through imports resulting in huge drain on the foreign exchange (Fig. 6). The current import bill is around ₹ 56,000 crores annually, which is indeed phenomenally higher than in the past.

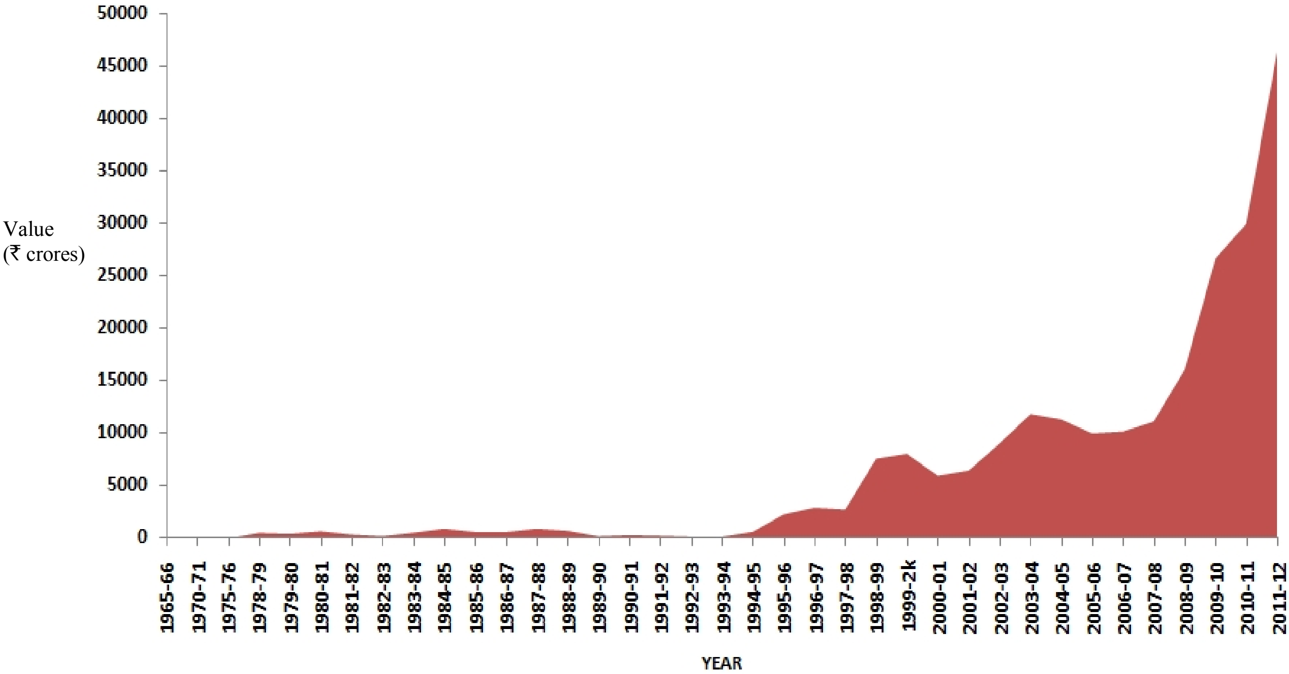
Export Trend

On the other hand, India made excellent inroads through export of oil meals and castor oil to the tune of ₹ 23,000 crores thus plugging almost 50% of the import bill. The advantage of exports can further be consolidated with proper policy back up and value addition. Overall trend of vegetable oilseeds and their products export as well as import has been increasing since 1987 except for a brief period in mid 1990's (Fig. 7).



Pre TMO = 1966-67 to 1985-86; TMO = 1986-87 to 1995-96; Post TMO = 1996-97 to 2012-13

Fig. 5. Compound annual growth rates of exports and imports of oilseed/oilseed products (%)



<---- Pre TMOP period ------> <------ TMO Period------> <------------- Post TMOP period ------------->

Fig. 6. Imports of oilseeds and oilseed products (₹ Crores)
(Source: Various issues of Economic Survey, Govt. of India)

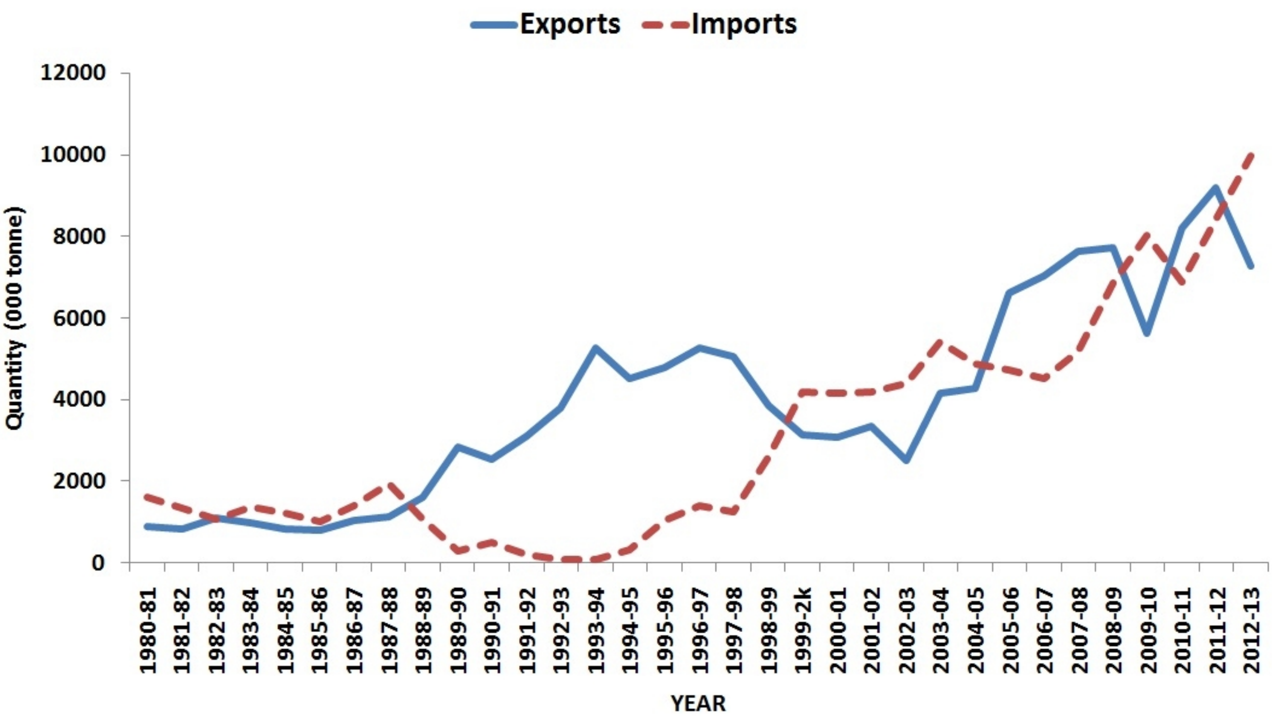


Fig. 7. Trends in quantities of exports and imports of edible oilseeds and products
(Source: Various issues of Five Year Plan Documents, Min. of Finance, DGCIS and Economic Survey, GOI)

FUTURE ROAD MAP

Policy Issues Needing Perspective Changes

The Government of India, in compliance with the requirements of WTO Agreements, and to meet the domestic demands of vegetable oils, took certain decisions during 1994-2000, opening flood-gates to oil imports, which were available at cheaper prices. Edible oils, except coconut oil and palm oil, were placed under Open General License (OGL). The import duty was reduced in steps, from 65 to 15%. The resulting heavy imports of edible oils led not only to vast drainage of foreign exchange but reflected cascading effect on Indian oil economy. There was a crash in the domestic prices causing serious impact on Indian oilseed industry with considerable disincentive to the oilseed farmers. A major concern for the policy planners is the fact that domestic prices of oilseeds and vegetable oils are not remunerative to enthuse farmers for encouraging oilseeds cultivation. The uncertainty is also due to non-implementation of Minimum Support Prices (MSP) due to lack of a procurement policy. The fluctuating and counter directional policies with respect to imports and domestic prices have left the stakeholders unsure of any long-term planning by both producers and processors, which ultimately hurt the national interest. It is obvious that we need forward looking policies on mitigation of various kinds of risks in oilseed production efficiency and profitability to ensure healthy oilseed economy. All options for risk mitigation like timely availability of inputs and credit, MSP and procurement, crop insurance, long-term policy, linking farmers to market, buffer stock options, and other commodity price stabilization schemes, etc., need to be put in place for oilseeds sector as a matter of priority.

Trade-related Policy Initiatives

Import policy has played a key role in determining the overall level and type of India's edible oil imports for decades. The Government of India, with a view to meet the demand of edible oils and to control the rise in prices, has been allowing import of edible oils. In pursuance of the policy of liberalization, there have been progressive changes in the import policy in respect of edible oils during the past few years. Edible oils, which were on the negative list of imports, were first dechannelized partially in April 1994 with permission to import edible vegetable palmolein under OGL at 65% duty. This was followed by enlarging the basket of oils under OGL import in March 1995, when all edible oils (except coconut oil, palm kernel oil, RBD palm oil and RBD palm steering), were brought under OGL import at 30% duty. The duty was then further reduced to 20% plus 2% surcharge in the regular budget for the year 1996-97. The balancing act of the Government to protect the interests of domestic oilseeds growers, consumers and processors and to regulate large imports of edible oils to the extent possible, the duty structure on edible oils has been getting revised frequently from time to time since 1994.

India was pursuing the policy of Import Substitution Industrialization (ISI) strategy until 1994-95, under which the oilseed/edible oil sector was protected through quantity restrictions (QRs). All imports of edible oils and oil meals were totally channelized through STC and the Hindustan Vegetable Oils Corporation (HVOC), which remained limited to the packaging of oils and channelling to the state governments for sale through the Public Distribution System (PDS).

It may be recognized that ISI strategy pursued until 1994-95 delivered significant benefits to the Indian economy. India was able to transform from a deficit to a virtually self-sufficient state in edible oils by the early-1990s. India has become a major exporter of oilseed meals, especially soy meal, a high-protein animal feed for which demand is increasing in the global markets. In fact, exports of oilseed cakes, the production of which exceeds domestic demand, were promoted by a variety of export incentive schemes established by GOI throughout the 1980s and early-1990s in an effort to generate foreign exchange. The exports of oil meals gained substantially, both in volume and share, because of the increasing demand for Indian oil meals in world market, which is mainly flooded with oil meals of genetically modified (GM) oilseeds. Indian oil meals command a premium because of its non-GM nature. Soy meal export is currently of US $ 2 billion annually. It is worth mentioning that the growth in the livestock industry will be a major force driving future demand for oil cakes with high income elasticity of demand for milk and milk products, meat, eggs, fish, etc. The accelerating growth in income will be a major factor for boosting domestic demand for livestock products in future, which in turn would promote a large scale shift towards improved animals or crossbreeds, including improved management and feeding practices (e.g. feed stalling for dairy).

Support Price

Unlike food crops, oilseed crops are grown solely for economic benefit and the growth in oilseed crops occurs when they have an edge over the competing crops in terms of profitability. Under the harsh growing conditions faced by Indian agriculture, oilseeds have a clear edge over many minor millets and pulses in terms of higher productivity. However, increase in cultivable area under oilseeds largely depends on higher profitability. The support price declared each year by the Government of India is evidently in clear favour of rice and wheat compared to oilseeds mainly on account of food security considerations (Fig. 8). Similar consideration for oilseeds is therefore, warranted.

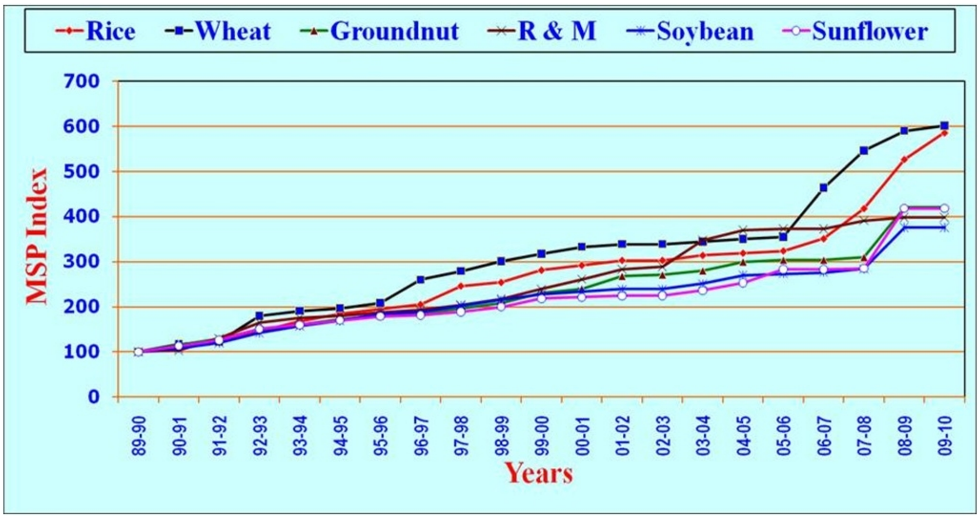


Fig. 8. Minimum support price of different crops in different years
(Source: Commission of Agricultural Costs and Prices, GOI, New Delhi)

Given the fact that input prices across crops remained the same, the relative prices should have been adjusted accordingly. On the contrary, the MSP index analysis clearly indicated that it mainly favoured wheat and paddy against pulses, coarse cereals and oilseeds. Over and above the relative discrimination in MSP for oilseeds, there was no mechanism for implementation of MSP without assured procurement. Hence, most of the times the wholesale prices were much lower than MSPs and the farmers were left at the mercy of the market forces to dispose the produce for the commodity that had no direct utility at farm level. During TMO period, there was effective implementation of MSP through NDDB that gave confidence to farmers about the minimum expected returns. It, therefore, fortifies revival of an institutional mechanism to implement MSP effectively for reaping the benefits by oilseed growers.

Need for Institutional Linkages

The research, development and technology dissemination infrastructure existing in the country for oilseed crops is the legacy of the past policies and interplay of public and private interest in the sector. Apart from the institutions as such, some institutional support programmes (National Dairy Development Board (NDDB), National Agricultural Marketing Federation (NAFED) and the flagship programme of the government in oilseed sector; Integrated Scheme on Oilseeds, Pulses, Oil palm and Maize (ISOPOM) have been tried in the past. These programs need to be studied for understanding their significance and impact so that efficient and functional institutional support is provided in future for the required growth of oilseeds sector. It must be recognized that the core strength for the success of technology mission on oilseeds was due to effective dovetailing and coordination among institutions linked with production, processing, input supplies, trade and pricing. Some systems need to be revisited again to give much needed push to oilseeds sector.

Eco-regional Approach for Productivity Enhancement

The concept of eco-regional approach can effectively be utilized for the oilseed crops. It refers to the practice of delineating efficient zones for specific crops for realizing potential yields with high input-use efficiency. Supporting services like input supply, marketing and processing have to be linked to these ecological zones besides strengthening research and extension systems and infrastructural facilities. The importance of crop ecological zoning in oilseeds is evidently based on following facts:

- 4 districts contribute 33% of groundnut area
- 4 districts contribute 37% of sunflower area
- 9 districts contribute 31% of mustard area
- 12 districts contribute 41% of soybean area

Concerted efforts on two categories of crop-wise eco-regions, *viz*., high area-low productivity and low area - high productivity zones will enhance efficiency in our efforts to increase production and productivity of oilseed crops.

The classical examples in high productivity of spring season sunflower in Indo-Gangetic Region of Punjab, Haryana, Western Uttar Pradesh and Bihar; high productivity of safflower in Malwa region (Madhya Pradesh) and Gujarat, high productivity of sesame in West Bengal in summer season, high productivity potential of soybean in Punjab, Haryana and Eastern UP, etc., are mainly due to the optimum ecological conditions which are beyond input and management. Hence, providing necessary input supply, technology, market and extraction facilities in these areas can help realise quantum jump in productivity with ease.

Natural Resource Management

With the current practices of crop cultivation under sub-optimal management, especially without nutrient application, significant soil nutrient mining is occurring. Correcting the present limitation and imbalance in soil nutrients can provide rich dividends. Declining *per capita* arable land and extending oilseeds cultivation to poor and marginal soils result in low productivity. Moreover, productivity of oilseed crops is limited owing to their cultivation under rainfed conditions. Currently only 28% of area is irrigated under oilseeds. Water requirement in oilseeds is, therefore, a key factor for ensuring higher yields. With dwindling water resources both in quantity and quality, water for irrigation will be costly and face severe competition from different enterprises within agriculture sector. Castor, in Gujarat and Rajasthan is cultivated under irrigation while in Andhra Pradesh it is mainly cultivated under rainfed condition. Safflower cultivation is limited to Vertisols and *rabi* season under receding soil moisture conditions. Sunflower is cultivated in all seasons and all soil types. Forty per cent of area under *kharif* sunflower is rainfed. Watershed management with appropriate rainwater harvesting both in situ with proper disposal and storage farm ponds provide excellent opportunity to mitigate the expected dual problems of long droughts and floods with advantage. Site specific land configuration and management for effective soil and moisture conservation and its economic use can operationalize the drought mitigation strategy. Enhancing drought tolerance in oilseed crops is therefore, a priority with associated practices to improve profitability through achieving 'more crop (oil) per drop' of water, resource use efficiency and preferential edge over other competing crops.

Besides, due to the low fertilizer use efficiency, the investments are not remunerative. Improving nutrient use efficiency of fertilizers through better product development and method of application should now be a priority for achieving profitable oilseeds production. Improving soil fertility to reduce external applications is an achievable solution through site specific management. Exploiting nutrient interactions as per the soil test and crop response results in higher efficiency and reduced cost. Organic manures are central in the integrated nutrient management (INM) of oilseeds under rainfed situation along with other components such as secondary and micronutrients, like use of sulphur bio-inoculants, crop residues, etc. Precision crop management with conservation agricultural practices and customized fertilizer application schedules would usher higher efficiency and profitability. Emphasis on integrated natural resource management in oilseeds should, therefore, be our high priority.

Crop Improvement Strategy

The gains in productivity of oilseed crops have been achieved primarily through exploitation of available genetic variability. Conventional breeding coupled with modern tools such as biotechnology should now be the primary focus in crop improvement programs. Heterosis breeding should be the major focus in crops like sunflower, castor, rapeseed-mustard, safflower and sesame. To facilitate better exploitation of the available gene pools and overcome the production constraints, research emphasis needs to be on (i) augmentation/ identification of trait specific germplasm; (ii) prebreeding and genetic enhancement; (iii) allele mining, (iv) functional genomics, proteomics, metabolomics, and interactomics; (v) marker assisted breeding and gene pyramiding; and (vi) trait improvement through genetic engineering.

Role of Biotechnology: The two main options of biotechnological approaches for crop improvement include molecular marker based selection and transgene manipulations. Both these approaches, though not mutually exclusive, have distinct niches with respect to their role in crop improvement. At present, biotechnological research on minor oilseed crops (safflower, castor, niger, sesame, linseed and sunflower) is in its infancy. Therefore, it is essential to initiate concerted efforts using tools of biotechnology in these crops. Some of the crop-specific needs that are to be addressed through biotechnological interventions include: pests like bud fly in linseed; *Antigastra* and phyllody in sesame, necrosis, leaf spot and powdery mildew in sunflower, wilt and *Alternaria* in safflower and Botrytis and lepidopteran pests in castor, quality aspects such as presence of anti-nutritional compounds (oxalic acid and phytates) in sesame, oil quality in mustard, toxic proteins (ricin and *Ricinus communis* agglutinin) in castor and herbicide tolerance in soybean. Apart from these crop-specific issues, there are research areas of generic nature such as abiotic stresses (drought, salinity, cold) tolerance, increased oil content, altered fatty acid profiles to suit different industrial and human consumption requirements, etc. Understanding the molecular basis of trait manifestations such as stress tolerance, oil accumulation and interactions among different metabolic pathways under varied environmental conditions and at crop growth stages are expected to pave way for development of designer oilseed crops to meet both domestic and industrial requirements. The success of 'doubled haploids' in developing superior inbreds is a potential area for immediate gain in oilseed crops limited by availability of superior inbred development. The required infrastructure and support need to be ensured for operationalization.

Transgenic approach: Transgenics are a reality in crops like canola and soybean and what the introgressed traits can do in sustaining and increasing the productivity of crops is already well demonstrated. Transgenic technology has removed the phylogenetic barriers for transfer of useful genes across organisms. Modifying the fatty acid profile of the oil to suit industrial, pharmaceutical, nutritional, cosmetological requirements using genetic engineering approaches has been a priority in application of biotechnology in oilseed crops. Similarly, imparting biotic and abiotic stress tolerance, improved resource use efficiencies through transgenic approaches have been the areas of focused attention for sustained productivity levels under changing as well as challenged environmental situations.

Transgenic technology, as any other technology (including space technology, nuclear technology) is facing stiff-resistance from a section of the society. There are a number of social and food safety related issues that are being associated with de-regulation of transgenic plants. It is the responsibility of scientists, policy makers, industry and knowledgeable people to allay the fears in public mind through scientific knowledge and empirical evidence regarding safety of GM crops. Once the biosafety of transgenic plants is established, they should be treated as any other variety or hybrid.

During the last decade, there has been considerable progress towards harnessing transgenic technology for oilseed improvement in India (Table 4).

Table 4 Biotechnological interventions in oilseed crops of India

Crop	Institute	Genes being used	Trait
Groundnut	DGR and UoH	*Annexin*	Leaf spot resistance
	ICRISAT	Rice *Chitinase*	Leaf spot and rust resistance, Aflatoxin reduction
	ICRISAT	*Coat protein* and *replicase*	BND, clump virus resistance
	ICRISAT	*DREB1A* from rice	Drought tolerance
	UAS, Bangalore	*Cry1X*	*Spodoptera* and pod borer resistance
	UAS, Bangalore	*EPSPS*	Glyphosate resistance
	UAS, Bangalore	*Tobacco 1,3 beta glucanase*	Leaf spot, *Aspergillus* resistance
	NABI, Manali	*Cry1EC*	*Spodoptera* resistance
Mustard	DU	*Barnase- Barstar*	Male sterility
	NRCPB	Rice *Chitinase*	*Alternaria* resistance
	Bose institute	Lectin (*ASAL1*)	Aphid resistance
	BARC	Synthetic *Cry1Ac*	Diamond back moth resistance
	NRCPB	*Glucanase*	*Alternaria* resistance
	NRCPB	*Wheat germ agglutinin*	Aphid resistance
	NRCPB	*Snow drop lectin*	Aphid resistance
Soybean	DSR, Indore	Marker and reporter genes	Transformation protocol development
	MKU	Full length and truncated movement protein	Viral resistance (Development stage)
	Bharathidasan University	*Alpha tocopehrol methyl transferase*	Vitamin E in oil
Castor	DOR	*Cry1Aa, Cry1Ec, Cry1abcf*	Lepidopteran defoliators
	DOR	Multiple genes (*ERF1, EBP1, BIK1, Chitinase, RsAFP2, AcAMP1*)	*Botrytis* tolerance
	DOR	Silencing of ricin and RCA	Reduction of endosperm toxins
Sunflower	DOR	TSV-Coat protein gene	SND resistance
Safflower	DOR	*orfH*522, u-nad3	Male sterility
	DOR	*DAGAT*1 and *GPAT*9	Increased oil content

At National Research Centre on Plant Biotechnology (NRCPB), *Alternaria* resistant transgenic mustard expressing either *glucanase* gene from tomato or other anti-fungal genes such as *annexin* and *osmotin* and aphid tolerant plants expressing either wheat germ agglutinin or snow drop lectin gene have been developed. Similarly, aphid tolerant mustard transgenic plants have been developed at the Bose Institute, Kolkata using lectin gene from garlic. At the University of Delhi, transgenic male sterility system has been developed in Indian mustard using the popular barnase-barstar system and the experimental hybrids obtained through this technology have already been tested in multi-location trails.

At Directorate of Groundnut Research (DGR), Junagadh, transgenic groundnut plants have been developed with coat protein genes for incorporating resistance to PBND and PSND (currently being evaluated in glasshouse), *mtl*D gene for enhancing tolerance of drought and salinity, defensin gene for enhancing resistance to fungal diseases and *annexin* and PR10 genes for enhancing tolerance of abiotic stresses. Also, transgenic groundnut plants expressing annexin gene has been developed at the University of Hyderabad as well as at DGR, Junagadh to fight against the leaf spot disease. Transgenic groundnut plants with resistance to Spodoptera, fungal diseases and glyphosate tolerance have been developed at UAS, Bangalore. At NABI, Mohali, *Spodoptera* resistant plants have been developed by deploying *cry1EC* gene. At ICRISAT, transgenic groundnut lines with aflatoxin resistance conferred by rice *chitinase* gene and bud necrosis virus resistance imparted by expressing viral coat protein gene have been developed and characterized. Similarly, improved drought tolerance has been achieved by deploying *DREB* gene. Limited field trials are being carried out to select the lines for further studies and commercialization.

In soybean, efforts are on to develop good transformation protocols for the Indian genotypes at Directorate of Soybean Research (DSR), Indore. At Bharathidasan University, transgenic soybean lines with enhanced vitamin E in the oil are being developed while at Madurai Kamaraj University, viral resistance is being achieved by expressing the movement protein of the virus.

At the Directorate of Oilseeds Research, transgenic castor lines with resistance to defoliators have been developed by deploying different cry genes with specificities against target pests (semilooper and *Spodoptera*). Limited field trials have been conducted with this material to select the lines with higher pest mortality potential and the selected events will be further tested in confined field trials. Also, multigene constructs have been developed to counter *Botrytis* disease and these constructs are being validated for their efficiency in controlling necrotrophic fungi. Similarly, *RNAi* gene constructs developed for suppressing genes encoding ricin and RCA are being validated using model plant system. In safflower, attempts are being made to develop transgenic male sterility and fertility restoration using *orf*H522 and *u-nad3* genes. Over-expression of the rate limiting enzymes (DAGAT and GPAT9) in a seed specific manner is being attempted to increase the oil content in safflower which currently is about 30% in the cultivated safflower varieties or hybrids. The problem of sunflower necrosis disease, which once threatened the very cultivation of sunflower crop, is also being tackled through transgenic approach using TSV coat protein in sense and anti-sense orientations. The material is in advanced stages for commercialization and biosafety tests.

Albeit the progress made, there are still gaps which require attention for efficient utilization of the technology. The main prerequisite for exploiting the power of transgenic technology is the availability of efficient, and preferably genotype independent, transformation protocols. Therefore, concerted efforts should be made to develop transformation protocols in all oilseed crops. Considering the financial and technical requirements needed for development of transgenic plants, there should be prioritization of crop and trait to be tackled through this technology. On the technology front, concerted efforts are being made in model plant systems to develop methods and strategies to have the transgenes inserted in targeted regions of the genome to avoid positional effects as well as insertional inactivation of unintended genes. Also, it is envisaged that technologies for cis-genesis, intra-genesis, gene-stacking, marker-free transgenesis, zinc-finger nucleases, RNA dependent DNA methylation, etc. once perfected in model crops should be adopted in improvement of oilseed crops. This information could be used in developing and realizing designer transgenic oilseed crops to meet pharmaceutical, nutraceutical and industrial demands.

In spite of the progress made in the use of transgenic technology in the oilseed crops, current policy controversy is a setback delaying the fruits of results to reach stakeholders.

Exploring frontier sciences: Significant innovations in frontier science and technologies such as nanotechnology, genetic engineering and biotechnology, synthetic lipid science and technology, information science and modeling, simulation and forecasting and the recent developments in related sciences such as hydroponics, vertical farming and protected agriculture, precision agriculture systems; biosecurity and biodiversity management provide unlimited opportunities for supporting higher production and product development to meet the changing requirements through precision farming and protection/conservation practices. Post production, developments in dynamic integration of production, processing, quality with global trade would make production of vegetable oils profitable and competitive. Oilseeds production will also benefit from innovations in industrial sector for oilseeds processing and small farm mechanization, *ex-ante* approaches for quantification of economic output. These frontier sciences will have to be harnessed and integrated into ongoing research programs for productivity improvement; increasing the resource use efficiency, improving processing, value addition, diversified uses, improved access to stakeholders through ICT, enhanced delivery systems, better targeting of technologies for yet better production and marketing environments, including supply chain mechanisms. The traditional knowledge should also be valued for its wisdom for technology generation, refinement and adoption.

Public Private Partnership and Linkages

Oilseeds, unlike other food crops, depend on other enterprises for its ultimate use/consumption. The necessity of extraction of oil from seeds provide inter-dependence of industry and oilseed producers in-between consumers, thus making success in vegetable oil production business inter-dependent at each stage of production, processing and pricing policies.

The potential of public-private partnership (PPP) through linkages in all aspects of oilseeds production and marketing needs to be harnessed for a win-win situation. The grey areas for PPP in oilseeds include incentives for seed production, forward/ backward linkages for processing, value addition, contract research in niche areas, contract farming, joint ventures for higher order derivatives and speciality products, etc.

The edible oil industry is largely dominated by the bulk segment which creates an opportunity for the Agri-Business sector. The unbranded segment accounts for anywhere between 80 and 90% of the total consumption which can be targeted for better value addition and thus, minimize health hazards that otherwise occur on account of adulteration of edible oils. The share of raw oil, refined oil and vanaspati in the total edible oil market is estimated at 35%, 55% and 10%, respectively. The former group is a viable Agri-Business venture. The shift in consumer preference for branded edible oils has resulted in the corporate sector targeting on packaged edible oil segment in the last few years. Hence, PPP mode for R&D efforts towards value addition emerges as a new priority to move forward.

Diversification and Value Addition

Profitability of oilseeds solely from the primary products like seed and oil will not be sustainable. Besides the primary product oil, oilseed crops provide immense scope for diversified uses with high value specialty products and derivatives. From the vegetable oil consumption point of view either for edible or for fuel purpose, the situation is envisaged towards valuing oil for its intrinsic value for calorie or for desired fatty acid that is beyond the realm of individual crop as perceived now. Designer oils with requisite blends can meet the expectation and to that extent individual oilseed crop's potential would be seen for the yield of oil or the desired fatty acid and not as oil from specific crop. Thus, the present wide diversity of oilseeds crops may narrow down to a few high oil yielding crops. As for unique non-oil value aspects for specific aroma or non-oil uses (medicinal, ornamental or other uses), individual oilseed crops would be grown for specialty purpose irrespective of productivity level.

