ISSN 0970-2776

Volume 40 Number 1 & 2 Mar. & June, 2023

Journal of Oilseeds Research

INDIAN SOCIETY OF OILSEEDS RESEARCH
Estt: 1983

Indian Society of Oilseeds Research
ICAR-Indian Institute of Oilseeds Research
Rajendranagar, Hyderabad-500030, India

THE INDIAN SOCIETY OF OILSEEDS RESEARCH

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

MEMBERSHIP TARIFF

(w.e.f. 01.06.2014)

Life Membership	**Annual Subscription**		**India**	**Abroad**
Individual : Rs.5000/- + Admn. Fee Rs.50/-	Individual	:	Rs. 1000/- + Admn. Fee Rs.50/-	US$ 100 Ordinary
	Institutions	:	Rs. 6000/-	US$ 200 Institutions
	Students	:	Rs. 500/- + Admn. Fee Rs.50/-	

For subscription, please contact ☛ The General Secretary, Indian Society of Oilseeds Research, ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad-500 030, India

Payment can be made online by fund transfer to account No. **52032213529** with IFSC Code: **SBIN 0020074.** After payment, the UTR No. and payment details may be sent by e-mail (oilseedsociety@gmail.com) / post to the General Secretary, ISOR, ICAR-IIOR, Rajendranagar, Hyderabad-500 030. For further details please visit: http://www.isor.in.

ANNOUNCEMENT

The Journal of Oilseeds Research has been rated at **4.59** by National Academy of Agricultural Sciences (NAAS) from January 1, 2021

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

JOURNAL OF OILSEEDS RESEARCH

Previous Issue : Vol. **39**, No. 3 & 4, pp. 165-267

Vol. **40**, No. 1 & 2 Mar. & June, 2023

CONTENTS

Short Communications

An Analytical Review

The Indian soybean revolution - Ascertaining the determinants and the tipping point

SIDDHARTHA PAUL TIWARI AND S P TIWARI*

Southeast Asia Interdisciplinary Development Institute (SAIDI), Antipolo City 1870, The Philippines

(Received: January 3, 2023; Revised: March 2, 2023; Accepted: March 16, 2023)

ABSTRACT

The landmark Indian soy-revolution was re-visited and an analytical review undertaken for ascertaining its tipping point and the factors responsible for its occurrence and early continuation. A score of enabling determinants of this watershed occurrence was elucidated, assessed and aggregated. Several specific notes on current situation, wherever required, were provided. Soybean revolution was observed to have reached its tipping point in the later part of the year 1972. Export-orientation of soy-derivatives and earning huge profit therefrom appeared as a crucial prospective recourse that, in due course, could change the traditional Indian soybean into a commercial crop and a highly processed commodity. Consequently, Indian soymeal emerged as the characteristic hallmark of country's soy-based export. Later, a high rise in domestic use of soymeal was also experienced. Availability of rainy-season fallow-land was another vital contextual factor, with zero opportunity cost, that enabled the soybean spread in its initial and early period. The fallow land happened to be in a suitable niche with appropriate latitudinal bearings that imparted a short duration to the soybean crop, making it to feasibly fit in the available cropping system. Soybean occupied the fallow-land and it right away enhanced the cropping intensity and the unit area profitability from the land use. There was an overwhelming enthusiasm of farmers to adopt this innovation despite it being risky due to low soybean yields but profitable due to low input-cost and high procurement cost. R&D organisations providing strong and specific technical backstopping existed when soybean had a little crop-area. These contextual pre-requisites got favourably aligned with eventual market intervention by the government and parastatal agencies, and several farmer-friendly initiatives of the cooperative organisations and the industry. Soybean crop expansion, unlike that in South America, happened in a relatively environment-friendly manner. Most of the essential ingredients were indigenous. Committed industrialists, scientists and farmers with changed mind-set led to the establishment of a new global chain of business. Soybean earned substantial foreign exchange and its trickle down brought about inclusive socio-economic upliftment. A high moral support abated the efforts of calling soybean an unacceptable foreign crop. These determinants and resultant benefits helped usher in the Indian soybean revolution that continues to contribute significantly towards agricultural economy and well-being of the country.

Keywords: India, Soybean Revolution, Soybean, Tipping point and determinants

Oilseed scenario of India is adorned with the landmark soybean revolution. Description of the revolution has been attempted earlier (Tiwari *et al.,* 1999, Tiwari, 2014). Some factors have been held responsible for the revolution and related industrial development (Bisaliah, 1986; Bapna, *et al.,* 1992; Tiwari *et al.,* 1999; Chand 2007; Tiwari 2017). Nevertheless, the revolution deserves a renewed contemporary relook translated into an exclusive and explicit narration of this historical saga, uncluttered with extraneous aspects. The factors responsible for initiating the soy-revolution and those being ancillary or accompanying in nature have often been treated at par. It was, hence, undertaken to ascertain and authentically elaborate the crucial determinants and the tipping point of the soy-revolution.

Analysis

Descriptive analytics was undertaken using historical data and events along with current updates to identify the trends and relationships. It was especially useful for understanding change over time by horizontally comparing each item to itself from a previous period. If the current status of an item or situation critically differed from the past established trend, warranting a decision-making in strategy or even modification in the regulatory frame, a specific note with a sub-heading, "Current situation", was provided. The events and related facts were gathered from published sources, data sources and interviews of some key persons. Long experience of one of the authors, Satya Prakash Tiwari

Fellow, The Royal Asiatic Society of Great Britain and Ireland (FRAS); Visiting Distinguished Fellow, SAIDI, The Philippines; E-mail ID: siddhartha@saidi.edu.ph;

[1]Ex-Vice Chancellor, SK Rajasthan Agricultural University, Bikaner; Ex-DDG, ICAR; Fellow, NAAS; Fellow, ISOR;

*Corresponding author's E-mail: drptsatyaptiwari@gmail.com

in soybean also came in handy as he was involved as a team-member with the uprising of traditional soybean as a commercial crop. Focused analysis, in contrast to a general over-analysis of dynamics of every possible variable, was aimed at. Basic year-wise soybean area and production data (MoA&FW, 2022) for the effective period were corroboratively used for analysis. Soybean yields fluctuate over years due to weather effects. Hence, triennium average data was also used for analysis. The compound growth rates (CGR) of area, production and yield of soybean from tentative start of soy-revolution for trienniums and decades were estimated using standard methods. The analytical tools used were geared to analyse the temporal and spatial shifts of soybean development in India. It was also attempted as to how the events, their timing, trend and group of people involved correspond to the tipping point, the law of the few, the stickiness factor and the power of context as per Gladwell (2000).

The determinants, events and characteristics of the revolution

1. The Law of the Few: Indore, in central India, has a long history of trade and associated activities in oilseeds including soybean. USDA Germplasm Collection Inventory (1989) records that 258 soybean accessions were imported by the USA from India during the years 1945 to 1985. Further, it also records that 54 PI numbers i.e. serially from 374, 154 to 374, 207 were collected from Mhow, Ujjain, Dewas, Simrol and Indore of central India that were all black-seeded (Bernard *et al.,* 1989; Tiwari, 2006). Some accessions refer to the noted Mahadev Bhai Shahra of Indore as the source. In late 1960s and early seventies, there were a few eminent and capable key people who could champion the idea of large-scale soybean farming for soymeal export and other business uses. These included Shahras (Mahadev Bhai and his son Kailash Chandra Shahra), N.N. Jain (later awarded with Padma Shri) and some more businessmen of Indore along with R.P. Kapoor (a senior bureaucrat), M.D. Tedia, M.L. Nahar and others on development side supported by a team of promoters and producers. Some names are mentioned herewith but there was a large but not very large team of connectors (bringing the idea to larger networks of stakeholders), mavens (soybean information experts) and grain procurement personnel akin to the key types described by Gladwell. The idea of exporting soymeal was different from earlier efforts of popularizing soybean for food uses. This innovative effort was to create a new value chain and opening up a new market out of India.

With the above realization, Shahras first set up a 50 tonne per day plant in 1973. This plant was modernized and upgraded in the next two years. With the addition of more plants by industrialists, the capacity increased. Soybean availability and its crushing grew steadily.

2. The Stickiness Factor: There was a stickiness factor operating owing to potential big profit by export of soymeal and other soy-derivatives and a degree of certainty in earning that profit. That also meant good assured buying of raw soybean. This altogether could easily catch on among industrialists, particularly those having or intending to have solvent extraction plants, cooperatives dealing in oilseeds, development persons and farmers. A profit-giving venture that was pinned on the prospects of huge export earnings was a sound reason for the stickiness of the group. Farmers started and continued growing soybean despite all odds that showed their willingness to adopt an innovation that was remunerative but risky due to low yields. Sustained interest of the group for a long period was necessary because crop growing for raw material availability year after year makes the transformation happening steadily and continuing for a long period. The related group stuck to the idea and successfully worked for it.

3. The Power of Context: The contextual situation was highly favourable for soy-revolution. Export-orientation, availability of solvent extraction plants, potential fallow land available for soybean cropping, suitable niche and appropriate latitudinal span imparting a short duration to soybean crop to fit in the existing cropping system, R&D set-up and technical backstopping, developmental support including minimum support price for soybean grain procurement, support of cooperatives and industry, and farmers' readiness to adopt a new crop were all timely and in certain cases were ahead of time. The context made a remarkable mind-set shift from production for the domestic food-use and oil market towards value addition for export market, turning Indian soybean into a commercial crop at global level. The set of circumstances, situations and facts, for having utilized the most of this favourable context, need to be analysed individually.

4. Export of soymeal loomed large as a profitable venture: Export-orientation, currency dynamics and favourable exchange rate (Tiwari and Tiwari, 2018) prevailing during early seventies made a conducive context for investments and venturing into soybean industry and farming. Export of de-oiled cake (soymeal) appeared propitious due to its relative advantages *viz.,* (a) relatively high protein content of Indian soymeal, (b) geographical proximity of India to certain importing countries, particularly those of Asia-pacific region, impacting favourably on logistics, freight advantage and overall transportation cost, (c) small contingents were also acceptable to Indian businessmen, (d) non-GMO status of Indian soymeal preferred by European countries, and (e) overall favourable currency dynamics imparting global competitiveness for export of Indian soymeal and other soy-derivatives.

Businessmen were ready to pay farmers remuneratively for their produce and procure soybean as raw material for solvent extraction plants. Existing solvent extraction plants in early seventies were not or little using soybean. Motiramani *et al.* (1979) studied six plants/oil mills in 1977-78 in Madhya Pradesh (M.P.) that crushed soybeans to yield soybean oil and meal, with a processing capacity of 400 tons/day. More than 25,000 tons of the soybean meal was exported. After an initial success, there was a surge of using soybean in solvent extraction plants for its oil, soymeal and lecithin. The capacity of existing plants was increased and establishment of new ones was undertaken. Presently there are about 120 processing plants with an installed capacity of over 25 million metric tonnes (MMT), much more than the Indian soybean production.

5. Available fallow land- Soybean fulfilling a developmental need: The early rapidity and selectivity of soybean area expansion was much dependent on fallow land available, fortunately at zero opportunity cost. Central India had sizeable farming land lying vacant in rainy-season, called as '*kharif*' fallows, potentially available for soybean crop to occupy it. Economic benefits of soybean, particularly high economic return to farmers with less input-cost, were established in early 1970s and mid-1980s (Dovring *et al.,* 1974; Bapna *et al.,* 1992). Williams *et al.* (1974) estimated 10% of 'wet season' or rainy-season fallow land for soybean coverage in M.P. and U.P., amounting to only 1.03 million hectares (m ha). Also, 0.99 m ha land availability was estimated by replacing crops like sorghum, pearlmillet, minor millets upland rice, etc. On adding these area figures, the total estimated land was 2.02 m ha that was potentially available for soybean. Soybean surpassed these underestimates in 1989-90 when its area approached 2.25 m ha. Bisaliah (1986) later analysed the situation and provided higher than the earlier estimates for fallow land. He stated that about 5 million hectares of land was left fallow during 1971-72 mainly in the central and western districts. The fallow land as percentage of net area decreased from about 30% in 1971-72 to about 26% in 1981-82 when soybean started occupying it. Soybean expansion was not affected by the size of land-holdings. As a result, small-, medium- and large-sized land-holdings were almost well distributed in regard to their share in soybean area in M.P. (Bapna *et al.,* 1992). The leading districts experiencing sizeable soybean spread were in the state of M.P. Some of the top districts, in descending order, were Hoshangabad, Indore, Betul, Ujjain, Dewas, Sehore, Shajapur, Dhar, Chhindwara, Raisen, Rajgarh and Vidisha, covering about 85% of total area in the years 1981 to 1983. Whatsoever may be the estimates, the availability of fallow lands will always be remembered as a major contributing context in starting the revolution and early spread of soybean. Thus, soybean fulfilled a developmental need of central India. This resulted in an enhancement in the cropping intensity and an increase in the unit area profitability from the land use. Soybean spread was not confined to M. P., having the largest soybean area and industry, but had significant cascading effect on neighbouring states particularly Maharashtra, now in a dominant position, and Rajasthan. Soybean eventually occupied about 13 m ha in 2020-21.

6. Short duration of soybean crop matched the available niche: A major characteristics of the revolution was that Indian soybean crop matured appreciably earlier than that in the USA and other major soybean growing countries. Within India also, this photoperiod-sensitive crop matured earlier under central Indian locations than those under northern Indian locations. Early maturity enabled its perfect fit in the existing cropping system per se in M.P. More than that, the short duration brought about a unique and highly profitable cropping system namely, early soybean-potato-late sown wheat in Malwa region around Indore. Incidentally, this quality of Indian soybean was also highlighted by a progressive farmer, Kewal Singh Patel of Hatod village near Indore, while he was participating, along with two other progressive farmers namely, Bane Singh Chauhan and Manohar Singh Chandel, in the World Soybean Research Conference VI held at Chicago, USA in 1999. Comparisons of high yields of certain foreign countries with moderate Indian yields would be valid only when the observed yield figures are adjusted for maturity duration. Factors like (i) available crop duration, (ii) per day productivity, (iii) unit area profitability from the land use, across the seasons and cropping systems, and (iv) overall system efficiency need to be taken into account to make such comparisons worthy of consideration. A large yield gap, however, exists to be feasibly filled up along with pursuing other desiderata in order to increase the Indian soybean productivity (Tiwari 2014).