Major opportunities for oilseed crop diversification and value addition include introduction as catch crop in paddy fallows to utilize residual moisture and fertility; component crop in major widely spaced field crops such as sugarcane, pigeonpea, cotton, maize, etc., for sunflower; and as main crop with groundnut, soybean, finger millet, pigeonpea, cluster bean, short duration pulses, etc., for castor and sunflower; with chickpea and coriander for safflower; *rabi* castor under limited irrigation protection and sunflower for Indo-Gangetic plains of Punjab, Haryana, Western Uttar Pradesh in spring and Bihar, Odisha and West Bengal in rabi/summer. Soybean also offers opportunity for rice wheat cropping system in the north.

Adaptation to Climate Change

The low productivity and uncertain production of oilseeds is mainly due to their cultivation under rainfed conditions (about 70%). The inherent tolerance of oilseeds to drought and other edaphic stresses is construed as though they are low input requiring crops. On the contrary, oilseeds need higher inputs for increased productivity. Adaptation strategy for drought, high temperature and rainfall variations must, therefore, be put in place as a matter of priority.

Oilseeds production is constrained by several biotic stresses like insect pests and diseases that are being further aggravated by changing climatic conditions. *Botrytis*, root rot and capsule borer have emerged as major threats to castor production. Sunflower production is limited by diseases like *Alternaria* leaf blight, sunflower necrosis, downy mildew and powdery mildew while mealy bug is an emerging pest. The foliar diseases, *Alternaria* and *Cercospora* leaf spots and *Macrophomina* root rot are becoming increasingly important while wilt and aphid continue to challenge safflower production. Global warming induced climate change is expected to trigger major changes in population dynamics of pests, their biotypes, activity and abundance of natural enemies and efficacy of crop protection technologies. Studies on the epidemiology of plant diseases including variation in pathogen population in the light of climatic change are necessary to develop integrated disease management (IDM) modules. Studies on wilt disease etiology in the context of reniform nematode in castor and sunflower and root-knot nematode in sunflower coupled with identification of sources of resistance deserve attention. There is a need to generate information on the likely effects of climate change on pests so as to develop robust technologies that will be effective. The approach to pest management has seen a significant change over the years from chemical control to IPM with emphasis currently on bio-intensive integrated pest management (BIPM) involving use of pest-resistant varieties, bio-agents, bio-pesticides and natural products like botanical pesticides and pheromones. Several eco-friendly products of biological origin have been developed at DOR for management of important pests of oilseed crops like castor semilooper, sunflower head borer, tobacco caterpillar as well as wilt of castor and safflower. However, the relative efficacy of many of these pest control measures is likely to change as a result of global warming necessitating identification of temperature tolerant strains.

Transfer of Technology

Concerted efforts are urgently needed for the dissemination of technologies and new approaches on a participatory mode are to be strengthened for effective delivery mechanism by show-casing the potential technologies/products. The Farmer-Institution-Industry linkage mechanism should be strengthened besides the existing formal delivery mechanisms so that the gap between the potentially attainable yield and the yield realized on the farmers' fields is reduced and it makes the industry more vibrant and profitable on account of assured quality supply, reduced obstacles in supply chain, enhanced capacity utilization and increased economic surplus with benefits to both the producer and the consumer. The potential Information and Communication Technology (ICT) tools should be harnessed on a dynamic and interactive mode. This can minimize the dissemination loss while sharing information and provide benefits to all the stakeholders involved in oilseeds. Also a dedicated TV channel on agriculture will help in faster dissemination of knowledge. Creation of agri-clinics with provision of outsourcing through involvement of new breed of young well trained technology agents would go a long way in upscaling innovation for a greater impact.

SPECIFIC RECOMMENDATIONS

Following research, development and policy strategies would be needed urgently for increasing both oilseeds production and vegetable oils availability in the country.

Research

- Greater emphasis on innovation to achieve quantum jump in productivity using new science and translational research.
- Integration of all oilseed research institutes under NARS for holistic research approach on systems mode.
- Develop short duration, high yielding genotypes for better adaptation to climate change through integration of modern biotechnological tools like MAS and transgenic breeding, supplementary to conventional breeding and develop cultivars with in-built resistance to biotic and abiotic (specially drought and heat) stresses. In this context, greater use of germplasm through pre-breeding will be highly desirable.
- Develop small farm machinery for different operations specific to each crop so as to ensure timely farm operations and efficient use of costly inputs.
- Increased emphasis needs to be given on post harvest technology and value addition for diversified uses in order to ensure higher profitability.

Development

- Establishing strong linkages for successful operation of 'seed village concept' with producers, technocrats, certifying agencies and concerned State Departments of Agriculture for timely procurement and distribution to ensure higher seed replacement by improved varieties/hybrids.
- Promote oilseeds cultivation in new and non-traditional areas and seasons for ensuring crop diversification and additional area for expansion. Eastern region offers option for potential area expansion especially in paddy fallows. Similarly, soybean offers great opportunity for diversification of rice-wheat cropping system in Northern India.
- Adopt location specific efficient dry farming technologies for drought proofing and sustainable oilseeds production. Integrate oilseeds production with watershed programmes for holistic development and to ensure life support irrigation for assured harvest.
- Increase area under protective irrigation and promote efficient irrigation methods, especially micro-irrigation, for achieving higher production and stability.
- Promote adequate and balanced fertilization with emphasis on use of sulphur and limiting micronutrients through proper soil amendments, based on soil testing.
- Effective transfer of technology with assured input, market and technological backstopping by both public and private sector agencies.
- Promote intercropping systems involving oilseeds for achieving higher efficiency of resources, profitability and risk minimization.
- Adopt need-based plant protection measures through effective and bio-intensive integrated pest management (IPM).

- Large scale production of promising small farm equipments through involvement of state governments that will help in improving efficiency in farm operations. Also provision of credit and incentives for manufacturing of small farm equipments and machinery by small scale industries and promotion of custom hiring to ensure resilience in farming.
- Greater thrust on use of soybean as food rather than only as oil and feed will help the nation in addressing current major concerns for protein malnourishment, while ensuring nutrition security.
- Exploit additional features of crops like high value safflower petals and linseed fiber for realizing additional profits. Also, there is a need to accelerate area expansion of oil palm plantations and extend assured irrigation, power, local processing facility and competitive prices for realizing higher production of vegetable oil per unit area per unit time.
- Avoid use of rice bran directly as feed in order to promote greater extraction and use of rice bran oil.
- Promote scientific processing of cotton seed for higher oil recovery and to get high protein retention (42%) compared to traditional processing practices (22%).
- Improve efficiency of extraction of oil through solvent extraction for hard seeds (<20% oil) and expeller extraction for soft seeds (35 to 40% oil).

Policy

- Regulate import of vegetable oils through adoption of appropriate import policy aiming at increased domestic production. Hence, vegetable oils should be viewed beyond export - import balance with the goal of achieving self sufficiency to a greater extent. The need for achieving self sufficiency in vegetable oils should be seen in the context of improved livelihood, higher profitability of oilseed farmers and for processing industry.
- Ensure market intervention for effective implementation of MSP through needed procurement of oilseeds, being a major national priority.
- Appropriate regulations to amend the Agricultural Produce Marketing Act for making it pro oilseeds producers and enhance proper trading and fair pricing to both producer and consumer.
- Encourage establishment of large scale 'captive plantations' and specialized 'seed gardens' of oil palm by declaring oil palm as a plantation crop and also ensure proper pricing policy for profitability.
- Creation of enabling environment to strengthen private participation in collaborative research, development, extension and marketing operations.
- To avoid diversion especially of edible oils for biodiesel production and other industrial uses.
- Similar to sugarcane model, oil expeller industry should promote local/regional oilseeds production for assured and adequate supply of raw material as per pre-determined assured prices. 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.

CONCLUSION

Increased availability of vegetable oils would involve greater commitment of various stakeholders (farmers, scientists, policy makers, NGOs, private sector industry, etc.). Assessing the problems and prospects of all these stakeholders and the establishment of strong as well as viable linkages among them towards the goal of improving vegetable oils situation in the country is indeed a challenging task. The success of 'Yellow Revolution', achieved through mission mode approach of TMOP during eighties, fully justifies revival of Oilseeds Mission approach with greater zeal and commitment of all to tide over the present crisis of large scale import of edible oils. In my view, we must have a clear national policy of bridging the yield gaps and increased oilseeds production with specific aim to reduce our vegetable oil imports, as was achieved during earlier TMOP. No doubt to achieve this, we would need clear policy directions and also missionary zeal and commitment of all concerned. I am sure, we all collectively can do it.

I salute Padma Shri Dr. M.V. Rao for his committed efforts and valuable contributions made to strengthen Indian agriculture.

My hearty congratulations once again, to the Indian Society of Oilseeds Research for initiating this lecture series.

Dr. R.S. Paroda, former Director General, ICAR and Secretary, DARE, GOI has made valuable contributions in the field of agriculture. He received several national/international awards and recognitions, including the most prestigious "*Padma Bhushan*". He has been conferred honorary D.Sc. Degree by 14 Agricultural Universities and Fellow of several National and International Science Academies. Currently, he is serving as Chairman of the Trust for Advancement of Agricultural Sciences and as Chairman of Haryana Farmers' Commission. He is responsible for the drafting and release of State Agriculture Policies both in Haryana and Rajasthan.

Variability for seed germination and seedling vigour in aging groundnut (*Arachis hypogaea* L.) seeds after storage under ambient conditions

P JANILA, P NAGESH, S S MANOHAR AND S N NIGAM

International Crops Research Institute for the Semi-Arid Tropics, Patancheru-502 324, Andhra Pradesh

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ABSTRACT

Seed germination and seedling vigour in aging seeds of 32 groundnut genotypes was studied under ambient storage conditions to assess the extent of variability for these traits under storage. The association, if any of these traits with seed soil content and seed mass was also examined. Both, seed germination and seedling vigour declined with aging of the groundnut seeds in all test genotypes. However, the rate of decrease varied among the genotypes suggesting significant genotypic difference and possibility of their improvement through breeding. Aging also has strong negative effect on both, root and shoot growth of the seedlings, but profound effect was observed on root growth. Seed germination and seedling vigour are not associated with seed oil content, but seedling vigour is positively correlated with seed mass. The results indicate the possibility of developing new groundnut genotypes that retained good levels of seed germination and seedling vigour even in storage for 12 months under ambient conditions. Further, it is also possible to combine enhanced high seed oil content with high seed germination and seedling vigour. As seed germination and seedling vigour are associated with pod yield, it may be desirable to evaluate the advanced breeding lines for these traits besides other yield and yield parameters.

Keywords: Aging, Germination, Groundnut, Seedling vigour, Storage

Groundnut (*Arachis hypogaea* L.), also known as peanut is an important oilseed, food and feed crop grown on 24 million ha worldwide with a total in-shell production of 38.6 million tons in 2011 (FAOstat, 2012). Globally, over 50% of the groundnut produced is crushed for extraction of oil for human consumption and industrial uses and slightly less than 40% is used directly as food, raw or processed as snack (Birthal *et al*., 2010). Over 95% of global groundnut area is in Asia and Africa where it is cultivated in semi-arid tropics under limited water and nutrients. The groundnut crop in general experiences several serious biotic and abiotic challenges that limit pod yields. After harvest, storage of pods poses a serious limitation in groundnut due to bulk nature of pods which require large storage space and quick loss of seed quality during storage besides storage pest infestation and *Aspergillus* infection. Seed germination and seedling vigour are two important parameters that determine seed quality. Seed germination is defined as the emergence and development of the essential structures from a seed embryo which are indicative of the ability to produce a normal plant under favorable conditions. On the other hand, seedling vigour reflects the ability of those seeds to produce normal seedlings under less than optimum or adverse growing conditions similar to those which may occur in the field. In general, seed germination and seedling vigour may influence crop yield through both indirect and direct effects (Ellis, 1992). Being a self-pollinated crop, farmers can save own seed for next 4-5 seasons without loss of genetic purity of the variety, however farmers in general do not store groundnut seed for next season as stored groundnut seed losses seed germination and seedling vigour quickly besides other limitations. As a consequence farmers purchase groundnut seed every season mostly from traders incurring huge input cost.

In general, the seeds rich in lipids have limited longevity (Tubic *et al*., 2010). Groundnut seeds have about 48-50% oil and are hygroscopic in nature consequently absorb moisture from surrounding storage environment and loose germination rapidly. Groundnut seeds rapidly lose their seed germination when stored under natural conditions (Ntare *et al*., 2006). The deterioration of seed quality was also observed in both, natural and accelerated aging groundnut seeds (Perez and Arguello, 1995). Lipid peroxidation on storage, which has the potential to damage membranes of the seed tissues, is responsible for reduced seed quality. The biochemical changes in aging groundnut kernels include enhanced lipid peroxidation and increased peroxide accumulation in the axis and cotyledons (Sung and Jeng, 1994), deterioration of specific iso-esterases (Aung and Mc Donald, 1995) and decline in phosphatidic acid, phosphatidyl choline and phosphatidyl ethanol amine (Soliya and Chakraborty, 1991) that affect seed quality. In addition to various biochemical changes, the stage of harvesting (Nautiyal *et al*., 2010) and procedures of harvesting, drying, storage and shelling (Dey *et al*., 1999), and condition of storage particularly temperature, relative humidity, seed moisture and oxygen pressure can also affect the seed germination in groundnut.

E-mail: p.janila@cgiar.org

Groundnut seed with good germination and seedling vigour can result in enhanced pod yields as a consequence of optimal plant population in the field, an important factor that determines the pod yield in groundnut. In groundnut, use of recommended seed rate and good quality seed ensures optimum plant population. High seedling vigour results in quick establishment of seedling and studies has shown that field performance of high vigour seeds is much better than that of low vigour seeds, ensuring rapid, uniform and satisfactory stand establishment under a wide range of environmental conditions (Ghassemi-Golezani *et al*., 2008) as seedling vigour and field emergence is positively correlated (Knauft *et al*., 1990; Vindhavarmann *et al*., 1990; Detroja *et al*., 1993). Seed is the most expensive inputs in groundnut crop owing to high seed rate. In case seed with low seed germination is used for planting, higher seed rate (calculated based on germination percent of the seed) has to be used to obtain optimum plant population. However, farmers do not use high seed rate even when seed germination is poor due to several reasons such as, lack of knowledge, non-availability of seeds, increased inputs cost etc. Consequently, the plant population remains poor resulting in depressing pod yields.

Studies on genotypic variability for seed germination and seedling vigour in aging groundnut seeds under storage are limited although we have some reports on how these parameters respond to aging during storage and the physical and environmental factors influencing them (Dey *et al*., 1999; Ntare *et al*., 2006; Nautiyal *et al*., 2010). Sharma *et al*. (2013) showed significant differences for seed germination, vigour index and fresh and dry weigh of seedlings of the genotypes, SG 99 and M 522 when stored for three months under ambient conditions. The present study was conducted to study the responses of seed germination and seedling vigour to aging and understand the variation for these traits in aging seeds of 32 groundnut genotypes after storing for 13 months under ambient conditions. Associations, if any of seed germination and seedling vigour with seed oil content and seed mass were also examined.

MATERIALS AND METHODS

The study material comprised of 32 groundnut genotypes that include 27 lines bred at ICRISAT and five released cultivars (ICGV 87846, ICGV 91114, JL 24, TAG 24 and GPBD 4) in India. The test genotypes were grown in 6 m2 plots during 2010-11 post rainy season in Alfisol precision fields of ICRISAT. Row to row distance was 30 cm and plant to plant distance within a row was 10 cm. Standard package of practices, 60 kg P2O5 per ha as basal application, seed treatment with mancozeb (2 g per kg of seed) and imidacloprid (2 ml per kg of seed), pre-emergence application of pendimethalin (1 kg active ingredient per ha), irrigation soon after planting and subsequently as and when needed in the rainy season. At peak flowering stage 400 kg gypsum per ha was applied in the soil. Pods of the test genotypes were harvested manually by pulling the plants following light irrigation in the month of May in 2011. After harvest the pods were dried in shade to bring the seed moisture content to about 8%, and stored in gunny bags under normal room temperature for a period of 13 months (June 2011 to July 2012) by stacking them one above the other in 6 columns at ICRISAT Center, Patancheru, Andhra Pradesh (17°31'4"N 78°16'43"E). The mean temperature (of 10 days) at ICRISAT Center ranged between 22°C and 31°C during the period of 13-months. From each genotype a random sample of pods was drawn from the gunny bag at specific intervals and the bag was closed tightly and placed to its position in store room. The sample of pods that were drawn from the bag was shelled and sound mature kernels (SMK) were used for the experiment. Seed was drawn at monthly interval for the experiment from 4-months of storage to 13-months. Thus, each genotype was evaluated 10-times for germination percent, seedling vigour index and root shoot ratio during the period of storage. The observations on germination percent were recorded over three replications and the observations for seedling vigour and shoot-root ratio were taken on 100 seeds of each genotype kept for germination without replications.

Germination percent: A sample of pods was drawn from each bag and shelled. For each batch 100 healthy and undamaged seeds of each genotype were kept for germination in three plastic trays of size 30 cm × 42 cm filled with sterilized sand. Seeds were germinated in three trays each with 30-35 seeds and each tray was considered a replication. Captain (75 % WP) and thiram (75 % WP) were mixed in 1:1 ratio and this mixture was used (4 g per kg of seeds) for fungicide treatment that was given before keeping seeds for germination. Seeds were also treated by spraying 5% ethrel (cis-N-((1,1,2,2-tetrachloroethyl)thio)4-cyclo-hexene-1,2-dicarboximide) solution to break the seed dormancy, if any. Perforations were made on the bottom of the tray to enable drainage of excess water, 30-35 seeds were placed in each and optimum moisture was maintained by sprinkling water every day. The trays were kept under natural sunlight in an open area covered with nets to prevent rodent and bird damage. The germination count was taken after 10 days after sowing and expressed as percent.

Seedling vigour index: 10-day old seedlings were harvested and used for recording seedling vigour index. Seedlings were removed from the sand trays and loose soil, if any, was washed off with water. The seedlings were blotted to remove any free surface moisture. The root was separated by cutting at the soil line from the shoot. The remaining cotyledons were cut off and kept separately. The roots and shoots were packed in separate paper bags and kept in an oven for drying for 48 hours at 60°C temperature. The dry weight of root and shoots were recorded from the oven dried germinated seedlings (10-days old) which together constituted total seedling dry weight. As dried seedling components weighed less due to high water content in fresh seedlings, enough care is taken while recording the weights of roots and shoots in grams. Seedling vigour index was determined and expressed in whole number.

Seedling vigour index = germination percentage × seedling dry weight in g.

The average germination percentage over three replications for each genotype was taken to derive seedling vigour index.

Data analysis: Germination percent is transformed using Arcsin function. The estimates of time, genotype x time, and error variance for germination percent of 32 genotypes are calculated by restricted maximum likelihood (REML) analysis using GenStat 14 (VSN International Ltd.) with time as random effect and genotypes as fixed effects. As both, time and interaction of time with genotypes are significant GGE biplot analysis is performed to identify stable genotypes over the time i.e., genotypes that retained good seed germination during storage. The time periods are grouped based on the germination data using Duncan Multiple Range Test. Simple correlations between the traits are calculated using PROC CORR in SAS 9.2 software.

RESULTS AND DISCUSSION

Groundnut genotypes used in the study belong to two sub-species, *fastigiata* and *hypogaea* of the cultivated groundnut (*Arachis hypogaea* L.). The *A. hypogaea* subsp. *hypogaea* has alternate pairs of vegetative and reproductive axes on branches (alternate branching) and does not bear flowers on the main axis, inflorescence is simple, generally has two seeds per pod, with moderate seed dormancy, seed coat is generally tan in colour and medium to late maturing. In var. *hypogaea*, cultivars with medium seed size are Runner market type and those with large seeds are Virginia market type. In contrast, *A. hypogaea* subsp. *fastigiata* var. *vulgaris* (Spanish market type) has floral axes on main stem, irregular pattern of vegetative and reproductive branches with reproductive branches predominating on branches (sequential branching), inflorescence compound, mostly two seeds per pod and with little or no dormancy (Janila and Nigam, 2013). The test genotypes included Virginia and Spanish market types that the most commonly cultivated across the semi-arid tropics of Asia and Africa. The genotypes represent a good range of variation for both, seed oil content and seed mass (measured as hundred seed weight (HSW)); seed oil content range between 45% (ICGV 06236) and 57% (ICGV 05155) and HSW range between 36g (TMV 2) and 82g (ICGV 87846). The F-test results comparing the genotypes showed significant differences among them for oil content as well as HSW (data not shown).

For germination percent, REML analysis on 32 genotypes showed that the variance component was significant for time and interaction of genotypes with time (Table 1). Since the interaction of genotype with time was significant, GGE biplot analysis was carried out to identify the genotypes that remained stable with aging. The scatter plot for germination percent is given in (Fig. 1).

Table 1. Estimated variance components of 32 groundnut genotypes evaluated for germination percent

Variable	Variance component	s.e.	Z-value	Probability
Time	0.01852	0.00909	2.03	0.0212
Time x genotype	0.00585	0.00142	4.12	<.0001

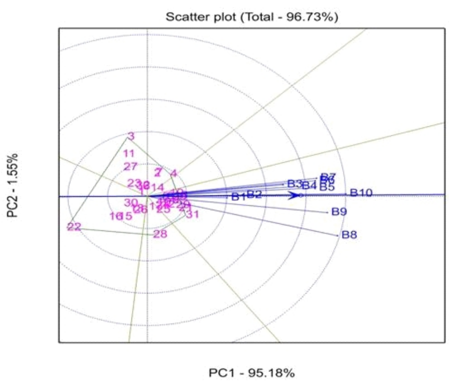

Fig. 1. Scatter plot for germination percent over the 10 batchs, represented by B1 to B10. B1 represents germination percent after 4 months of storage followed by one month increase in storage from B2 to B10. The genotpes are represented by numbers, 1 to 31. PC1 and 2 first and second principal components, respectively

The length of the vertex is an indicative of the extent of variation in that time period, thus the variation for germination percent among the genotypes was maximum in batch 10 and minimum in batch 1. In Fig. 1, the genotypes are represented by the numbers (1 to 32) and the batches representing time periods are given as B1 to B10 (Batch 1 to 10). Average Tester Coordinate (ATC) (line with an arrow head in the biplot figure (Fig. 1) on x-axis passes through the biplot origin and represents the average of the batches, which is defined by the average of PC1 and PC2 (first and second principal components, respectively) scores over all batches. The genotypes falling on or close to ATC are stable across the time periods (batches). All the genotypes on the right-hand side of the coordinate on y-axis that is perpendicular to ATC are the once that perform above average and the farther they are form the origin the better is their performance. A genotype falling away from the co-ordinate of the y-axis and at the same time on or close to ATC has high germination percent as well as stable across the batches. Based on this, the best genotypes that retained good germination under storage were identified. The 10-batches were divided into four groups using Duncan Multiple Range Test; batch 1 and 2 constituted the first group, batches 3 to 7 the second group, batches 8 and 9 the third group and the last batch constituted the fourth group. Comparisons for seedling vigour were also done between the same groups. Growth and development in groundnut is largely driven by temperature (Ong, 1986) and the mean optimal air temperature range for vegetative growth of peanut is between 25°C and 30°C (Ong, 1984). The temperature regime during the different periods of experiment was near optimum (22°C and 31°C).

Variation for seed germination and seedling vigour: The range of germination percent of the genotypes, which was initially between 75 and 100 %, became wider to 49 to 93% after 13 months of storage indicating significant negative impact on germination and it can be clearly visualized by the length of the vertex in Fig. 1. Germination percent decreased in all the genotypes with aging but, the percent decrease showed significant genotypic differences (Table 2). After 13 months of storage, the decrease in germination percent among the genotypes range from 7% to as high as 57%. Sixteen of the 32 genotypes retained >80% germination up to 9 months of storage. Based on GGE biplot, seven genotypes (ICGV 00351, ICGV 03043, ICGV 06139, ICGV 06423, ICG V06424, ICGV 91114 and TAG 24) were identified as stable genotypes for germination that ranged between 78% and 100% across all the batches. The genotypic differences observed for seed germination during storage indicate the possibility of genetic improvement for seed storability without affecting its germination.

Table 2 Mean values of germination percent of 32 groundnut genotypes stored for 13 months under ambient conditions at ICRISAT Center, Patancheru, India

Genotype numbers	Genotype	Group 1 $^{\$}$ (Mean of batch 1 &2)	Group 2$^{\$}$ (Mean of bathes, 3,4,5,6 &7)	Group 3$^{\$}$ (Mean of batch 8 & 9)	Group 4$^{\$}$ (Batch 10)	% decrease of germination percent from group 1 to 4 ((4 to 13 months of storage)
1	ICGV 00350	90	80	70	69	23
2	ICGV 00351	90	88	76	78	13
3	ICGV 03042	89	79	59	60	32
4	ICGV 03043	99	94	84	86	13
5	ICGV 03057	98	92	85	82	17
6	ICGV 03128	90	83	72	69	24
7	ICGV 04061	95	88	76	79	17
8	ICGV 04093	95	90	83	79	17
9	ICGV 05097	98	95	88	83	16
10	ICGV 05100	96	87	81	76	21
11	ICGV 06042	86	75	58	61	29
12	ICGV 06046	96	89	84	78	19
13	ICGV 06049	90	76	69	58	36
14	ICGV 06050	95	86	76	68	28
15	ICGV 06051	86	70	63	60	30
16	ICGV 06069	80	67	60	49	39
17	ICGV 06138	93	84	77	72	22
18	ICGV 06139	99	95	88	87	12
19	ICGV 06420	98	94	86	78	20
20	ICGV 06423	99	94	89	85	14
21	ICGV 06424	99	96	92	91	8
22	ICGV 07014	75	48	39	32	57
23	ICGV 07018	87	77	65	59	32
24	ICGV 07038	95	88	81	71	25
25	ICGV 07165	94	88	82	73	23
26	ICGV 07166	87	78	71	64	27
27	ICGV 07222	85	76	62	55	35
28	ICGV 87846	93	85	82	73	22
29	ICGV 91114	99	96	90	87	13
30	JL 24	88	75	64	57	35
31	TAG 24	100	99	96	93	7
32	GPBD 4	93	80	69	61	34

$^{\$}$ The batches were grouped based on germination percent using DMRTest using 1 to 32 genotypes; Batch 1-10 represents storage period of four to thirteen months

Earlier studies reported rapid loss of seed germination in stored groundnut seeds under natural conditions (Ntare *et al*., 2006; Perez and Arguello, 1995), and significant genotypic differences for seed germination were also observed under normal (Nautiyal *et al*., 1990) and during storage under ambient conditions (Sharma *et al*., 2013). Besides genotype that effects seed germination, Sisman (2005) reported other factors such as, the environment under which the seed is stored that include temperature, moisture and storage duration as the most important individual factors which effect seed germination. Nautiyal *et al*. (2010) also observed effect of maturity stage of the seed on its germination.

The seedling vigour among the genotypes in group 1 (mean of batch 1 and 2) ranged between 3267 and 6220, indicating significant variation for the trait among the test genotypes. Seedling vigour too showed a decline in aged seeds indicating a negative response to aging; however the rate of decline varied significantly among the genotypes (<5% to 79 %) indicating genotypic differences for rate of decrease in seedling vigour and thus it is possible to improve groundnut genotypes with enhanced seedling vigour during storage. Sharma *et al*. (2013) also observed significant genotypic differences for seedling vigour in two groundnut genotypes during storage under ambient conditions. The mean seedling vigour index over four groups (grouping done based on germination percent using Duncan's Multiple Range Test) and the percent decrease over 13 months of storage are given in Table 3. Decline in seedling vigour is due to decrease in seed germination as well as seedling dry weight. Both shoot and root growth of the seedling decreased with aging although root growth seems to be more profoundly affected compared to shoot during aging (data not shown). Thus storage seems to have a more profound negative effect on root than shoot growth of the seedlings. From GGE biplot, genotypes that are stable for seedling vigour over the different periods of storage are ICGV 00350, ICGV 00351, ICGV 03043 and ICGV 04093, ICGV 06046, ICGV 06139, ICGV 06424, ICGV 87846 and ICGV 91114.

Table 3 Mean values of seedling vigour index of groundnut genotypes stored for 13 months under ambient conditions at ICRISAT Center, Patancheru, India

Genotype numbers	Genotypes	Group 1$ (Mean of batch 1 &2)	Group 2$ (Mean of bathes, 3,4,5,6 &7)	Group 3$ (Mean of batch 8 & 9)	Group 4$ (Batch 10)	% decrease of seedling vigour index from group 1 to 4 (4 to 13 months of storage)
1	ICGV 00350	3513	3034	2183	3416	<5
2	ICGV 00351	3393	3810	2556	3188	<5
3	ICGV 03042	4034	3424	1011	1572	65
4	ICGV 03043	5157	4796	3020	4437	13
5	ICGV 03057	4845	4257	2844	2392	50
6	ICGV 03128	4052	3298	2066	1704	60
7	ICGV 04061	4717	4263	2462	3365	31
8	ICGV 04093	3873	3568	3658	3534	13
9	ICGV 05097	5586	5057	4400	3696	35
10	ICGV 05100	5713	4295	4044	3785	34
11	ICGV 06042	3397	2427	1075	2118	27
12	ICGV 06046	3749	3647	3341	3128	20
13	ICGV 06049	3963	2657	2441	1081	76
14	ICGV 06050	4143	3251	2698	1882	56
15	ICGV 06051	3300	1771	1625	889	74
16	ICGV 06069	3634	2509	2575	1236	68
17	ICGV 06138	3612	2420	2539	2074	45
18	ICGV 06139	4704	3616	3870	4254	<5
19	ICGV 06420	4098	3599	1919	880	79
20	ICGV 06423	5272	4277	3764	3156	33
21	ICGV 06424	4243	4428	4133	4446	<5
22	ICGV 07014	3318	944	592	400	89
23	ICGV 07018	3837	2952	1926	1328	62
24	ICGV 07038	4658	3735	3298	2076	56
25	ICGV 07165	5836	4855	5291	3353	44
26	ICGV 07166	4263	3486	3405	2825	32
27	ICGV 07222	4212	3101	2036	1415	69
28	ICGV 87846	6220	5438	4847	4012	6
29	ICGV 91114	4326	4191	3684	3366	18
30	JL 24	3694	2241	1565	964	76
31	TAG 24	3538	3501	2981	2599	28
32	GPBD 4	4038	2573	1643	1210	69

$The batches were grouped based on DMRT for germination percent and mean of each group was determined. Batch 1-10 represent storage period from four to thirteen months.

The seedling vigour of ICGV 91114 is high and it even after storage for one year the decrease in seedling vigour is 18% as against decrease of up to 89%. ICGV 91114, a drought tolerant variety bred at ICRISAT and released in India during 2006 (Birthal *et al.*, 2011), drought adaptation of the genotype may in part be contributed by high seedling vigour. High seedling vigour results in quick establishment of seedling and it was also shown that field performance of high vigour seeds is much better than that of low vigour seeds under a wide range of environmental conditions (Ghassemi-Golezani *et al.*, 2008) as seedling vigour and field emergence is positively correlated. Thus, seedling vigour can be particularly important for groundnuts cultivated in less favorable conditions such as, moisture stress conditions. The seed size of ICGV 91114 is medium (HSW of 48 g), thus ruling out the possibility of seed mass contributing to high vigour of seedlings.

Traits Association: The estimated correlation between germination percentage and seed oil content was not significant (-0.22). Acceleration of loss of seed germination with increased seed oil content in general was observed in oil seeds (Tubic *et al.*, 2010). Among the seven genotypes identified for stable seed germination during storage, ICGV 00351, ICGV 03043, ICGV 06139, ICGV 06423, ICG V 06424 have oil content ranging between 50 and 57%. The correlation between seedling vigour and oil content was also not significant (-0.02) indicating absence of association between the two traits. Dwivedi *et al*. (1990) based on their study on 64 genotypes observed absence of association of seed oil content with seed mass. The study showed the possibility of breeding groundnut genotypes with high oil content, seed germination and seedling vigour as the former is not associated with either of the later.

As seedling vigour is a function of both germination percent and seedling dry weigh, it is significantly and positively correlated with germination percent (0.72) and total dry weight of seedling (0.92) (data not shown). The correlation between HSW and seed germination was non-significant (0.04) indicating absence of association between them. Trivedi and Bhatt (1994) observed that seeds of different sizes (medium and small) of cultivar GG 2 have equal response to seed germination. However, some studies have shown effect of seed size on germination, field emergence, variations in crop stand in groundnut (Singh *et al.*, 1998; Devi *et al.*, 1999), and pod yield (Nautiyal *et al.*, 1990). Knauft *et al*. (1990) also observed that larger seeds show high germination rates, resulting in vigorous growth and high yield. The association of HSW with seedling vigour index was highly significant (0.69) as larger and sturdy seedlings are produced from large sized seeds. Studies have shown association of seed size with field emergence (Singh *et al.*, 1998; Devi *et al.*, 1999) as a consequence of positive association of seed size with seedling vigour (Trivedi and Bhatt, 1994; Ghassemi-Golezani *et al.*, 2008) and resulting in enhanced effective pods and thus pod yields (Knauft *et al.*, 1990; Vindhavarmann *et al.*, 1990; Detroja *et al.*, 1993). Because of this strong association, seedling vigour index alone can sometimes be misleading and to avoid confounding effects of seed mass on seedling dry weight and consequently on seedling vigour it is desirable to compare seedling vigour among the genotypes with similar seed mass. Despite strong association of seed mass with seedling vigour, increase in seed size can not a viable option as large seed size increases the seed rate and consequently the input cost.

Decrease in seed germination and seedling weight, and consequently seedling vigour was observed in aging groundnut seeds stored under ambient conditions. Significant genotypic differences for rate of decrease of seed germination and seedling vigour were observed among 32 groundnut genotypes. While aging affects both root and shoot growth, it is more profound on root growth. No association of seed oil content with seed germination and seedling vigour was observed during storage, thus it is possible to breed groundnut varieties with high seed oil content, seed germination and seedling vigour. The genotypes, ICGV 00351(50%), ICGV 03043 (54%), ICGV 06139 (54%), ICGV 06423 (54%), ICGV 06424 (54%) and ICGV 06046 (55%) have high seed germination and seedling vigour during storage. Four of them have oil content between 54 and 55% and hence can be potential parents in breeding programs to enhance seed oil content as well as seed germination and seedling vigour. It is also possible to promote these advance breeding lines for cultivation following local adaptation trials. Understanding the factors, genotypic and environmental, affecting seed germination and seedling vigour during storage will have applied value in development of improved groundnut genotypes as well as better methods for storage of groundnut seed.

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Maintainer/restorer identification for different CMS lines in sunflower (*Helianthus annuus* L.)

H P MEENA AND M SUJATHA

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

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ABSTRACT

Thirty one uniform and stable germplasm accessions of economic importance of sunflower were crossed with five cytoplasmic male sterile lines viz., CMS-234A, CMS-17A, CMS-338A, CMS-851A and ARM-243A in a Line x Tester fashion to study their maintainer or restorer reaction during *kharif*-2012 in a Randomized Block Design in two replications. The accessions TSG-22, TSG-24, ID-7, SCG-37, RHA-464 and ID-25 acted as restorers for all five CMS lines. It was found that ID-33 of the restorer for ARM-243A was maintainer for other CMS lines. The use of stable germplasm with restorer behaviour in heterosis breeding programmes and those with maintainer behaviour in the development of new CMS lines through conversion has been suggested. The identification of new restorers to the good combiner CMS sources assembled should receive priority for hybrid synthesis.

Keywords: CMS sources, Maintainer, Restorer, Sunflower

Sunflower (*Helianthus annuus* L.) belongs to *Asteraceae* family. Its allogamous nature offers scope for development of hybrids for commercial cultivation. In sunflower, hybrids are superior over open-pollinated cultivars in terms of yield, self-fertility and resistance to diseases (Miller, 1987). The first cytoplasmic male sterile source was *H. petiolaris* (PET-1), discovered by Leclercq (1969), for which fertility restoration genes were subsequently identified by Kinman (1970). This led to the exploitation of hybrid vigor and commercial use of hybrid sunflowers. From 1972 onwards, many hybrids were developed and released for commercial cultivation. Success in heterosis breeding programme is largely dependent upon the development of inbreds with broad genetic base (Giriraj, 1998). The best inbreds identified have to be converted into CMS lines before being used in hybrid development, those inbreds from maintainer gene pool are used for new CMS lines development and those from restorer gene pools are used as male lines in hybrid breeding programme. An attempt has been made at the Directorate of Oilseeds Research, Rajendranagar, Hyderabad, to identify effective restorers for the newly developed CMS sources.

MATERIALS AND METHODS

Thirty one germplasm accessions of economic importance of sunflower consisting of 12 sunflower core germplasm (SCG) lines (SCG-96-2, SCG-37, SCG-95, SCG-80, SCG-74, SCG-6, SCG-30, SCG-66, SCG-108, SCG-102, SCG-26 and SCG-27), 14 trait specific germplasm (TSG) lines (TSG-12, TSG-13, TSG-17, TSG-18, TSG-20, TSG-21, TSG-22, TSG-24, TSG-31, TSG-38, TSG-44, TSG-52, TSG-53 and TSG-54), 3 intrerspecific derivative (ID) lines (ID-7, ID-25 and ID-33), one pre-bred line (PS-4045) and one RHA line (RHA-464) were used for crossing with five CMS lines in Line x Tester design during the winter season of 2011. The material used in this study (Table 1) was received from United States Department of Agriculture (USDA), ARS-AMES, USA. Before flowering (star bud stage) all the heads in the lines (CMS lines) and testers (SCG, TSG, ID, and pre-bred lines) were covered with cloth bags to prevent open pollination. The pollen from the male lines was collected separately in Petri-dishes with the help of camel hair brush, during morning hours (9:00 to 11:00 AM) and pollinated to each of the female lines (CMS-234A, CMS-17A, CMS-338A, CMS-851A and ARM-243A) separately and cloth bags were replaced immediately after pollination. The crossing was repeated (alternate day) till all the disc florets completed their opening. Each test hybrid (150 hybrids) was grown in a single row of 4.0 m with 60 x 30 cm row to row and plant to plant distances during the rainy season of 2012 at the Directorate of Oilseeds Research, Rajendranagar, Hyderabad in Randomized Block Design with two replications. All the agronomic practices (fertilizer application, earthing up, irrigation, insecticide spraying) were followed to raise a successful experimental crop. For fertility restoration studies, at the time of flowering, individual plants in each cross were observed for anther exertion and pollen shedding at anthesis stage and the crosses were categorised into male fertile, male sterile and partially fertile which correspond to restorer, maintainer and partial restorer behaviours of germplasm lines, respectively.

E-mail: hari9323@gmail.com

Table 1 PI number and characteristics of breeding material received from United States Department of Agriculture (USDA)

DOR Identity	PI Number	Character
SCG-96	EC-430539	Early maturity
TSG-18	PI-497930	High oil
TSG-20	PI-552941	High oil
TSG-21	PI-552942	High oil
TSG-22	PI-599766	High oil
TSG-24	PI-599786	High oil
TSG-52	PI-650625	Dwarf, high oil
TSG-53	PI-650626	Medium height, high oil
TSG-44	PI-650561	Medium height, high oil
TSG-12	PI-307941	Medium height
TSG-13	PI-372178	Medium height
TSG-17	PI-483077	High oleic acid
TSG-38	PI-650444	Medium height
ID-33	PI-564518	-
SCG-108	PI-650727	Dwarf
SCG-26	PI-431516	Dwarf , early maturity
SCG-27	PI-431529	Dwarf, early maturity
TSG-54	PI-650654	Medium height, early maturity
SCG-95	PI-287230	Early maturity
ID-25	PI-539895	Powdery mildew resistance
SCG-102	PI-650534	Dwarf, early maturity
PS-4045	-	Medium height
SCG-6	PI-175723	Tall
SCG-80	PI-307934	Very dwarf
RHA-464	EC-687402	Powdery mildew resistant
ID-7	PI-539913	-
SCG-66	PI-483077	High oleic acid
SCG-74	PI-650370	Medium height
TSG-31	PI-650359	Dwarf
SCG-30	PI-431558	Medium height
SCG-37	PI-505839	-

RESULTS AND DISCUSSION

The data indicated that majority of the lines being tested, behaved as maintainers for all CMS lines (Table 2). Frequency of tested material as maintainers/restorer lines based on percent fertility restoration over different CMS sources is presented in Table 3. The restorer for one CMS line behaved as maintainer for other CMS line and vice versa, confirming the diversity among the CMS lines. In this study we found that only seven out of thirty lines tested behaved as restorers for all five CMS lines and produced fertile hybrids. Similar results were also reported by Reddy *et al*. (2002); Reddy *et al.* (2008) and Satish Chandar *et al.* (2011). Rukminidevi *et al.* (2006) and Sujatha and Vishnuvardhan Reddy (2008) also reported lack of fertility restorers other than PET-1.

From trait specific germplasm, only two accessions (TSG-22 and TSG-24) behaved as restorers for all the five CMS lines. While, out of 13 sunflower core germplasm lines, only one line SCG-37 could restore fertility for all the CMS lines. However, from ID lines, out of three, two lines acted as restorers for the tested CMS lines. It was found that ID-33 behaved as restorer of ARM-243A while, behaved as maintainer of other CMS lines.

PS-4045 line acted as maintainer for most of the CMS lines while acted as partial restorer for ARM-243A. Sunflower core germplasm line SCG-80 acted as partial restorer for CMS-234A while, SCG-29, TSG-31 and

PS-4045 acted as partial restorers for ARM-243A but acted as maintainers for other CMS lines. A few crosses showed segregation with one or two fertile/sterile plants in their progeny. This was attributed either to contamination of foreign pollen or the heterozygosity of the lines to restorer genes (Virupakashappa *et al.,* 1991) or may be due to modifying effects of genes (Dominguez-Gimenez and Fick, 1975).

Regarding maintainer behaviour of germplasm lines, most of the lines acted as maintainers for all CMS lines (Table 2). A few partial restorers were also identified for five CMS lines. The differential behavior of the lines for fertility/sterility reaction may be attributed to genetic architecture especially the number of genes controlling and their interactions with cytoplasm in restoring fertility. Thus the present study helped in identification of a few effective restorers (based on seed setting in F_1 hybrids) for the available CMS lines, which can be exploited in hybrid development or may be utilized in the development of new restorer lines. Large numbers of maintainers are available when compared to restorers in the experimental material indicating that there is wide choice for CMS conversion programmes. The newly identified restorers for the different CMS sources will be useful for exploiting heterosis and combining ability. The maintainers identified for the new sources of male sterility can be converted into new CMS lines, which will serve the purpose of broadening the genetic base of cultivated sunflower.

Table 2 Restorer/maintainer reaction of different sunflower accessions in the background of five CMS (PET-1) sources

Genotype	CMS-234A	CMS-851A	CMS-338A	CMS-17A	ARM-243A
SCG-96	M	M	M	M	M
TSG-18	M	M	M	M	M
TSG-20	M	M	M	M	M
TSG-21	M	M	M	M	M
TSG-22	R	R	R	R	R
TSG-24	R	R	R	R	R
TSG-52	M	M	M	M	M
TSG-53	M	M	M	M	M
TSG-44	M	M	M	M	M
TSG-12	M	M	M	M	M
TSG-13	M	M	M	M	M
TSG-17	M	M	M	M	M
TSG-38	M	M	M	M	M
ID-33	M	M	M	M	R
SCG-108	M	M	M	M	M
SCG-26	M	M	M	M	M
SCG-27	M	M	M	M	M
TSG-54	M	M	M	M	M
SCG-95	M	M	M	M	M
ID-25	R	R	R	R	R
SCG-102	M	M	M	M	M
PS-4045	M	M	M	M	PR
SCG-6	M	M	M	M	M
SCG-80	PR	M	M	M	M
RHA-464	R	R	R	R	R
ID-7	R	R	R	R	R
SCG-66	M	M	M	M	M
SCG-74	M	M	M	M	M
TSG-31	M	M	M	M	PR
SCG-30	M	M	M	M	M
SCG-37	R	R	R	R	R

M = Maintainer R = Restorer PR = Partial Restorer

Table 3 Frequency of tested material as maintainers/restorer lines based on percent fertility restoration over different CMS sources

CMS line	No. of germplasm lines tested	Maintainer	Percentage (%)	Restorer	Percentage (%)
CMS-234A	31	25	80.64	6	19.35
CMS-17A	31	25	80.64	6	19.35
CMS-338A	31	25	80.64	6	19.35
CMS-851A	31	25	80.64	6	19.35
ARM-243A	31	24	77.42	7	22.58

The restorer for one CMS source behaved as maintainer for other CMS sources and vice versa, confirming the diversity among the CMS sources. This study indicates limited availability of effective good restorers for different CMS sources. The new restorers identified in the present investigation will help in exploiting new CMS sources in hybrid development by ensuring better heterosis and diversity of cytoplasm in sunflower. The newly identified maintainers, after testing for *per se* performance, combining ability and agronomic performance, will be converted into new CMS lines for utilization in hybrid breeding programs for developing diverse hybrids with better heterosis and resistance to diseases and insect pests.

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Study on gene action, heterosis and inbreeding depression for yield and quality traits in castor (*Ricinus communis* L.)

M S PATEL AND R M CHAUHAN

S.D. Agricultural University, Sardarkrushinagar-385 505, Gujarat

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ABSTRACT

Gene action, heterosis and inbreeding depression study for yield and quality traits in castor (*Ricinus communis* L.) was carried out through six parameter generation mean analysis at Main Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar (SK Nagar). The experimental material included six families (P_1, P_2 ,F_1 ,F_2, BC_1, BC_2) of six crosses SH 72 x PRT 44, SKI 215 x SKI 166, PCS 124 x 37504, PCS 124 x JH 118, SKI 1 x JH 118 and HC 8 x JH 118. The characters studied were days to flowering, days to maturity, stem length, number of nodes on main stem, effective length of primary raceme, number of capsules on primary raceme, number of effective branches/plant, seed yield/plant, 100-seed weight, oil content in seed, endosperm content, oil content in endosperm, palmatic acid content, oleic acid content, linoleic acid content, linolenic acid content and ricinoleic acid content. The analysis of variance showed significant differences between all the generations in majority of the characters of the crosses. The estimation of scaling tests showed that non-allelic interactions played an important role in the genetic control of all the characters. All the generations differed significantly for their mean(m) performance of all the traits. The estimates of gene effects revealed that both additive and non-additive gene actions were important for days to flowering, days to maturity, stem length, number of nodes on main stem, effective length of primary raceme, number of capsules on primary raceme, number of effective branches/plant, endosperm content, 100-seed weight, seed yield/plant, oil content in seed, linoleic acid content, linolenic acid content and ricinoleic acid content. Whereas, non-additive as well as epistatic gene actions were important for oil content in endosperm, palmatic acid content and oleic acid content. Crosses showing low heterobeltiosis effects also displayed high inbreeding depression for seed yield/plant in general. Utilization of biparental mating and reciprocal recurrent selection schemes which has the virtue of effectively exploiting, both additive and non-additive components, was suggested for exploiting present set of materials for obtaining high yielding genotypes of castor.

Keywords: Castor, Gene action, Oil content, Seed yield

Castor (*Ricinus communis* L.), 2n = 22 is an important non-edible oil yielding crop of arid and semi-arid regions of India. It belongs to the genus Ricinus of Euphorbiaceae family. India is the largest castor producer in the world. Gujarat shares about 47% of the total area and 71% of the total castor production of the country. For the systematic and successful breeding programme, the knowledge of gene action involved in the inheritance of various quantitative characters of economic importance will help in framing an efficient breeding plan for rapid improvement in any crop. In castor, most of the characters of economic importance are quantitatively inherited and therefore, improvement in yield through yield contributing traits depends on the nature, magnitude and heritable variation. Yield, a complex character controlled by polygenes, had much influence of environmental fluctuations and is the final product resulting from interaction of yield attributing characters. Therefore, information on the mode of inheritance and type of gene action will enable breeder in deciding suitable breeding methodology to be adopted for improvement of castor (Patel and Chauhan, 2013). The partitioning of heritable variation into its components is useful to provide information on the inheritance of quantitative characters. One of the common approaches followed for the purpose is to understand the nature of gene effects by growing different generations and carrying out the generation mean analysis using first-degree statistics.

MATERIALS AND METHODS

Gene action study for yield and quality traits in castor was carried out following six parameter generation mean analysis at Main Castor-Mustard Research Station, SDAU, SK Nagar. Six F_1 crosses, (I) SH 72 x PRT 44, (II) SKI 215 x SKI 166, (III) PCS 124 x 37504, (IV) PCS 124 x JH 118, (V) SKI 1 x JH 118 and (VI) HC 8 x JH 118 were generated in *kharif* 2006-07, whereas F_2, BC_1 and BC_2 of the said crosses were generated in *kharif* 2007-08. These experimental material comprising six families involving six generations were evaluated with three replications in a Compact Family Block Design during *kharif* 2008-09. A single replication comprised of one row of parents and F_1's, two rows of the backcrosses and four rows of the F_2's. There were ten plants in a row at inter and intra row spacing of 90 cm x 60 cm. Recommended agronomic practices in vogue along with necessary plant protection measures were timely adopted for successful raising of the crop. The observations were recorded for days to flowering (primary raceme), days to maturity (primary raceme), stem length (cm), number of nodes on main stem, effective length of primary raceme (cm), number of capsules on primary raceme, number of effective branches/plant, seed yield/plant (g), 100-seed weight (g), oil content in seed (%), endosperm content (%), oil content in endosperm (%), palmatic acid content (%), oleic acid content (%), linoleic acid content (%), linolenic acid content (%) and ricinoleic acid content (%). The data were subjected to analysis of variance for Compact Family Block Design. Crosses showing significant differences among the entries (progenies) for the character were subjected to generation mean analysis for the estimation of gene effects using six parameter model.

RESULTS AND DISCUSSION

The character expression is related to the type of gene action involved and its interactions with the environment. The type of gene actions *viz*., additive, dominance and epistasis with their relative magnitude determine the breeding methodology to be adopted for the genetic improvement of the characters under study were studied. Production of hybrids as opposed to inbreds or open pollinated varieties depends largely on the level of dominance or epistasis (dominance x dominance) or both. Again level of dominance and forms of epistasis is influenced by the selection of parents to develop open pollinated varieties. Thus, estimation of additive, dominance and epistasis components of genetic variances are of paramount importance for planning plant improvement programme. Number of genetic models assuming basic requirements have been proposed for the estimation of the gene effects and estimating relative importance of additive and dominance gene effects. Epistatic gene effect was assumed to be negligible. However, significant epistatic gene effects have been reported for quantitative traits in many crops. Partitioning of total heritable variance into additive and dominant components ignoring the presence of interallelic gene action would not give a correct picture of the gene action involved. If the epistatic gene actions are not separated, they tend to inflate dominance variance and lower the additive variance.

The analysis of variance due to the generation means were significant for most of the characters in all the crosses, except days to flowering, number of nodes on main stem and number of capsules on primary spike in cross V, number of effective branches/plant in crosses I, IV and V, oil content in seed in crosses I, III and IV, endosperm content in crosses IV, V and VI and oil content in endosperm in cross I, palmatic acid content in crosses II, III and V, stearic acid content in all crosses, oleic acid content in cross III.

The scaling tests (A, B, C and D) indicated appreciable amount of epistasis present in different characters of six crosses under study (Table 1). Similar results have been reported by Geeta and Rana (1987) and Hussain *et al.* (1988). The estimates of scaling tests revealed significant values in all crosses for all the characters, which indicated presence and importance of non-allelic type of gene interactions in the inheritance of respective traits. In all the traits, significant values of 'm' suggested that all the generations differed significantly from one another for their performance.

Among the six crosses studied, all the crosses indicating significant differences for seed yield/plant and were subjected to scaling tests and estimation of gene effects (Table 1). All the gene effects, *viz*., additive, dominance and epistatic, were found significant in crosses II, III and VI. In cross V, dominance x dominance gene effect was greater in magnitude, while, in cross VI, dominance x dominance gene effect was greater in magnitude, followed by additive and additive x additive and opposite signs of dominance and dominance x dominance effects indicated presence of duplicate epistasis in the inheritance of seed yield/plant. The results indicated importance of non-additive gene effects in the inheritance of seed yield/plant. In cross V, dominance x dominance gene effect was greater in magnitude, while in cross VI, dominance x dominance gene effect was greater in magnitude, followed by additive and additive x additive and opposite signs of dominance and dominance x dominance effect indicated presence of duplicate epistasis in inheritance of this trait, whereas, in case of crosses I, II, III and IV, the same signs of dominance and dominance x dominance effects indicated presence of complementary type of epistasis in the inheritance of seed yield/plant (Table 1).

Seed yield is an ultimate economical product in castor. It is influenced by several yield attributes like length of primary raceme, number of branches/plant, number of capsules on primary raceme and 100-seed weight, etc. The results of the present study revealed that seed yield was controlled by both additive and non-additive gene effects in all the six crosses. Hence, cyclic method of breeding could be profitably utilized to take advantage of both additive and non-additive type of gene actions for improvement of this trait. When major components for seed yield are influenced by dominance and over dominance, heterosis breeding could be advocated for the quantum jump in production, as always advocated in Gujarat.

All types of gene actions i.e., additive, dominance, additive x additive, additive x dominance and dominance x dominance were observed for linolenic acid content in all crosses whereas, linoleic acid content and oleic acid content (except cross PCS 124 x 37504), ricinoleic acid content (except cross SKI 215 x SKI 166), effective length of primary raceme (except cross SKI 215 x SKI 166 and SKI 1 x JH 118), stem length (except SH 72 x PRT 44, SKI 215 x SKI 166 and SKI 1 x JH 118) and seed yield/plant (except cross SH 72 x PRT 44, PCS 124 x JH 118 and SKI 1 x JH 118). In cross, SH 72 x PRT 44 seed yield/plant and palmatic acid content was controlled by the gene actions additive, dominance, additive x dominance, dominance x dominance. In cross PCS 124 x JH 118 seed yield/plant was controlled by the gene actions additive, dominance, additive x additive and dominance x dominance. In cross SKI 1 x JH 118 seed yield/plant was controlled by additive, dominance and additive x additive gene actions. Overall, the results revealed that different types of gene effects controlled inheritance of same characters in different crosses and for different characters in the same crosses.

The present findings are akin to the results obtained by Patel (1992), Natarajan *et al.* (1993), Patel (1996), Gondaliya *et al.* (2001) and Solanki *et al.* (2003) who reported the role of both additive and non-additive gene effects in the expression of yield and its components, while Goyani *et al.* (1993) reported the importance of additive gene effects for the inheritance of yield and its components. However, Vindhiyavarman and Ganesan (1995), Solanki and Joshi (2000), Kavani *et al.* (2001), Ramu *et al.* (2002) and Lavanya and Chandramohan (2003) also observed the role of non-additive gene effects in the expression of yield and its components.

An attempt was made to estimate the extent of heterosis (heterobeltiosis) for seed yield, yield attributes and quality traits in castor. In addition, inbreeding depression was also estimated for seed yield, yield attributes and quality traits (Table 2). The results revealed that significant and positive and negative heterobeltiosis was recorded in many crosses for different characters studied. Among all the crosses, the magnitude of better parent heterosis varied over characters which indicated genetically different populations under the present study.

Table 1 Estimation of scaling tests and gene effects for different characters in castor

Crosses	Scaling Test				Six parameters model					
	A	B	C	D	m	d	h	i (aa)	j (ad)	l (dd)
Days to flowering (Primary raceme)										
I	-19.33**	-7.67**	-22.3**	3.33**	66.00**	-1.67**	-9.83**	-4.67**	-5.83**	31.67**
II	18.13**	8.33**	15.67	3.67	76.00**	-2.33**	-9.50**	-7.33**	-4.17**	-1.00
III	-7.33**	-27.00**	-41.0**	-3.33	63.00**	-1.33**	-6.50**	6.67**	9.83**	27.67**
IV	-5.33**	-11.00**	-23.7**	-3.67**	59.67**	2.33**	8.83**	7.33**	2.83**	9.00**
V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VI	-8.00**	0.33	-15.7**	-4.00*	63.00**	4.17**	3.5**	8.00**	-4.17**	-0.33
Days to maturity (Primary raceme)										
I	-12.00**	0.33	-13.67**	-0.67	136.00**	-2.00**	-1.5	1.33	-5.83**	11.00
II	933.00**	11.00**	6.33**	-7.00**	141.00**	3.00*	9.83**	14.00**	-0.83	-34.3**
III	-7.00**	-30.67**	-39.00**	-0.67	136.33**	-0.67**	-8.83**	1.33	11.83**	36.33**
IV	-5.67**	-14.00**	-27.00**	-3.67**	124.67**	0.33	8.50**	7.33**	4.17**	12.33**
V	-6.67*	-0.67	-1.33**	1.33**	134.33**	-0.67	4.00**	-2.67**	4.00**	4.00**
VI	-1.67	-13.67**	-7.33**	4.00**	131.00**	9.33**	-11.0**	-8.00**	6.00**	23.33**
Plant height (Stem length)										
I	-28.13	-1.40	17.67**	23.60**	105.18**	-0.50	-53.8**	-47.2**	-13.4**	76.73**
II	-15.37**	-17.50**	-53.07**	-10.10**	98.98**	4.40*	16.57**	20.20	1.067**	12.67
III	-0.27	-2.13**	-9.8**	-3.70**	60.73**	-30.9**	89.07**	103.73**	13.73**	-54.5**
IV	-27.33**	-23.60**	-45.93	2.50**	50.95**	-3.6**	13.20**	-1.87*	-55.9**	-5.00**
V	-22.47**	26.73**	6.60	1.17	73.48**	-9.67**	-2.53	-2.33	-24.6**	-1.93
VI	8.47	32.47**	-13.27	-27.10**	79.22**	10.40**	10.98*	-15.62**	-55.9**	22.20**
Number of nodes on main stem										
I	-4.27**	-2.93**	-2.93**	2.13**	18.62**	0.03	-4.57**	-4.27**	-0.67**	11.47**
II	-0.27	0.40	-1.2*	-0.67**	20.12**	0.57**	0.70**	-0.20**	-1.07	1.33
III	-0.27	-2.13**	-9.80**	-3.70**	16.12**	-1.40**	6.27**	-5.00**	7.40**	0.93**
IV	-2.20**	-1.80**	-6.33**	-1.17**	16.22**	-0.20	2.87**	-0.20	1.67*	2.33**
V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VI	1.40**	1.87**	1.07**	-1.1**	19.00**	0.83**	1.4**	2.20**	-0.23	-5.47**
Effective length of primary raceme										
I	-17.20**	-1.00	1.73	9.97**	64.28**	3.73**	-11.50**	-19.93**	-8.10**	38.13**
II	-10.4**	7.00	-3.73**	-0.17	61.45**	-5.93**	-1.10	0.33	-8.70**	3.07
III	-1.13	-11.80**	-48.87**	-17.97**	42.13**	-6.63**	36.57**	35.93**	5.33**	-23.00**
IV	-29.73**	-19.4**	-49.07**	0.03	31.70**	-2.30**	9.2**	-5.17**	49.2**	-0.07**
V	-8.80**	12.53**	2.33	-0.70	45.97**	-5.83**	9.30**	1.40	-10.67**	-5.13
VI	-0.60	6.57**	-3.1	-4.53**	47.70**	8.00**	10.78**	9.07	3.58**	-15.03**

Table 1 (Contd...)