7. Environment-friendly crop expansion: In South America particularly Argentina and Brazil, soybean expansion has been blamed for neo-tropical deforestation directly or indirectly (Barona *et al*., 2010; Gasparri *et al*., 2013; Richards *et al*., 2012). The Indian soybean spread has been viewed from this angle and found to be largely environment-friendly (Tiwari and Tiwari, 2018). Soybean is naturally an ideal component of an environmentally sound agricultural system. Several intrinsic attributes of this crop plant include less loss and even some reported increase in yield due to increased CO_2, most economical source of protein with carbon opportunity cost of 17 kg CO_2 equivalent per kg of protein, 'tofu' having a carbon footprint of 1.98 kg CO_2 equivalent per 100 g of protein (Carlson *et al*., 2016; Poore and Nemeck, 2018), efficient nitrogen user being a leguminous crop, and increasing adoption of voluntary sustainability standards. Unlike that in South America, Indian soy-revolution, occupied its new niche in the form of fallow land and replaced some minor crops in its early spread. It did not result in the loss of pastures and forests and did not obliterate any sequestration reserve. Soybean, in fact, may be recommended for crop switching, replacing inefficient rainy-season and upland rainy-season crops wherever feasible, as an adaptation strategy to climate change. Its inclusion could lead to sustainable cropping systems and provide plant-based protein for human consumption besides increasing farmers' income.

8. A robust R&D set-up: Several farm universities particularly Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur and Uttar Pradesh Agricultural University (UPAU) that was later named as Govind Ballabh Pant University of Agriculture and Technology (GBPUA&T), Pantnagar and some other centres were carrying out R&D in case of soybean in early and mid-sixties. Those were selecting and breeding suitable varieties, recommending agronomical practices and carrying out other related basic and applied research at a time when soybean area and production was negligible. Soybean was then not a crop in true sense and was only traditionally grown in northern hills and scattered pockets in other places of the country. A history of soybean in its very early and early stage in Indian Subcontinent has been given in detail by Shurtleff and Aoyagi (2010). The All India Coordinated Soybean Research Project (AICSRP) was started by the Indian Council of Agricultural research (ICAR) in April 1967 with its HQs at IARI, New Delhi. Dr. Harbhajan Singh of IARI was nominated as the Project Coordinator for AICSRP (Randhawa 1986) as he was one of the earliest plant scientists to realize the importance of the soybean crop in India. AICSRP (later called as AICRP on Soybean) had IARI as the main centre, Jabalpur and Pantnagar as special centres and other six sub-centres spread over the country (Saxena 1976). The AICRPS HQs soon moved to Pantnagar. An account of mid-60s' developments particularly at GBPUA&T, Pantnagar has been given by Singh (2006). Technology Mission on Oilseeds (TMO) was launched in May, 1986 with the aim of mainly increasing the production of oilseeds and to reduce the country's dependence on import of edible oils. It covered oilseed crops including soybean. National Research Centre for Soybean (NRCS, ICAR) was established in December 1986 at Indore. It was the brain-child of Dr. M. V. Rao, Padma Shri Awardee, Special Director General, ICAR. The potato farm of the M.P. state near Bhanwar Kua on Khandwa Road, Indore was taken over by the ICAR on December 11, 1986 but the scientists (Drs. P.S. Bhatnagar A.D., S.P. Tiwari, Prabhakar and A.N. Sharma) and other staff were camped in the IARI's Wheat Station near Agriculture College of Indore before shifting to NRCS-site proper on May 14, 1987. AICRPS HQs were also moved from GBPUA&T, Pantnagar to NRCS at Indore. NRCS was eventually upgraded to Directorate of Soybean Research and then to Indian Institute of Soybean Research (IISR, ICAR). Thus, the R&D set-up in soybean was ahead of its time and existed even when a little area was under the soybean crop (Table 1).

Feasibility of soybean cultivation in India was demonstrated in early- and mid-1960s using yellow-seeded soybean varieties like Bragg, Clark 63, Improved Pelican, Hardee, Davis and Lee introduced from the USA. With the collaboration of University of Illinois, USA in early sixties, pioneering work on testing of soybean varieties was initiated at JNKVV, Jabalpur and UPAU (now GBPUA&T), Pantnagar. Encouraging results were obtained from small scale and informal trials in 1963-64 by Edwin Bay, Extension Advisor. It was followed by more extensive trials in 1965 by Earl Leng and S.D. Buddemeier, both being agronomists from the University of Illinois stationed at Jabalpur and Pantnagar respectively (Shurtleff and Aoyagi 2010). US varieties like Clark-63, Bragg and Hardee could give high yield in a shorter duration (97 to 111 days) than that in the USA and Brazil (134-149 days). Further, a total of 39 varieties were tested in ten locations in M.P. during 1969-73 (Mehta *et al.,* 1980).Later, through International Soybean Program (INTSOY), in collaboration with the University of Illinois, the varietal trials were conducted along with other multi-disciplinary outreach programmes. Consequently, the cultivation practices suitable for Indian conditions (Saxena *et al*., 1971; Sharma *et al*., 1973; Singh and Saxena, 1979; Motiramani *et al*., 1979) along with several promising soybean varieties (Saxena and Pandey, 1971; Lal and Mehta, 1972; Lal *et al*., 1974; Singh and Saxena, 1975) were identified and recommended for farmers. Agricultural implements specific to the crop such as soybean thresher (Singh *et al*., 1977) were developed. In late 1960s and 1970s, food uses were promoted and needed technology developed particularly by A.I. Nelson, Surjan Singh and Robert W. Nave through the Nave Technical Institute, Soya Production and Research Association (SPRA) and their associates (details in Shurtleff and

Aoyagi, 2010). The state agricultural universities involved were Jabalpur and GBPUA&T, Pantnagar where recipes for Indian cuisine were also standardized using soybean in one form or the other (Kanthamani, 1970; Kanthamani *et al.*, 1978; Singh, 1970). There were some agencies (e.g. Ruchi Soya Industries Ltd.) and people who were involved in both types of endeavours i.e. food uses and export of soy-derivatives. The production technology, seed and overall technical backstopping were made available to farmers by the universities and centres. Although the food uses of soybean were promoted in 1960s and early1970s, the potential for soymeal export and resultant huge foreign exchange earnings largely remained unrealized and unfathomed during this early period.

Table 1 Existence/establishment of major soybean R&D set-up

Year/Period	Start/existence of R&D set-up	Soybean area in m ha	Soybean production in MMT
Early and mid-60s	JNKVV and UPAU (later named as GBPUA&T) were the main farm universities providing overall R&D support in case of soybean; both collaborated with Univ. of Illinois for germplasm introduction and soybean trials with US varieties	Negligible	Negligible
1967	All India Coordinated Soybean Research Project of ICAR started, later known as AICRP on Soybean	Negligible	Negligible
Late 70s and early 80s	INTSOY (formed in 1973) trials by JNKVV and UPAU in collaboration with Univ. of Illinois; Released ISVEX (International Soybean Variety Evaluation Experiment) cultivars Jupiter, Bragg, Lee-74 and Improved Pelican (INTSOY 1984, Progress Report 1973-1984)	0.77 in 1982-83	0.49 In 1982-83
1986	Technology Mission on Oilseeds (TMO) covering oilseeds crops including soybean; its Mini Mission I on crop production technology was led by the ICAR	1.53	0.89
1986	National Research Centre for Soybean, ICAR at Indore (now upgraded to ICAR-IISR).	1.53	0.89

Note: m ha = million hectares; MMT million metric tonnes

9. Availability of indigenous 'Kali Tur' variety followed by the mega-varieties of JNKVV, Jabalpur: Indigenous soybean variety 'Kali Tur' was already being grown in some pockets. It was this trusted black-seeded variety that served as the vehicle of soybean spread and started occupying a large area in 1970s. It possessed desirable characters such as relatively small seeds with good storability, high germination under field conditions and less input requirement. 'Kali Tur', thus, was less expensive for farmers to produce and obtain a good crop establishment in field. In 1977-78, about 95% of total soybean area was under this black soybean, 'Kali Tur', and the rest 5% under yellow soybeans. It was much later that yellow soybean varieties replaced 'Kali Tur' when its certain drawbacks such as high shattering of pods, viny habit, long maturity duration and low yield potential were felt calling for a replacement (Motiramani *et al.*, 1979). Soybean varieties bred in JNKVV, Jabalpur replaced 'Kali Tur' and ruled over the major soybean area. These JNKVV varieties occupied about 90% of soybean area and seed indents. Variety 'Gaurav' (JS 72-44) released in 1980 and notified in 1982 was a mega-variety replacing 'Kali Tur'. Later, another mega-variety 'JS 335', replaced 'Gaurav'. Principal breeders of these mega-varieties, S.K. Mehta and H.M. Sharma, are really the unsung heroes of soy-revolution whose varieties were extremely liked by the farmers and covered vast soybean area for a long period. Much later, early varieties of JNKVV, Jabalpur ruled over the soybean area supplemented by varieties of different states like Maharashtra, Rajasthan, Karnataka and others.

9.1. Current situation - The advent of Indian specialty soybeans: Presently, several specialty soybean genotypes and varieties, have been developed and some have been commercialized also (Kumar *et al.*, 2013; Rani and Kumar, 2015). These include, among others, the released varieties such as NRC 127 (Kunitz trypsin inhibitor free), NRC 147 (high oleic acid), NRC 132 (lipoxygenase-2 free) and also vegetable-type soybean varieties KBVS 1 ("Karune") and "Swarna Vasundhara" (Pan *et al.*, 2010) that have early-picked green pods suitable for human consumption. NRC 142, first double-null specialty soybean, is free from anti-nutritional factor Kunitz trypsin inhibitor and off-flavour generating lipoxygenase 2. Promoting the specialty soybean would mean carving a new commercial niche, putting in place the contracts and intellectual property management, facilitating entrepreneurship opportunities, creating specific infra-structure and handling methods, like blanching and long cold-storage of green pods of vegetable-type soybeans, deriving consumers' benefits and ultimately upgrading the health of the populace. Success stories have started emerging.

10. Cooperatives' and industry's support: In 1979, two sizeable and effective organisations were established in Madhya Pradesh that promoted soybean in many ways. These were the Madhya Pradesh Oilseeds Growers' Federation (MPOILFED) and the Soybean Processors Association of India (SOPA). MPOILFED was unlike common-sense parastatal cooperatives and functioned like an industry in crushing soybeans, having solvent extraction plants, exporting soy-meal, undertaking several related activities in the value chain and helping farmers and other concerned. MPOILFED, National Dairy Development Board (NDDB) and the Rajasthan Oilseed Growers' Federation (Tilam Sangh/RAJFED) were the main cooperatives operating for soybean particularly in Madhya Pradesh, Maharashtra and Rajasthan states where soybean cultivation picked up rapidly. Declaration of support price by the government and its effective operationalization through market intervention by National Agricultural Cooperative Marketing Federation of India (NAFED), the state marketing federations, NDDB and related agencies was a significant step taken in favour of soybean farmers. The agencies tried to maintain the soybean price within a desirable band where the minimum of this band guaranteed an incentive price to the farmer soon after the harvest and the maximum ensured that the consumer got the edible oil in the lean season at a reasonable price.

The support policy provided a reasonably moderate help. During the year 1979, about 20% of the total quantity sold in Madhya Pradesh was purchased by NAFED, 43% was purchased and processed by soybean industries in the state and about 11% was purchased by processors and traders from other states (Bisaliah, 1986). In the year 1972-73, when it all started, the procurement/support price announced by the government was ₹ 100 per quintal (100 kg) whereas the ruling market price was in the range of ₹120-150 per quintal. The market prices exceeded the support price and this trend continued for long, evincing the demand and competition among the processors to procure the soybean grain as raw material for solvent extraction.

SOPA, besides providing business coordination and facilitation, also undertook a Soybean Development Programme (SDP) with activities namely; frontline demonstrations, training of farmers to use improved technology, seed multiplication and enhancing seed availability to farmers, agri-extension services and crop survey. Moreover, coming together of all stakeholders and remaining committed to the cause came about and that unison, like a symphony orchestra, continued for decades (Fig. 1).

Figure 1. Coming together on a soybean field demonstration: (Front row Left to right) SP Tiwari (NRCS, ICAR), MD Tedia (MPOILFED), NN Jain (noted industrialist representing the industry and SOPA, later awarded Padma Shri,), VL Chopra (Padma Bhushan awardee, Secretary DARE and DG, ICAR), PS Bhatnagar (AD, NRCS, ICAR), Kewal Singh (progressive farmer, Hatod village).

11. Developmental support of agriculture departments: Chronic shortage of vegetable oils was one of the major reasons to undertake soybean development in the late 1960s. A centrally sponsored scheme for soybean development is worth mentioning that was sanctioned as early as 1971-72 for the states of Madhya Pradesh, Uttar Pradesh, Maharashtra and Gujarat. This special assistance to soybean was provided because soybean oil had a major share in India's oil imports which was a big drain on the country's foreign exchange reserve. The scheme had provisions namely, (i) arrangement for supply of seed and bacterial culture inoculum for the leguminous nitrogen-fixing crop of soybean, (ii) support for seeds, (iii) insecticide subsidies, (iv) training of extension staff, and (v) staff at field level for input-supply and technical guidance. A crop-specific approach for soybean was followed like reduced amount of nitrogenous fertilizers, more phosphatic and sulphur-containing fertilizers, bacterial culture etc. Bacterial culture inoculum was distributed to farmers that made the soil ready for nitrogen-fixation by the leguminous crop of soybean. Initially, Bradyrhizobium japonicum strains USDA 110, USDA 6 and USDA 122 in formulations like Nitragin, introduced from the USA, were distributed to farmers. Besides, Agriculture Departments of soybean-growing states had many farmer-oriented schemes and programmes, and worked arduously to facilitate the spread of soybean in their respective regions.