					Number of capsules on primary raceme					
I	-27.87**	-14.47**	-20.13**	11.10**	43.77**	8.37	-21.13**	-22.20**	-6.70*	64.53**
II	-9.80**	-7.40**	-17.53**	-0.17	53.70**	-4.83**	13.77**	0.33	-1.20	16.87**
III	-5.80**	8.40**	-26.67**	-14.63**	33.05**	-10.73**	33.30**	-7.10**	-3.87**	29.27**
IV	-7.67**	-3.93**	-30.13**	-9.27**	29.30**	-8.60**	19.40**	-1.87**	-6.93**	18.53**
V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VI	-11.00**	2.93*	18.8**	-5.37**	41.85**	0.80**	0.03	10.73**	-6.97**	-2.67
					Number of effective branches/plant					
I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
II	-0.07	-0.33	0.27	0.33**	3.77**	1.47**	-1.27**	1.07	-0.67*	0.13
III	0.20	0.60**	2.07**	0.63**	3.77**	0.63**	-1.23**	-1.27**	-0.20	0.47
IV	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VI	-0.20*	-0.27**	1.47**	0.97**	4.13**	0.43**	-1.87**	-1.93**	0.03	2.40**
					Seed yield/plant (g)					
I	-82.67**	-53.00**	-113.7**	11.00**	200.33**	32.33**	31.17**	-22.00	-14.83**	157.67**
II	166.33**	-133.3**	-215.0**	-99.00**	166.67**	137.67**	233.83**	124.83**	-181.0**	198.00**
III	-49.67**	-176.0**	-99.00**	63.33**	177.33**	15.00**	-69.50**	62.83**	361.00**	-126.0**
IV	-163.7**	-71.33**	-251.0**	-8.00	160.33**	3.33	121.50**	-47.83**	222.33**	16.00**
V	-35.33**	43.00**	3.00	-2.32	182.33**	-11.00**	32.83**	-39.17**	-12.33	4.67
VI	-16.00*	-60.00**	-8.67	33.67**	170.67**	27.00**	-39.67**	-67.33**	22.00**	143.33**
					100-seed weight (g)					
I	0.81	2.20**	4.6**	0.79	37.93**	-2.27**	1.55	-1.59	-0.70	-1.43
II	2.68**	-6.00**	-9.33**	-3.00**	34.31**	2.38**	8.93**	6.00**	4.34**	-2.67
III	-0.60	-5.84**	-9.01**	-1.29**	29.52**	-5.54**	0.02	2.57**	2.62**	3.86**
IV	-2.22**	2.42**	-1.89*	-1.05	28.94**	-5.81	2.56*	-2.32**	-2.30	2.09
V	2.22**	-0.05	5.36**	1.59**	37.78**	2.21**	-0.55	-3.19**	1.14**	1.01
VI	-1.24	6.85**	2.81*	-1.40**	34.75**	-2.28**	4.25**	2.81**	-4.05**	-8.42**
					Oil content in seed (%)					
I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
II	-0.20	-5.28**	-7.26	-0.89*	50.48**	1.16**	4.23**	1.78*	2.54**	3.70
III	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
IV	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V	-2.74**	-1.24*	-7.42**	-1.72**	50.01**	1.39**	5.83*	3.44**	-0.75*	0.54
VI	-0.38	1.95**	0.01	-0.78*	50.07**	0.89**	3.23**	1.56*	-1.17**	-3.13*
					Endosperm content (%)					
I	-1.70**	2.80**	4.89**	1.90**	78.15**	-1.97**	-2.073**	-3.79**	-2.25**	2.69**
II	-3.17**	-0.79*	-1.64**	1.13**	77.13**	-2.11	0.53	-1.19**	6.15**	-2.25**
III	1.45	1.47	0.97	-0.97	74.84**	-3.95**	-1.45*	-0.02	-4.85**	1.95**
IV	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VI	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
					Oil content in endosperm (%)					
I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
II	-1.09**	0.37**	-1.36**	-0.32**	61.02**	-0.09*	2.08**	0.64**	-0.73**	0.08
III	-1.12**	-2.23**	-3.38**	-0.01	59.95**	-0.70**	0.64**	0.03**	0.56**	3.33**
IV	-0.94**	2.07**	1.88**	0.38**	60.95**	-0.70**	0.64**	-0.75**	-1.51**	-0.38
V	-2.02**	-1.39**	-5.83**	-1.21**	59.21**	0.48**	3.27**	2.41**	-0.32**	1.00**
VI	-0.27	-1.26**	-0.00	0.76**	59.53**	1.81**	-1.52**	-1.53**	0.50**	3.06**
					Palmatic acid content					
I	-0.14*	0.06	-0.43**	-0.17**	1.04**	-0.07*	0.32**	-0.27	-0.10**	0.35**
II	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
III	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
IV	-0.12**	-0.08**	-0.21**	-0.01	1.18**	-0.04*	-0.21**	0.01	-0.02	0.19*
V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VI	-0.14**	0.05	-0.62**	-0.27**	1.12**	-0.07**	0.55**	0.53**	-0.10**	-0.45**
					Oleic acid content (%)					
I	-1.62**	-0.77**	-1.45**	0.47**	2.79**	-0.21**	-0.85**	-0.94**	-0.42**	3.33**
II	-0.27**	0.81**	3.14**	1.30**	4.29**	-0.31**	-1.64**	-2.60**	2.06**	2.06**
III	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
IV	0.96**	-0.80**	-0.65**	-0.41**	4.14**	0.48**	1.32**	0.81**	0.88**	-0.98**
V	-0.48**	-1.29**	-7.02**	-2.67**	2.28**	0.19**	5.84**	5.25**	0.40**	-3.48**
VI	-0.50**	0.05	1.57**	1.01**	3.05**	-0.40**	-3.48**	-2.02**	-0.28**	2.47**

Table 1 (Contd...)

					Linoleic acid content (%)					
I	-0.24**	-0.15**	0.14**	0.6**	5.05**	-0.04**	-0.40**	-0.53**	-0.04**	0.91**
II	-0.20**	-0.01*	-0.48**	-0.13**	4.94**	-0.09**	0.39**	0.27**	-0.10**	-0.05**
III	-0.11**	-0.07**	0.58**	0.38**	4.99**	-0.01**	-0.68**	-0.76**	-0.02	0.94**
IV	0.12**	0.29**	-0.36**	-0.39**	4.77**	-0.14**	0.70**	0.77**	-0.09**	-1.19**
V	0.12**	-0.17**	-0.64**	-0.30**	4.76**	0.06**	0.59**	0.59**	0.14**	-0.54**
VI	0.23**	0.06**	0.97**	0.34**	4.92**	-0.05**	-0.82**	-0.68**	0.08**	0.39**
					Linolenic acid content (%)					
I	0.14**	0.31**	-0.78**	-0.61**	0.56**	-0.08**	1.20**	1.23**	-0.08**	-1.68**
II	0.12**	0.29**	0.62**	0.11**	0.92**	-0.04**	0.12**	-0.21**	-0.09**	-0.20**
III	-0.33**	-0.08	-1.11**	-0.35**	0.92**	-0.19**	0.63**	0.70**	-0.13**	-0.29**
IV	-0.38**	-0.25**	-0.8**	-0.08**	0.77**	-0.02**	-0.06**	0.17**	-0.06**	0.47**
V	0.08**	-0.13**	2.29**	1.17**	1.36**	0.06**	-2.46**	-2.34**	0.11**	2.39**
VI	-1.71**	-0.20**	-4.12**	-1.11**	0.74**	-0.03**	1.87**	2.21**	-0.75**	-0.31**
					Ricinolic acid content					
I	2.86**	0.68**	3.75**	0.11*	91.24**	0.63**	1.00**	-0.21*	1.09**	-3.33**
II	0.04	-2.92**	-5.90**	-1.51**	88.28**	0.91**	1.19**	3.03**	1.48**	-0.15
III	-2.42**	0.39**	-2.82**	-0.40**	88.44**	-1.56**	1.20**	0.79**	-1.41**	1.24**
IV	-0.62**	1.53**	5.47**	2.28**	91.00**	-0.64**	-4.44**	-4.56**	-1.08**	3.65**
V	0.65**	2.86**	4.49**	0.49**	91.55**	-0.56**	-1.60**	-0.98**	-1.10**	-2.53**
VI	5.66**	0.48**	9.45**	1.66**	92.65**	1.22**	-1.25**	-3.31**	2.59**	2.82**

* and ** = Significant at 5 and 1% level of significance, respectively

Table 2 Magnitude of heterobeltiosis (%) and inbreeding depression (%) for various characters in castor

Name of character	Crosses											
	I		II		III		IV		V		VI	
	Hb	ID	Hb	ID	Hb	ID	Hb	ID	Hb	ID	Hb	ID
Days to flowering (Primary raceme)	-11.92**	4.348*	-5.33*	-7.04	-26.74**	5.5**	1.531	10.05**	-1.02	0.00	-11.82**	2.58
Days to maturity (Primary raceme)	-4.61**	1.449	-5.51**	-2.67**	-13.85**	3.31**	-1.98**-	5.56**	1.50**	0.74	-4.6**	0.25
Stem length (cm)	-16.65**	-7.92	-5.93	10.37**	-39.28**	33.69**	29.90**	28.77**	-17.42	-2.44	-34.48**	-11.99
Number of nodes on main tem	-4.95	3.04	-6.48**	0.41	-16.45**	10.46	3.04	10.24**	-1.13	-1.62	-9.24**	-3.64
Effective length of primary raceme (cm)	-4.76	5.56	-6.38**	0.35	-17.17*	22.93	15.17**	34.77**	15.81**	6.82**	-16.67*	3.31**
Number of capsules on primary raceme	-22.11*	11.28	35.75**	17.13**	0.97	20.81**	-13.60**	21.38**	-19.43	-15.98	-30.95**	-1.58
Number of effective branches/plant	-2.27	-9.30	-36.25**	-10.78	-19.67**	-15.31	-4.76	2.92	-2.0	4.08	-8.07	-8.77**
Seed yield/plant (g)	2.41	21.54**	10.68	30.07**	3.91	23.01**	24.44**	42.05	0.0	6.81**	13.82*	8.57
100-seed weight (g)	4.25*	1.09	2.61	9.96**	-26.00**	3.20**	-9.28*	2.37	3.43	-1.85	-0.91	0.07
Oil content in seed (%)	4.09*	1.98	2.05	5.68*	-0.91	5.00	-29.74	-33.38	0.47	5.75*	-0.76	1.63
Endosperm content (%)	1.89	-0.47	2.42*	2.29	-9.13**	-2.66**	-1.24	-1.86	0.98	1.86	2.70	0.89
Oil content in endosperm (%)	0.27	0.76	2.28**	1.71**	-0.18	1.54	0.95**	0.37	0.10	3.09	-2.15**	0.01
Palmatic acid content (%)	0.30	8.24**	11.46	-6.94**	4.37	2.46	-15.29**	-5.03	-1.59	-0.81	3.77	12.73
Oleic acid content (%)	10.48**	12.72**	42.43**	-7.70**	-6.09*	-28.08**	24.77**	9.08*	22.55**	47.34**	-41.00**	-58.41**
Linoleic acid content (%)	2.77**	0.59**	2.61**	3.52	1.67*	-2.19**	-0.34	1.11	1.58**	3.19**	-0.29	-6.80**
Linolenic acid content (%)	-3.48	24.32**	67.67**	1.07	-1.14	20.69**	-17.36**	10.12**	-8.33**	-85.91**	31.15**	53.75**
Ricinolic acid content (%)	1.87**	-0.36	-1.41**	0.63**	0.63**	1.02**	0.63*	-1.46	-0.09	-1.59**	3.90**	-1.46**

* and ** = Significant at 5 and 1% level of significance, respectively

Among the six hybrids studied for seed yield/plant, significant positive better parent heterosis was recorded in the crosses PCS 124 x JH 118 (24.44%) and PCS 124 x JH 118 (13.82%). Low to medium positive heterobeltiosis was recorded for seed yield. For other biometrical traits like number of effective branches/plant, number of capsules/ main raceme, plant height and oleic acid content, low to medium heterosis was observed, whereas, for number of nodes/plant, 100-seed weight, oil content in seed, endosperm content, oil content in endosperm and effective length of primary raceme, very low heterosis was observed. For ricinoleic acid content almost all the crosses expressed low, but significant better parent heterosis. Heterosis of economic use in castor has been reported by several earlier workers, Patel (1996) observed significant and desirable heterobeltiosis. Tank *et al.* (2003) reported moderate heterosis for seed yield/plant, number of effective branches/plant and low heterosis for effective length of primary spike.

In general, crosses showing low heterobeltiosis effects also displayed high inbreeding depression for seed yield (Table 2). Further, the values obtained for heterobeltiosis were generally higher than the values for inbreeding depression. Only two crosses *viz*., cross PCS 124 x JH 118 and cross PCS 124 x JH 118 recorded significantly higher yield over better parent. It is interesting to note that these two crosses did not display significant inbreeding depression in F_2. The result suggested predominance of additive gene action in these crosses hence; these crosses have potential to throw heritable segregants in subsequent generation. Under this situation pedigree method could be advocated for crop improvement. The data revealed that heterotic hybrids for seed yield did not show significant heterobeltiosis for all the yield and quality components. In fact, appreciable heterosis for one or two characters manifested heterosis for seed yield. The results are in agreement with the findings of Golakia *et al*. (2004) who reported that inbreeding depression was significant for effective length of primary raceme, number of capsules on primary raceme, 100-seed weight and seed yield/plant.

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Influence of NPK fertilization on growth, yield and economics of sunflower (*Helianthus annuus* L.) varieties and hybrids

K ASHOK KUMAR, S NEELIMA, P MUNIRATHNAM AND A S R SARMA

Regional Agricultural Research Station, Nandyal-518 502, Andhra Pradesh

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ABSTRACT

A field experiment was conducted at Regional Agricultural Research Station, Nandyal, Andhra Pradesh during 2007 and 2009 to study the comparative assessment of hybrids over varieties grown under rainfed condition with different levels of fertilizers. The results revealed that application of 100 and 150% RDF produced large sized heads (12.8 and 12.9 cm, respectively) coupled with higher seed weight (5.2 g/100 seeds) lead to higher seed yields (921 and 863 kg/ha, respectively). The magnitude of seed yield increase with 100 and 150% RDF was 31.1 and 39.9%, respectively over control. Among the genotypes evaluated, significantly higher seed yield (906 kg/ha) was obtained with NDSH-1 followed by Sunbred (866 kg/ha). Application of 150% RDF produced higher net returns (₹10,301/ha) whereas the B:C ratio recorded with 150% RDF was equal to that of 100% RDF.

Keywords: Fertilizer levels, Hybrids, Sunflower, Varieties

Sunflower (*Helianthus annuus* L.) is one of the important edible oilseed crops cultivated in different parts of the world and has become the fourth most important oilseed crop in India. It is grown in an area of about 1.90 million hectares with a production of 1.25 million tonnes (Anonymous, 2010). Sunflower cultivation in India was started with varieties introduced from outside the country and subsequently the hybrids were developed and are being grown widely covering nearly 95% of the cultivated area. Generally, hybrids have higher yield potential compared to varieties. In recent years, a few high yielding varieties/populations were also released for cultivation in different parts of the country (Anonymous, 2008). Nevertheless, in some areas, farmers opined that some varieties/populations are as productive as hybrids. Further, Singh *et al.* (1999) reported that the sunflower hybrids require more nutrients than varieties. On the other hand, if the hybrids are not fertilized with optimum level of nutrients then the available soil nutrients may be greatly depleted. The present investigation was, therefore, taken up to study the comparative assessment of yield gain with hybrids over varieties grown under rainfed condition with different levels of fertilizer input.

MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Nandyal, Andhra Pradesh during 2007 and 2009. The soils were deep black cotton soils and slightly alkaline in nature with pH 8.2. The soil of the experimental site was low in available N (273 kg/ha), high in available P_2O_5 (68 kg/ha) and K_2O (475 kg/ha). The treatments comprised combination of four levels of fertilization (0, 50, 100 and 150 % recommended dose of NPK) and four sunflower genotypes (DRSF-108, DRSH-1, Sunbred and NDSH-1). The treatments were arranged in Randomized Block Design (Factorial) and replicated thrice. The recommended levels of fertilizers were 60:60:30 kg N, P_2O_5 and K_2O/ha. The crop was sown in June and September during 2007 and 2009, respectively. A spacing of 60 cm x 30 cm was adopted. Full dose of P and K along with half of N as per the treatment was applied as basal and the remaining half of N was top dressed at 35 days after sowing. Standard package of practices were followed in raising the crop. A total rainfall of 1233.0 and 603.0 mm was received during the crop period in 2007 and 2009, respectively. The crop was raised under rainfed condition in both the years of study. Data on seed yield was recorded after harvest and expressed on air dry basis.

RESULTS AND DISCUSSION

Growth parameters: Plant height at maturity was affected significantly by different levels of nitrogen, phosphorus and potassium over control. Maximum plant height recorded with 150% RDF (139.1 cm) which was statistically at par with 100% RDF (136.4 cm) but significantly superior over 50% RDF (117.3 cm) and control (104.9 cm). The same trend of increase in plant height due to fertilization was noticed by Malik *et al.* (2004). Among the genotypes tested, NDSH 1 and Sunbred (127.9 cm) recorded significantly higher plant height over DRSH 1 (122.3 cm) and DRSF 108 (119.6 cm). However, days taken to 50% flowering was not influenced by fertilization levels. NDSH 1 (57) and Sunbred (58) took less number of days to 50% flowering compared to DRSF 108 (60) and DRSH 1 (61).

Yield components and yield: Fertilizer treatments produced significantly higher head diameter than control. The plants in plot fertilized with 150 % RDF produced large sized heads (12.9 cm) but it was at par with all other fertilization treatments (100 and 50% RDF). These results are quite in line with the work of Osman *et al.* (1980) who reported that nitrogen alone or in combination with phosphorus and potash increased head diameter over control. All the hybrids *viz*., NDSH-1 (12.9 cm), Sunbred (12.6 cm) and DRSH-1 (12.60 cm) produced large sized heads but comparable with each other while the variety DRSF-108 (12.3 cm) produced small sized heads. However, all the genotypes tested were statistically at par with each other.

Significant increase in test weight was noticed with N, P and K fertilization over control. Application of 150 and 100% RDF produced significantly higher test weight (5.2 g) compared to 50% RDF (5.0 g) and control (4.3 g). However, genotypes did not differ significantly for test weight.

Significantly higher seed yield was obtained with 150% RDF (906 kg/ha) but remained statistically at par with 100% RDF (866 kg/ha). A perusal of the data furnished in Table 1 clearly indicates that large sized heads were produced with the application of 100% RDF (12.8 cm) and 150% RDF (12.9 cm) coupled with higher 100 seed weight (5.2 g) which in turn has resulted into higher seed yields. The magnitude of increase with 100% and 150% RDF was 31.1 and 39.9% respectively. Sunflower is a heavy feeder of nutrients and high yields need the application of larger doses of nutrients (Hegde, 1998). Among the genotypes tested, significantly higher seed yield (906 kg/ha) was obtained with NDSH-1 which was comparable with Sunbred (866 kg/ha). The variety DRSF-108 and the hybrid DRSH-1 produced significantly lower seed yields (665 and 749 kg/ha, respectively). The large sized heads with Sunbred and NDSH-1 greatly influenced the seed yield of sunflower. However, the interaction effect between different fertilizer levels and variety/hybrids was non significant for seed yield.

Table 1 Comparative assessment of yield gain from sunflower varieties/hybrids under different levels of fertilization (pooled data of two years)

Treatments	Plant height (cm)	Days to 50% flowering	Head diameter (cm)	100 seed weight (g)	Seed yield (kg/ha)	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
Fertilization level									
Control	104.9	59	12.0	4.3	658	15134	8000	7134	1.8
50% RDF	117.3	58	12.6	5.0	743	17089	8961	8128	1.9
100% RDF	136.4	58	12.8	5.2	863	19849	9921	9928	2.0
150% RDF	139.1	59	12.9	5.2	921	21183	10882	10301	2.0
SEm±	4.1	0.5	0.2	0.1	43.2	--	--	--	--
CD (P=0.05)	14.2	NS	0.6	0.3	150	--	--	--	--
Variety/Hybrid									
DRSF-108	119.6	60	12.3	4.9	665	15295	8900	6395	1.7
DRSH-1	122.3	61	12.6	4.9	749	17227	9440	7787	1.8
Sunbred	127.9	58	12.6	5.0	866	19918	9780	10138	2.0
NDSH-1	127.9	57	12.9	5.0	906	20838	9640	11198	2.2
SEm±	2.2	0.7	0.1	0.1	37	--	--	--	--
CD (P=0.05)	6.6	2.1	0.4	NS	107	--	--	--	--
Interaction					NS				

Economics: Though the application of 150% RDF produced higher gross returns (₹21,183/ha) and net returns (₹10,301/ha), the B:C ratio was equal (2.0) even with the application of 100% RDF. This is mainly due to reduction in cost of fertilizer with 100% RDF than with 150% RDF. The net returns obtained with 150% RDF were marginally higher (₹10,301/ha) than 100% RDF (₹ 9,928/ha). However, there was a substantial increase in net returns with 100 and 150% RDF (₹ 2794 and ₹ 3164/ha, respectively) over control which produced ₹7134/ha. Higher gross returns (₹20,838/ha), net returns (₹ 11,198/ha) and there by B:C ratio (2.2) were obtained with NDSH-1 and this was closely followed by Sunbred. The lower net returns (₹ 6395/ha) and B:C ratio (1.7) were recorded with DRSF-108.

Based on the present investigation, it can be concluded that application of 100% RDF could be sufficient for getting higher net returns in sunflower. Similarly, hybrids performed far better than the varieties in terms of seed yield and net returns.

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Effect of integrated nutrient management on seed yield and economics of sesame (*Sesamum indicum* L.) in assured rainfall zone of North Maharashtra

H S MAHAJAN, N A HIRVE[1] AND M R DESHMUKH[2]

Oilseeds Research Station, Jalgaon-425 001, Maharashtra

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ABSTRACT

Field experiments were conducted during *kharif* seasons of 2007, 2008 and 2009 on sesame cv. JLT-7 in deep black soil of Mamurabad farm, Oilseed Research Station, Jalgaon, Maharashtra to find out appropriate combination of organic and inorganic sources of nutrient with bio-inoculants. The organic sources (FYM, vermicompost and castor cake) were integrated with nitrogen fertilizer and biofertilizer (*Azospirillum* and Phosphorus solubilizing bacteria) and bioagents (*Trichoderma viride* and *Psuedomonas fluorescens*). The experimental result showed that, application of 75% recommended dose of N (37.5 kg/ha) along with 2.5 ton of Castor cake or FYM in combination with biofertilizer/bioinoclants was found to be not only promising for yield maximization but also for realizing higher returns under rainfed condition of North Maharashtra region.

Keywords: Bio-inoculants, Economics, Organic sources, Sesame

Sesame is one of the most important *kharif* oilseed crop cultivated in Maharashtra. It covers on area of 0.56 million ha (30.93% of country) with an annual production of 0.15 million tons and productivity of 268 kg/ha (Damodaram and Hegde, 2010). The yield of Maharashtra state is low as compared to national yield (354 kg/ha) and the main reason for low productivity in the state are its cultivation under rainfed condition with the use of negligible inputs, imbalance plant nutrition. Sesame responds very well to application of NPK fertilizer (Majumdar *et al.,* 1978) and organic manures (Mondal *et al.,* 1992). There is sufficient scope to increase the productivity of sesame with application of adequate quantity of fertilizer. The socio-economic status of farmer in sesame growing belt in the state is quite poor and farmers are unable to afford the use of costly agro inputs particularly fertilizer for increasing the productivity. Use of biofertilizer and organic manures are efficient alternative source of plant nutrition especially for nitrogen (Hegde, 1998). Therefore, an approach of integrated nutrient management (INM) appears to be promising for enhancing the productivity of sesame. The information pertaining to effect of inorganic, organic sources of nutrients and biofertilizer/bioinoculants [*Azospirillum,* Phosphorus solubilizing bacteria (PSB), *Trichoderma viride,* and *Psuedomonas fluorescens*] in combination with each other as well as in organic fertilizer on sesame crop is lacking. Hence, the present investigation was conducted.

[1] Krishi Vigyan Kendra, Mamurabad Farm, Jalgaon, Maharashtra
[2] Project Coordinating Unit (Sesame & Niger), J.N. Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh

MATERIALS AND METHODS

Field experiments were conducted during rainfed seasons of 2007, 2008 and 2009 on sesame cv. JLT-7 at Mamurabad farm of Oilseed Research Station, Jalgaon, Maharashtra. The soil of experimental plot was deep black, clayey in texture with pH 7.7 and low in organic carbon (0.43%), having available N 188.16 kg/ha, available P_2O_5 21.7 kg/ha and available K_2O 812 kg/ha. The crop was sown during first week of July in all the three year using seed rate of 5 kg/ha in 30 cm rows with a plant to plant spacing of 15 cm. The rainfall received during growing season was low in 2008 (454.8mm) while it was normal in 2007 (674.8 mm) and 2009 (746.4mm). Ten treatments including control were tried in randomized block design with three replications (Table 1). The treatments consist of combination of nitrogen level and organic manures *viz*., FYM, vermicompost and castor cake applied each @ 2.5 t/ha at sowing as per treatment combination. The application of bioinoculants i.e., *Azospirillum* (5kg/ha) + PSB (5 kg/ha) + *Trichoderma viride* (2.5 kg/ha) + *Psuedomonas fluorescens* (2.5 kg/ha) were applied as soil application and common to all treatment except control. The recommended dose of nitrogen (RDN) i.e., 50 kg/ha was applied in two equal split doses, at sowing and 30 days after sowing through urea. The data on seed yield were recorded in respective year and economics of treatments were worked out. Statistical analysis of the data was carried out using standard analysis of variance.

RESULTS AND DISCUSSION

Yield attributing character and seed yield: The sesame responded well to additional application of organic manures along with different level of nitrogen (Table 1). The application of 100% recommended dose of nitrogen (RDN) (50 kg N/ha) along with organic sources significantly increased plant height over 50% RDN with organic sources during 2007 as well as 2009. However, it was at par with 50% RDN with castor cake application in 2008. Number of branches/plant were increased with level of N application with organic sources, but it was found to be statistically nonsignificant for all growing season. The application of 75% and 100% RDN along with organic sources significantly increased number of capsules/plant and found to be at par with each other during all growing season. The application of 75% and 100% RDN along with organic sources increased plant height along with more number of branches and capsules/plant reflected in yield maximization on sesame.

The application of 100% RDN (50 kg N/ha) along with organic sources significantly increase yield over 50% RDN (25 kg N/ha) with vermicompost and FYM during all the years including their mean over the years (Table 1). The results obtained may be due to integration of chemical fertilizer along with organic manures which fulfill the nutrient requirement of the crop in the initial stage of crop growth. The uniform distribution of rainfall may accelerate the rate of decomposition and mineralization of organic sources. In the latter stage of crop growth, the release of nutrient from castor cake/vermicompst/FYM by soil organism favored to nutritional requirement, sustained sesame crop and thereby resulting in higher yields. These results corroborate the findings of other worker from their studies on inorganic and organic nutrient management from different location of the country (Tiwari *et al.,* 1995; Duhoon *et al.,* 2001; Narkhede *et al.,* 2001).

Table 1 Effect of integrated nutrient management on yield attributing characters and seed yield of sesame

Treatment	Plant height (cm)			No. of branches/plant			No. of capsules/plant			Seed yield (kg/ha)			
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	Mean
T_1 : 50% RDN*(25 kg N/ha) + FYM** (2.5 t/ha)	127	128	128	5	3	4	78	44	93	680	469	591	580
T_2 : 50% RDN (25 kg N/ha) +Vermicompost (2.5 t/ha)	127	127	126	4	3	4	75	44	84	666	448	510	541
T_3 : 50% RDN (25 kg N/ha) + Castor cake (2.5 t/ha)	128	130	127	4	4	4	75	42	89	697	592	552	614
T_4 : 75% RDN (37.5 kg N/ha) + FYM (2.5 t/ha)	133	131	129	4	4	4	77	47	91	788	588	669	682
T_5 : 75% RDN (37.5 kg N/ha) + Vermicompost (2.5 t/ha)	133	129	132	4	4	4	77	47	95	782	549	662	664
T_6 : 75% RDN (37.5 kg N/ha) + Castor cake (2.5 t/ha)	137	129	136	5	4	4	85	47	92	852	568	720	713
T_7 : 100% RDN (50 kg N/ha) + FYM (2.5 t/ha)	144	147	134	5	4	5	80	50	99	827	601	768	732
T_8 : 100% RDN (50 kg N/ha) + Vermicompost (2.5 t/ha)	145	147	135	5	4	4	83	49	97	810	587	730	709
T_9 : 100% RDN (50 kg N/ha) + Castor cake (2.5 t/ha)	147	148	137	5	4	5	86	51	101	890	625	778	764
T_{10} : Control (50 kg N/ha)	122	111	121	4	3	4	77	40	93	707	507	588	634
SEm ±	5.8	7.4	3.3	0.4	0.40	0.3	3.4	1.9	4.7	45.8	37.6	52.3	54.4
CD (P=0.05)	14.5	18.8	8.2	NS	NS	NS	8.8	4.9	11.6	136	111	156	163

*RDN = Recommended Dose of Nitrogen, ** FYM=Farm Yard Manure
Market price of sesame (₹/kg) = ₹ 37 for 2007, ₹ 50 for 2008 and ₹ 55 for 2009

The pooled seed yield data over the years indicated corresponding increase in sesame seed yield with increasing level of nitrogen (Table 1). Application of RDN with castor cake or FYM was significantly superior over rest of the treatment tested in the investigation with exception that 75% RDN was at par with RDN. These results are in close conformity with the findings of Mitra and Pal (1999) and Ahmad *et al.* (2001).

Economics: All the economic parameters viz., gross monetary return, net monetary return and B:C ratio in sesame were maximum with application of castor cake. However, these parameter recorded higher values with castor cake were being at par with FYM application at both 75% and 100% RDN application. Among the different level of N tested RDN with all organic sources recorded significantly higher values of gross monetary return and B:C ratio over rest of RDN treatments, with an exception of 75% RDN with castor cake as well as FYM (Table 2). This was mainly due to higher seed yield and lower cost of cultivation than vermicompost. Application of 75% RDF (NPK) along with FYM or mustard as one of remunerative and efficient integration is also reported in sesame by Barik and Fulmali (2011) from their investigation which confirms the result of the present study.

On the basis of the results obtained from the present study it could be conclude that, application of 75% RDN (37.5 kg/ha) to sesame either integrated with 2.5 ton of castor cake or FYM was more remunerative in assured rainfall zone of North Maharashtra region.

Table 2 Effect of integrated nutrient management on seed yield and economic analysis of sesame

Treatment	Cost of cultivation (₹/ha)				Net monetary return (₹/ha)			B:C Ratio		
	2007	2008	2009	Mean	2007	2008	2009	2007	2008	2009
T_1 : 50% RDN*(25 kg N/ha) + FYM** (2.5 t/ha)	11311	15361	18433	15035	9769	8089	14072	1.86	1.52	1.76
T_2 : 50% RDN (25 kg N/ha) +Vermicompost (2.5 t/ha)	15381	19182	23018	19194	5265	3168	5032	1.34	1.17	1.55
T_3 : 50% RDN (25 kg N/ha) + Castor cake (2.5 t/ha)	11438	15683	18820	15314	10169	8917	11655	1.89	1.56	1.62
T_4 : 75% RDN (37.5 kg N/ha) + FYM (2.5 t/ha)	11449	16425	19710	15861	12979	12475	17103	2.13	1.80	1.87
T_5 : 75% RDN (37.5 kg N/ha) + Vermicompost (2.5 t/ha)	15519	20249	25000	20256	8723	7201	11410	1.56	1.36	1.46
T_6 : 75% RDN (37.5 kg N/ha) + Castor cake (2.5 t/ha)	11576	16467	19760	15934	14836	11933	19822	2.28	1.73	2.00
T_7 : 100% RDN (50 kg N/ha) + FYM (2.5 t/ha)	11589	16761	20113	16154	14048	13289	22109	2.21	1.79	2.10
T_8 : 100% RDN (50 kg N/ha) + Vermicompost (2.5 t/ha)	15659	20714	24857	20410	9451	8636	15311	1.60	1.42	1.62
T_9 : 100% RDN (50 kg N/ha) + Castor cake (2.5 t/ha)	11716	17092	20510	16439	15874	14158	22262	2.35	1.82	2.10
T_{10} : Control (50 kg N/ha)	10000	11396	16745	12714	11917	11396	21095	2.19	1.67	1.89
SEm ±	-	-	-	-	1333.8	1809.1	2882.3	0.14	0.14	0.18
CD (P=0.05)	-	-	-	-	3955.3	5371.2	8560.1	0.42	0.42	NS

*RDN = Recommended Dose of Nitrogen, ** FYM=Farm Yard Manure
Market price of sesame (₹/kg) = ₹ 37 for 2007, ₹ 50 for 2008 and ₹ 55 for 2009

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Weed management in irrigated castor (*Ricinus communis* L.) through herbicides

ISHWAR SINGH, M S RATHORE, M L MEHRIYA[1], R S CHAWRA AND M S CHANDAWAT

Agricultural Research Station, S.K. Rajasthan Agricultural University, Mandor, Jodhpur-342 304, Rajasthan

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ABSTRACT

A field experiment was conducted to find out most suitable and cost effective weed management practice for irrigated castor grown on the light textured soils of Western Rajasthan. Ten treatment combinations comprising of four herbicides with or without inter culture along with weedy, weed free check and farmers practice were compared in Randomized Block Design with three replications. Three season's pooled results revealed that pre-emergence application of pendimethalin @ 1.0 kg/ha + inter culture 40 days after sowing (DAS) produced maximum seed yield of 3652 kg/ha with weed control efficiency of 96.4% besides maximum net return of ₹ 74,464/ha and B:C ratio of 3.78. The weed competition index was also observed to be lowest in this treatment (0.4%). However, pendimethalin @ 1.0 kg/ha (pre-emergence) + inter culture 40 DAS, fluchloralin @ 1.0 kg/ha (pre-plant incorporation) + inter culture 40 DAS and weed free plots remained at par with each other. Application of either quizalofop-ethyl or fenoxaprop-p-ethyl @ 50 g/ha at 25 DAS also brought down the weed stand and weed drymatter significantly compared to weedy check though the extent of control was not equivalent to weed free plots. This treatment (pre-emergence application of pendimethalin @ 1.0 kg/ha + inter culture 40 DAS) validated at five sites in farmer's fields recorded higher seed yield and net return compared to farmer's practice of weed control.

Keywords: Castor, Fenoxaprop-p-ethyl, Fluchloralin, Pendimethalin, Quizalofos-ethyl, Weed control

Castor (*Ricinus communis* L.) is an important non edible oilseed crop of the arid and semi arid regions of India. Castor oil is used for deriving products like dyes, detergents, paints, varnish, grease, jet-engine lubricants and cosmetics. Castor wax, produced by the hydrogenation of pure castor oil, is used in polishes, electrical condensers, carbon paper and as a solid lubricant. India is the world leader having maximum area, production and productivity (14.69 lakh ha, 23.39 lakh tonnes and 1592 kg/ha, respectively) and meets about 90% of the world's requirement of castor oil. India is earning about ₹ 2253 crores of foreign exchange through export of castor oil and its derivatives with high level of demand rising annually at 3-5%/annum (Hegde, 2010). Due to increasing industrial demand and high profit, the crop is spreading in the Rajasthan state at a very fast pace. The productivity of castor grown in 2.91 lakh ha area in the state is only 1408 kg/ha (Anonymous, 2012).

Weed infestation is one of the constraints limiting in realizing potential production of castor. Prevalence of high temperature coupled with high relative humidity and frequent rainfall favours luxuriant weed growth which not only smother crop by restricting its growth particularly during early stage of crop growth but also offers severe weed competition for essential natural and manmade resources during the entire crop season. Castor being a wider spaced crop with slow initial growth makes it vulnerable to weed competition. A period of 40 days ranging between 20-60 days after sowing is critical for weed management in castor. Though the conventional method of weed control is very effective but it is expensive, labour intensive & time consuming and most often protracted rains do not allow or delay the weeding during the critical period. Labour scarcity is another big hurdle in this context. This necessitate for an alternative cost effective economically viable weed management practice that can serve as a substitute for manual weeding. Information regarding herbicidal weed control in castor under irrigated condition is lacking. In view of the above rationale, an attempt has been made to work out an effective weed management strategy based on herbicides applied alone or in combination with inter culture for the crop grown under irrigated condition in Arid Western Plain Zone of Rajasthan.

MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Station, Mandor (Jodhpur) for three consecutive seasons from 2008-09 to 2010-11. The soil of the site was loamy sand in texture with low available nitrogen (159 kg/ha), medium available phosphorus (32 kg/ha) and potash (295 kg/ha). Ten treatments comprising of pre-plant incorporation (PPI) of fluchloralin @ 1.0 kg/ha, fluchloralin @ 1.0 kg/ha (PPI) + inter culture 40 DAS, pre-emergence (PE) application of pendimethalin @ 1.0 kg/ha, pendimethalin @ 1.0 kg/ha (PE) + inter culture 40 DAS, intercropping castor with groundnut in 1:4 ratio, quizalofop-ethyl @ 50 g/ha 25 DAS, fenoxaprop-p-ethyl @

E-mail: isingh_1963@yahoo.com
[1] Asst. Professor, College of Agriculture, Mandor, Jodhpur, Rajasthan

50 g/ha 25 DAS, farmer's practice (weeding 25 DAS followed by two inter culture at 45 and 60 DAS), weed free (three hand weeding at 20, 40 and 60 DAS) and weedy check were compared in Randomized Block Design with three replications. All the herbicide treatments were applied through water solution @ 600 l/ha using conventional knap sack sprayer with flat fan nozzle.

The gross plot size was 7.2 m x 6.0 m. Castor hybrid RHC-1 was sown in the 2nd fortnight of July every season at 120 cm row-to-row and 60 cm plant-to-plant spacing through dibbling. Half the nitrogen (40 kg/ha through urea and DAP), full phosphorus (50 kg/ha through DAP) and sulphur (20 kg/ha through gypsum) were applied as basal dose while opening furrows. Remaining half nitrogen (40 kg/ha) was applied through top dressing of urea in two equal splits at 35 and 90 DAS either with rain or irrigation water. The total rainfall received during the crop span in season 2008, 2009 and 2010 was 183, 75 and 482 mm, respectively. The crop was initially raised as rain fed crop but after withdrawal of rain, eight irrigations were given at 15-20 days interval. Spikes were harvested in five pickings at 25-30 days interval starting from 100 DAS. Adequate plant protection measures were taken to keep the insect pest under check.

Weed density and weed drymatter were recorded with help of a quadrant placed randomly at two spots in the respective plots. Weed seedlings within this quadrant were counted, and the efficacy of the different weed control treatments was evaluated by comparing the density with the weedy check plot. The data on weed population were subject to square root transformation prior to statistical analysis. Weeds were cut to the ground level, washed with tap water, sun dried, and then oven dried at 70°C for 48 h, and then weighed. B:C ratio was worked out by dividing gross return by cost of the treatment. Weed flora in the experimental field and on farm validation sites consisted of grasses *Cynodon dactylon* (L.) Pers, *Cenchrus ciliarus,* sedges- *Cyperus rotundus* L. and broad leaved weeds *Amaranthus viridis* L., *Digera arvensis* Forsk, *Celotia argentea* L., *Setaria glauca, Amaranthus spinosis* L., *Trianthema portulacstrum* L., *Boerharia diffusa* L. etc.

RESULTS AND DISCUSSION

Weed growth and bio mass: Broad leaved weeds were dominant weed flora in the field during all the three seasons of experimentation. During all the years, different weed control treatments including herbicidal weed control practices applied either alone or in combination with hand weeding significantly reduced the species wise weed population and weed dry weight compared to weedy check (Table 1). Sole application of either fluchloralin (PPI) or pendimethalin (PE) @ 1.0 kg/ha proved to be significantly superior to weedy check. Integration of one hand weeding 40 DAS with either of these herbicides resulted in significant reduction of weed density and weed biomass when compared with respective sole application of these herbicides. Improvement in weed control efficiency to the tune of 22 to 23% was recorded when one hand weeding was super imposed with sole application of fluchloralin (PPI) and pendimethalin (PE). The lowest weed density (2.6/m^2), minimum weed dry weight (34 g/m^2) and the highest weed control efficiency (96.4%) was recorded with pre-emergence application of pendimethalin @ 1 kg/ha super imposed with hand weeding 40 DAS (Table 1). Manickam *et al.* (2009) reported pre-emergence application of metolachlor @ 1.0 kg/ha followed by weeding 40 DAS significantly increased the yield of *kharif* castor. Intercropping of castor with groundnut in 1:4 ratio recorded weed count and weed drymatter of 5.8 and 172 g/m^2 as against 10 and 956/m^2 in un weeded check. Intercropping of castor and groundnut in 1:4 row ratio covered more surface area resulting suppressed weed growth but it was not most effective practice. Application of either quizalofop-ethyl or fenoxaprop-p-ethyl @ 50 g/ha 25 DAS also brought down the weed stand and weed drymatter significantly compared to weedy check though the extent of control was not at par with weed free plots. These herbicides are selective thus killed grasses only. High density of broad leaf weeds and their poor control in the plots treated with Quizalofop-ethyl or fenoxaprop-p-ethyl increased weed competition and reduced weed control efficiency. Broad leaved weed density of 6.0 and 5.6/m^2 with weed bio mass of 533 and 492 g/m^2, still persisted in the plots treated with Quizalofop-ethyl and fenoxaprop-p-ethyl applied @ 50 g/ha 25 DAS, respectively as against weed density of 1.6 and 2.0 and weed bio mass of 34 and 56 g/m^2 in pendimethalin (PE) + inter culture 40 DAS and fluchloralin (PPI) + inter culture 40 DAS treated plots. Dungarwal *et al.* (2002) reported that pre-emergence application of alachlor @ 2.0 kg/ha supplemented with hoeing 40 days DAS showed remarkable effect on reducing weed density (95%) and weed drymatter (89%) in castor.

Growth, yield attributes and seed yield: The data on growth attributes (plant height and number of nodes up to primary raceme), yield attributing characters (100-seed weight, number of spikes/plant, primary raceme length) and oil content for the three seasons were pooled analysed. In weedy check plots, the plant stand was significantly reduced by 6.3 and 6.5 thousand/ha, respectively compared to weed free and pendimethalin + inter culture 40 DAS treated plots. In weedy check plot, presence of weeds suppressed the crop growth to a maximum extent, even killed the crop plant due to smothering effect resulting in significant reduction in plant stand. Crop plants in weedy check plot became long, thin with elongated internodes. It was due to increased competition for sun light, space and moisture. Un weeded control resulted in lowest values of all the growth and yield attributing characters (Table 2).

Table 1 Weed competition index, weed dry weight, weed control efficiency and weed count of castor as influenced by weed management practices (Pooled data of 2008-09, 2009-10 and 2010-11)

Treatment	Weed competition index (%)	Weed dry weight (g/m^2) at harvest	Weed control efficiency (%)	Category wise weed count ($No./m^2$) at harvest*			Total weed count ($No./m^2$) at harvest*
				Grasses	Sedges	Broad leaf	
Fluchloralin @ 1.0 kg/ha (PPI[1])	18.3	272	71.5	2.1 (4.1)	2.7 (6.9)	6.1 (16.6)	5.3 (27.6)
Fluchloralin @ 1.0 kg/ha (PPI) + weeding 40 DAS	1.2	56	94.1	1.7 (2.5)	1.6 (2.1)	2.0 (3.7)	3.0 (8.3)
Pendimethalin (PE[2]) @ 1.0 kg/ha	20.5	256	73.2	1.8 (2.6)	2.0 (3.5)	3.6 (12.6)	4.4 (18.7)
Pendimethalin (PE) @ 1.0 kg/ha + inter culture 40 DAS	0.4	34	96.4	1.5 (1.7)	1.7 (2.4)	1.6 (2.1)	2.6 (6.2)
Intercropping (castor + groundnut at 1:4 ratio)	20.5	172	82.0	1.6 (2.0)	2.6 (6.5)	5.0 (24.8)	5.8 (33.3)
Quizalofop-ethyl @ 50 g/ha 25 DAS	29.0	533	44.2	1.3 (1.3)	2.0 (3.7)	6.0 (35.4)	6.4 (40.4)
Fenoxa prop-p-ethyl @ 50 g/ha 25 DAS	43.7	492	48.6	1.7 (2.4)	2.6 (6.4)	5.6 (30.5)	6.3 (39.3)
Farmer's practice (weeding 25 DAS+ interculture 45, 60 DAS)	0.5	25	97.4	2.3 (4.6)	1.9 (1.4)	1.9 (3.4)	3.1 (9.4)
Weed free check	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Weedy check	69.5	956	0.0	2.6 (6.4)	2.9 (8.2)	9.3 (86.4)	10.0 (101.0)
SEm ±	1.0	32	2.6	0.02	0.1	0.6	7.0
CD (P=0.05)	3.1	95	7.6	0.06	0.3	1.8	2.15

[1]Pre plant incorporation, [2]Pre emergence,
*Figures in parentheses are the means of original values. Data subjected to square root transformation

Table 2 Growth, yield attributes, oil (%), seed yield and economics of castor as influenced by weed management practices (Pooled data of 2008-09, 2009-10 and 2010-11)

Treatment	Plant stand ('000/ha)	Plant height upto primary raceme (cm)	No. of nodes up to primary raceme	Primary raceme length (cm)	No. of spikes/ plant	Oil (%)	100- seed weight (g)	Seed yield (kg/ha)	Net return** (₹/ha)	B:C ratio
Fluchloralin @ 1.0 kg/ha (PPI[1])	18.4	70	16	50.3	13.7	50.2	26.2	2996	56665	3.25
Fluchloralin @ 1.0 kg/ha (PPI) + weeding 40 DAS	18.2	66	15	52.4	16.8	49.5	28.2	3621	73141	3.76
Pendimethalin @ 1.0 kg/ha (PE[2])	17.3	71	17	50.4	14.4	49.8	25.9	2913	55811	3.18
Pendimethalin @ 1.0 kg/ha (PE) + interculture 40 DAS	18.3	66	15	54.9	16.6	50.1	27.9	3652	74464	3.78
Intercropping castor + groundnut (1:4)	17.9	70	16	48.5	13.9	49.7	25.1	2913 (308)*	56780	2.92
Quizalofop-ethyl @ 50 g/ha 25 DAS	16.0	76	17	44.6	12.5	50.7	25.5	2701	53962	3.16
Fenoxa prop-p-ethyl @ 50 g/ha 25 DAS	15.7	76	18	49.2	11.2	50.2	24.7	2575	49220	2.94
Farmer's practice (weeding 25 DAS+ inter culture 45, 60 DAS)	17.7	67	17	55.2	16.7	49.2	27.2	3646	70464	3.73
Weed free check	18.1	67	16	56.6	18.0	50.7	28.8	3665	68526	3.75
Weedy check	11.8	73	19	35.9	7.2	47.9	23.0	1119	7682	1.30
SEm ±	0.6	2.2	0.9	2.2	1.2	0.5	0.6	188	810	--
CD (P=0.05)	1.5	6.5	2.9	6.9	3.5	1.4	2.0	562	2459	--

[1]Pre-plant incorporation, [2] Pre-emergence, *seed yield of groundnut, ** Average sale rate of castor bean ₹ 26.67/kg

There was significant improvement in primary raceme length, 100-seed weight and no. of spikes/plant by 52.9, 21.3 and 130.6%, respectively due to pendimethalin applied at 1.0 kg/ha (PE) + inter culture 40 DAS compared to weedy check. Pendimethalin at 1.0 kg/ha (PE) applied without inter culture was less effective as it improved these traits by 40.4, 12.6, and 100.0% only, respectively. Longer weed free period prevailed under the treatment where pendimethalin was super imposed with interculture 40 DAS, which in turn increased the yield attributes and decreased the drymatter production and population of weeds. Clean condition prevailed under pendimethalin at 1.0 kg/ha (PE) + inter culture 40 DAS also influenced oil per cent in seed by 2.2% compared to weedy check plot.

Pendimethalin applied @ 1.0 kg/ha (PE) + weeding 40 DAS produced maximum seed yield of 3652 kg/ha with 25.4 and 21.9% superiority over pendimethalin and fluchloralin applied at 1.0 kg/ha alone, respectively. This treatment was found to be at par with weed free season long and farmer's practice of weeding 25 DAS + two inter culture at 45 and 60 DAS. Integration of hand weeding 40 DAS along with pre-emergence application of herbicide provided better control of weeds for longer crop growth period resulting in better yield advantage compared to sole application of herbicides. Dungarwal *et al.* (2002) reported that effectiveness of pre-emergence application of pendimethalin (1.0 kg/ha) was improved greatly when it was applied in combination with hoeing 40 DAS in castor.

Broad leaved weeds were not controlled fully in Quizalofop-ethyl and fenoxaprop-p-ethyl (50 g/ha at 25 DAS) treated plots hence they were proven inferior to pendimethalin @ 1.0 kg/ha (PE) + weeding 40 DAS. However, these treatments significantly increased seed yield by 1582 and 1456 kg/ha over weedy check plot, respectively. Respective increase in seed yield due to pendimethalin @ 1.0 kg/ha (PE) + inter culture 40 DAS was 2533 kg/ha. High density of broad leaved weed at the experimental site and their poor control with application of Quizalofop-ethyl and fenoxaprop-p-ethyl (50 g/ha 25 DAS) was the strong reason behind poor performance of these herbicides. Intercropping of castor ground nut in 1:4 ratio was proven better over weedy check plot but this treatment failed to smother weeds to a fullest extent, hence the yield level in this treatment was significantly low compared to weed free plots.

Seed yield of castor was negatively correlated with the drymatter of weed. The seed yield decreased exponentially as the weed drymatter increased and the weeds accounted for three fold reduction in yield of castor.

Economics: Implication of any of the weed management practice resulted in better monetary return when compared with weedy check. Unweeded control culminated in lowest net returns (₹7,682/ha) and B:C ratio (1.30:1). Pendimethalin at 1.0 kg/ha (PE) + inter culture recorded significantly higher net return of ₹ 74,464/ha besides higher B:C ratio of 3.78 than other treatments but it was at par with fluchloralin at 1.0 kg/ha (PE) + inter culture (₹73,141/ha; 3.76). The net return recorded with these two treatments were higher over weedy check by ₹ 66,782 and ₹ 65,459/ha, respectively. Increased cost of production due to engagement of more labourer in farmer's practice grown crop for one weeding 25 DAS + two inter culture at 45 and 60 DAS resulted in comparatively low net return and B:C ratio when compared with their respective application of herbicides (pendimethalin and fluchloralin) + inter culture (Table 2).

Validation: The research results were further validated through farmer's participatory approach by conducting on farm trials under field conditions (Table 3). Mean of five sites (1000 m^2 treated plot/farmer's practice) at farmer's fields by the Agronomist, Adaptive Trials Centre, Rampura (Jodhpur) during 2010-11 revealed that pendimethalin at 1.0 kg/ha (PE) + inter culture 40 DAS recorded additional seed yield and net return of 200 kg/ha and ₹ 6,300/ha, respectively over farmers practice of one weeding and two inter culture.

Table 3 Seed yield and net return of castor as influenced by weed management through herbicide at farmer’s fields in Tehsil-Osian, District-Jodhpur (Mean of five sites, season: 2010-11)

Treatment	Seed yield (kg/ha)	Net return (₹/ha)
Pendimethalin at 1.0 kg/ha (PE) + inter culture 40 DAS	2100	34500
Farmer’s practice (weeding 25 DAS followed by two inter culture at 45 and 60 DAS)	1900	28200

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Impact of mobile phone based agro-advisories on knowledge of sunflower (*Helianthus annuus* L.) farmers'

G D S KUMAR, M PADMAIAH, K ALIVELU AND P MADHURI

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

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ABSTRACT

The productivity of *rabi* sunflower (*Helianthus annuus* L.) is low in Andhra Pradesh (892 kg/ha). In order to achieve higher productivity of sunflower, farmers need to access a wide range of information related to production technologies, post-harvest processes, remunerative markets, credit and weather. The increasing penetration of mobile phone networks and handsets in India presents an opportunity to make useful information more widely available and plays a significant role in technology transfer. This study was conducted with sunflower farmers of Mahaboobnagar district, Andhra Pradesh, India with the objectives of assessing the farmers preferred extension delivery methods, their needs and perceptions of use of mobile phones and the gain in knowledge on sunflower production technologies due to mobile phones. The knowledge scores showed significant differences between pre- and post-dissemination of messages over mobile phones, which indicated that substantial improvement in knowledge, is possible with the use of mobile phones as source of knowledge access.

Keywords: Agro-advisories, Dissemination, Oilseeds, Impact, SMSs, Text messages

Oilseed crops occupy 14% of gross cropped area of the country. These are cultivated in an area of 26.48 m. ha, with a production of 30.01 m. t (Directorate of Economics and Statistics, 2012). Oilseeds account for 1.4% of gross domestic product and 8% of value of all agricultural products. The *per capita* consumption of vegetable oil is rising continuously and is 14.2 kg/year in 2011-12 and would be around 16.38 kg/year by 2020. At present, the oilseeds production in India is not meeting the local demands and heavily dependent on imports. The reasons for low productivity are many and one of them is lack of access to knowledge on oilseed cultivation. To meet the challenges posed through huge demand for vegetable oils, the productivity has to be increased substantially. In Andhra Pradesh the productivity of *rabi* sunflower (*Helianthus annuus* L.) is around 892 kg/ha. The frontline demonstrations conducted in farmers fields indicated that the seed yield can be improved up to 1356 kg/ha (51% increase) (Kumar and Varaprasad, 2012) in sunflower. In order to achieve productivity improvement in sunflower, farmers need to access a wide range of information related to production technologies, post-harvest processes, remunerative markets, credit and weather. The National Sample Survey Organization results indicate that the main sources of information to farmers till today are neighbors, input dealers, radio, TV, news paper and extension worker.

The information and communication technologies (ICTs) play an important role in their endeavor of reaching the unreached farmers. The increasing penetration of mobile phone networks and handsets in India presents an opportunity to make useful information more widely available. The typical ICT tool *viz*., mobile phone with a subscriber base of more than 920 million and overall tele-density of 61.38 may play significant role in technology transfer. The studies conducted on the impact of mobile phone based dissemination in many countries indicted that adoption of mobile phones by fishermen and wholesalers was associated with a dramatic reduction in price dispersion, the complete elimination of waste, and near-perfect adherence to the law of one price. Both consumer and producer welfare increased (Jenson, 2007). Among the modern information and communication tools (ICTs) mobile telephony has been widely accepted mode of delivering information not only in India but also in other South Asian and African countries (Mittal, 2011). Mobile phone helps in accessing to valuable information on far away commodities. Mobile phone coverage and adoption have had positive impacts on agricultural and labor market efficiency and welfare in certain countries (Aker and Mibiti, 2010).

The present study was conducted with sunflower farmers of Mahaboobnagar district, Andhra Pradesh, with the objectives of assessing the farmers preferred extension delivery methods, their needs and perceptions of use of mobile phones and the gain in knowledge on sunflower production technologies due to mobile phones.

MATERIALS AND METHODS

The study used an expost facto and experimental designs for survey and knowledge dissemination, respectively. The villages were selected based on the highest area under sunflower and 120 registered respondents were selected by random sampling method. A scale was designed to measure farmers' perceptions of use of mobile phones. The scale consisted of 13 items and the responses were recorded on a five point continuum with scores 'strongly agree' = 5, agree = 4, undecided = 3, disagree = 2 and strongly disagree = 1. Before the start of the *rabi* season, (July-September, 2011) interviews were conducted with farmers to assess their level of knowledge. During *rabi,* 2011-12, knowledge on sunflower production technologies was disseminated through text and audio messages. The SMSs were sent to farmers in regional language (telugu) through National Informatics Centre server and the audio messages were sent in regional language through IFFCO Kisan Sanchar Limited. The text and audio messages were disseminated four times a week during the season. After the end of the season during March-April, 2012, the knowledge of farmers was assessed with the help of semi-structured telephone and personal interviews. The details of text and audio messages are as follows:

Items	Text messages	Audio messages	No. of farmers
Pre-sowing	8	6	120
Sowing and production	15	12	120
Plant protection	8	6	120
Harvest and post harvest management	5	4	120
Total	36	28	-

An interview schedule was developed and validated by field data. SAS software was used to analyze descriptive statistics such as frequency, mean, per cent and paired t test. McNemar test was used to test the effectiveness of mobile phone based dissemination (pre- and post-) as the data is mostly at nominal level of measurement.

RESULTS AND DISCUSSION

The results showed that majority of farmers (95.8%) preferred personal contacts followed by exposure visits to institutions (93.3%) and training by research organizations (91.7%). More than 70% of farmers preferred mobile phones as an extension delivery method. Meetings were the least preferred extension methods for the farmers (Table 1). Venkattakumar and Padmaiah (2012) reported that television, FLD farmers, family members, researcher/ scientists, progressive farmers (*Adarsha Rythu*) and neighbours were the major sources of information for sunflower farmers. Farouque and Takeya (2009) reported that farm and home visit, neighbors, relatives/friends, result demonstration, field day, farmer field school, folk song, film and poster were the most preferred methods by small and marginal farmers. The medium and large categories of farmers, preferred mobile phones, office call, method demonstration, tour/excursions, group meetings, newspaper and television. Ammani *et al.* (2011) reported that T & V system is the most preferred (86% of respondents) extension delivery method followed by radio and television (23%), printed media (4%) and none of the farmers preferred mobile phones. These findings imply that farmers preferred diverse and multiple extension delivery methods.

Table 1 Farmers' preferred extension delivery methods

Method	%	Rank
Personal contact	95.8	I
On-farm demonstrations	16.7	XII
Local educational meetings	33.3	IX
Mandal educational meetings	16.7	XII
District educational meetings	8.3	XIII
News and reports through farm media	66.7	VI
Phone help lines	20.8	XI
Printed literature (bulletins/folders)	50.0	VII
Training by farm input dealers	41.7	VIII
Video films	25.0	X
Training by government departments	83.3	IV
Training by research organizations	91.7	III
Exposure visits to research farms	93.3	II
Exposure visits to successful farmers' fields	91.7	III
Rythu sadassu	25.0	X
Mobile phones	70.8	V

The data on farmers' perceptions of use of mobile phones indicated that farmers strongly agreed to the utility of mobile phones in networking with other farmers, scientists, extension workers and development personal (4.85), in getting useful, timely and basic information related to markets (4.50), weather (4.45), availability of inputs (4.02) and technical information on agriculture (3.95). They disagreed that use of mobile phones are costly and not affordable (1.30) and preferred over personal contacts (1.45) (Table 2).

The information needs of the sampled farmers were high for improved cultivars (86.7%), market prices (91.7%) and weather (83.3%), whereas, the information need was low for seed treatment and method of sowing (62.5% each), water management (45.8%), fertilizer management (50.0%), manual weed management (70.8%), herbicide application (90.0%), micro nutrient management (80.0), harvesting (84.2%), post-harvest management (82.5%) and farm implements (62.5%) (Table 3). Mittal *et al.* (2010) reported that information regarding seeds is the most frequently accessed information by farmers followed by mandi prices, plant protection and fertilizer application.

Table 2 Farmers' perceptions of use of mobile phones

Statement	Score
Entertainment purpose	3.62
Useful for social interactions	4.14
Costly and are not affordable	1.30
Useful in getting timely and needful information	4.28
Helps in getting basic information	4.50
Plays an important role in networking	4.85
Helpful in getting advance information on weather (rains)	4.45
Getting technical information on agriculture	3.95
Market prices	4.50
Enhancing the knowledge of farmers	3.52
Information on meetings and other extension related activities	3.54
Availability of seeds, fertilizers and chemicals	4.02
Preferred over personal contacts	1.45

Interpretive scales: 4.26-5.00 = strongly agree; 3.26-4.25 = agree; 2.26-3.25 = undecided; 1.26-2.25 = disagree; 1.25 or less = strongly disagree

The overall mean knowledge scores pre-dissemination (8.47) and post-dissemination (15.39) showed improvement, which was highly significant (t = 24.79). Significant improvements were observed in all individual knowledge items post-dissemination as compared to pre-dissemination of messages over mobile phones (Table 4).