12. Complementary soy-based initiatives: Consolidation of early gains in soybean expansion was supported by several soy-based initiatives that helped soybean farmers in production and post-production activities. The initiatives that were noticeable for their size and contribution were:

(i) ITC's e-Choupals/Soy-Choupals initiative using ICTs for technology adoption by farmers, providing a direct marketing channel for farmers, domestic trade facilitation and developing an efficient supply chain,

(ii) development of Indore as a "neo-seed hub" with many seed companies at Indore prominently dealing with high volume-low value seed also,

(iii) farmer-friendly extension services in soybean by the private sector and cooperatives namely, private extension of Dhanuka, and farmers' participatory approach of Gramin Vikas Trust supported by Krishak Bharati Cooperative Ltd. (KRIBHCO), and

(iv) futures exchange Soybean Board of Trade that became National Board of Trade Ltd. (NBoT), Indore incorporated on 30 July, 1999, well begun then, is now changed to National Board of Trade Private Ltd., Indore.

Enumeration of these examples, as above, should suffice hereby as the importance and contribution of these initiatives have been amply detailed by Tiwari (2008) and Tiwari (2017).

13. An additionality: In its early spread, soybean coverage and production came largely as an additionality to Indian agriculture. Soybean did not replace any food-grain crop sizeably. It did not put any pressure on prices of major food grains by reducing their area and production. Bisaliah (1986) has studied the soybean-concentrated districts during that period and stated that soybean replaced sorghum and other low-return crops in some districts but largely occupied fallow land. Soybean gave additional edible oil (~ 1.6 to 1.8 MMT annually now) to our country. Soybean also contributed, inter alia, through its considerable export earning to help offset the huge edible oil import bill. Being a leguminous and biological nitrogen-fixing crop, it did not put pressure on demand of nitrogenous fertilizers.

13.1 Current situation - Soybean replacing other crops: Later, when the area of soybean grew sizably, it started replacing crops like millets and other less remunerative crops. Soybean area in Maharashtra increased at the cost of millets namely, sorghum, pearl millet and, to some extent, finger millet and other marginal crops. Low returns from other crops forced the farmers to switch over to remunerative soybean cropping. Maharashtra has already emerged as a dominant soybean state and has started leading in both the soybean production and productivity, leaving M.P. to a second place. Maharashtra reaps higher soybean yields of about 1.2 tonnes per hectare than about one tonne per hectare of M.P. Serious efforts are needed to increase soybean productivity in M.P., even to come at par with Maharashtra.

14. A major contributor towards "Yellow Revolution": Soybean distinguished itself as one of the three major contributors to "Yellow Revolution", along with rapeseed-mustard and groundnut (Table 2). These oilseed crops greatly helped in doubling the oilseed production from 10.83 million metric tonnes (MMT) in 1985-86 to 21.50 MMT 1993-94, with an addition of 10.67 MMT. Soybean revolution was continuing during this period of "Yellow Revolution" when the soybean production increased from 1.02 MMT in 1985-86 to 4.75 MMT in 1993-94. Soybean production increase of 3.73 MMT amounted to 35% of the total additional oilseed production of 10.67 MMT (Table 2). In 1992-93, the edible oil economy emerged as a net foreign exchange earner owing to export-earnings including those from soymeal and other soy-derivatives. This trend continued for five years till 1997-98, when the value of exports of oilseed sector reached INR 4740 crores (Shenoi 2003).Other contributions of soybean have already been stated in the present study. Gross value added (GVA) from soybean to Indian economy is substantial. It was nearly 255 billion INR in the year 2020.

Table 2. Contribution of three major oilseeds to "Yellow Revolution" during 1985-86 to1993-94

Oilseed	Production in1985-86 in MMT*	Production in 1993-94 in MMT	Increase in production in MMT	% increase in production	% share in total production of 21.50 MMT	% share in total increase of 10.67 MMT
Soybean	1.02	4.75	3.73	466%	22.09%	34.96%
Rapeseed-mustard	2.68	5.33	2.65	199%	24.79%	24.83%
Groundnut	5.12	7.83	2.71	153%	36.42%	25.40%
The Three oilseeds	8.82	17.91	9.09	203%	83.30%	85.19%
Total oilseeds	10.83	21.50	10.67	198.52%	100.00%	100.00%

* MMT = Million metric tonnes; Source for basic data: MoA&FW (2022)

Table 3 A noteworthy triennium for high soymeal and oil production (in MMT)

Year	Soybean crushed	Oil produced	Extraction or meal produced	Soymeal exported*
2010-11	10.155	1.828	8.327	5.169
2011-12	10.516	1.893	8.623	4.877
2012-13	10.121	1.822	8.299	4.943

Source: SOPA: https://www.sopa.org/yearly_processing_of_soybean ; *Oilseeds -World Markets and Trade, USDA.

15. Establishing a global chain of business: The spread of soybean owes much to the global trade and commerce (Tiwari, 2017) and its trickle-down effect towards ultimate welfare of the populace (Badal *et al.,* 2000). A global value chain comprising soybean production, procurement of soybean grain, solvent extraction for obtaining soy-derivatives for feed and food uses, marketing and export, foreign exchange earnings and its sharing was all an innovative endeavour. Soymeal became the characteristic hallmark of Indian soy-based export. When 'Kali Tur' soybean variety was phasing out, the Prestige Group of Industries, led by N.N. Jain and Davish Jain, produced a pure yellow soymeal for the first time in India in early 1980s that was readily accepted in the world market with an edge. Soymeal export was around 1850 tonnes in 1974-75, 50,000 tonnes in 1978-79, 0.1 million metric tonnes (MMT) in 1980-81, 1.24 MMT in 1990-91 (Bisaliah1986) and 4.27 MMT (out of 5.38 MMT of soymeal produced) in 2005-06. India's soymeal output reached a notable level of 8.6 MMT in the year 2011-12 out of which 4.9 MMT was exported. The oil produced was 1.9 MMT during this year. During the year 2010-11, the quantity of soymeal exported amounted to 5.2 MMT. The period of these three years in continuation i.e. 2010-11 to 2012-2013 is, hence, noteworthy (Table 3). Historical data of this noteworthy period of 2010-11 to 2012-13 was also studied for the cost of soymeal, currency exchange rates i.e. USD to INR, and export earnings. India follows managed floating exchange rate system since March 1993, wherein the exchange rate is determined by the market forces; however, the volatility is managed through the instruments deployed by the RBI (Acharya 2001). Analysing the historical record maintained by SOPA for daily rates of soybean meal, it was observed that the exchange rate of USD to INR varied from about 46 to 62 INR and soymeal rates per tonne ranged from USD 380 (in September 2010-11) to USD 621 (in June 2012-13). Rates were higher than 500 USD per tonne in the year 2012-13. The rates approximately corresponded to a range from a low of INR 18,000 to a high of 35,800 per tonne cost of meal. Thus, during 2010-2013, the USD-INR currency exchange rate was volatile yet favourably pushing up the export earnings. Other factors such as high production, quantity of soybean available for crushing and rates offered by other competing exporting countries also mattered. The depreciation in INR increases the export value in INR. There have been instances when appreciation of the Indian rupee led to cessation of soymeal export contracts by the suppliers. Also, soymeal buyers of some countries were reported to have reneged on deals with India after the soymeal prices came down. This forced the Indian exporters to renegotiate the contracts and offer lower rates. Such trends keep on coming up as it happens in a global business. The Indian export earnings from soymeal have been up to INR 15,000 crores (about US$ 2.5 billion) annually. Thus, soybean gave a boost to Indian agricultural economy. It still does despite all complexity in trade but a look on the present situation in case of soymeal is warranted.

15.1 Current situation -State of affairs in soymeal: Characteristic properties of soybean make it more a protein crop than an oilseed crop. Of late, increasing urbanization and changing food habits of people towards more protein-rich food along with the global prices of soy-derivatives have started impacting upon the Indian soymeal scenario. The Indian soymeal (about 7 million tonnes annually) is exported and also used domestically. The domestic consumption of Indian soy-meal, particularly for poultry meat and egg production as also in plant-protein industry, has recently increased sizably (Table 4). Soymeal consumption started rising spectacularly from the year 2008 onwards when it reached about 2 million tonnes. The trend continued and consumption was 4.5 million tonnes in 2014, 5.5 million tonnes in 2018 and 6.5 million tonnes in 2022. According to USDA estimates, the annual growth rate of feed use of soybean meal in India was about 12% during the 1990s, 20% in the late 1990s, and 21% in the past decade since 2017 (Suresh Persaud 2019). As a result, Indian soymeal exports were reported to have declined in the last two decades owing to a concurrent increase in domestic consumption. Other dominant soybean producing countries stand to benefit from the situation. Economic Research Survey of USDA suggested that India could appropriately lower its tariff barriers to soybean imports to tackle the situation (Suresh Persaud 2019). Global price disparity of Indian soymeal, particularly when compared with the less costly soymeal from Argentina and Brazil, has further aggravated the situation. In 2021, India imported about 6.5 lakh tonnes of soymeal out of a permitted 1.2 million tonnes; the remainder 5.5 lakh MT was allowed in 2022. The poultry industry was said to be 'reeling under the inflation in local soymeal prices', reaching Rs. 10,000 per quintal (100 kgs). For the first time, import of foreign soymeal from genetically modified i.e. GM-origin was allowed. Organisations like SOPA did not support this import. Several such never-before trends make the scenario of soy-based export ever-changing and challenging in nature calling for a vigil and coping strategy.

Table 4 Indian soymeal domestic consumption

Market year	Domestic consumption (,000 tonnes)	Growth over the previous year	Market year	Domestic consumption (,000 tonnes)	Growth over the previous year
1970	7	-	2012	3530	6.33%
1980	199	-	2013	3640	3.12%
1990	470	-	2014	4500	23.63%
2000	1305	-	2015	4460	-0.89%
2005	835	-	2016	4674	4.80%
2006	805	-3.59%	2017	4739	1.39%
2007	810	0.62%	2018	5530	16.69%
2008	1920	137.04%	2019	5780	4.52%
2009	2540	32.29%	2020	5850	1.21%
2010	2775	9.25%	2021	6273	7.23%
2011	3320	19.64%	2022	6580	4.89%

Source: United States Department of Agriculture

16. Growth in soybean area and production during the specific period: Soybean farming of some significance in India really began in the early seventies. The agricultural area under soybean was only about 30,000 hectares in 1970-71and was stagnant as the following two years, 1971-72 and 1972-73, also had the same area. The specific period from 1972-73 to 2012-13 was considered, as analysed for year wise, triennium-wise and decade-wise growth and trend. The area started increasing after 1972 when it rose to 0.05 million hectares in 1973-74. Production also increased from 1973 onwards. The spread of soybean continued thereafter for decades to come! A steady decade-wise growth of soybean area and production was observed (Table 5). The growth for area expansion for the ensuing decade, specifically from 1972-73 to 1981-82, was about 25 times. The production growth was brought about almost solely by area expansion. Sharma (2016) reported the overall growth in soybean area at the rate of 9.6% and production at the rate of 11.5% in the country during the period 1980-2012.

In case of decade-wise analysis, the compound annual growth rate (CAGR) was maximum for the first decade i.e.1972-73 to 1981-82 being 40.8% for soybean area and 36.7% for soybean production (Table 6). The trend of growth continued thereafter for decades albeit with a reduced pace. Overall long-span CAGRs (for four decades i.e. from 1972-73 to 2011-12) were 13.1% for area and 14.2% for production when based on yearly data and were 13.8% and 15.2% respectively when based on triennium average. Of late, some improvement in yield was also noticed, CAGR for yield being 3.4% for the decade 2002-03 to 2011-12.

Soybean area crossed 10 million hectares (m ha) in 2011-12 and the maximum area of about 13 m ha was reached in 2020-21.A current situation note on upcoming of Maharashtra as a dominant soybean state has already been provided in an earlier section.

Table 5 Decade-wise growth in area and production of soybean during the specific period of soybean spread

Year (in the corres-ponding decade)	Soybean Area in million ha	Soybean Production in million tonnes
1972-73	0.03	0.03
1982-83	0.77 (25.66)*	0.49 (16.33)
1992-93	3.79 (4.92)	3.39 (6.91)
2002-03	6.11 (1.61)	4.65 (1.37)
2012-13	10.84 (1.77)	14.67 (3.15)

*Figures in parentheses give growth (x or times) over that of last decade

Table 6 Compound annual growth rate (CAGR) during the specific period of soybean spread

Period (decade)	Area CAGR (%) based on		Production CAGR (%) based on		Yield CAGR (%) based on	
	Yearly average	Triennium average	Yearly average	Triennium average	Yearly average	Triennium average
1972-73 to 1981-82	40.8	41.3	36.7	42.7	-2.0	1.0
1982-83 to 1991-92	15.9	16.7	19.4	19.6	2.9	2.4
1992-93 to 2001-02	6.2	8.1	6.2	9.5	0.0	1.3
2002-03 to 2011-12	5.7	5.8	9.3	9.1	3.4	3.2
Overall (4 decades)	13.1	13.8	14.2	15.2	1.0	1.3

17. Ascertaining the tipping point: The tipping point is that amazing point in time or a period when an idea, trend, or social behaviour extends across a threshold, tips, and spreads rapidly thereafter (Gladwell, 2000).Tipping depends on various crucial factors. Initiation of an increasing trend of soybean area and production could be the outcome of a remarkable change elsewhere and, hence, this alone cannot parochially determine the tipping point. These parameters could only indicate that the tipping point has already come about before the area and production started increasing i.e. before the year 1973.The determinants and the observed effects, as discussed, also point this out. Soybean and soy-derivatives are highly affected by global developments. In an initial export-driven ambiance, the reaching of tipping point was dependent on apparent and ensured export prospects. The industrialists were convinced and started blazing a trail in 1972 before the soybean area started increasing. A competitive market price was being offered for procurement of soybean grain by the industry right in the year 1972-73 (Bisaliah1986) when soybean area was negligible. Further, a race for acquiring solvent extraction plant or using existing plant for soymeal extraction was also apparent right in the year 1972. All this could happen only after reaching the tipping point and, thus, confirming 1972, and not 1973, as the year of reaching the tipping point. Business-men were sure of their profit but farmers were needed to be assured well before the sowing time otherwise that season or year would pass by. Farmers gained a high profit from selling soybean grain yield harvested from the static or unchanged area in 1972 and, thus, the tipping point was reached in 1972 itself. This resulted in a rush for obtaining seed of the then reliable and oft-used "Kali Tur" variety for the ensuing crop season of 1973. Resultantly, soybean area started increasing from the year 1973 onwards, after reaching the tipping point in the later part of the year 1972.

18. High moral support: Highly esteemed great personality of the Father of the Nation, Mahatma Gandhi ji, was in support of soybean. Of specific mention is the article by him which he published in his journal "Harijan" in 1935. He detailed soybean cultivation practices, referred to black, yellow and other colours of soybean grain and recommended that soybean flour can be mixed with wheat flour in the proportion of 1:5 for making the flat Indian bread, the "chapaties'. He specifically mentioned in the article that timely harvest is a must otherwise pod-shattering will occur in soybean. He had keen interest in soybean and had taken the details largely from an article published in a Gujarati magazine by the Food Survey Office of the erstwhile Baroda State, Gujarat (c.f. Kale 1936). Later when some resistance to soybean cultivation, like calling it an unacceptable foreign crop emerged, then it could be abated by citing such moral support.

19. Aggregating the determinants of Indian soy-revolution

Based on above, the determinants of Indian soy-revolution can be summed up. These factors can easily be seen as (i) those crucial ones which belonged to early inception of the revolution and were directly responsible for bringing about soy-revolution, and (ii) those which operated to support and sustain at later stage and provided a continuation of the revolution over decades. These roles of the factors are already discussed and, hence, not elucidated further in regard to their crucial or supporting role. Summarising, the factors responsible are enumerated hereunder.

1) Export-orientation, currency dynamics and favourable exchange rate creating huge potential of monetary profit from export of Indian soymeal and other soy-derivatives,

2) Global competitiveness of Indian soy-meal,

3) Entrepreneurship of certain sticky, zealous and risk-taking traders and businessmen of Indore and adjoining area,

4) Concurrent availability/establishment of a number of solvent extraction plants using soybean as a raw material,

5) Availability of large rainy-season fallow lands and intrinsic characteristics of soybean that rendered Indian soy-revolution feasible and relatively environment-friendly

6) Progressive risk-taking mindset of farmers of central India for rapid adoption of soybean, regardless of size of land holdings, as a relatively new crop despite its low yields,

7) Concentrated area of cultivation otherwise, soybean being a highly photo-sensitive crop, could face difficulty in its rapid adoption,

8) Availability of indigenous black-seeded variety 'Kali

Tur' that required less inputs and gave assured crop stand in the field,

9) A characteristically shorter duration of Indian soybean crop than that of major soybean growing foreign countries, enabling its fit in the available cropping pattern and also bringing about a highly profitable cropping system namely, early soybean-potato-late sown wheat in some areas,

10) Lack of major biotic stress factors like yellow mosaic virus in central India (then a problem predominantly in Northern India),

11) Chronic shortage of vegetable oils in the country and major share of soybean oil in the imports necessitating soybean developmental efforts in the late 1960s and afterwards,

12) A centrally sponsored scheme for soybean development sanctioned during 1971-72 for the states of Madhya Pradesh, Uttar Pradesh, Maharashtra and Gujarat with a developmental package; Strong and continued developmental support from state agriculture departments,

13) Established research organizations in soybean R&D in 1960s mainly, state agricultural universities namely, JNKVV, Jabalpur and GBPUA&T, Pantnagar; both the universities had active collaboration with University of Illinois, USA; All India Coordinated Research Project on Soybean (ICAR) since 1967,

14) Support from robust cooperatives like MPOILFED and others along with developmental programmes of industry such as Soybean Development Programme of SOPA,

15) Market intervention by NAFED, the state marketing federations, NDDB and related agencies to minimize the volatility in price of soybean,

16) Other soybean-based initiatives such as (i) ITC's e-Choupals/Soy-Choupals using ICTs for farmer-centered efficient supply chain development, (ii) development of Indore as a "neo-seedhub? and (iii) private extension of Dhanuka, and farmers' participatory approach of Gramin Vikas Trust, KRIBHCO,

17) Overall availability of needed technology, technical backstopping, and policy support ensuring feasibility and profitability of soybean farming,

18) At a later stage, mechanisms like Technology Mission in Oilseeds (TMO) set up in May 1986; National Research Centre for Soybean (ICAR) established in 1986 at Indore (later upgraded to ICAR-IISR); Continued central minimum support price,

19) Overall economic reforms particularly those towards globalisation and export facilitation,

20) High moral support to soybean in its very early period that abated any resistance to the cultivation and use of soybean.

In conclusion, the present study and review showed that the Indian soy-revolution reached the tipping point in the later part of the year 1972 and its manifestation was realised 1973 onwards. A score of determinants were ascertained and elaborated. Along with export-orientation and currency dynamics, there was a great and crucial strength of context like availability of solvent extraction plants for production of soymeal and other soy-derivatives, availability of fallow land, strong research and development back-up, and support of industry and cooperatives, among others. Consequentially a soy-based global value chain was developed that opened up a profitable avenue for farmers, traders, millers, exporters and the entire feed and food industry. Other factors, as already discussed, later contributed towards sustaining and expanding the soy-revolution. The impact was that soy-revolution brought about socio-economic welfare in the country.

Overarching impact of the fourth industrial revolution (Schwab, 2016/2017, Micklethwait and Wooldridge, 2014) has started unfolding on physical, digital and biological world. Soybean, being the most globalised, traded and processed crop commodity, is bound to be affected by these changes. We should rapidly embrace the positive changes for restructuring, even for creative destruction in the long run, and thereby enhance our relevance and productivity. We have to be incessantly progressive and innovative in production, processing and quality aspects and develop such sustainable farm-prosperity value chains that ensure a continuum of the benefitting outcomes of the Indian soybean revolution.

ACKNOWLEDGEMENTS

The authors are grateful to SOPA, Indore and ICAR-IISR, Indore as also to several experts from other soybean-related organizations for their direct and indirect support. Satya P. Tiwari wishes to place on record the unstinted care and support by his wife, Pushpa Tiwari, during this endeavour.

REFERENCES

Acharya Shankar 2001. India's macro-economic management in the ninetees. Pp. 1-67. Indian Council for Research on International Economic Relations (ICRIER), New Delhi.

Badal P S, Praduman Kumar, Billore S D, Sharma A N and Joshi O P 2000. Socio-economic impact of soybean cultivation in Madhya Pradesh. Project Report of IARI and NRCS (ICAR), pp. 1-35.

Barona E, Ramankutty N, Hyman G and Coomes OT 2010. The role of pasture and soybean in deforestation of the Brazilian Amazon. *Environmental Research Letters,* **5**:1-9.

Bapna S L, Seetharaman S P and Pichholiya K R 1992. *Soybean system in India.* Oxford & IBH Publi. Co. Pvt. Ltd., New Delhi.

Bernard R L, Juvik G A and Nelson R L 1989. USDA Soybean Germplasm Collection Inventory (Volume 2). Pp. 203. International Agricultural Publications. INTSOY Series No. 31.

Bisaliah S 1986. Soybean Development in India. UN/ESCAP CGPRT Centre: Bogor, Indonesia. CGPRT Centre (The Regional Coordination Centre for Research and Development of oarse Grains, Pulses, Roots and Tuber rops in the Humid Tropics of Asia and the Pacific) Paper No. 5. pp. 77. [http:// www. uncapsa.org/Publication/cg5.pdf].

Carlson K M, Gerber J S, Mueller N D, Herrero M, MacDonald G M, Brauman K A, Havlik P, O'Connell C S, Johnson J A, Saatchi S and West P A 2017. Greenhouse gas emission intensity of global croplands. Nature Climate Change 7:63-68. https:/doi.org/ 10.1038/nclimate3158.

Chand Ramesh 2007. Agro-industries characterization and appraisal: Soybeans in India. Working Document 20 of the FAO-AGSF, pp. 1-39.

Dovring F, Jindia J R and Misra R S 1974. Economic production possibilities of soybean in northern India: A preliminary study. Pub. Series No. 1, Univ. of Illinois, Urbana-Champaign, Office of International Agriculture.

Gandhi, M K (Father of the Nation Mahatma Gandhi Ji) 1935. "Soyabean ki kheti". Harijan, November 9, 1935 Issue. (Reproduced in 'Kheti', October, 1995 Issue, ICAR Publi.). (In Hindi).

Gasparri NI, Grau H R and Gutierrez Angonese J 2013. Linkage between soybean and neotropical deforestation: Coupling and transient decoupling dynamics in a multi-decadal analysis. *Global Environmental Change,* 23(6): 1605-1614.

Gladwell, Malcolm 2000. The Tipping Point: How Little Things Can Make a Big Difference, pp. 304. Publisher: Little Brown.

INTSOY 1984. INTSOY (International Soybean Program) Summary of Progress 1973-1984. Pp. 1-24. PD-AAR-337, 40186. University of Illinois at Urbana-Champaign.

Kale F S 1936. Soybean, its value in dietetics, cultivation and use. Baroda, India: Baroda State Press, and New Delhi, India: International Book and Periodicals Supply service.

Kanthamani S 1970. Tasty recipes from soybean. JNKVV, Jabalpur Publi.

Kanthamani S, Nelson A I and Steinberg M P 1978. Home preparation of soymilk: a new concept. In: Whole Soybean Foods for Home and Village Use Ed. Nelson A I and Steinberg M P and Wei L S. INTSOY Series 14. University of Illinois, Urbana, Illinois, USA. Pp. 5-11.

Kumar V, Rani A, Rawal R and Hussain S M 2013. Lipoxygenase-2 free Indian soybean genotypes. *Current Science,* **104**: 586-587.

Lal M S and Mehta S K 1972. Performance of soybean varieties from the USA. *Indian Journal of Agricultural Sciences,* **42**(6): 461-3.

Lal M S, Mehta S K and Pandya S C 1974. Stability of performance of soybean varieties in Madhya Pradesh. *Indian Journal of Agricultural Sciences,* **44**: 217-20.

Mehta SK, Beohar A B L, Nigam P K and Lal M S 1980. Varietal suitability and potential areas of soybean in Madhya Pradesh. *JNKVV Research Journal,* **14**(3/4): 75-79.

Micklethwait John and Wooldridge Adrian. 2014. The Fourth Revolution: The Global Race to Reinvent the State. Published by arrangement with The Penguin Press, a member of Penguin Group (USA), LLC.

MoA&FW 2022. *Agricultural Statistics at a Glance 2022.* Ministry of Agril. and Farmers' Welfare, Govt. of India.

Moriramani D P, Rathod K L and Kashiv R C 1979. Developing appropriate production technology - A case of soybeans in Madhya Pradesh. *Agricultural Situation in India,* **34**(8) : 523-28.

Pan R S, Singh A K, Kumar S, Sharma J P and Das B 2010. Soybean cv. Swarnaa Vasundhara. *ICAR News* (January-March 2010). **16**(1): 11.

Poore J and Nemecek T 2018. Reducing food's environmental impacts through producers and consumers. Science 360 (6392): 987-992.

Randhawa M S 1986. A history of agriculture in India. Volume IV. 1947-1981. pp. 716. (See p. 484). Indian Council of Agricultural research, New Delhi.

Rani Anita and Kumar Vineet 2015. Development and commercialization of first ever kunitz trypsin inhibitor free soybean genotype. *Current Science,* **109**:1-3.

Richards P D, Myers RJ, Swinton SM and Walker RT 2012. Exchange rates, soybean supply response and deforestation in South America. *Global Environmental Change,* **22**(2): 454-462.

Saxena M C.1976. Soybeans in India. Ed. RM Goodman. Expanding the Use of Soybeans. INTSOY Series No. 10. pp. 226-31.

Saxena M C and Pandey R K 1971. Characteristics and performance of some promising varieties of soybean (*Glycine max* (L.) Merr.) at Pantnagar. *Indian Journal of Agricultural Sciences*, **41**(4): 355-60.

Saxena M C, Pandey R K and Hymowitz T 1971. Agronomic requirements of soybean (*Glycine max* (L.) Merr.). *Indian Journal of Agricultural Sciences,* **41**(4): 339-44.

Schwab Klaus. 2016*/ 2017. The Fourth Industrial Revolution. Crown Business publication, pp. 184. [*First and originally published by World Economic Forum, Geneva, Switzerland].

Sharma D, Singh Laxman and Maheshwari S K 1973. In M.P. soybean-arhar ensures more profit. *Indian Farming,* **23**: 33 and 40.

Sharma P. 2016. Dynamics of growth of soybean in India: Role of income and risk. Agricultural Situation in India, LXXIII (6):37-46.

Shenoi P V 2003. Oilseeds Production, Processing and Trade: A policy framework. Pp. 1-119. Occasional Paper-26. National Bank for Agriculture and Rural Development (NABARD), Mumbai Publi.

Shurtleff W and Aoyagi A 2010. History of Soybeans and Soyfoods in South Asia/Indian Subcontinent (1656-2010)-Extensively Annotated Bibliography and Sourcebook. Soyinfo Center, Lafayette, USA.

Singh BB 2006. Success of soybean in India: The early challenges and pioneer promoters. *Asian Agri History,* **10**(1): 43-53.

Singh B B and Saxena M C 1975. Soybean varieties for different agro-climatic zones in India. *Seed Technology News,* **5**: 5-7.

Singh BB and Saxena M C 1979. Soybean production in India. *Indian Farming,* **28**(10): 7-9.

Singh BS, Kulsheshtra S P and Ram Krishna 1977. Development and performance of soybean thresher. GBPUA&T Publication No. AER-9, Pantnagar (Nainital). pp. 1-49.

Singh, Rajeshwari 1970. Soyahar: Indian recipes of soybean. U.P. Agric. University, Pantnagar, Edn.1, pp. 1-215.