Table 3 Information needs of oilseed growers

Information need	Number of respondents		
	High	Medium	Low
Cropping systems	82 (68.3)*	30 (25.0)	8 (6.7)
Improved cultivars	104 (86.7)	16 (13.3)	0
Seed treatment	20 (16.7)	25 (20.8)	75 (62.5)
Method of sowing	25 (20.8)	20 (16.7)	75 (62.5)
Irrigation and water management	45 (37.5)	20 (16.7)	55 (45.8)
Fertilizer management	35 (29.2)	25 (20.8)	60 (50.0)
Manual weed management	10 (8.3)	25 (20.8)	85 (70.8)
Herbicide application	5 (4.2)	7 (5.8)	108 (90.0)
Insect pest management	48 (40.0)	56 (46.7)	16 (13.3)
Disease management	65 (54.2)	51 (42.5)	4 (3.3)
Micro-nutrient management	6 (5.0)	18 (15.0)	96 (80.0)
Harvesting	7 (5.80	12 (10.0)	101 (84.2)
Post harvest management	8 (6.7)	13 (10.8)	99 (82.5)
Market prices	110 (91.7)	10 (8.3)	0
Weather forecast	100 (83.3)	20 (16.7)	0
Farm implements	15 (12.5)	30 (25.0)	75 (62.5)

*Figures in parentheses are percentages

Table 4 Farmers' knowledge pre- and post- dissemination of messages over mobile phones

Items	Farmers' knowledge (frequency and %)		Simple kappa coefficient	Mc Nemer test statistic
	Pre-	Post-		
Type of soils	64 (53.3)	81 (67.5)	0.31	35*
Preparatory cultivation	72 (60.0)	89 (74.2)	0.69	17*
Recommended cultivars	29 (24.2)	85 (70.8)	0.23	56*
Optimum time of sowing	83 (69.2)	91 (75.8)	0.67	4**
Recommended seed rate	28 (23.3)	76 (63.3)	0.30	48*
Recommended spacing	30 (25.0)	87 (72.5)	0.23	56*
Seed treatment	33 (27.5)	87 (72.5)	0.25	54*
Recommended fertilizers	43 (35.8)	89 (74.2)	0.33	46*
Time of application	31 (25.8)	88 (73.3)	0.22	57*
Application of S	13 (10.8)	48 (40.0)	0.31	35*
Application B	18 (15.0)	45 (37.5)	0.45	27*
Application Zn	12 (10.0)	35 (29.2)	0.43	23*
Chemical weed control	37 (30.8)	45 (37.5)	0.85	7*
Manual weed control	78 (65.0)	104 (86.7)	0.44	26*
Thinning	25 (20.8)	79 (65.8)	0.24	54*
Critical stages of moisture stress	64 (53.3)	75 (62.8)	0.81	11*
Management of insect pests	62 (51.7)	108 (90.0)	0.21	46*
Management of diseases	63 (52.5)	85 (70.8)	0.63	22*
Application of biological control agents	39 (32.5)	80 (66.7)	0.39	41*
Supplementary pollination methods	37 (30.8)	91 (75.8)	0.25	54*
Optimum time of harvesting	83 (69.2)	99 (82.5)	0.47	10.7*
Mechanical harvesting	24 (20.0)	88 (73.3)	0.17	63*
Sunflower thalamus as animal feed	49 (40.8)	92 (76.7)	0.35	43*

Figures in parentheses are percentages; * significant at < 0.01 level of probability ; ** significant at < 0.05 level of probability

The McNemer test values showed that maximum number of farmers gained knowledge on mechanical harvesting (63), followed by timely application of fertilizers (57), improved cultivars and recommended spacing (56 each), thinning, seed treatment and supplementary pollination (54 each). Labour scarcity in villages forced the farmers to look for alternate approaches such as mechanization for timely operations, which resulted in their interest and gain in knowledge. Farmers showed interest in improved cultivars and simple and 'low-cost/ no-cost' agronomic practices such as spacing and thinning which resulted in gain in knowledge. Less number of farmers gained knowledge of optimum time of sowing (4), chemical weed control (7), optimum time of harvesting (10.5), critical stages of moisture stress (11) and preparatory cultivation (17) as the sampled farmers already know these aspects. Kumar and Padmaiah (2012) reported significant improvements in knowledge of castor growers due to mobile based agro-advisories. Pawan Kumar (2011) reported that the information obtained through mobile phones improved soil health, which resulted in increased agricultural productivity and farm income. More than 75% of the farmers view mobile phone assisted services useful, the amount and quality of the services and the speed of services delivery have been improved significantly as a result of mobile phone intervention (Xiaolan Fu and Shaheen Akter, 2012). This clearly indicates the effect of mobile based dissemination in improving the knowledge of farmers.

Mobile phones can play an important role of creating awareness and increasing knowledge about improved technologies such as new cultivars, efficient management of weeds and insect pests, timely harvesting of the crop and value addition. Mobile phones are clearly not a substitute for human intermediation and the limits of stand-alone ICT initiatives should be clearly understood. Mobile based communication cannot solve the underlying institutional bottlenecks that constrain the extension agencies from interacting with farmers.

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Impact of sunflower (*Helianthus annuus* L.) frontline demonstrations in Akola district of Maharashtra

R VENKATTAKUMAR, M PADMAIAH[1], C SARADA[1], A M MAHAJAN[2], M K MOON[2] AND S N DESHMUKH[2]

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

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ABSTRACT

To assess the determinants of technology adoption by sunflower farmers towards improved sunflower production technologies, a study was conducted in Akola district of Maharashtra. The assessment was done on a comparative basis between 60 each of farmers who participated in the frontline demonstrations (FLDs) organized by Crop Research Unit, Dr.Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola, Maharashtra (FLD farmers) and farmers who did not participate in the FLD programme but belong to the same villages wherein FLDs were organized (non-FLD farmers). The respondents were selected through multi-stage random sampling procedure. There was highly significant difference between FLD and non-FLD respondents with respect to their adoption behaviour and sunflower productivity. There was significant difference among non-FLD farmers with small, medium and large size of land holdings with respect to their adoption behaviour and sunflower productivity, while there was no such difference was observed among the FLD farmers. Most of the non-FLD farmers had low to medium level of sunflower productivity, while most of the FLD farmers had medium to high level of sunflower productivity. Overall, there was 11% mean seed yield increase obtained by the FLD farmers over that of non-FLD farmers with ₹ 2254/ha additional net returns. The personal, socio-economical, biotic and abiotic determinants of sunflower production and perceived information needs were assessed and the strategies for improving the sunflower production scenario in the study area were suggested.

Keywords: Sunflower, Frontline demonstrations, Impact

Sunflower has been grown worldwide, in an area of 23.7 million ha, with a production of 31.3 million tonnes and productivity of 1322 kg/ha (Hegde and Damodaram, 2007). In India, the crop has been cultivated in an area of 1.9 million ha, with a production of 1.5 million tonnes and productivity of 765 kg/ha (Anonymous, 2009a). Cultivation of sunflower in India has mainly been confined to Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu. Cultivation of sunflower in marginal and sub-marginal lands with poor management practices, monocropping, poor nutritional supplementation, vulnerability of the crop to fungal and viral pathogens, lack of availability of quality seed material were the factor that contributed for stagnation of area, production and productivity of the crop in India. The AICRP (Sunflower) researchers have been addressing such factor for harnessing the productivity potential of sunflower, which can be easily replicated under real farm situations.

Crop Research Unit at Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola is one of such AICRP centres that have been involved in developing eco-region specific improved sunflower production technologies and transferring such technologies to the sunflower farmers. The centre had organized 398 out of the 469 FLDs allotted from 1990-91 onwards, with 85% implementation rate. The concurrent results of such FLDs show that there exists a huge gap between potential yield of the crop when improved technologies were adopted and the actual yield obtained by general sunflower farmers whose adoption towards improved technologies was generally low (Venkattakumar and Hegde, 2009). Hence, an expost-facto impact study was conducted to assess the impact of sunflower FLDs with improved production technologies on enhancing productivity and profitability of sunflower as a long-term effect and in turn on increasing the area and production of the crop in Akola district of Maharashtra, with the objectives to assess the adoption behaviour of FLD and non-FLD sunflower farmers and the resultant sunflower productivity in Akola district; delineate the demographic, biotic and abiotic determinants affecting the adoption behaviour and the resultant sunflower productivity and suggest strategies for improving sunflower production scenario in Akola district.

MATERIALS AND METHODS

Expost-facto impact study was conducted in Akola district of Maharashtra during September 2009. The impact assessment was done on comparative basis between FLD farmers and non-FLD farmers. A total of 60 each FLD and non-FLD farmers were selected as respondents based on simple random sampling procedure. The respondents were

E-mail: kumar_4173@rediffmail.com
[1]Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030
[2]Crop Research Unit, Dr. PDKV, Akola, Maharashtra

belonging to villages of Akola (60), Buldana (30) and Amaravathi (30) divisions, wherein the FLDs were organized. The respondents were selected based on the criteria that they had involved in sunflower FLDs or cultivation during last 4-5 years, so that they can recall the production constraints they encountered. Post-survey stratification was one to categorize the farmers into small (with farm size of ≤ 2 ha), medium (with farm size of 2-5 ha) and large (with farm size of ≥ 5 ha) using percentage analysis. Information pertaining to the demographic variables of the respondents; their adoption behaviour towards improved sunflower production technology, cost of sunflower cultivation and resultant sunflower productivity pertaining to the previous year; perceived production constraints and training needs of the respondents based on their overall experience were collected through personal interview method in a structured data collection tool. Apart from these primary data, secondary data on area ('000 ha), production ('000 t) and productivity (kg/ha) of sunflower in Akola district during 1994-95 to 2007-08 were compiled (Hegde and Damodaram, 2007; Anonymous, 2009b) to measure the temporal and spatial spread of the crop in the study area as an overall impact. The collected data were coded, tabulated and analyzed. The adoption behaviour of the respondents was measured by assigning unit score towards adoption of each recommended technology. Mean and standard deviation (SD) measures were used to assess the level of adoption behaviour and sunflower productivity. Significance of difference between FLD and non-FLD farmers with respect to their adoption behaviour and sunflower productivity was assessed through Mann-Whitney U (M-W U) test. Kruskal Wallis (K-W) test was done to find out the significance of difference between three categories of FLD and non-FLD farmers with respect to their adoption behaviour. Rank based quotient (RBQ) analysis (Shenoy *et al.,* 2006) was used to ascertain and prioritize the perceived production constraints and training needs of the respondents.

RESULTS AND DISCUSSION

Comparative assessment of adoption behaviour and sunflower productivity: The M-W U test implied that there was highly significant difference between FLD and non-FLD respondents with respect to their adoption behaviour (Table 1). Similar difference was observed between the respondents from irrigated and rainfed situations. Better awareness and experience of the FLD farmers over the non-FLD farmers with respect to improved sunflower production technologies. This may be due to frequent contact of FLD farmers with researchers and development departmental officials and specialized on-campus and on-farm training on sunflower production technology received by the FLD farmers during the conduct of demonstration, might be the reasons for such results. Rainfed situation often bring-in certain amount of risk factor to cultivation of any crop and thus to sunflower also due to the factors like severe incidence of insect-pests and diseases, failure of monsoon and unseasonal heavy rains etc. Hence, the usual tendency of sunflower farmers to invest comparatively less under rainfed situations resulted in significant difference between adoption behaviour of respondents from rainfed and irrigated situations. The highly significant difference between FLD and non-FLD farmers as well as between respondents from irrigated and rainfed situations, resulted in highly significant difference in the resultant sunflower productivity also.

Table 1 Adoption behaviour and sunflower productivity of the respondents (N=120)

No.	%	No.	%	M-W U test value	
				Adoption behaviour	Productivity
Based on farmers' category					
FLD		NFLD			
60	50.0	60	50.0	U=1047.0; Z=4.136**	U=999.0; Z=4.223**
Based on situation					
Irrigated		Rainfed			
28	23.3	92	76.7	U=583.5; Z=4.575**	U=529.0; Z=4.731**

**=Significant at 1% level; NFLD-Non-FLD

The results of K-W test revealed that most of the FLD (85%) and non-FLD farmers (90.0%) had medium to large size of land holdings (Table 2). There was no significant difference observed among FLD farmers with small, medium and large size of land holdings with respect to their adoption behaviour towards improved sunflower production technologies. Again, the better awareness and experience of the FLD farmers with respect to improved sunflower production technologies irrespective of size of land holdings brought such results. This non-significant difference observed among FLD farmers with small, medium and large size of land holdings with respect to their adoption behaviour towards improved sunflower production technologies, resulted in non-significant difference in sunflower productivity also. However, there was highly significant difference among non-FLD farmers with small, medium and large size of land holdings with respect to their adoption behaviour towards improved sunflower production technologies (Table 2). This kind of difference had resulted in significant difference in the sunflower productivity also. Difference among the three categories of farmers in awareness and lack of conviction towards the recommended sunflower production technologies might have brought such results.

Most of the FLD farmers with small, medium and large size of land holdings had medium to high level of sunflower productivity (Table 3). However, most of the non-FLD farmers with small, medium and large size of land holdings had low to medium level of sunflower productivity. The better adoption behaviour of the FLD farmers over the non-FLD farmers with respect to improved sunflower production technologies irrespective of their size of land holdings might have brought the resultant medium to high level of sunflower productivity. The seed yield increase experienced by the FLD farmers was ranging from 5 to 7% over that of non-FLD farmers at rainfed and irrigated situations respectively at Akola division (Table 4). The additional net returns accrued was ₹ 1486/ha and ₹ 1522/ha, respectively at rainfed and irrigated situations of the division. Here, the overall mean seed yield increase of FLD farmers over that of non-FLD farmers was 6% with ₹1519/ha additional net returns. Under rainfed situations of Buldana division, the seed yield increase was 19% with ₹3510/ha additional net returns. In Amaravathi division, the seed yield increase experienced by FLD farmers was ranging from 4 to 13% at irrigated and rainfed situations, respectively with corresponding additional net returns of ₹2418/ha and ₹1734/ha. Here, the overall mean seed yield increase obtained was 9%, and the additional net returns achieved was ₹1734/ha. Across the divisions and situations, 11% mean seed yield increase was obtained by the FLD farmers over that of non-FLD farmers with ₹2254/ha additional net returns.

Table 2 Category-wise adoption behaviour and resultant productivity (N=120)

Type of farmers	Category of farmers	Number	%	K-W test value	
				Adoption	Productivity
FLD	Small	9	15.0	0.748 NS	0.035 NS
	Medium	29	48.3		
	Large	22	36.7		
Non-FLD	Small	6	10.0	7.055**	4.758*
	Medium	20	33.3		
	Large	34	56.7		

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

Table 3 Distribution of respondents according to sunflower productivity (kg/ha) (N=120)

Type of farmers	Level of adoption	Farmers' category (%)			Total	Mean	SD
		Small	Medium	Large			
FLD	Low	3.3	6.7	3.3	13.3	1269	259
	Medium	6.7	25.0	25.0	56.7		
	High	5.0	16.6	8.3	30.0		
	Total	15.0	48.3	36.7	100.0		
Non-FLD	Low	6.7	5.0	8.3	20.0	1066	215
	Medium	1.7	28.3	43.4	73.3		
	High	1.6	0.0	5.0	6.7		
	Total	10.0	33.3	56.7	100.0		

Table 4 Sunflower productivity and profitability under real farm conditions (N=120)

Division	No. of farmers (Situation)		Mean seed yield (kg/ha)		% yield increase	Additional net returns (₹/ha)	B:C ratio	
	FLD	Non-FLD	FLD	Non-FLD			FLD	NFLD
Akola	16 (I)	5 (I)	1455	1360	7	1522	2.5	2.5
	14 (R)	25 (R)	1188	1062	5	1486	2.6	2.5
	Mean		1287	1211	6	1519	2.5	2.5
Buldana	15 (R)	15 (R)	1174	983	19	3510	3.6	3.5
Amaravathi	1 (I)	6 (I)	1125	1079	4	1050	3.5	3.4
	14 (R)	9 (R)	1319	986	13	2418	3.4	3.4
	Mean		1123	1033	9	1734	3.5	3.4
	Grand mean		1195	1076	11	2254	3.1	3.0

Demographic, biotic and abiotic determinants of sunflower production and perceived training needs: Correlation between demographic variables of the overall respondents and dependent variables implied that the 'number of training programmes' attended by the respondents, 'contact with researchers' and 'contact with extension agency' had highly significant and positive relationship with both adoption and sunflower productivity experienced by the respondents. However, the variable 'age' had negative and highly significant relationship with sunflower productivity experienced by the respondents. These results imply that transfer of technology programmes of extension agencies and research organizations targeting young sunflower growers as contact farmers might bring desirable results in influencing the adoption behaviour of respondents in the study area and the resultant sunflower productivity. RBQ analysis on the perceived production constraints of the respondents implied that high cost of sunflower seeds, non-availability of quality seeds of the improved cultivars, damage due to unseasonal rains and lack of irrigation facilities were the major production constraints with RBQ values more than that of mean RBQ (Table 5). These results imply the urgent need for making the seeds of improved sunflower cultivars pertaining to public sector penetrate the seed chain through appropriate and effective strategies and the need for developing and popularizing micro-irrigation technology for sunflower. Similarly, information on thinning and maintaining optimum plant population, improved sunflower cultivars and integrated nutrient management were the major training needs with RBQ more than the mean RBQ value. These training needs are to be focused during the training programmes targeting both sunflower farmers and the extension personnel.

Analysis of the secondary data pertaining to area ('000 ha), production ('000 t) and productivity (kg/ha) of sunflower in Akola district during 1994-95 to 2004-05, indicated that sunflower area declined by 6.3 times and production by 7.7 times (Fig.1). This might be due to the decline in productivity by 108 kg/ha during the same period. Stiff competition for sunflower from Jowar and cotton+pigeonpea intercropping system during *kharif* and chickpea during *rabi* season towards area expansion also might be the reasons for decline in sunflower area as opined by the respondents during the survey. However, the secondary data pertaining to Akola district for 2004-05 to 2007-08 implied that the area increased by 2.2 times and the production by 3.4 times (Fig.1). This might be due to the increase in sunflower productivity by 282 kg/ha. This might also be due to increased cost of cultivation for cotton, though pigeonpea had comparatively higher prices as opined by the respondents during the survey. The productivity increase in sunflower may also be attributed to the overall increase in the adoption behaviour of sunflower farmers in the study area.

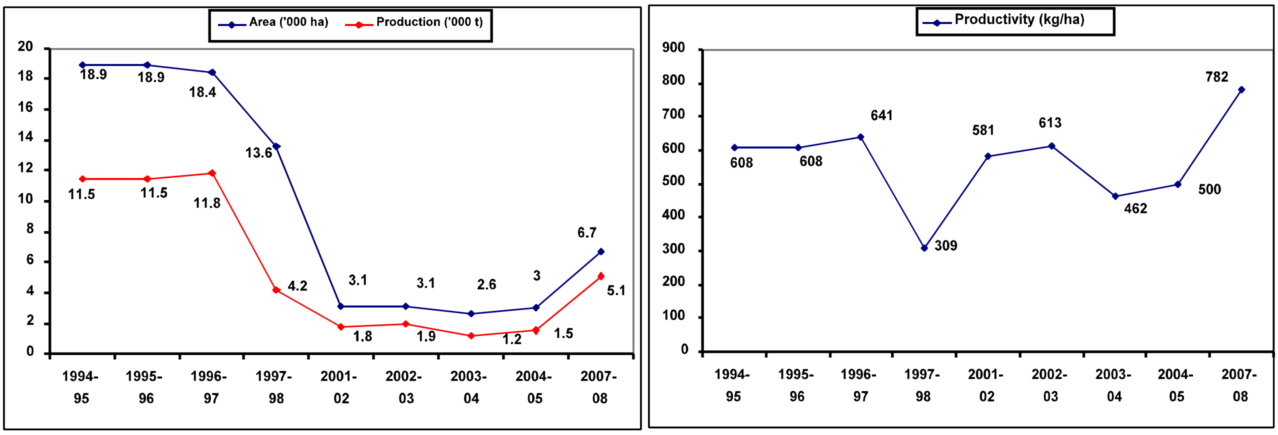

Fig. 1. Performance of sunflower in Akola district of Maharashtra during 1994-95 to 2007-08

Implicative strategies for improving sunflower production scenario in Akola district of Maharashtra: Transfer of technology efforts need to be strengthened to improve the adoption behaviour and the resultant sunflower productivity of general sunflower farmers (non-FLD) and those especially from rainfed situations. It can be done through conducting more number of FLDs and selecting sunflower farmers representing rainfed situations as the major target group of the transfer of technology activities including FLDs. The results imply that there exists a gap in sunflower productivity between FLD and non-FLD farmers. Hence, transfer of technology efforts (training programmes, awareness campaigns and field days) are to be intensified to improve the adoption behaviour and the resultant sunflower productivity. Young sunflower farmers may be imparted training on improved sunflower production technologies by the sunflower researchers and extension personnel and may be utilized as the contact farmers to influence the fellow farmers to have better adoption level and resultant sunflower productivity. The results of constraints analysis imply the urgent need for making the seeds of cultivars pertaining to public sector penetrate the seed chain through appropriate and effective strategies and the need for developing and popularizing micro-irrigation technology for sunflower. The training needs of the respondents are to be highlighted in the information given to the sunflower farmers and officials of development departments during training programmes. FLDs on the training needs are to be implemented and if they are already being implemented, to be continued at a larger scale.

Table 5 Biotic and abiotic determinants and training needs (N=120)

Production constraints	Mean RBQ	Rank
High cost of seeds	100.0	1
Non-availability of quality seeds of improved cultivars	85.2	2
Damage due to unseasonal rains	77.8	3
Lack of irrigation facility	66.7	4
Damage due to insect-pests and diseases	44.5	5
Loss due to weeds	37.1	6
Fluctuations in the procurement price of sunflower seeds	33.3	7
High cost of labours	29.6	8
Damage due to birds	29.6	8
Overall mean RBQ value	56.0	
Training needs	**Mean RBQ**	**Rank**
Maintaining optimum plant population	100.0	1
Improved sunflower cultivars	80.9	2
Integrated nutrient management	76.2	3
Integrated pest management	47.6	4
Weed management	42.9	5
Irrigation management	38.1	6
Sunflower-based cropping systems	14.3	7
Overall mean RBQ value	57.1	

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Assessment of genetic variability, correlation and path analysis for yield and its components in groundnut (*Arachis hypogaea* L.)

MUKESH CHOUDHARY, S P SHARMA, ABHAY DASHORA AND S R MALOO

Dept. of Plant Breeding and Genetics, Rajasthan College of Agriculture,
Maharana Pratap University of Agriculture and Technology, Udaipur-313 001, Rajasthan

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ABSTRACT

Genetic variability, heritability, correlation and path analysis were carried out in 27 groundnut genotypes. Analysis of variance revealed significant differences among the genotypes for all the characters. The estimated PCV and GCV indicated existence of fairly high degree of variability for dry pod yield/plant, kernel yield/plant, number of branches/plant, number of mature pods/plant and seed protein content. In corollary to high heritability, estimates of genetic advance as per cent of mean was also observed for dry pod yield/plant, kernel yield/plant, number of mature pods/plant and seed protein content indicating predominance of additive gene effects for these traits. The association study among characters revealed that dry pod yield was positively and significantly correlated with number of pegs/plant, number of mature pods/plant and kernel yield/plant. Path coefficient analysis revealed that kernel yield/plant, biological yield/plant and harvest index had maximum positive direct effect on dry pod yield/plant. The study shows that greater emphasis should be given on these characters while selecting for higher yield and related traits in groundnut.

Key words: Correlation, Groundnut, Path coefficient, Variability

Groundnut (*Arachis hypogaea* L.) is one of the major oilseed crops accounting for 33% of area and 32% of total oilseed production in India. To formulate efficient breeding programme, knowledge about the presence of genetic variability for yield and yield component traits is essential. Selection of elite genotypes from the available genetic variation forms an important component of genetic improvement of any crop. The genetic variability along with heritability gives a reliable picture of the genetic advance to be expected from selections while the heritability, coupled with genetic advance aids in predicting the valuable conclusion for effective selection based on phenotypic performance. In case of groundnut, pods develop below the ground level and hence genotypes for yield cannot be screened or evaluated prior to harvest so association studies are very important. Correlation and path analysis will establish the extent of association between yield and its component and also bring out the relative importance of their direct and indirect effects, giving a clear understanding of their association with yield. Keeping this in view, the present investigation was carried out to explore the genetic variability, by determining the magnitude of genotypic coefficient of variation, heritability estimates and expected genetic advance of different biometric traits, their correlation and effects in 27 groundnut genotypes.

The experimental material consisted of 27 diverse genotypes of groundnut (Table 1). Each genotype was grown in a Randomized Block Design with three replications in *kharif*, 2011 at Instructional Farm, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur. In each replication, the genotypes were planted in the plot size of 5.0 m x 0.9 m size accommodating three rows of 5 m length spaced 30 cm apart with an intra-row spacing of 10 cm maintaining by dibbling. All the recommended packages of practices were followed to raise a healthy crop. The observations were recorded on five randomly selected plants from each genotype in each replication for characters *viz*., plant height (cm), number of branches/plant, number of pegs/plant, number of mature pods/plant, dry pod yield/plant (g), shelling out-turn (%), kernel yield/plant (%), 100-kernel weight (g), sound mature kernel (%), biological yield/plant (g), harvest index (%), seed protein content (%) and seed oil content (%) while for days to 50% flowering and days to maturity, the data was recorded on whole plot basis.

Analysis of variance was done by the method suggested by Panse and Sukhatme (1985). The phenotypic and genotypic coefficient of variation, heritability and genetic advance were computed. The genotypic and phenotypic correlation coefficients and path coefficient analysis were calculated by following standard statistical methods.

The analysis of variance indicated significant difference among genotypes for most of the traits studied indicating presence of significant variability in the experimental materials (Table 2). The range, mean and standard error of mean, phenotypic coefficient of variation (PCV), genotypic

E-mail: nandadeep_12@yahoo.com

coefficient of variation (GCV), heritability (h^2) in broad sense and expected genetic advance as per cent of mean for various characters are presented in Table 3. The range of variability indicated existence of variability for all the characters. The highest range was observed for plant height followed by sound mature kernel, 100-kernel weight and seed oil content. In general, PCV values were relatively higher than respective GCV values indicating influence of environment on the expression of the character. The estimated of PCV and GCV indicated the existence of fairly high degree of variability for dry pod yield/plant, kernel yield/plant, number of branches/plant, number of mature pods/plant and seed protein content. High magnitude of PCV and GCV was also observed for dry pod yield/plant by Sarala and Gowda (1998), Dashora and Nagda (2002), Kumar and Rajamani (2004) and John *et al.* (2009). Moderate variability was observed for 100-kernel weight, harvest index, number of pegs/plant and biological yield/plant, while for rest of the traits, the estimates of PCV and GCV have been found relatively low.

Table 1 List of genotypes used in present study and their pedigree

Name of genotype	Pedigree
UG 85	ICGV 86031 x TAG 24
UG 86	(ICGS 44 x CSMG 84-1) x GG 2
UG 87	TAG 24 x ICGS 76
UG 88	PBS 20176 x Code 26
UG 89	ICGX 000102
UG 90	ICGS 76 x ICGV 86031
UG 91	TAG 24 x ICGS 76
UG 92	PBS 29017 x NRCG 4829
UG 93	(ICGS 44 x CSMG 84-1) x ICGV 86031
UG 94	TAG 24 x ICGS 76
UG 95	ICGS 44 x CSMG 84-1
UG 100	PBS 20176 x Code 26-1
UG 101	(ICGV 86031x TAG 24) x ICGS 76
UG 102	ICGS 44 x CSMG 84-1
UG 103	(ICGS 44 x CSMG 84-1) x GG 2-1
UG 104	PBS 11039 x ICGV 86031
UG 105	PBS 11039 x TAG 24
UG 106	(ICGV 86031xTAG 24) x CSMG 84-1
UG 108	ICGS 76 x ICGV 86031
UG 109	Selection from ICGX 000103
UG 110	ICGS 44 x CSMG 84-1
UG 111	PBS 11039 x TAG 24
UG 112	PBS 29031 x ICGV 86031
UG 114	ICGS 76 x ICGV 86031
UG 115	PBS 11039 x NRCG 4829
TG 37A	TG 25 x TG 26
Pratap Mungphali 2	ICGV 86055 x ICG (FDRs 10)

The highest difference between PCV and GCV were observed for number of branches/plant followed by biological yield/plant indicating that the characters were influenced by environment. The lowest difference between PCV and GCV were observed for seed protein content, 100-kernel weight, number of mature pods/plant, dry pod yield/plant and kernel yield/plant indicating the stability of characters. This observation draws supports from the very high value of heritability (> 80%) recorded for these traits (Table 3).

Heritability estimates give an idea of expected efficiency of selection on the basis of phenotypic performance. To assess selection effect more accurately predicting the resultant effect of selection on phenotypic expression genetic advance was also computed because high heritability was not associated with higher genetic gain. In corollary to high heritability, estimates of genetic advance as per cent of mean was also observed high for dry pod yield/plant, kernel yield/plant, number of mature pods/plant and seed protein content indicating predominance of additive gene effects for these traits. This is in conformity with the observation of Dashora and Nagda (2002) for dry pod yield/plant and kernel yield/plant.