Suresh Persaud 2019. Impacts on India's farmers and processors of reducing soybean import barriers. Pp. 1-33. ERS-USDA Report, OCS-19J-02.www.ers.usda.gov.

Tiwari S P 2006. Plant introductions in soybean - Achievements and opportunities. *Indian Journal of Plant Genetic Resources,* **19**:371-383.

Tiwari S P 2014. Raising the yield ceilings in soybean - An Indian overview. Soybean Research, **12**(2): 1-43.

Tiwari Siddhartha Paul 2008.Information and communication technology initiatives for knowledge sharing in agriculture. *Indian Journal of Agricultural Sciences,* **78**: 737-47.

Tiwari Siddhartha Paul 2017. Emerging trends in soybean industry. *Soybean Research,* **15**(1): 1-17.

Tiwari Siddhartha Paul and Tiwari S P 2018. Is export-oriented and currency dynamics-based Indian soy-revolution environment-friendly? *Current Science*, **114**(8): 1604-05.

Tiwari S P, Joshi O P and Sharma A N 1999. The saga of success - The advent and renaissance of soybean: A landmark in Indian agriculture. NRCS, ICAR Publication, pp. 54.

Williams S W, Hendrix W E and von Oppen 1974. Potential production of soybean in north central India. Univ. Illinois, Urbana. INTSOY Ser.5.

Review

Policy interventions, market, and trade considerations with special reference to rapeseed and mustard

ANUPAM BARIK*

Ex-Additional Commissioner (Oilseeds), Dept. of Agriculture & Farmers Welfare, Krishi Bhavan-110001, New Delhi

(Received: December 19, 2022; Revised: January 4, 2023; Accepted: January 6, 2023)

ABSTRACT

Rapeseed and mustard oil is one of the most consumed edible oils in India due to pungency and colour. India needs nearly 15-20 million tonnes of rapeseed and mustard seed to meet its growing demand as against current production of 9-10 million tonnes of seeds. As per WHO standards, mustard oil with low saturated fatty acid content and high mono unsaturated fatty acid content is a healthy oil and therefore needs special importance in domestic edible oil basket. Currently (2022-23), Government of India (GOI) is implementing National Food Security Mission (NFSM) - (Oilseeds & Oil palm) for increasing oilseeds production and area expansion under oil palm. The NFSM (OS&OP) will be dropped and two new Scheme National Mission on Edible oils (NMEO)-Oilseeds and NMEO-Oil Palm will be implemented with the aim to enhance the edible oilseeds production and oils availability in the country by harnessing oilseeds and palm oil productivity and to reduce import burden on edible oils. Besides, NMEO-OS the private participation in technology demonstration, input supply, procurement of produce, value addition, infrastructure development and honey production are very much essential to increase edible oils production.

Keywords: Edible oilseed crop, Market and Policy interventions, Rapeseed and mustard

India is the third largest rapeseed-mustard producer in the world after China and Canada with 14 per cent of world's total production. This crop accounts for nearly one-third of the oil produced in India, making it the country's key edible oilseed crop. Rapeseed-Mustard is the major source of income even to the marginal and small farmers in rainfed areas since these crops are cultivated mainly in the rainfed and resource scarce regions of the country. Its contribution to livelihood security of the small and marginal farmers in these regions is also very important. Due to its low water requirement (80-240 mm), rapeseed-mustard crops fit well in the rainfed cropping system. Being a major *rabi* (winter season) oilseed crop and having an advantage of soil moisture conserved during monsoon, it has greater potential to increase the availability of edible oil from the domestic production.

It is cultivated in 26 states in the northern and eastern plains of the country, over an area of 67.76 lakh ha in 2019-20 and increased to 80.58 lakh ha in 2021-22. Nearly 32% area under rapeseed-mustard is under rainfed farming. Indian mustard is grown in Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana and Gujarat as well as in some areas of southern states like Andhra Pradesh, Telangana, Karnataka and Tamil Nadu. Yellow Sarson is taken up as *rabi* crop in Assam, Bihar, Orissa and West Bengal whereas in Punjab, Haryana, Uttar Pradesh and Himachal Pradesh it is taken as a catch crop. The top mustard producing states of the country are Rajasthan (46.62%), Haryana (11.62%), Madhya Pradesh (14.35%), Uttar Pradesh (8.80%), and West Bengal (6.48%) (Table 1).

The productivity of rapeseed-mustard in India is the lowest among the major rapeseed-mustard growing countries. As against the world average of 2144 kg/ha, highest productivity of 3640 kg/ha of European Union, the average yield of India was only 1286 kg/ha during 2013-14 to 2019-20. However, the productivity increase to 1458 kg/ha during 2021 having highest productivity in Gujarat (1996 kg/ha) followed by Haryana (1914 kg/ha), Rajasthan (1627 kg/ha) and Punjab (1573 kg/ha). The yield of rapeseed and mustard in Uttar Pradesh and Madhya Pradesh is around 1300 kg/ha while in Assam and Jharkhand the yield is as low as 650 to 800 kg/ha despite the sizable area under rapeseed and mustard (Table 1).

Among the seven annual edible oilseeds cultivated in India, rapeseed-mustard oil contributed 30.23% during 2016-17 which further decreased to 22-29% during 2017-18 to 2019-20. But the percentage contribution increased to highest so far 40.37% in total edible oils production (78.59 lakh tons) followed by groundnut (31.62%) and soybean (24.81%) during 2020-21 (Table 2). Out of total edible oils produced in the country around 70% is from primary sources and remaining 30% from secondary sources.

Write up of the speech delivered by Dr. Anupam Barik, Ex-Addl. Commissioner (Oilseeds), DA&FW, New Delhi during the International Conference on Vegetable Oils 2023 in Hyderabad on January 20, 2024.

Corresponding author's e-mail: anupam.barik2708@gmail.com

Whole package Front Line Demonstration (FLDs) of rapeseed-mustard under rainfed condition in various states resulted yield advantage of 30% in Improved Practices (IP) over Farmers Practices (FP). Whole package FLDs of Rapeseed-Mustard under irrigated condition in various states resulted mean seed yield of 2000 kg/ha in Improved Practices (IP) and 1500 kg/ha in Farmers Practices (FP) having yield advantage of 33%.

It is evident from the productivity potentials and profitability of improved rapeseed mustard production technologies that there exists vast potential to improve the productivity under real farm situations. It can be understood that rapeseed-mustard productivity at national level could be improved by 25-30% by bridging the yield gaps. Similarly, the National Rapeseed-Mustard production could be increased from 120 to 130 lakh tons by bridging yield gaps. This indicates the presence of significant yield reservoir which can be exploited through spread of appropriate improved new varieties and production technologies among the farmers.

Table 1 Area, production, and yield of rapeseed and mustard in 2019-20 and 2021-22

States	2019-20			2021-22			Production share (%) 2021-22
	Area	Production	Yield	Area	Production	Yield	
Rajasthan	2948.1	4218.8	1431	3366.10	5476.64	1627	46.62
Haryana	641.3	1149.9	1793	713.60	1365.83	1914	11.62
Uttar Pradesh	759.3	956.7	1280	755.00	1034.35	1370	8.80
Madhya Pradesh	675.0	914.0	1354	1226.00	1686.98	1376	14.35
West Bengal	610.4	763.0	1250	610.34	762.93	1250	6.48
Gujarat	172.2	344.6	2001	251.10	501.20	1996	4.26
Jharkhand	291.4	225.3	540	406.39	332.83	819	2.82
Bihar	290	186.2	642	78.56	88.22	1123	0.75
Assam	80.8	95.9	1187	300	182.53	636	1.54
Punjab	38.6	57.8	1497	53.60	84.31	1573	0.70
Others	268.90	203.40	756	298.01	230.23	772	1.95
All India	6776.0	9115.6	1345	8058.70	11746.05	1458	100

Area: '000 ha, Production: '000 tones, Yield: kg/ha

Table 2 Rapeseed and mustard contribution in edible oil basket of the country

Year (Oct-Nov)	Primary Sources oil Production (Lakh tons)	R&M Oil Production (Lakh tons)	% Of Total Domestic Bastet
2016-17	73.09	22.10	30.23
2017-18	73.56	17.59	23.91
2018-19	74.26	22.09	29.74
2019-20	79.20	17.97	22.69
2020-21	78.59	31.37	40.37

Policy framework of GOI towards Edible Oils

Currently (2022-23) Government of India (GOI) is implementing National Food Security Mission (NFSM) - (Oilseeds and Oil palm) for increasing oilseeds production and area expansion under oil palm. The NFSM (OS & OP) will be dropped and two new Scheme National Mission on Edible oils (NMEO) - Oilseeds and NMEO - Oil Palm will be implemented with the aim to enhance the edible oilseeds production and oils availability in the country by harnessing oilseeds and palm oil productivity and to reduce import burden on edible oils. NMEO-Oil palm already launched by GOI in August 2021 with a budget allocation of ₹ 11,040 crore by 2025-26 and under implementation to cover additional area of 6.5 lakh ha under oil palm. NMEO-OS is under the consideration by Cabinet and may launch soon and expected budget would be ₹ 6000 to 6500 crores by 2025-26.

The target fixed for oilseeds production by 2025-26 under NMEO-Oilseeds is given below:

- To increase domestic production of edible oils from 10.40 to 18.00 million tons from Primary (13.50 million tons) and Secondary Sources (4.50 million tons) by 2025-26 (Table 3).
- To produce 54.10 million tonnes of oilseeds with productivity of 1687 kg per ha from current production of 37.00 million tons oilseeds and 1236 kg per ha yield.
- To bring additional oilseeds area from 27.00 million ha to 32.28 million ha through rice fallow, intercropping, non-traditional states, Mustard Mission and crop diversifications.
  - Increase area under cultivation by 22%
  - Increase productivity by 21%
  - Overall production increase by 48%
- To reduce import dependency from 60% to 40% by 2025-26
- To create consumer awareness for optimum consumption of edible oil

NMEO-OS: Strategies

The scheme would be implemented in a mission mode through active involvement of all the stakeholders. Fund flow would be monitored to ensure that the benefit of the Mission reaches the targeted beneficiaries in time to achieve the targeted results. The strategy to implement NMEO-OS will include

- Increasing Seed Replacement Ratio (SRR) with focus on varietal replacement, seed rolling plan, seed hubs, seed minikits, seed distribution.
- Improving productivity of oilseed crops.
- Increasing irrigation coverage under oilseeds.
- Diversification of area from low yielding cereal crops to oilseed crops.
- Inter-cropping of oilseeds with cereals/ pulses/sugarcane.
- Use of fallow land after paddy /potato cultivation.
- Special Mission on Mustard/Soybean, Sunflower/ Groundnut to increase productivity.
- Mass awareness of Optimum use of Edible Oils (12 kg/person/year) as against current consumption of 20 kg/person/year.

NMEO-OS Interventions

- Demonstrations (FLDs/Cluster FLDs) on improved technologies/ varieties with Geo-Tagging/Geo Fencing.
- Distribution of seeds (HYVs/Hybrids).
- Production of Seeds through Seed Hubs and Model Seed Farms.
- Promotion of INM techniques.
- Resource conservation technologies/tools/ farm mechanization.
- Area expansion through:
  - Popularization of intercropping
  - Utilization of rice fallows
  - Promotion in non-traditional states
  - Targeting high potential districts
  - Special Mustard/ Soybean/ Groundnut Mission
- Support for Tree Borne Oilseeds (TBOs), Castor & Linseed.
- Assistance for Consumer Awareness to promote optimum consumption.

NMEO-Oilseeds will be a Centrally Sponsored Scheme and the cost will be shared between 60:40 between the Central and the State Government for General states and 90:10 for Hilly and NE states, 100% UT and for central agencies. Private organization/Associations/Processors will be involved through Central agencies, Indian Council of Agricultural Research (ICAR), Crop Development Directorates (CDDs) and State Government as per norms. The NMEO-Oilseeds will cover development of all aspects of oilseeds having long term seed rolling plan, implementation of special projects. Based on the current needs, the various components of NMEO-Oilseeds have been modified with increased assistance.

Special thrust of DA&FW on R&M

The government is giving high priority to crop diversification with a focus on Self Sufficiency in Oilseeds. Oilseeds production has shown a growth of 42% from 25.25 million tons in 2015-16 to 37.69 million tons in 2021-22. Action Plan for 3 years Seed Rolling Plan (2021-22 to 2023-24) for all oilseeds have been formulated which will produce a total of 14.7 lakh quintals of quality seed of new HYVs in next 3 years. Increasing productivity and acreage under oilseeds are the two-pronged approaches along with the strategies/action plans. The average yield gap in edible oilseeds is about 60%. Reducing the yield gap to 20% in the next five years leading to 13-14 million tons additional production of edible oilseeds (3-4 MT edible oils) without bringing any additional area.

Since *rabi* 2020, DA&FW has launched special program for rapeseed and mustard to increase its area from around 73 lakh ha to around 84 lakh ha and production from around 115 lakh tons to around 164 lakh tons by 2025-26 (current production 117.46 lakh tons) (Table 4). A total of 368 districts of 13 states have been identified for increasing yield of Rapeseed Mustard through high yielding varieties/hybrids seed distribution/seed minikits (more than 20 q/ha yield) and improved crop demonstrations. Mustard Mission showed impressive satisfaction and production has jumped by 29% from 91.24 to 117.46 lakh tons in the last two years. Productivity saw 10% jump from 1331 to 1458 kg/ha. The area under rapeseed & mustard has increased by 17% from 68.56 in 2019-20 to 80.58 lakh ha in 2021-22. The farming community and the State Governments deserve congratulations for this commendable achievement. The increased mustard production will help in bridging the gap of imports of palm and sunflower oil. The government is also implementing Special Soybean and Sunflower Missions on the pattern of Mustard Mission.

- Increase area under cultivation by 15%.
- Increase productivity by 24.5%.
- Overall production increased by 43%.
- Increase oil production by 55%

Suggested Policy initiatives on rapeseed and mustard

The following policy initiatives are suggested.

Crop diversification

Policy measures for encouraging the farmers to make a shift from rice (*kharif*)-wheat (*rabi*) cycle and Crop diversification in Punjab, Uttar Pradesh, Assam, Tripura without sacrificing the food and nutritional security of the country. Extend oilseed cultivation to non-traditional areas and non-traditional seasons, mustard in northeastern states etc. Promote inter-cropping of mustard, for which large number of FLDs/cluster FLDs may be undertaken. The area under mustard can be enhanced by substituting it for wheat in Punjab, Haryana and Western U.P. With increased yield and higher Minimum Support Price (MSP), it will be able to compare well with wheat in inter-crop parity. Mustard may also be promoted in unconventional areas including northeastern states (Assam, Tripura). There is scope for wheat substitution area by 5-10 per cent.

Need for private sector involvement

Different Oil Associations / Industries (such as Solvent Extractors Association (SEA), Soybean Processors Association of India (SOPA), Saurashtra Oil Mills Association (SOMA), National Dairy Development Board (NDDB), ITC, Patanjali Foods Limited (PFL), Solidaridad) are engaged in extension activities for increasing oilseeds production with their limited resources for different oilseed crops. In August 2021, GOI has launched National Mission on Edible Oils (NMEO)-Oil Palm which is directly linked with Oil palm Processing companies. The Mission provides different type of subsidies for oil palm development to both the farmers and processors. This is lacking in the NMEO-Oilseeds. There is a need to link with seed companies, Oil processing companies, marketing bodies, associations through Central Agencies for increasing oilseeds and edible oils production under NMEO-OS in Mission mode.

The private seed companies/Associations can be involved for Seed production, Seed distribution, Model Seed Production Farm cum Training centre through NSC and Creation of seed hubs of oilseeds through ICAR-IIOR on 100% funding basis to increase the SRR/VRR mainly for Soybean, Mustard, Sunflower and Groundnut. The NMEO-OS do not have any support for processing of oils and value addition. Therefore, it is suggested to include new components for the private seed companies /associations.

- Support for Model Farm demonstrations of various oilseed crops through ICAR (DRMR, IIOR, IISR, DGR)
- Support for modern oil extraction cum refining facilities through ICAR Central Institute of Agriculture Engineering (CIAE)
- Support for secondary sources of edible oils (Rice bran, cotton, TBOs) through ICAR Central Institute of Agriculture Engineering (CIAE)
- Support for FPOs of edible oils through SFAC/National Agricultural Cooperative Marketing Federation (NAFED)
- Infrastructure development and honeybee production linked with rapeseed and mustard

Need for seed hub of rapeseed and mustard by private seed companies

AICRP (Rapeseed and Mustard) network till 2020 has developed more than 300 varieties of Rapeseed-Mustard. The crop is cultivated in the country over an area of 60-70 lakh ha for which 3.00 to 3.5 lakh qtls certified seed is required on 100% SRR basis. Being self-pollinated crop 33% SRR is desirable for which 1.23.to 1.32 lakh quintals certified seeds are sufficient. The current SRR of rapeseed and mustard varies from 25 to 50% among the states and the yield level are poor mainly due to adoption of old and low yielding varieties. During 2019, only 6% breeder seed indent was of new varieties and rest 94% was of old varieties (above 10 years). However, the situation improved in 2020 with new variety share of 27.46% and old variety share of 72.54%. Therefore, it is essential to increase the new variety share at least by 75% in next 5 years through proper seed planning.

Presently eight (8) mustard seed hubs, established during 2018-19 and 2019-20 under NFSM (OS) on rapeseed and mustard in eight locations, producing nearly 5000 quintals of certified seeds of new varieties every year. But in order to meet the requirement of quality seeds of newly released varieties of rapeseed and mustard with VRR of 75%, it is suggested to establish another 22 seed hub of rapeseed and mustard across the country to produce desired quantity of breeder, foundation and certified seeds involving private seed industries.

DA&FW created 35 oilseed seed hubs for seven edible oil crops including 8 for rapeseed and mustard to support seed production and distribution of newly released varieties. Under the new seed hubs, a total of 6.25 quintals of Breeder seed, 1250 quintals Foundation seed and certified seed of 2.5 lakh quintals are expected to be produced in five years by which 20.48 lakh ha can be covered with new varieties/hybrids. A total of an area of 50.00 lakh ha/year can be covered with best suited HYV across the country through the seed production of 30 R&M seed hubs (8 old & 22 new) seed distribution, minikits with an expected total production of 100.00 lakh tonnes. Private seed companies should be involved by ICAR-DRMR for setting up of new seed hubs under NMEO-OS.

No Blending of Mustard Oil

Blended Edible Vegetables Oils (BEVO) was permitted by Ministry of Health Family Welfare in 1990 to overcome the shortage of oil in India. In 1992, an admixture of any two was allowed with one to be maximum 20%. The sealed packed to be sold only under AGMARK certification.

The Food Safety Standards Authority of India (FSSAI) has banned blending of mustard oil for production of Multi Sourced Edible Vegetable Oils (MSEVOs) with effect from 01.10. 2020. The regulation includes that the MSEVOs shall not be sold in loose form. It shall be sold in sealed packages weighing not more than 15 kgs. But the order was withdrawn as per stay order of High Court (representation of stakeholder).

Again, FSSAI Gazette Notification dated 08th March 2021 - Third Amendment Regulations, 2021 i.e. 8th June 2021 was enforced. Sale of any MSEVOs containing Mustard Oil manufactured on or after 8th June 2021 is prohibited. The MSEVOs shall not be sold in loose form. It shall be sold in sealed packages weighing not more than 15 kgs only under AGMARK certification. The regulation was with the following objectives.

- Providing remunerative prices to mustard growing farmers.
- Motivating farmers to grow more Rapeseed &Mustard.
- Availability of pure and single source oils
- Mitigating the risk posed to the health of the people by blended oil products.
- To discourage adulteration.

What required is strict enforcement of the regulation and suggested for development of rapid blending testing kits by ICAR and Central Institutes funded by FSSAI for the use of manufacturer and consumers.

Table 3 Target of different edible oils production by 2025-26

Annual crops Rapeseed & Mustard	Edible oil production (lakh tons)		% Contribution			
			Primary sources		Total edible oil	
	2019-20	2025-26	2019-20	2025-26	2019-20	2025-26
Rapeseed-mustard	28.30	55.24	39.07	40.54	25.79	29.74
Soybean	17.97	37.89	24.81	27.81	16.38	20.40
Groundnut	22.90	34.95	31.61	25.65	20.87	18.82
Sesame	2.34	4.29	3.23	3.15	2.13	2.31
Sunflower	0.73	2.80	1.00	2.05	0.67	1.51
Safflower	0.09	0.59	0.13	0.43	0.08	0.32
Niger seed	0.11	0.51	0.15	0.37	0.10	0.27
Primary sources	72.44	136.27	100.00	100.00	66.02	73.37
Secondary sources	37.29	49.47	-	-	33.98	26.63
Total edible oil	109.73	185.74	-	-	100.00	100.00

Table 4 Target of enhanced rapeseed and mustard and oil production under NMEO-OS

Parameter	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Area (lakh ha)	73.00	75.00	77.80	79.80	81.80	83.80
Production (lakh tons)	115.00	122.40	131.80	142.00	152.90	164.40
Yield (kg/ha)	1575	1615	1694	1779	1869	1962
Edible Oil Production (lakh tons)	35.67	38.56	42.18	46.22	50.61	55.24

Table 5 Existing seed hub under NFSM (OS)

Name of the centre	Varieties
KVK, Kota, Rajasthan	DRMR IJ -31
RVS KVV, ZARS Morena, MP	NRCHB-101, DRMRIJ-31, RVM-2, RH-749 and RH-725
KVK, Kamrup, AAU, Jorhat, Assam	NRCHB 101 and TS 36
DG, KVK, Saragachi, R.K Mission, Mursidabad West Bengal	NRCHB-101, YSH-0401, PM-30 and PM-28
ARS, SKRAU, Sriganganagar, Rajasthan	RGN – 298, RGN – 229, RGN – 236 and DRMRIJ-31
RLBCAU, Jhansi, Uttar Pradesh	DRMRIJ-31, RH-749, RH-406 and PM-30
BHU, KVK, Barkachha, Mirzapur, Uttar Pradesh	NRCHB-101, DRMRIJ-31, RH-749, PM-28 and RH- 725
CCSHAU, RRS, Bawal. Hisar, Haryana	RB-50, RH-725, RH-749, and DRMRIJ 31

Table 6 Procurement of Pulses and Oilseeds by NAFED

Year/Season	Quantity procured (Lakh MT)	Value at MSP (₹ in crore)	Farmers benefited. (lakh No.)
2020-21 (*Kharif* & *Rabi*)	34.56	16,854	18.00
2021-22 (*Kharif* & *Rabi*)	31.09	17,093	14.69
2022-23 (*Kharif*) upto 4.12.2022	1.04	916	0.62

Table 7 Procurement of pulses and oilseeds by NAFED in last five years

Crops	2016-17	2017-18	2018-19	2019-20	2020-21	Average (lakh tons)
Pulses procurement	8.73	20.27	41.83	15.07	23.56	21.89
Total pulses production & (% procurement)	231.3 (3.77)	254.2 (7.97)	220.8 (18.94)	230.3 (6.54)	254.6 (9.25)	238.24 (9.18)
Oilseeds procurement (Soya, G. Nut, R&M and Sunflower)	2.22	11.81	16.16	18.17	11.00	11.87
Total oilseeds production & (% procurement)	312.8 (0.70)	314.6 (3.75)	315.2 (5.12)	332.2 (5.46)	359.5 (3.05)	326.86 (3.63)

Honey production linked with mustard cultivation

A National Beekeeping and Honey Mission (NBHM) has been launched in 2020 as part of the Atma Nirbhar Bharat Abhiyan. 114 projects for financial assistance of about ₹ 139.23 crores are approved/sanctioned for funding under National Beekeeping and Honey Mission (NBHM) during 2020-21, 2021-22 & 2022- 23. India's production of Honey has touched about 133,200 metric tonnes in 2021-22 catapulting India to the second spot in the world behind

China. India is also one of the world's top honey exporters and exported 74,413 MT of honey in 2021-2022 for a total of ₹ 1221.17 crore. The major markets for Indian honey are Germany, the USA, the UK, Japan, France, Italy, Spain etc. There is a need to integrate apiculture (honeybee rearing) with the mustard project for the next five years.

Rapeseed-mustard areas of the country have vast potential for honey production which can help in enhancing farmers' incomes and can also provide employment to the rural youths. Honeybees are reportedly enhancing about 15 to 20% the seed yield of mustard. 3-5 colonies of *Apis cerana*/*Apis mellifera* should be kept per hectare when rapeseed-mustard crop is at 10-12 per cent bloom (mid-December to end of February) for increasing quantitative and qualitative yield parameters of mustard. A farmer can get about 20-25 kg honey/hive from one ha of mustard crop. Therefore, it is essential to integrate apiculture (honey bee rearing) with the mustard project for next five years. PPP mode Honeybee demonstration, processing infrastructure and marketing to be included under NMEO-OS in collaboration with National Honey Mission.

Assured Procurement by National Agricultural Cooperative Marketing Federation (NAFED) & Central agencies

Since markets are not in a steady state of demand and supply, the farmers face a fluctuating farm-gate price for their output. This price variation is further aggravated when other market abnormalities come into play. To mitigate the farmers from such extreme vagaries, there is an option to try out a Price Deficiency Payment System (PDPS).

Pradhan Mantri Annadata Aay SanraksHan Abhiyan' (PM-AASHA) is an umbrella scheme to ensure Minimum Support Price (MSP) to farmers. It comprises the erstwhile Price Support Scheme (PSS) with certain modifications and rolling out of new schemes of Price Deficiency Payment Scheme (PDPS) and pilot of Private Procurement and Stockist Scheme (PPSS). Under PM-AASHA, States/UTs are offered to choose either PSS or PDPS in a given procurement season with respect to particular oilseeds crop for the entire State. Pulses and Copra are procured under PSS.

In Agriculture Marketing reform sector, DA&FW has formulated a new Model Agricultural produce and Livestock Marketing (Promotion & Facilitation) Act, 2017 and circulated to States/UTs on 24.04.2017 for adoption. DA&FW launched the National Agriculture Market (e-NAM) scheme in 2017 to enhance transparency in transactions, price discovery and farmers' reach to larger number of markets to sell their produce to buyers of their choice at their convenience. DA&FW notified Farmers' Produce Trade and Commerce (Promotion and Facilitation) Rules, 2020

The Scheme of DA&FW, PDPS, is an assured income transfer mechanism and is hassle free in respect to the transaction including storage. This scheme is more relevant for regions and crops where the government's Minimum Support Price (MSP) procurement is not being reached and where the procurement system is not geared up to meet the challenges in disposal of the procured stock. However, where there is a large market deficit, as in case of oilseeds and edible vegetable oil, this mechanism can help promote production. Since there is already a situation of high demand and short supply, there may not be a challenge to evacuate large surpluses from farms. The DFI committee recommended PDPS as an intervention for oilseeds, as one of the options.

Government should broad base and strengthen procurement operations to cover oilseeds (other than wheat and paddy) and be secular across the production. The procurement operations are conducted with a view to stabilizing market prices and not as income transfers. The government adopts a procurement threshold level of at least 25% of the marketed surpluses for oilseeds under PDPS.

NAFED is one of the Central Nodal Agencies for procurement of 16 notified agricultural commodities including Oilseeds under Price Support Scheme (PSS). The procurement by NAFED under *kharif* and *rabi* seasons during the year 2021-22 were 31.08 lakh MT of pulses, oilseeds and copra having MSP value of ₹ 17,093.13 crore benefiting 14.69 lakh farmers has been done. Further, during *kharif* 2022-23 season a quantity of 1,04 lakh MT of pulses, oilseeds and copra having MSP Value of ₹ 915.79 crore benefiting 61,339 farmers as on 04.12.2022 (Table 6) were recorded.