Correlation revealed the mutual relationship between two characters and it is important parameter for taking a decision regarding the nature of relation to be followed for improvement in the crop under study. The genotypic and phenotypic correlation among the yield and yield components in groundnut are presented in Table 4. Significant correlation of characters suggested that there is much scope for direct and indirect selection for further improvement. In general, the estimates of genotypic correlation coefficient were higher than their corresponding phenotypic correlation, thereby suggesting strong inherent association among the characters studied. In the present investigation dry pod yield was positively and significantly correlated with number of pegs/plant, number of mature pods/plant and kernel yield/plant. Therefore, these characters should be considered while making selection for yield improvement in groundnut. These results are in accordance with the results of Azad and Hamid (2000) for number of mature pods/plant and kernel yield/plant; Suneetha *et al.* (2004) and Shinde *et al.* (2010) for mature pods/plant.

Yield is the sum total of the several component characters which directly or indirectly contributed to it. The information derived from the correlation studies indicated mutual association among the characters, whereas path coefficient analysis helps in understanding the magnitude of direct and indirect contribution of each character on the dependent character like dry pod yield/plant. Partitioning of correlation coefficient into direct and indirect effects provides the information about the nature and magnitude of effects of other characters on dry pod yield. The results of the present investigation on path coefficient analysis as presented in

Table 5 revealed that kernel yield/plant, biological yield/plant and harvest index had maximum positive direct effect on dry pod yield/plant. This is in conformity with the observation of Shinde *et al.* (2010) for biological yield/plant; Dashora and Nagda (2002) and Awatade *et al.* (2010) for kernel yield/plant. Kernel yield/plant had highest positive correlation with dry pod yield via indirect effect of biological yield/plant and harvest index. Similarly, number of mature pods/plant had highest positive correlation with dry pod yield via indirect effect of kernel yield/plant and harvest index. Low magnitude of the residual effect (0.02) suggesting that almost all the yield contributing characters have been included in path analysis.

In the light of above findings it may be concluded that improvement in characters like kernel yield/plant, biological yield/plant and harvest index will help in improving the dry pod yield in groundnut both directly and indirectly. Therefore, these characters should be considered for yield improvement in groundnut breeding programme.

Table 2 Analysis of variance showing mean sum of squares for different characters in groundnut

Character	Replication [2]	Genotype [26]	Error [52]
Days to 50% flowering	3.81**	8.64**	0.57
Days to maturity	38.71**	12.69**	5.19
Plant height (cm)	0.77	14.43**	0.50
Branches/plant	5.43	3.30**	1.35
Pegs/plant	0.01	10.21**	0.61
Mature pods/plant	0.20	13.95**	0.72
Dry pod yield/plant	0.35	11.67**	0.74
Shelling percentage	3.90	23.16**	1.71
Kernel yield/plant	0.15	4.68**	0.35
100-Kernel weight (g)	8.81**	29.43**	1.29
Sound mature kernel (%)	4.04	25.87**	2.40
Biological yield/plant	0.16	27.80**	7.29
Harvest index (%)	2.27	21.99**	2.53
Seed protein (%)	0.13	21.59**	0.15
Seed oil (%)	0.04	22.26**	0.11

[ ] Figures in parenthesis are degrees of freedom; *, ** Significant at 5 % and 1 % levels, respectively

Table 3 Range, mean, phenotypic and genotypic coefficient of variation, heritability and genetic advance as per cent of mean for characters in groundnut

Character	Range	Mean±SE	PCV (%)	GCV (%)	h^2 (%)	GA as % of mean
Days to 50% flowering	26.67-34.67	31.56±0.44	5.72	5.20	82.48	9.72
Days to maturity	105-113.67	107.21±1.32	2.59	1.48	32.52	1.73
Plant height	32.13-49.53	39.83±0.41	7.15	6.79	90.21	13.29
Number of branches/plant	3.87-7.67	5.82±0.67	24.34	13.86	32.45	16.27
Number of pegs/plant	17.33-24.40	20.10±0.45	9.71	8.90	83.90	16.79
Number of mature pods/plant	12.87-21.87	16.13±0.49	14.05	13.03	85.92	24.87
Dry pod yield/plant	9.52-17.35	12.74±0.50	16.44	14.98	83.00	28.11
Shelling out-turn	60.49-69.69	65.06±0.76	4.58	4.11	80.64	7.60
Kernel yield/plant	5.92-11.26	8.28±0.34	16.18	14.51	80.43	26.80
100-Kernel weight	25.71-36.65	31.05±0.66	10.52	9.86	87.83	19.04
Sound mature kernel	69.09-80.13	73.63±0.90	4.34	3.80	76.49	6.84
Biological yield/plant	24.69-34.87	29.43±1.56	12.77	8.89	48.39	12.73
Harvest index	22.98-33.58	28.16±0.92	10.66	9.04	71.93	15.80
Seed protein content	17.67-26.90	22.77±0.22	11.86	11.74	97.94	23.94
Seed oil content	41.58-52.52	46.46±0.20	5.89	5.85	98.47	11.95

Table 4 Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among different characters in groundnut

Character	DF	DM	PH	BP	PP	MPP	DPY	Shelling	KY	HKW	SMK	BY	HI	Seed protein	Seed oil
DF	1.00	0.69**	-0.58**	-0.05	0.35	0.37	0.37	-0.16	0.33	0.04	-0.21	0.35	0.22	-0.03	0.25
DM	0.38	1.00	-0.89**	-0.55**	0.41*	0.29	0.33	0.02	0.34	0.23	0.06	0.69**	-0.11	-0.26	-0.18
PH	-0.45*	-0.43*	1.00	0.54**	-0.38	-0.37	-0.35	-0.07	-0.38	-0.12	0.06	-0.51**	-0.11	-0.03	0.11
BP	-0.04	-0.19	0.31	1.00	-0.62**	-0.40*	-0.31	0.11	-0.28	0.24	0.25	-0.19	-0.21	0.23	-0.10
PP	0.28	0.15	-0.35	-0.26	1.00	0.90**	0.82**	0.15	0.86**	0.31	0.06	0.65**	0.71**	-0.33	0.08
MPP	0.29	0.12	-0.32	-0.18	0.81**	1.00	0.96**	-0.12	0.94**	0.08	-0.07	0.65**	0.82**	-0.18	0.10
DPY	0.28	0.11	-0.31	-0.15	0.72**	0.93**	1.00	-0.18	0.96**	0.01	-0.07	0.73**	0.79**	-0.11	0.07
Shelling	-0.16	0.03	-0.06	0.02	0.09	-0.08	-0.16	1.00	0.09	0.86**	0.82**	0.17	0.01	0.14	-0.20
KY	0.23	0.12	-0.33	-0.15	0.74**	0.91**	0.96**	0.13	1.00	0.25	0.16	0.79**	0.80	-0.07	0.01
HKW	0.03	0.16	-0.10	0.08	0.25	0.10	0.02	0.84**	0.26	1.00	0.76**	0.26	0.16	0.06	-0.13
SMK	-0.19	0.00	0.03	0.09	0.02	-0.08	-0.07	0.73**	0.14	0.68**	1.00	0.24	0.06	0.43*	-0.05
BY	0.21	0.21	-0.34	-0.15	0.43*	0.56**	0.68**	0.16	0.74**	0.23	0.17	1.00	0.27	0.01	-0.01
HI	0.13	-0.05	-0.10	-0.02	0.57**	0.67**	0.62**	0.03	0.62**	0.12	0.04	-0.06	1.00	-0.06	0.00
Seed protein	-0.02	-0.14	-0.02	0.13	-0.30	-0.15	-0.09	0.13	-0.06	0.06	0.35	0.01	-0.05	1.00	0.03
Seed oil	0.23	-0.11	0.10	-0.06	0.08	0.09	0.06	-0.18	0.01	-0.12	-0.03	-0.00	0.00	0.03	1.00

DF- Days to 50 % flowering; DM- Days to maturity; PH- Plant height; BP- Branches/plant; PP-Pegs/plant; MPP-Mature pods/plant; DPY-Dry pod yield/plant; KY- Kernel yield/plant; HKW-Hundred kernel weight; SMK- Sound mature kernel; BY- Biological yield/plant; HI- Harvest index.

Table 5 Direct (diagonal) and indirect effects of different characters on dry pod yield/plant in groundnut

Character	Number of pegs/plant	Number of mature pods/plant	Kernel yield/plant	Biological yield/plant	Harvest index	Correlation with dry pod yield
Number of pegs/plant	0.09	-0.05	0.34	0.24	0.26	0.82**
Number of mature pods/plant	0.08	-0.06	0.37	0.24	0.30	0.96**
Kernel yield/plant	0.07	-0.05	0.39	0.29	0.29	0.96**
Biological yield/plant	0.06	-0.04	0.31	0.37	0.10	0.73**
Harvest index	0.06	-0.05	0.31	0.10	0.36	0.79**

Residual effect = 0.02

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Genetic variation and correlations for some physiological characters and seed yield in Indian mustard (*Brassica juncea* L.) under rainfed conditions

MAHARAJ SINGH AND J S CHAUHAN[1]

CAZRI Regional Research Station, Jaisalmer-345 001, Rajasthan

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ABSTRACT

An experiment was conducted with 42 Indian mustard genotypes in Randomized Complete Block design to estimate genetic parameters and correlations of some physiological characters and seed yield under rainfed conditions. Specific leaf area, transpiration rate and relative water content were recorded at 30 (vegetative stage), 45-50 (50% flowering stage) and 60-65 days after sowing (full flowering stage). Total drymatter, harvest index, pod intensity, pod area on main and primary branches, seed : husk ratio and seed yield were recorded at the time of harvest. The analysis of variance indicated highly significant differences among the genotypes for all the characters studied. The maximum phenotypic and genotypic variability was observed for transpiration rate at full flowering stage. Heritability estimates in broad-sense were high for all the characters except relative water contents (RWC) at all the 3 stages, pod area of main and primary branches and pod intensity on main shoot. High heritability combined with high genetic advance was observed for specific leaf area at all the 3 stages, transpiration rate at 50% and full flowering and total drymatter/plant suggested scope for selection for these characters owing to predominance of additive effects in the expression of these characters. Seed yield/plant had significant and positive correlations with harvest index (r = 0.581**), total drymatter/plant (r = 0.869**), pod intensity on main shoot (r = 0.467**), pod area of main (r = 0.536**) and primary branches ((r = 0.317*) and RWC at all the 3 developmental stages. Thus, selection for high harvest index, total dry matter/plant and pod intensity coupled with low transpiration rate at flowering stage, resulting in maintenance of high RWC in leaves, should be emphasized to increase yield under rainfed conditions.

Key words: *Brassica juncea,* Genetic variability, Relative water content, Specific leaf area, Transpiration

Of the rapeseed-mustard group of crops, mustard crop accounts for more than 80% of the total cropped area under these crops in India, is cultivated for edible oil under semi-arid to arid tropical zones with nearly 26% area under rainfed cultivation where low soil moisture (drought) had deleterious effects on crop growth and development, consequently seed yield. Moisture availability during flowering to pod development, stage is quite critical for the productivity of the crop as available water in soil profile at post anthesis appreciably affect seed yield. Drought has also been reported to influence plant water relations through regulating stomatal conductance thereby transpiration rate, gaseous exchange and total drymatter production. Studies on the effects of drought stress on growth and yield components in Brassica and their importance as selection criteria for tolerance to drought has been well documented (Singh *et al.,* 2003a; Chauhan *et al.,* 2007). Decreased leaf water potential and relative water content lead to reduced photosyntyhesis, increased stomatal resistance and subsequently lower yield (Singh *et al.,* 2003b,c; 2009). Genetic improvement in crop species for achieving higher productivity depends upon available genetic variability for selection. Limited published information is available on the nature and magnitude of variability for physiological characters in Indian mustard. The present study attempts to assess the available genetic variability for physiological characters present in the improved germplasm and their amenability to selection for improvement as well as their relationship with seed yield.

The experimental material comprised 42 genotypes of Indian mustard evaluated in a Randomized Complete Block Design with two replications under rainfed conditions. There were 5 rows of 5 m length for each genotype. The spacing between rows and plants was kept at 30 cm and 15 cm, respectively. The fertilizer dose of 40 N: 20 P_2O_5 kg/ha was applied before sowing. Five plant from 75 cm row length were taken to record leaf area index, specific leaf area (SLA), transpiration rate, diffusive resistance and relative water content (RWC) at 30 (vegetative stage), 45-50 (50% flowering) and 60-65 days after sowing (full flowering). Leaf area was measured by using LICOR-LI 3100 automatic leaf area meter. The leaves were dried up to constant weight at 80°C and finally recorded it as dry weight. SLA was computed as the ratio of leaf area to dry weight and expressed in cm^2/g. The transpiration rate was recorded on 3rd and 4th fully expended leaf from the top on three randomly taken plants with the help of LICOR-LI 1600 steady state porometer. At harvest 5 competitive plants/genotype/

[1]Asst. Director General (Seeds), Indian Council of Agril. Research, Krishi Bhawan, New Delhi-110 001; E-mail: js_chau09@rediffmail.com

replication were taken to record pod intensity on main shoot, total pod area of main and primary branches, seed: husk ratio, total dry matter/plant, seed yield/plant and harvest index (%). The surface area of pods was estimated by geometrical measurement of the dimension of the pods by assuming the pod shape to be nearly cylindrical. The length of the pod was measured by a scale and varnier caliper was used to measure the diameter of the pod. Surface area of the pod was determined with the help of formula following Kar and Chakarvarty (2000). Analysis of variance was done using the mean values of the genotypes. Genotypic (GCV), phenotypic coefficients of variability (PCV), heritability genetic advance at 5% selection intensity and simple correlation coefficients were worked out following standard statistical methods.

Analysis of variance revealed highly significant differences among the genotypes for all the characters investigated. The SLA at vegetative stage ranged from 35.7 (BPR-150-B-29-B) to 113.7 cm^2/g (BPR-150-B-206-12-B) with a mean value of 85.7 cm^2/g. It increased from vegetative to 50% flowering stage and reached maximum during full flowering stage (Table 1). The RWC, an indicator of the state of water balance of a plant, varied from 63.2 (BPR-141-B-54-B) to 79.4% (BPR-150-B-167-B); 67.8 (RC-53)-86.5% (BPR-141-B-51-B) and 62.2 (BPR-150-B-176-3-B)-76.4% (BPR-141-B-148-4-B), respectively, at vegetative, 50% flowering and full flowering stage. The mean RWC peaked during 50% flowering stage and declined thereafter. The genotype BPR-141-B-51-B and BPR-150-B-167-B at vegetative (77.8-79.4%) and 50% flowering (86.5-83.7%) stages and the genotypes BPR-150-B-20-B and BPR-141-B-46-B (76.1%) maintained higher RWC at full flowering stage. The genotype BPR-558 (8.46 $\mu g/cm^2/s$), BPR-150-B-224-B (4.03 $\mu g/cm^2/s$) and BPR-560-1-B (1.62 $\mu g/cm^2/s$) showed lowest transpiration rates among the genotypes at vegetative, 50% and full flowering stage, respectively. The highest transpiration rate was recorded during 50% flowering (Table 1). The pod area of main and primary branches also showed substantial variation among the genotypes. The mean pod area of main shoot was higher than that of primary branches. On main shoot, the maximum area (7.43 cm^2) was observed in the genotype BPR-560-1-B while genotype BPR-148-B-135-DI exhibited the highest pod area (6.34 cm^2) of primary branches thereby indicating longer pods on main shoot. The genotype, BPR-560-1-B also showed high pod intensity on main shoot (0.83 pods/cm) and accumulated maximum dry matter (29.5g/plant) at harvest. Seed:husk ratio, a measure of translocation of drymatter from pods to seed, varied from 0.80 (BPR-516) to 1.53 (RC-53). The seed yield/plant ranged from 2.3 g for the genotype BPR-558 to 8.2 g for the genotype BPR-560-1-B closely followed by BPR 141-B-54-B (7.1g). The high seed yield could be because of their higher area of pods on main shoot and primary branches, high total drymatter accumulation and harvest index. The genotype BPR-148-B-135-DI showed maximum harvest index (28.7%) closely followed by BPR-141-B-54-B (28.1%).

Transpiration rate at 50% and full flowering stage, SLA at 50% flowering stage and total drymatter/plant had high phenotypic and genotypic variability (PCV and GCV >25%). Except RWC at different development stages, which exhibited low phenotypic and genotypic variability (PCV and GCV < 10%), the rest of the characters showed moderate variation (Table 1). The heritability in broad-sense varied from 41.8% (RWC at vegetative stage) to 97.5% (total drymatter/plant). Closeness between estimates of PCV and GCV were also reflected in high heritability (>75%) for SLA and transpiration rate at all the three stages, seed:husk ratio, total drymatter and harvest index. Pod area and intensity exhibited low heritability (< 50%). The genetic advance (as per cent of mean) was the highest for transpiration at full flowering (73.0% and lowest for RWC at 50% flowering (5.3%). The SLA and transpiration at all the three stages investigated and total drymatter at harvest showed high estimates for genetic advance (> 35%). Except RWC, other characters such as pod area of primary branches and pod intensity on main shoot also showed substantial genetic advance (Table 1). Estimates of heritability and genetic advance in combination are more important for predicting selection efficiency than heritability alone. High heritability coupled with high genetic advance was observed for SLA at all the 3 stages, transpiration rate at 50% and full flowering and total drymatter/plant suggested scope for selection for improvement owing to predominance of additive effects in the expression of these characters. Moderate heritability coupled with moderate genetic advance for pod area of main shoot indicated that the character could be amenable for selection but in advanced generations where dominance effects were considerably reduced. Low heritability and low to moderate genetic advance for RWC, pod area on primary branches and pod intensity on main shoot was suggestive of complex nature of inheritance and these characters appeared to be more sensitive to environmental conditions.

Total drymatter/plant had positive and significant association with RWC at 3 developmental stages, pod intensity on main shoot and pod area of main shoot. However, the interrelationship of SLA at full flowering and total dry matter/plant was negative and significant. Association of harvest index was positive and significant with RWC at vegetative and 50% flowering stage, pod area of primary branches and pod intensity on main shoot. But its relationship was negative and significant with SLA and transpiration rate at full flowering (Table 2). Seed yield/plant had significant and positive correlations with harvest index (r = 0.581**), pod intensity (r = 0.467*), total dry matter/plant (r = 0.869**), pod intensity on main shoot (r = 0.467**), pod area of main (r = 0.536**) and primary branches (r = 0.317*) and RWC at all the 3 developmental stages. But, Tyagi and Chauhan (2003) and Misra *et al.* (2007) reported that harvest index was negatively correlated with seed yield while Meena *et al.* (2006) observed seed yield / plant to be positively and significantly correlated with harvest index. Nevertheless, SLA at full flowering had significant and negative correlation with seed yield. Thus, selection for high harvest index, total drymatter/plant and pod intensity associated with low transpiration rate at flowering stage, resulting in maintenance of high RWC in leaves, should be emphasized to increase yield under rainfed conditions.

Table 1 Range, mean, phenotypic (PCV), genotypic coefficient of variability (GCV), heritability (%) and genetic advance (as % of mean) for physiological characters under rainfed conditions

Character	Range	Mean ±SEm	PCV (%)	GCV (%)	Heritability	Genetic advance
Specific leaf area (cm^2/g)						
Vegetative stage	35.7-113.7	85.7 ± 4.0	22.8	21.3	87.8	41.2
50% flowering stage	75.7-192.3	128.5±3.6	26.2	25.8	96.7	52.3
Full flowering stage	97.4-270.0	161.4±9.7	21.5	21.2	97.0	43.1
Relative water content (%)						
Vegetative stage	63.2-79.4	70.2±2.8	6.3	4.1	41.8	5.5
50% flowering stage	67.8-86.5	75.0±2.8	6.1	4.0	42.6	5.3
Full flowering stage	62.2-76.2	69.7±3.1	7.4	5.0	46.3	7.0
Transpiration rate (µg/cm^2/s)						
Vegetative stage	8.5-19.2	14.6±0.7	21.0	19.1	82.6	35.8
50% flowering stage	4.0-12.5	8.0±0.7	28.5	26.3	85.8	50.3
Full flowering stage	1.6-6.9	3.7±0.7	43.4	39.2	81.6	73.0
Pod area (cm^2)						
Main branch	3.9-7.4	5.3±0.4	19.9	14.4	53.6	21.9
Primary branches	3.3-6.3	4.5±0.4	19.6	13.7	48.7	19.7
Pod intensity on main shoot (pods/cm)	0.45-0.83	0.61±0.04	17.9	12.6	49.9	18.5
Seed : husk ratio	0.81-1.38	1.06±0.003	14.1	13.0	84.8	24.7
Total drymatter/plant (g)	13.2-29.5	20.0±0.5	25.8	25.5	97.5	51.8
Harvest index (%)	15.8-28.9	23.1±0.9	15.8	14.0	78.7	25.7

Table 2 Interrelationships of physiological characters and seed yield in Indian mustard under moisture stress

Character	Total drymatter/plant	Harvest index	Seed yield/plant
		Specific leaf area	
Vegetative stage	-0.088	-0.177	-0.017
50% flowering stage	-0.076	-0.188	-0.164
Full flowering stage	-0.662**	-0.463*	-0.778**
Relative water content			
Vegetative stage	0.527**	0.377*	0.628**
50% flowering stage	0.722**	0.506*	0.848**
Full flowering stage	0.483*	0.112	0.418*
		Transpiration rate	
Vegetative stage	-0.083	0.177	-0.154
50% flowering stage	-0.139	0.239	-0.213
Full flowering stage	-0.128	-0.372*	-0.295
		Pod area	
Main branch	0.456*	0.243	0.536**
Primary branches	0.154	0.368*	0.317*
Pod intensity on main shoot	0.353*	0.336*	0.467*
Seed: husk ratio	0.232	0.130	0.264
Total drymatter/plant		0.121	0.869**
Harvest index			0.581**

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

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Genetic diversity analysis for seed yield and quality characters in sesame (*Sesamum indicum* L.)

S R KUMHAR, B R CHOUDHARY AND S PAROHA[1]

Agricultural Research Station, Swami Keshwanand Rajasthan Agril. University, Mandor, Jodhpur-342 304, Rajasthan

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ABSTRACT

Genetic divergence was studied by growing thirty six genotypes of sesame, *Sesamum indicum* L. at Agricultural Research Station, Mandor, Jodhpur during rainy season 2010. The mean sum of squares were significant for all the characters, indicating the presence of variability. Characters like seed yield, free fatty acid, oxalic acid content, number of productive capsules/plant and productive branches/plant exhibited high heritability coupled with high genetic advance revealing that these characters were controlled by additive gene action. The hierarchical cluster analysis indicated the presence of considerable genetic divergence among the genotypes. The genotypes were grouped into seven clusters using Ward's minimum variance method. The intercluster Euclidean^2 distance was maximum between cluster III and VII (42.71) followed by cluster VI and VII (41.90) and cluster II and VII (39.03) which indicated that the genotypes included in these clusters will give high heterotic response and thus better segregants. The maximum cluster means were revealed by cluster III for days to 50% flowering, maturity, number of productive branches/plant, oxalic acid content and free fatty acid followed by cluster VI for seed yield, number of productive capsules/plant and oil content, and cluster I and IV for plant height and 1000 seed weight, respectively. While cluster VII showed minimum cluster mean for days to maturity, plant height and free fatty acid and cluster I and IV for oxalic acid and days to 50% flowering. Among the 10 characters, number of primary branches/plant contributed the most (12.06%) towards the divergence of genotypes.

Key words: Genetic advance, Genetic divergence, Genetic variability, Heritability, Sesame

Sesame is the oldest indigenous oilseed crop cultivated in India for its excellent cooking, medicinal, cosmetic and nutritional qualities of oil. It is a rich source of oil (50%), protein (24%), carbohydrates (15%), and sesame oil primarily contributes oleic, linoleic, palmitic and steric acid. India is the world leader with the largest area, maximum production and highest export of sesame seed with the foreign earnings of ₹ 2000 crores (Rangnatha *et al.,* 2012). Rajasthan is the major sesame growing state in the country, which contributes 29.2% in area and 24.1% in production with productivity of 408 kg/ha during 2011-12 (Anonymous, 2012). Looking to low productivity levels and to improve the quality of sesame seed and oil, genetic variability and divergence are of great interest to the plant breeder as they play a vital role in framing a successful breeding programme. The nature and magnitude of genetic divergence in a population is essential for selection of diverse parents which upon hybridization leads to a wide spectrum of gene recombination for quantitatively as well as qualitatively inherited traits. The objective of the research was to assess quantum of variability, heritability, genetic advance and genetic diversity in available varieties so that breeding efforts can be initiated to evolve early maturing, high yielding sesame varieties with low values of free fatty acid and oxalic acid content. The high value of free fatty acid (FFA) adversely affects the quality and preference of sesame oil as cooking medium and less than 2% FFA in oil are considered of good quality for health, similarly low values of oxalic acid content is also desirable (below 1.0%) and higher value impart unpleasant and undesirable bitter test and unpalatable for direct consumption.

The materials for present investigation comprised of 36 released and notified varieties of sesame and the same were grown in Randomized Block Design with three replications during rainy season 2010 at Agricultural Research Station, Mandor, Jodhpur. Each genotype was sown in two rows of 4 m length following crop geometry of 30 cm × 15 cm. The data were recorded on five competitive plants taken from each replication for plant height (cm), number of productive branches/plant and number of productive capsules/plant. Seed yield (kg/ha), 1000 seed weight (g), oil content (%), free fatty acid (%), oxalic acid content (%), days to 50% flowering and maturity were recorded considering plot of varieties in each replication. Free fatty acids in seed sample were estimated by the standard method (Anonymous, 1980) and oxalic acids in seed sample were estimated by potassium permagnet method (Anonymous, 1980) and as per Pearson (1976) at Project Coordinating Unit (Sesame and Niger), AICRP on Sesame and Niger (ICAR), JNKVV Campus,

[1]Project Coordinating Unit, AICRP (S&N), JNKVV, Jabalpur-482 004, Madhya Pradesh; E-mail: srkumhar@gmail.com

Jabalpur. The data were subjected to analysis of variance as suggested by Panse and Sukhatme (1985). Genotypic and phenotypic coefficients of variance, broad sense heritability and genetic advance (GA) as per cent of mean at 5% selection intensity were estimated by following standard statistical methods. Clustering was performed by procedure of Ward's minimum variance method.

The analysis of variance revealed significant differences among the genotypes for all the characters indicating the presence of variability. Wide variability was observed for seed yield i.e., from 271 (TC-289) to 1292 kg/ha (MT-75). The variety, Brijeswari was found earliest in days to 50% flowering (41 days) and Savitri found early in maturity (73 days). The range of plant height was from 110 (TC-289) to 196 cm (AKT-64), number of productive branches/plant from 2.0 (JT-7) to 4.3 (TMV-6), number of productive capsules/plant from 39 (AKT-101) to 70 (GT-3), 1000 seed weight from 2.07 (Nirmala) to 3.43 g (Brijeswari), oil content from 36.5 (Nirmala) to 48.1% (Shekhar), oxalic acid content 0.48 (PKV-NT-11) to 1.28% (TMV-3) and free fatty acid from 0.39 (PB Til-1) to 2.87% (GT-10). The high magnitudes of phenotypic as well as genotypic coefficient of variation for seed yield, free fatty acid, oxalic acid content, number of productive branches/plant and number of productive capsules/plant indicated the presence of ample amount of variation for these characters. The high heritability (75-99%) combined with high genetic advance as percent of mean for seed yield, free fatty acid, oxalic acid content, number of productive branches/plant and productive capsules/plant revealed that these characters were controlled by additive gene action, suggesting that selection for these traits would be effective for crop improvement. These results are in agreement with those reported by earlier workers (Solanki and Gupta, 2004; Babu *et al.,* 2004; Solanki and Kumhar, 2009).

A hierarchical cluster analysis of Ward's minimum variance method produced a dendrogram showing successive fusion of individuals which clearly partitioned the genotypes into seven clusters (Fig. 1). The cluster IV contains maximum (9) varieties, while cluster II and VII have least (2) varieties (Table 1). The genotypes within each cluster were closer to each other than the genotypes grouped in to different clusters.

The maximum intracluster Euclidean^2 distance was observed in cluster VII (12.14) followed by cluster III (11.29) and cluster VI (10.60) indicating wide genetic variability within the genotypes of these three clusters. The highest intercluster distance was observed between cluster III and VII (42.71) followed by cluster VI and VII (41.90) and cluster II and cluster VII (39.03), suggesting wide diversity between genotypes of these clusters. Therefore, genotype belonging to these clusters may be used in hybridization programme for improvement and which might be yielded better segregants. The least intercluster distance was observed between clusters IV and V (11.26) indicating close relationship between the genotypes of these two clusters.

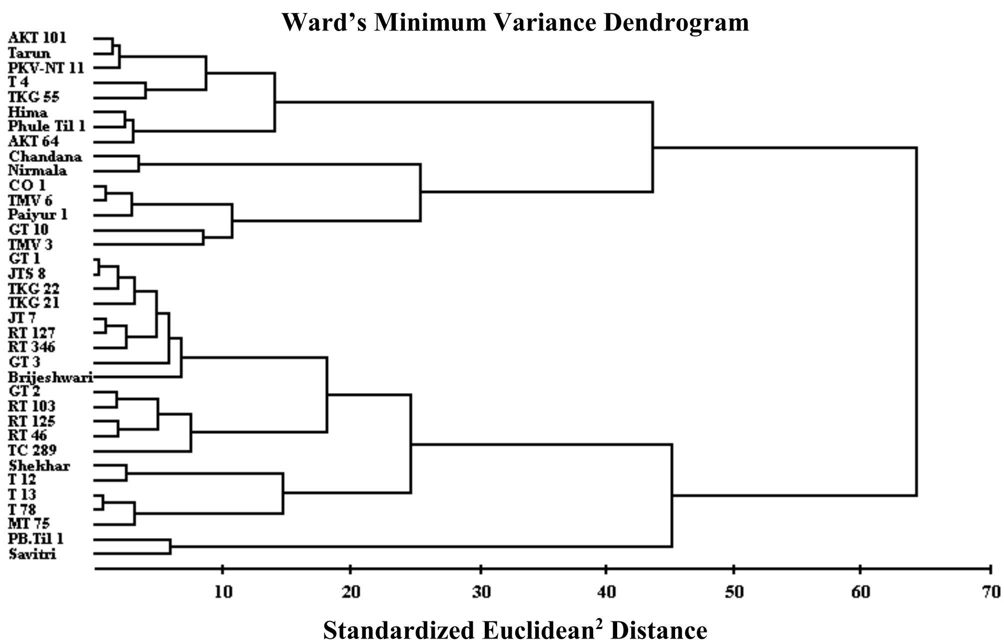

Fig. 1. Dendrogram showing clustering pattern of sesame varieties

Table 1 Distribution of 36 sesame varieties in different clusters

Cluster	No. of varieties	Varieties/ genotypes
I	8	AKT-101, Tarun, PKV-NT-11, T-4, TKG-55, Hima, Phule Til-1, AKT-64
II	2	Chandana, Nirmala
III	5	CO-1, TMV-6, Paiyur-1, GT-10, TMV-3
IV	9	GT-1, JTS-8, TKG-22, TKG-21, JT-7, RT-127, RT-346, GT-3, Brijeshwari
V	5	GT-2, RT-103, RT-125, RT-46, TC-289
VI	5	Shekhar, T-12, T-13, T-78, MT-75
VII	2	PB.Til-1, Savitri

The diversity was also supported by the appreciable amount of variation among the cluster means for different characters. The maximum cluster means were revealed by cluster III for days to 50% flowering, maturity, number of productive branches/plant, oxalic acid and free fatty acid content followed by cluster VI for seed yield, number of productive capsules/plant and oil content, and cluster I and cluster IV for plant height and 1000 seed weight, respectively. While cluster VII showed minimum cluster means for days to maturity, plant height and free fatty acid and cluster I and IV for oxalic acid and days to 50% flowering. These results showed that different clusters genotypes were superior for different characters and genotypes having these characters would offer a good scope of improvement of sesame through selection.