During last five years (2016-17 to 2020-21), NAFED made procurement of 3.63% of total oilseeds and 9.18% of total pulses production under the PSS which need to be increased at least to 25% as per new policy (Table 7). The five years average pulses procurement was 21.89 Lakh MT while oilseed procurement was 11.87 Lakh MT. Government has increased the MSP for all mandated kharif, rabi and other commercial crops with a return of at least 50 per cent over all India weighted average cost of production from 2018-19.

Mobilizing Farmer Producer Organizations (FPOs) on Rapeseed and Mustard

A new Central Sector Scheme for Formation and Promotion of new 10,000 FPOs launched by Hon'ble Prime

Minister on 29th February, 2020 with budget outlay of ₹ 6865 crore till 2027-28. As on 30.11.2022, 4016 numbers of FPOs registered under new FPO scheme.

The FPOs are the potential solution to address the challenges related to smallholder farmers in terms of access to inputs, quality seeds, infrastructure, and market linkages etc. FPOs would be contributing towards strengthening the farmers' negotiation position in relation to the buyers and reduce the transaction costs faced by farmers to bring them closer to the market, enabling them to derive benefit in agriculture.

The support to Industry/Associations will potentially play prominent role in empowering farmers by forming FPOs, to make their agricultural enterprise more viable and profitable to improve upon their socio-economic status and betterment. It is important to recognize the fact that in initial years, Cluster Based Business Organization (CBBOs)/Associations are not only trying to settle into a business environment but are also competing with prevailing market forces. In addition to this it is crucial to develop a business case, so that FPOs would be able to leverage from markets as from the formal financial sector.

FPO Implementing agencies like Small Farmers Agri-business Consortium (SFAC), NABARD, NAFED, NCDC will support the FPOs for management cost, equity grant and credit guarantee loans as per operational guidelines of 10,000 FPOs scheme. All the above grants will be availed for sustainable growth of each FPOs. CBBOs will also connect the FPOs and farmer members of the catchment area for various services such as input supply, customized crop advisory, credit linkage, market linkages and other relevant rural services through its network platform and existence in targeted states. Each CBBOs will be granted incubation cost of FPOs for 3 years as per guidelines of 10000 FPOs.

Here Industry will play a role of providing hand-holding support to FPOs for Logistics Support, Warehousing and Market Linkages and processing of pure oils. It is propose an innovative model of Rural Entrepreneurship exclusively for pure mustard oil processing and production. FPOs would be engaged through services such as advisory/extension, inputs, farm equipment, finance, aggregation/procurement of produce, storage, transportation, and value addition etc. Digital Solutions Platform may be created for yield estimation, easy access of technology to the farmers through precise advisories, Geo-tagging etc. Market linkage is also one of the important pillars of the FPOs and therefore need to create a direct linkages between farmers and industry with following objectives.

- Mobilize support from the industry for setting-up of procurement centres
- Educate farmers about different aspects of post-harvest management - Sensitize them about maintaining the quality as per industry standards.
- Create awareness among farmers about the benefits of direct market linkages facilities.
- Encourage farmers for collective sale at the procurement centre.
- Price discovery at farmers' doorstep based on the quality conditions.

Conclusion

GOI is very aggressive to boost domestic edible oils production both from primary and secondary sources and formulated two separate Mission i.e. NMEO-OS and NMEO-OP for its implementation Nationwide with the aim to enhance the edible oilseeds production and oils availability in the country by harnessing oilseeds & palm oil and to reduce import burden on edible oils. NMEO-Oil Palm is already launched by GOI in August 2021 with a budget allocation of Rs.11,040 crore by 2025-26 and under implementation to cover additional area of 6.5 lakh ha under oil palm.

NMEO-OS is under the consideration by Cabinet and may launch soon and expected budget would be Rs. 6000 to 6500 crores by 2025-26. The target fixed for oilseeds production by 2025-26 under NMEO-Oilseeds is to increase area under cultivation by 22%, increase productivity by 21%, overall production increase by 48% and to reduce import dependency from 60% to 40% by 2025-26. The strategy to implement the proposed NMEO-OS will include increasing Seed Replacement Ratio (SRR) with focus on varietal replacement; improving productivity of oilseed crops, increasing irrigation coverage under oilseeds, diversification of area from low yielding cereals crops to oilseeds crops, inter-cropping of oilseeds with cereals/ pulses/ sugarcane; use of fallow land after paddy /potato cultivation.

Since *rabi* 2020, DA&FW has launched a special program for rapeseed and mustard to increase its area from around 73 lakh ha to around 84 lakh ha and production from around 115 lakh tons to around 164 lakh tons by 2025-26 (current production 117.46 lakh tons). A total of 368 districts of 13 states are under implementation for increasing yield of Rapeseed Mustard through high yielding varieties/ hybrids seed distribution/ seed minikits (more than 20 q/ha yield) and improved crop demonstrations.

Different Oil Associations / Industries are engaged in extension activities for increasing oilseeds production with their limited resources. In August 2021, GOI has launched NMEO-Oil Palm which is directly linked with Oilpalm Processing companies. The Mission provides different type of subsidies for oil palm development both the farmers and processors. This is lacking in the NMEO-Oilseeds.

The private seed companies/Associations can be involved for Seed production, Seed distribution, Model Seed Production farm cum Training centre through NSC and Creation of seed hubs of oilseeds through ICAR-IIOR on 100% funding basis to increase the SRR/VRR mainly for Mustard. The NMEO-OS do not have any support for processing of oils and value addition. Therefore, the following Suggested Policy initiatives and Market interventions may be considered for involvement of Industry as well Associations under NMEO-OS especially for rapeseed and mustard.

- Crop diversification/intercropping/rice fallow area.
- Need for private sector involvement.
- Need for seed hub of rapeseed and mustard by private seed companies.
- No blending of mustard oil
- Honey production linked with mustard cultivation.
- Assured procurement by NAFED and Central agencies.
- Mobilizing Farmer Producer Organizations (FPOs) on rapeseed and mustard.

Besides, NMEO-OS the private participation in technology demonstration, input supply, procurement of produce, value addition, infrastructure development and honey production are very much essential to increase edible oils production. Various GOI schemes resources should be converged with NMEO-OS.

Rapeseed and mustard oil is one of the most consumed edible oils in India due to pungency and colour. India needs nearly 15-20 million tonnes of rapeseed and mustard seed to meet its growing demand as against current production of 9-10 million tonnes of rapeseed and mustard seeds. As per WHO standards, mustard oil with low saturated fatty acid content and high mono unsaturated fatty acid content is a healthy oil and therefore needs special importance in domestic edible oil basket. The cold pressed and chemical free-kachighani Mustard oil is rich in natural pungency due to presence of allyl isothiocyanate.

REFERENCES

AICRP-R&M 2021. Annual report 2019-20/2020-21. All India Co-ordinated Research Project on Rapeseed-Mustard. ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan.

DES 2022. 4th advance estimates, 2021-22, Department of Agriculture & Farmers Welfare (DA&FW), New Delhi.

DA&FW 2022. Doubling farmers income documents, Department of Agriculture & Farmers Welfare (DA&FW), New Delhi.

FSSAI 2020. Food safety and standards (Prohibition and restriction on sales) Amendment regulations 2020.

FPO 2022. FPO guidelines of SFAC.

NAFED 2021. Annual report 2020-21. National Agricultural Cooperative Marketing Federation of India (NAFED).

NBHM 2022. National Beekeeping and Honey Mission, Department of Agriculture & Farmers Welfare (DA&FW), New Delhi.

NMEO-OS 2022. NMEO-OS framework document, Department of Agriculture & Farmers Welfare (DA&FW), New Delhi.

PDPS 2022. Price Deficiency Payment Scheme (PDPS), Department of Agriculture & Farmers Welfare (DA&FW), New Delhi.

Review

Valorization of a biomass: phytochemicals in oilseed by-products

SELIN SAHIN*

Chemical Engineering Dept., Faculty of Engineering, Istanbul University-Cerrahpasa, Avcilar, 34320 Istanbul, Turkey

(Received: December 5, 2022; Revised: January 4, 2023; Accepted: January 6, 2023)

ABSTRACT

Agri-food industry generates a wide variety of waste by-products in huge amounts every year. These by-products possess various phytochemicals which are known as high value addeded substances. Oilseed crops produces residuals, which have potential source of high added-value phytochemicals. This study gives the types of oilseed by-products and their high added value phytochemicals by summarizing the recent studies on the valorization of different wastes of several oilseed crops. Furthermore, future perspectives are also discussed.

Keywords: Biomass, By-products, Oilseed crops, Phytochemicals, Value addition

Valorization of waste by-products of agri-food industry has been a promising research field due to the exhaustion of natural resources and raw materials. From the economic, social, and ecological aspects, conversion of biowaste into high value-added substances has been getting great attention recently. This is also valuable considering the concept of "zero waste economy", where waste is converted into new valuable products that find applications in new areas and also by serving great potential in energy savings (Mirabella *et al*., 2014). Food processing industries such as fruit juice, alcohol, and oil produce high amounts of waste by-products such as seeds, leaves, pomaces, and peels. Among the fruit pomace and peels, and plant leaves and husks, seeds of oil crops have been getting greater interest nowadays due to their residues being rich in a great variety of lipophilic and hydrophilic phytochemicals that might be precious sources of natural antioxidants (Peschel *et al*., 2007). Oilseed processing by-products comprise approximately 35 million tons of seed for oil in European Union. Soybean is the first in processing, accounting for almost 50% of the total crop, followed by rapeseed and sunflower seeds (Oreopoulou and Tzia, 2007). Even though the residue of oilseed crops are extremely significant due to their various valuable ingredients, the resultant biowaste is generally consumed as animal feed or fertilizer in their production areas.

Oilseed sources and their phytochemical ingredients

Biomass from castor, rapeseed, mustard, olive, sesame, sunflower, flaxseed, soybean, palm kernel and evening primrose are the examples of agricultural and industrial by-products, presently used for reducing organic wastes in the form of production of energy or as reputable source of phytochemicals.

Corresponding author's E-mail: selins@istanbul.edu.in

Castor (*Ricinus communis*), which is grown in India, Africa, and Southeastern Mediterranean countries belongs to the family of Euphorbiaceae. It has fatty acids and phytochemicals such as triterpenoids, flavonoids, lignin, tannins, alkaloids and glycosides (Muhammed *et al.*, 2015).

Evening primrose (*Oenothera biennis*) with its common name "evening star" comes from Onagraceae family. It is consumed for its nutraceutical value includings its diverse medical effects (Munir *et al.*, 2017). This crop is generally produced in USA and China. The residue of this oil processing is also rich in various phytoconstituents, which is verified by HPLC method. Antioxidant and antimicrobial activities of the cake extracts have also been confirmed by in vitro analysis (Ratz-Lyko *et al.*, 2014).

Flax (*Linum usitatissimum*) seed, also known as "linseed" belongs to Linaceae family. This crop is grown in Canada, USA, China, India and Argentina (Herchi *et al.,* 2014) for its fiber and phenolic and flavonoid contents with antioxidant properties (Wang *et al.*, 2017). Yang et al. (2012) displayed its anti-oxidative power and protective effect for the membranes of erythrocytes.

Mustard (*Brassica juncea*), from Brassicaceae family is another plant crop produced for oil is grown in generally Canada, Nepal, Russia and Asian, North African, European and North American countries. This oil is also rich in carotenoids, alkaloids, flavonoids and glycosides (Oh *et al.*, 2016). Thukral *et al.* (2017) extracted the leaf samples by different solvents (chloroform, ethyl acetate, methanol, petroleum ether and hexane), and detected a vast variety of phytochemical compounds according to the solvent type used for extraction.

Olive (Olea europaea) of Oleaceae family is one of the most consumed vegetable oilseed crops due to its high amount of phenolic compounds and tocopherols (Sahin and Bilgin, 2018). Most of the production is supplied by

Mediterranean countries such as Spain, Italy, Greece, Turkey and Tunisia (Türkekul *et al.,* 2010). Olive leaf has been very popular with a great variety of phenolic compounds having anti-atherogenic, anti-inflammatory, antimicrobial and anti-cancer properties owing to its major compound, oleuropein (Sahin and Bilgin, 2018). Goldsmith *et al.,* showed the anti-pancreatic cancer activity of the leaf depending on the olive cultivar and solvent type used (Goldsmith *et al.,* 2015).

Although olive oil is extremely rich in phenolic compounds, only 2% of the total in olive is transferred to the extracted olive oil (Alhamad *et al.*, 2017). The rest (approximately 98%) stays in olive cake during olive oil production. This by-product has a great variety of biologically active hydrophilic ingredients such as oleuropein, hydroxytyrosol, tyrosol, verbascoside, rutin, catechol, caffeic acid, coumaric acid, vanillic acid and elenolic acid (Sahin *et al.,* 2019).

Palm (*Elaeis guineensis*) kernel is an efficient seed, giving approximately 44% of oil yield (Akhtar *et al.*, 2014), coming from the plant family of Palmae. Therefore, it is cultivated for just oil production. Latin American countries, Malaysia and Indonesia constitute the leading countries producing palm oil (Pardo *et al.*, 2015).

Rapeseed (*Brassica napus*) also known as "canola" is in the same family as mustard. It is produced mainly in China, India, Canada, USA, Russia and Europe (Yang *et al.*, 2015). Its wastes such as leaf, root and cake are rich in bioactive compounds. Szydlowska-Czerniak et al. identified sinapine and sinapic acid as the major phenolic compounds of the rapeseed cake (Szydlowska *et al.,* 2010). Other residues of rapeseed such as leaf and root also contain many compounds having health benefits (Cartea *et al.*, 2011).

Sesame (*Sesamum indicum*), belonging to the plant family Pedaliaceae is mostly consumed for its seeds and oil in India, Myanmar, Sudan and China (accounting for almost 70% of world crop) (Reshma *et al.*, 2010). Sesame cake, which is the waste of sesame oil industry is utilized as a cattle feed if not valorised for compensating for synthetic antioxidants. Nadeem *et al.* applied sesame cake extract as natural antioxidant into the lipid-containing food products (Nadeem *et al.*, 2014).

Soybean (*Glycine max*) from Fabaceae family is cultivated for generally edible purposes because of its high nutritional value in African countries, Brazil, Paraguay, Bolivia and Argentina (Sinclair *et al.*, 2014). Soybean contains isoflavone aglycones, glycosides, and phenolic acids, contributing to its antioxidant capacity.