Amongst the characters, number of productive branches/ plant contributed maximum towards genetic divergence (12.06%) followed by days to 50% flowering (11.90%), oxalic acid content (10.63%), seed yield (10.48%), days to maturity (10.32%) and plant height (10.00%), while characters, number of productive capsules/plant and 1000 seed weight contributed least to genetic divergence. These results are in conformity with those reported by Rao, 2004; 2006; Anuradha and Reddy, 2005 and Kumhar and Solanki, 2009.

Since varieties with narrow genetic base are more vulnerable to diseases and adverse climatic conditions, therefore, the availability of the genetically diverse genotypes for hybridization programme becomes more important. In the present study the maximum intercluster Euclidean2 distance was between cluster III and VII (42.71) followed by cluster VI and VII (41.90) and cluster II and VII (39.03), and crosses among genotypes of these clusters *viz*., Co-1, TMV-6, Paiyur, GT-1, TMV-3, PB Til-1, PKV-NT-11, Savitri, Shekhar, T-12, T-13, T-78, MT-75, Chandana and Nirmala could be resulted into transgressive segregation. Since quantitative characters *viz*., number of productive branches/plant, days to 50% flowering, seed yield, days to maturity, and plant height and qualitative inherited character oxalic acid content contributed maximum towards the divergence, direct selection of these traits help in crop improvement.

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Seed and oil quality characteristics in castor (*Ricinus communis* L.)

S K SHAH, D K PATEL, R M PATEL, P S PATEL AND D U PATEL

Main Castor Mustard Research Station, S.D. Agricultural University, Banaskantha-385 506, Sardarkrushinagar, Gujarat

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ABSTRACT

Eighteen castor (*Ricinus communis* L.) genotypes (hybrids/varieties/parental lines) were studied for seed, oil quality as well as fatty acid profile. The maximum 100 seed wt (37.7 g) was observed in 48-1 genotype and the oil content (50.7%) was recorded in SKP-84 pistillate line. Hundred seed weight showed a positive correlation with kernel % (r=0.472*) and seed oil content has positive correlation with kernel oil content (r=0.664**). Industrially important oil qualities like specific gravity, colour, viscosity were also measured. The free fatty acid as oleic acid varied between 1.93 to 7.03%. Among the fatty acids, the ricinoleic acid content was ranging from 84.3 to 87.8% and the maximum was recorded in GCH-4 hybrid.

Key words: Castor genotypes, Fatty acid, Oil quality, Ricinolic acid

India is playing a lead role in the production and productivity of castor (*Ricinus communis* L.) in the world with a production of 2.34 million tonnes seeds while China, the second largest producer, produced 0.18 million tonnes of castor (FAO, 2013). Castor oil is non-edible but very important industrial oil which is characterized by its high viscosity, specific gravity and acetyl value. Ricinoleic acid (12-hydroxy-9-octadecenoic acid) is the principal component of castor oil, which occurs upto the extent of 90-95% of the total fatty acid and is responsible for the high viscosity and other unique characteristic of oil. The industrial important physicochemical properties of castor oil are due to combination of fatty acids, triacyl glycerol and oil content that varies from varieties and other factors such as climatic conditions and soil type (Ogunniyi, 2006). The fatty acids, being biological in origin, the composition is affected by the edaphological characteristics (Abolfazl *et al.,* 2011). Considerable variation in fatty acids composition have been found due to differences in the varieties and the growing conditions (Salunkhe *et al.,* 1992). Looking to the importance of the castor oil as industrial raw material, eighteen genotypes (hybrids/varieties/parental lines) were studied for seed physical characteristics and oil quality characteristics and fatty acid composition.

Eighteen castor hybrids/varieties/parental lines (Table 1) were grown during 2009-10 in the irrigated conditions at Main Castor Mustard Research Station in Entisols of S.D.A.U., Sardarkrushinagar, Gujarat. Standard agronomic practices were followed for growing the crop. The seeds were harvest at physiological maturity and analysed for seed physical properties *viz*., 100 seed weight (g), seed oil content (%), kernel oil content (%), kernel (%), seed coat (%). The castor seed oil was extracted as per method prescribed in AOCS (Aa 4-38) on soxhlet apparatus. The oil quality parameters like viscosity was determined on viscometer (A&N Vibro Viscometer, Model SV 10) and the colour value was determined on Levibond tintometer with one inch cell. The other oil quality parameters like specific gravity, refractive index and the fatty acid profile was determined on FTNIR (Bruker Optics-IFS MPA System) as per standard methods. Correlation coefficient was worked out for the various character studied.

The highest 100 seed weight (37.1g) was found in GCH-5 hybrid and the lowest (17.1 g) was observed in GAUC-1 variety (Table 1). Seed weight is considered as the most important characteristic for milling. The present study showed a significant positive correlation with kernel % (r=0.472*) and negative correlation with seed coat (r=-0.484*). The highest seed oil content (50.7%) was recorded in SKP-84 female line and the lowest (48.0%) was observed in JP-65 female line. The study reveals that among genotypes, the variation in the oil content was 2.7%. This might be due to genotypic as well as edaphological factors. Lavanya *et al.* (2012) reported the similar findings. The highest kernel oil content (60.3%) was determined in GC-2 variety and the lowest (57.3%) was observed in SH-72 male line. The kernel oil content is significantly and positively correlated with seed oil content (r=0.664**). The highest kernel per cent (73.8%) was determined in JI-96 male line and the lowest (67.9%) was observed in VP-1 female line. The seed coat had a significant negative correlation with kernel % (r=-0.996**). Lower seed coat % is desirable character for better oil recovery (Moskin, 1986).

Among the castor genotypes, specific gravity, refractive index varied from 0.958 to 0.962 and 1.4773 to 1.4782, respectively. The values of specific gravity were in line with the findings of Salunkhe *et al.* (1991) and Abitogun *et al.* (2009). The variation was attributed to differences in genotypes, and planting and harvesting conditions and extraction of the oil (Akpan *et al.,* 2006). The viscosity of castor oil was in the range of 556 to 700 centipoise with the lowest in 48-1 male line and the highest value in SKP-84 female line. The hydroxy group of recinoleic acid imparts a very high degree of viscosity and oxidative stability which was four times more stable than the olive oil (Patel *et al.,* 2004). The oil is mainly used as a lubricant because of its property to remain liquid at very low temperatures (-32°C), high density and viscosity (18 times that of other vegetables oil) (Nagaraj, 1995). The colour of crude castor oil was yellow to brown and the value was in the range of 2.0 to 5.0. The variation in oil colour is attributed to colour of seed hull. For different industrial utilization, colourless oil is preferred. Industry could take benefit of the natural colour value of the oil for different uses. The high value was as a result of the presence of high number of red pigment.

The quality of oil is a function of its fatty acid composition. The content of free fatty acid as oleic acid is varied from 1.93% (GCH-6 and JI-35) to 7.03% (GCH-2) (Table 2). However, the oil of high content of free fatty acid could be modified by subjecting it to refining and this would also improve its quality for industrial usage. This could be used to check the level of oxidative deterioration of the oil by enzymatic or chemical oxidation. A good quality castor oil should have the acid value within the range of 3-4. Expelled castor oil has generally of low fatty acidity (<3) while solvent extracted oils has higher acid value than the required standard.

Among the fatty acid profiles, the variability for palmitic, stearic, oleic, linoleic, linolenic and ricinoleic fatty acids were also recorded. The saturated fatty acids, palmitic and stearic acids were in range of 1.11 to 1.74% and 1.26 to 1.92%, respectively. Both the saturated fatty acids had significant negative correlation with the viscosity (r=-0.546* and -0.486*). Palmitic acid has positive correlation with stearic acid (r=0.718**). These values are in corroboration with findings of Lavanya *et al.* (2012). Mono unsaturated fatty acid- oleic acid varied from 3.39 (SH-72) to 6.20% (JI-35). Higher value of oleic acid is a desirable trait for high oxidative stability hence suitability of castor oil for bio-diesel, or pharmaceutical application (Rojas *et al.,* 2004). The poly unsaturated fatty acid like linoleic and linolenic acid were in the range of 3.39 to 6.09 and 0.65 to 1.13, respectively. The maximum value of both the fatty acids were found in hybrid GCH-5. Both linoleic and linolenic acids were significantly and positively correlated (r=0.557*).

Ricinoleic acid, the predominant mono unsaturated fatty acid varied among castor genotypes from 84.3 (GAUCH-1) to 87.8% (GCH-4). The functional group causes ricinoleic acid to be unusually polar and also allows chemical derivatization that is not practically possible with most other vegetable oils. It is the hydroxyl group which makes castor oil ricinoleic acid valuable as chemical feed stocks. In the present study, the ricinoleic acid content was significantly and negatively correlated with palmitic acid (r=-0.517*); oleic acid (r=-0.624**) and linolenic acid (r=-0.619**). Present study showed variation in the seed characteristics and fatty acid profile due to genotypic differences.

Table 1 Determination of seed quality characteristics of released castor hybrids/varieties and parental lines

Genotype	100 Seed wt. (g)	Oil content (%)	Kernel oil content (%)	Kernel (%)	Seed coat (%)	Specific gravity (g/Cc) at 25°C	Refractive Index (nd) at 25°C	Viscosity (cp) at 25°C	Colour value (Y+R)
GAUCH-1	25.9	48.6	59.0	70.8	29.2	0.960	1.4778	584	2.0+0.6
GCH-2	24.7	49.8	59.9	70.6	29.4	0.960	1.4780	621	5.0+1.1
GCH-4	32.2	49.7	59.2	71.6	28.2	0.961	1.4783	678	2.0+0.5
GCH-5	37.1	49.8	59.0	72.4	27.6	0.962	1.4780	656	2.0+0.5
GCH-6	31.3	49.9	59.3	70.7	29.3	0.962	1.4778	632	2.0+0.6
GCH-7	29.9	49.6	58.3	69.4	30.6	0.961	1.4881	635	3.0+0.5
GC-2	28.8	50.1	60.3	70.0	30.0	0.962	1.4781	675	3.0+0.9
GC-3	36.0	50.4	59.3	72.2	27.2	0.960	1.4777	611	3.0+0.9
GAUC-1	17.1	49.1	57.7	70.6	29.4	0.960	1.4773	589	3.0+0.7
JI-35	25.7	50.6	60.2	69.5	30.5	0.959	1.4778	642	2.8+0.8
48-1	37.7	50.1	59.6	72.0	28.0	0.958	1.4774	556	4.0+0.6
SH-72	30.1	48.4	57.3	69.3	30.7	0.958	1.4775	587	3.0+0.9
JI-96	30.5	50.3	58.9	73.8	26.2	0.969	1.4778	680	3.0+0.1
SKI-215	35.6	50.2	58.8	73.5	26.5	0.958	1.4781	688	3.7+0.7
VP-1	24.0	50.2	57.8	67.9	32.1	0.961	1.4781	637	5.0+0.7
Geeta	34.3	48.7	58.4	70.6	29.4	0.961	1.4782	660	3.0+1.4
JP-65	36.7	48.0	57.7	69.8	30.2	0.960	1.4780	684	3.0+0.8
SKP-84	32.8	50.7	59.7	73.7	26.3	0.960	1.4782	700	3.0+0.9
Mean	30.6	49.7	58.9	71.0	28.9	0.961	1.4785	640	
SEm±	1.3	0.2	0.2	0.4	0.4	0.001	0.0006	10	
SD	5.5	0.8	0.9	1.7	1.7	0.002	0.0024	42	
Range	17.1-37.7	48.0-50.7	57.3-60.3	67.9-73.8	26.2-32.1	0.958-0.969	1.4773-1.4881	556-700	

Table 2 Fatty acid composition of castor hybrids/varieties and parental lines

Genotype	% Free Fatty acid as Oleic acid	Fatty acid composition (%)					
		Palmitic	Stearic	Oleic	Linoleic	Linolenic	Ricinoleic
GAUCH-1	2.49	1.58	1.70	5.40	5.88	1.11	84.3
GCH-2	7.03	1.53	1.47	5.35	6.05	0.82	84.8
GCH-4	1.97	1.11	1.26	4.16	4.98	0.70	87.8
GCH-5	1.95	1.56	1.63	4.64	6.09	1.13	85.0
GCH-6	1.93	1.18	1.44	4.96	5.10	0.98	86.3
GCH-7	2.50	1.26	1.27	4.82	5.24	0.82	86.6
GC-2	1.96	1.30	1.42	4.33	5.54	0.93	86.5
GC-3	1.96	1.67	1.92	5.81	4.48	0.65	85.5
GAUC-1	2.49	1.28	1.54	4.28	5.51	0.78	86.6
JI-35	1.93	1.48	1.88	6.20	3.39	0.74	86.3
48-1	4.68	1.52	1.58	4.48	5.79	0.97	85.7
SH-72	3.10	1.74	1.58	3.93	4.74	0.65	87.4
JI-96	3.92	1.41	1.48	4.06	5.35	0.80	86.9
SKI-215	4.11	1.13	1.33	4.05	5.23	0.69	87.6
VP-1	4.75	1.36	1.35	4.92	5.88	0.78	85.7
Geeta	4.09	1.26	1.34	4.82	5.73	0.95	85.9
JP-65	4.74	1.45	1.35	4.97	5.87	0.80	85.6
SKP-84	1.98	1.30	1.43	4.80	5.38	0.75	86.3
Mean	3.20	1.40	1.50	4.78	5.35	0.84	86.2
SEm±	0.34	0.04	0.04	0.15	0.16	0.03	0.2
SD	1.46	0.18	0.19	0.62	0.66	0.14	0.9
Range	1.93-7.03	1.11-1.74	1.26-1.92	3.93-6.20	3.39-6.09	0.65-1.13	84.3-87.8

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Effect of calcium and boron on sunflower (*Helianthus annuus* L.) seed yield in Alfisols

I Y L N MURTHY, S N SUDHAKARA BABU, CH V HARIPRIYA AND M BHASKARA REDDY

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

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ABSTRACT

A field experiment was conducted in red sandy loam (Alfisol) soil, deficient in calcium (Ca) and boron (B) with sunflower hybrid DRSH-1 as test crop to study the influence of Ca and B application on sunflower drymatter yield, seed yield, Ca and B nutrient uptake and interaction. Sunflower drymatter yield varied from 1742.7 to 2522.9 kg/ha. Higher seed yield (882.5 kg/ha) was recorded in $Ca_{30}B_3$ however, it was at par with $Ca_{30}B_2$ treatment. The Ca x B interaction significantly influenced Ca and B uptake by the sunflower plant. Ca x B interaction effects were also found significant in soil available Ca and B. Application of calcium at 30 kg/ha and boron at 2 kg/ha resulted in high sunflower seed yield in Ca and B deficient red sandy loam soils.

Key words: Alfisol, Boron, Calcium, Seed yield, Sunflower, Uptake

Sunflower (*Helianthus annuus* L.) is an important oilseed crop cultivated in different soil types of India. The crop productivity varies depends on the soil fertility. In the semi arid tropics, (SAT) the crop occupies approximately 30% of its cropped area. These soils have limitations of soil depth, poor water and nutrient-holding capacity, excessive drainage, runoff and are generally poor in soil fertility. Especially, the deficiencies of sulphur, boron (B) and zinc (Zn) nutrients were more widespread in farmers' fields in Andhra Pradesh, Karnataka, Madhya Pradesh, Tamil Nadu and Gujarat (Sahrawat *et al.,* 2007). Sunflower is one of the predominant oilseed crops in these states. However, under good agronomic management, the SAT soils can be used for sunflower seed production profitably.

Calcium (Ca) and boron (B) influence the germination of the pollen grain and the pollen tube growth (Gupta, 2001), with these nutrients also performing similar functions in carbohydrate transport from leaves to roots, which is reflected in nodulation of leguminosae (Clark, 1984). Considering Ca and B participation in the same functions or processes, Kanwal *et al.* (2008) and Pavinato Paulo *et al.* (2009) pointed out that both nutrients must be balanced for adequate plant growth. Present study was conducted to find out the optimum Ca and B fertiliser application to achieve higher sunflower seed yield as well as the Ca and B nutrient status in soil and sunflower.

A field experiment was conducted at Narkhoda farm of DOR during the rainy season of 2011 in a red sandy loam soil (Alfisol). Physico-chemical characteristics of the initial soil were pH: 7.0, EC: 0.23 dS/m, available N, P, K, Ca and B were 210, 12, 280 kg/ha, 10.0 meq/100g and 0.2 mg/kg, respectively. The initial soil was found deficient in Ca and B contents. Sunflower (cv. DRSH-1) was grown with 5 levels of Ca (0, 10, 20 30 and 40 kg/ha) as CaO and 4 levels of B (0, 1, 2 and 3 kg/ha) as borax treatments in a factorial Randomized Block Design with three replications. All the cultural practices were followed as per the package of practices to grow the sunflower crop. At maturity sunflower leaf, head, stem and seed components were harvested. Leaf, head and stem portions were air-dried and then oven dried at 70°C and powdered. Powdered samples were digested in di-acid (HNO_3: $HClO_4$ in 9:4 respectively) and analysed for Ca and B contents as per the standard procedures. Estimated Ca and B contents of leaf, head and stem were pooled and considered as plant portion while seed portion was analysed separately. Post-harvest soil samples were also analysed for available Ca and B contents. Drymatter yield, seed yield and nutrient uptake were computed and analysed statistically.

Sunflower drymatter yield varied from 1742.7 to 2522.9 kg/ha (Table 1). Interaction effect of Ca x B was found significant although the Ca and B levels were found non-significant. Further, Ca and B nutrient interaction on plant height, head diameter and number of seeds/head were found statistically non-significant. Seed yield was significantly influenced by Ca and B levels. Higher seed yield (882.5 kg/ha) was recorded in $Ca_{30}B_3$ however, it was at par with $Ca_{30}B_2$ treatment. Seed yield showed an increasing trend with increasing Ca and B levels. However, at high level of Ca and B there is a decline in seed yield which indicates an opposed effect of Ca and B at this level. Seed yield was also significantly influenced by Ca x B interaction (Table 1). Shekhawat Kapila and Shivay (2008) reported that application of 80 kg N/ha through calcium ammonium nitrate with 25kg S/ha and 1.5 kg B/ha would be sufficient to the higher productivity and quality of spring sunflower under north Indian conditions.

Table 1 Effect of calcium and boron levels on drymatter, uptake and seed yield of sunflower

	Drymatter yield (kg/ha)					Seed yield (kg/ha)				
	B_0	B_1	B_2	B_3	Mean	B_0	B_1	B_2	B_3	Mean
Ca_0	1903.3	2255.6	2186.5	2055.3	2100.2	452.1	563.0	683.1	526.6	556.2
Ca_{10}	2122.9	2284.1	2102.5	2144.0	2163.4	546.0	580.9	780.6	748.4	664.0
Ca_{20}	1894.2	2522.9	1751.7	1983.3	2038.0	658.9	671.2	742.2	795.1	716.9
Ca_{30}	2322.4	2129.1	2031.9	1957.7	2110.3	773.5	784.6	740.1	882.5	795.2
Ca_{40}	2013.4	2261.4	1816.3	1742.7	1958.4	643.3	742.9	649.3	379.8	603.8
Mean	2051.2	2290.6	1977.8	1976.6		614.8	668.5	719.1	666.5	
	Ca	B	Ca x B			Ca	B	Ca x B		
SEm±	136.2	121.77	272.3			28.1	25.1	56.1		
CD (P=0.05)	NS	NS	779.4			80.3	71.9	160.7		
	Plant uptake of B (g/ha)					Seed uptake of B (g/ha)				
	B_0	B_1	B_2	B_3	Mean	B_0	B_1	B_2	B_3	Mean
Ca_0	70.9	89.6	85.5	89.9	84.0	7.2	9.2	15.8	11.1	10.8
Ca_{10}	103.3	103.7	91.1	73.0	92.8	12.9	14.0	18.2	16.9	15.5
Ca_{20}	84.2	104.0	72.2	80.6	85.3	15.3	17.3	20.4	19.3	18.1
Ca_{30}	109.5	87.3	87.0	91.6	93.9	18.6	20.2	23.5	21.0	20.8
Ca_{40}	67.2	86.6	77.4	76.4	76.9	15.9	18.9	22.8	10.4	17.0
Mean	87.0	94.3	82.7	82.3		14.0	15.9	20.1	15.7	
	Ca	B	Ca x B			Ca	B	Ca x B		
SEm±	6.3	5.63	12.6			2.0	1.8	4.02		
CD (P=0.05)	NS	NS	36.1			5.8	NS	11.52		
	Plant uptake of Ca (kg/ha)					Seed uptake of Ca (kg/ha)				
	B_0	B_1	B_2	B_3	Mean	B_0	B_1	B_2	B_3	Mean
Ca_0	51.6	70.7	67.8	60.1	62.5	1.2	2.3	3.1	3.2	2.5
Ca_{10}	59.3	64.6	56.5	56.4	59.2	2.1	2.8	3.8	2.2	2.7
Ca_{20}	56.1	68.5	50.0	55.7	57.6	3.4	4.5	2.3	3.0	3.3
Ca_{30}	77.8	58.4	66.1	56.4	64.7	5.0	2.7	2.8	3.6	3.5
Ca_{40}	67.0	65.9	55.9	49.5	59.6	2.0	2.9	2.6	2.0	2.4
Mean	62.3	65.6	59.2	55.6		2.7	3.0	2.9	2.8	
	Ca	B	Ca x B			Ca	B	Ca x B		
SEm±	4.7	4.2	9.4			0.2	0.2	0.4		
CD (P=0.05)	NS	NS	27.0			0.5	NS	1.0		
	Total uptake of B (g/ha)					Total uptake of Ca (kg/ha)				
	B_0	B_1	B_2	B_3	Mean	B_0	B_1	B_2	B_3	Mean
Ca_0	78.1	98.9	101.3	101.0	94.8	52.8	73.0	70.9	63.2	65.0
Ca_{10}	116.2	117.7	109.3	89.9	108.3	61.4	67.4	60.3	58.6	61.9
Ca_{20}	99.5	121.4	92.6	99.9	103.3	59.5	73.0	52.2	58.7	60.8
Ca_{30}	128.1	107.6	110.5	112.6	114.7	82.8	61.1	68.8	60.0	68.2
Ca_{40}	83.1	105.6	100.2	86.8	93.9	69.0	68.7	58.6	51.5	62.0
Mean	101.0	110.2	102.8	98.1		65.1	68.6	62.2	58.4	
	Ca	B	Ca x B			Ca	B	Ca x B		
SEm±	6.9	6.2	13.9			4.7	4.2	9.4		
CD (P=0.05)	NS	NS	39.8			NS	NS	26.8		

The Ca x B interaction significantly influenced Ca and B uptake by the sunflower plant. Uptake of Ca varied from 49.5 to 77.8 kg/ha (Table 1). Similarly uptake of B varied from 70.9 to 109.5 g/ha among the treatments.

Seed uptake of Ca and B was significantly effected by Ca levels. Uptake of Ca by seed was found significant with the graded levels of Ca. An increasing trend in Ca uptake with increasing levels of Ca was observed. Uptake of Ca was significantly influenced by Ca x B interaction. Uptake of B by seed was higher at Ca_{30} level. A gradual increase in B uptake by seed with the increased levels of Ca was noticed. Interaction effects of Ca and B were also found significant. Higher B uptake in seed was observed in $Ca_{30}B_2$ treatment. However, higher levels of Ca and B showed a declining trend indicating the opposed effect of Ca and B. Ca x B interaction effects were found significant in soil available Ca and B.

Total uptake of Ca by above ground parts of sunflower varied from 51.5 to 82.8 kg/ha. Similarly total uptake of B ranged from 78.1 to 128.1 g/ha among the treatments. The Ca x B interaction significantly influenced the total uptake of Ca and B by above ground parts of sunflower.

It can be inferred from the above study that to attain higher sunflower seed yield in a red sandy loam soil having low available Ca and B, application of calcium at 30 kg/ha and boron at 2 kg/ha is required.

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Identification of groundnut germplasm resistant to tikka disease in Gujarat

A VIJAYA BHASKAR, A M PARAKHIA, A F AKBARI AND S V PATEL

Department of Plant Pathology, Junagadh Agricultural University, Junagadh-362 001, Gujarat

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ABSTRACT

Early and late leaf spots, caused by *Cercospora arachidicola* and *Phaeoisariopsis personata,* respectively are serious diseases of groundnut in Saurashtra region of Gujarat State. A total of 164 germplasms were screened along with susceptible check (GG-2) against both the diseases under natural epiphytotic conditions in *kharif* season to select resistant sources. The germplasms were scored using 1-9 scale at 90 days after sowing. The results indicate that no germplasm was immune or highly resistant to both the leaf spots. Thirty six entries showed resistant reaction to the diseases.

Key words: *Cercospora arachidicola,* Groundnut, Leaf spot, *Phaeoisariopsis personata,* Resistance

Groundnut (*Arachis hypogaea* L.) is one of the principal oilseed crops of the world. India holds the world's largest area of 59.7 lakh ha under groundnut, second by producing 72.9 lakh tonnes and yield 1220 kg/ha (Misra and Rathnakumar, 2011). The major biotic factors affecting groundnut yield and quality in India are foliar fungal diseases, stem rot, collar rot, root rot and seedling rot, etc. Early (*Cercospora arachidicola* Hori.) and late leaf spots [*Phaeoisariopsis personata* (Berk. and Curt.) Von Arx.] are the most widely distributed and economically important foliar diseases of groundnut causing severe damage to the crop (Satishchandra *et al*., 1995; Kokalis-Burelle *et al*., 1997). Each disease alone is capable of causing substantial yield loss but when they occur together, losses are further increased.

Early and late leaf spots commonly called as "tikka disease" become major problem for quality production in groundnut growing of Saurashtra region (Gujarat). So looking to the importance and severity of disease resulting in heavy losses, attempt was made to study the screening for sources of resistance to early and late leaf spots. The studies were conducted during *kharif* 2005 at Department of Plant Pathology and Research Farm, Main Oilseed Research Station, Junagadh Agricultural University, Junagadh. Naturally infected leaves of groundnut showing typical early and late leaf spot symptoms were collected from the farm and examined under a compound microscope for preliminary identification of the pathogen. Varietal screening of groundnut was undertaken in field condition to find out the resistant germplasm of groundnut against early and late leaf spot diseases. One hundred and sixty four germplasm/variety of groundnut were planted in rows of five meter each and susceptible cultivar GG-2 was sown after every two rows of groundnut germplasm. The spacing followed was 45 cm x 10 cm. The average disease score (modified 9 point scale) was recorded 90 days after sowing. The reactions of germplasm were categorized into immune (1 score), highly resistant (2 to 3 score), resistant (4 to 5 score), susceptible (6 to 7 score) and highly susceptible (8 to 9 score) according to Subrahmanyam *et al.* (1995).

Among 164 genotypes evaluated, none was immune or highly resistant reaction to early and late leaf spot. Thirty six entries showed resistant reaction. They are B-95, BAU-13, BPZ-68-overo, C-184, CSHG-83-1, CSMG-9101, Dh-81, Dh-86, Dh-992, GKP-942, ICG-243, ICG-859, ICG-911, ICG-2496, ICG-2800, ICGV-86590, ICGV-86564, ICGV-91085, M-13, M-395, ISK-1-2005-17, ISK-1-2005-19, IVK-1-2005-1, IVK-1-2005-2, IVK-1-2005-5, IVK-1-2005-6, IVK-1-2005-8, IVK-1-2005-10, IVK-1-2005-12, IVK-1-2005-13, LSVT-1-2005-5, LSVT-1-2005-6, TG-26, TAG-24, ICGS-86564 and M-335. Ninety two entries were found susceptible and 36 entries showed highly susceptible reaction to the diseases. Similar results were obtained by Satishchandra *et al.* (2004) on screening of groundnut varieties against leaf spot disease. Subrahmanyam *et al.* (1980) reported that the germplasm accessions, NCAC 17090 and EC 76446 (292) were found resistant to leaf spot among 6000 groundnut accessions screened. Ghewande *et al.* (1983) screened 3655 groundnut entries for leaf spot and rust disease. They identified two genotypes namely B-613 and Pl 341839 which were resistant to both diseases. Reddy *et al.* (1997) screened 33 groundnut advanced breeding lines against leaf spot diseases. They found that none of the lines was resistant to both early and late leaf spot diseases, while ICGV 86252 and JL 24 were moderate resistant to late leaf spot. The present study identified few resistance sources which can be utilized for breeding resistant cultivars against early and late leaf spots.

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