Another highly consumed oilseed crop is sunflower (*Helianthus annuus*) from Asteraceae family. Generally, it is cultivated in Ukraine and Russia (accounting for almost half of the world production). Other production areas are Argentina and some European countries (Konyali, 2017). Several by-products (such as floret, leaf, cake, and hull) of this crop have been investigated with respect to biological activity. Ye *et al.,* showed correlation between the antioxidant activity and the phenolic content of the floret extract (Ye *et al.*, 2015). Chen et al. showed that sunflower leaf extract could be a natural fungicide (Chen *et al.*, 2013). Franke *et al.,* identified the carotenoid content of sunflower cake by HPLC (Franke *et al.*, 2010). Abdeldaiem and Hoda (2014) examined the antioxidant activity and phenolic profile of the hull, the least investigated residue of sunflower (Ali, 2014).

Phytochemicals derived from the waste of oilseed crops might play a novel role in extending the shelf-life of several products (such as food, cosmetic and pharmaceutical) as well as providing value-added properties with their antioxidant and antimicrobial properties. However, health benefits and the non-toxicity of the natural phytochemicals must be provided to compensate for the synthetic materials in the relevant products with respect to safety concerns. On the other hand, additional studies are necessary to determine whether there is any link between the protective effect and the probable prominent compounds in the concerned products.

REFERENCES

Akhtar S, Khalid N, Ahmed I, Shahzad A, Suleria HAR 2014. Physicochemical Characteristics, Functional Properties, and Nutritional *Benefits of Peanut Oil*, **54**(12):1562-1575. http://dx.doi. org/ 101080/104083982011644353.

Ali G M 2014. Evaluation of Antioxidant Activity of Ethanolic Extract from Irradiated Sunflower (*Helianthus annuus* L.) Seeds Hull. *Journal of National Sciences Research*, **4**(1). www.iiste.org ISSN, Available from: www.iiste.org.

Alhamad M N, Rababah T M, Al-u'datt M, Ereifej K, Esoh R, Feng H, *et al.* 2017. The physicochemical properties, total phenolic, antioxidant activities, and phenolic profile of fermented olive cake. *Arabian Journal of Chemistry*, **10**(1): 136-140.

Cartea M E, Francisco M, Soengas P, Velasco P 2011. Phenolic compounds in Brassica Vegetables. *Molecules*, **16**(1):251-280. https://www.mdpi.com/1420-3049/16/1/251/htm

Chen F, Long X, Yu M, Liu Z, Liu L, Shao H 2013. Phenolics and antifungal activities analysis in industrial crop Jerusalem artichoke (*Helianthus tuberosus* L.) leaves. *Industrial Crops and Products*, **47**:339-345.

Franke S, Fröhlich K, Werner S, Böhm V, Schöne F 2010. Analysis of carotenoids and vitamin E in selected oilseeds, press cakes and oils. *European Journal of Lipid Science and Technology*, **112**(10): 1122-1129. https://onlinelibrary. wiley.com/doi/ full/ 10.1002/ ejlt.200900251.

Goldsmith C D, Vuong Q V., Sadeqzadeh E, Stathopoulos C E, Roach P D, Scarlett C J 2015. Phytochemical properties and anti-proliferative activity of *Olea europaea* L. leaf extracts against pancreatic cancer cells. *Molecules*, **20**(7): 12992-13004.https://www.mdpi. com/1420-3049/ 20/7/12992/htm.

Herchi W, Arráez-Román D, Trabelsi H, Bouali I, Boukhchina S, Kallel H, *et al.* 2014. Phenolic compounds in flaxseed: a review of their properties and analytical methods. An overview of the last decade. *Journal of Oleo Science*, **63**(1):7-14. http://www.jstage.jst.go.jp/ browse/jos/http://mc.manusript central.com/jjocs.

Konyali S 2017. Sunflower production and agricultural policies in Turkey. *Social Science Research Journal*, **6**(4):11-19. https://dergipark.org.tr/en/pub/ssrj/issue/32264/343313.

Mirabella N, Castellani V and Sala S 2014. Current options for the valorization of food manufacturing waste: a review. *Journal of Cleaner Production*, **65**: 28-41.

Muhammed Aziz D, Wsoo MA, Ibrahim BM 2015. Antimicrobial and antioxidant activities of extracts from medicinal plant ginger (*Zingiber officinale*) and identification of components by gas chromatography. *African Journal of Plant Science,* **9**(10):412-420.

http://www.academicjournals.org/AJPS.

Munir R, Semmar N, Farman M, Ahmad NS 2017. An updated review on pharmacological activities and phytochemical constituents of evening primrose (genus Oenothera). *Asian Pacific Journal of Tropical Biomedicine*, **7**(11):1046-1054.

Nadeem M, Situ C, Mahmud A, Khalique A, Imran M, Rahman F, *et al.* 2014 Antioxidant activity of sesame (*Sesamum indicum* L.) cake extract for the stabilization of olein based butter; antioxidant activity of sesame (*Sesamum indicum* L.) cake extract for the stabilization of olein based butter. https://aocs.onlinelibrary.wiley.com/ doi/pdf/10.1007/s11746-014-2432-3.

Oreopoulou V and Tzia C 2007. Utilization of plant by-products for the recovery of proteins, dietary fibers, antioxidants, and colorants. Util By-Products Treat Waste Food Industry, 209-232.https://link.springer.com/chapter/10.1007/978-0-38 7-35766-9_11.

Oh S K, Kim K W and Choi M R 2016. Antioxidant activity of different parts of Dolsan Leaf Mustard. *Food Science and Biotechnology*, **25**(5):1463-1477. https://link.springer.com/ article/10.1007/s10068-016-0227-z.

Peschel W, Dieckmann W, Sonnenschein M, Plescher A 2007. High antioxidant potential of pressing residues from evening primrose in comparison to other oilseed cakes and plant antioxidants. *Industrial Crops and Products,* **25**(1):44-54.https://www.sciencedirect.com/ science/article/pii/ S0926669006000963.

Pardo Vargas LE, Laurance WF, Clements GR, Edwards W 2015. The impacts of oil palm agriculture on Colombia's biodiversity: What we know and still need to know. *Tropical Conservation Science*, **8**(3):828-845. https://journals.sagepub. com/doi/full/10.1177/ 194008291500800317.

Ratz-Lyko A, Herman A, Arct J, Pytkowska K 2014. Evaluation of antioxidant and antimicrobial activities of *Oenothera biennis, Borago officinalis,* and *Nigella sativa* seedcake extracts. *Food Science and Biotechnology*, **23**(4):1029-1036. https://link. springer.com/article/10.1007/s10068-014-0140-2.

Reshma M V., Balachandran C, Arumughan C, Sunderasan A, Sukumaran D, Thomas S, et al. 2010. Extraction, separation and characterisation of sesame oil lignan for nutraceutical applications. *Food Chemistry*, **120**(4):1041-1046.

?ahin S, Bilgin M 2018. Olive tree (*Olea europaea* L.) leaf as a waste by-product of table olive and olive oil industry: a review. *Journal of the Science of Food and Agriculture*, **98**(4):1271-1279.

Sahin S, Cigeroglu Z, Özdemir OK, Bilgin M, Elhussein E, Gülmez Ö 2019. Recovery of hydroxytyrosol onto graphene oxide nanosheets: Equilibrium and kinetic models. *Journal of Molecular Liquids*, **285**:213-222.

Sinclair T R, Marrou H, Soltani A, Vadez V, Chandolu K C 2014. Soybean production potential in Africa. *Global Food Security*, **3**(1):31-40.

Szyd?owska-Czerniak A, Amarowicz R, Sz?yk E 2010. Antioxidant capacity of rapeseed meal and rapeseed oils enriched with meal extract. *European Journal of Lipid Science and Technology*, **112**(7):750-760.

Thukral AK, Kumar V, Bhardwaj R, Sharma A, Kanwar MK 2017. Phytochemical profiling of the leaves of *Brassica juncea* L. using GC-MS. *International Food Research Journal*. https://agris.fao.org/ agris-search/search.do? recordID=MY2021004513.

Türkekul B, Günden C, Abay C, M?ran B 2010. Competitiveness of Mediterranean countries in the olive oil market. *New Medit*, **9**(1):41-46.

Wang H, Wang J, Qiu C, Ye Y, Guo X, Chen G, et al. 2017. Comparison of phytochemical profiles and health benefits in fiber and oil flaxseeds (*Linum usitatissimum* L.). *Food Chemistry*, **214**: 227-233.

Yang W, Fu J, Yu M, Huang Q, Wang D, Xu J, et al. 2012. Effects of flaxseed oil on anti-oxidative system and membrane deformation of human peripheral blood erythrocytes in high glucose level. *Lipids in Health and Disease*, **11**(1):1-10. https://link.springer.com/ articles/10.1186/1476-511X-11-88.

Yang S-C, Arasu MV, Chun J-H, Jang Y-S, Lee Y-H, Kim IH, *et al.* 2015. Identification and Determination of Phenolic Compounds in Rapeseed Meals (*Brassica napus* L.). *Journal of Agricultural Chemistry and Environment*, **04**(01):14-23. http://file.scirp.org/Html/2-2750120_53624.htm.

Ye F, Liang Q, Li H, Zhao G 2015. Solvent effects on phenolic content, composition, and antioxidant activity of extracts from florets of sunflower (*Helianthus annuus* L.). *Industrial Crops and Products*, **76**: 574-581.

Review

Towards substantial self-reliance in vegetable oil - Policy prescription

G CHANDRASHEKHAR

Columnist, The Hindu Daily Newspaper, Chennai-600 002, Tamil Nadu

(Received: January 3, 2023; Revised: January 12, 2023; Accepted: January 13, 2023)

ABSTRACT

In India, oilseeds have been in chronic short supply for well over two decades amid a demand surge for edible oil driven by rising incomes, demographic pressure, and low per capita availability. Land constraints, water stress, and climate change are sure to hurt Indian agriculture in general and oilseeds cultivation in particular, as these crops are grown predominantly as rainfed crops. That makes comprehensive policy action inevitable. In this review, recommendations and strategies to boost domestic oilseed production are discussed.

Keywords: Domestic production, Oilseeds, Policy prescription, Strategies

Indian oilseeds sector defies conventional logic. When a commodity is in short supply, its prices must rise and producers must benefit. Sadly, Indian oilseed growers are an ironic exception. In India, oilseeds have been in chronic short supply for well over two decades amid demand surge for edible oil driven by rising incomes, demographic pressure and low per capita availability. Under normal circumstances, supply-demand mismatch ought to have motivated primary producers (oilseed growers) to produce more. But sadly, inadequate policy support has brought our economy to a situation where our import dependence on vegetable oil is at an alarming 60 percent. Our domestic production of vegetable oil is approximately 7-9 million tonnes while our import is around 13-14 million tonnes, costing the exchequer a whopping $ 12-14 billion annually and keeping the nation at the mercy of overseas suppliers.

The features of Indian oilseed sector include stagnant area, low yields, unsteady output, volatile prices (often below MSP), and weak procurement. So, there's no motivation for growers to produce more and no incentive to improve the production environment and agronomy. This is not an overnight phenomenon. This sorry state of affairs has developed over the last 25 years. Today, India cannot afford the 'business-as-usual' approach to this sector. The enormous drag on precious foreign exchange year after year ($ 12-14 billion) is becoming unaffordable and unsustainable. We need 'creative disruption' to address this situation.

In short-to-medium term, vegetable oil imports are inevitable. Liberal imports certainly advance consumer interest. But the import policy as practised by the government has failed to protect the domestic oilseed growers' interests. We need a holistic policy for this sector that promotes the interests of different stakeholders harmoniously, especially farmers and consumers.

Corresponding author's E-mail: gchandrashekhar@gmail.com

At the same time, we must recognize future risks. Land constraints, Water stress and Climate change are sure to hurt Indian agriculture in general and oilseeds cultivation in particular as these crops are grown predominantly as rainfed crops. That makes comprehensive policy action inevitable. This author has been tracking and working closely with the global and Indian oilseed-based industry and trade as well as providing policy inputs for the government for over three decades through his personal interaction with top policymakers and through his closely-followed newspaper columns and business television appearances.

Here is a set of six broad recommendations followed by an action plan for six quick wins.

Strategies to Boost Domestic Oilseed Production:

1. Enforce area expansion through crop rotation and incentives in grain mono-cropping states such as Punjab, Haryana and Uttar Pradesh.
2. Adopt multiple novel and recent technologies and technological interventions including Infotech, Agbiotech, Satellite tech, Nuclear agritech, Nanotech etc. to boost oilseeds production and productivity.
3. Work towards a breakthrough in seed technology in major oilseeds like soybean and rapeseed/mustard (technology in cotton provides a successful example); Sunflower seed too deserves strong support because of its high oil content.
4. Implement a robust procurement system. When oilseed prices fall below MSP (Minimum Support Price), procurement must soon kick-in to support prices.
5. Tap the potential of non-conventional oil sources such as rice bran, tree-borne oilseeds (TBO) and similar. We

have been talking about the vast potential of TBO for three decades, but not much has changed. Forest produce are a 'State' subject; so, Centre's engagement with States for a long-term lease policy is critical.
6. Invest in improving crushing / extraction efficiency.

Each one of the above is perfectly doable. The positive effects of these will be visible over a period of time. However, we need some 'quick wins' too. Here's a set of six policy actions for garnering some quick wins.

Six Policy Actions for Quick Wins

Given the wide supply gap, in the short-term, vegetable oil import is inevitable. But we can surely mitigate the negative impact of current import policy, especially on growers. It is critical to prevent speculation-driven, excessive, unrestrained import of vegetable oils that depress domestic oilseed prices and hurt growers' interest.

Policy Action # 1: Regulate and Monitor Imports: India's vegetable oil imports need strict regulation and monitoring. To consider an annual ceiling on import volume may not be out of place. Monitoring of import is critical. Quarterly reviews of import performance may be undertaken. Tariffs/ duties have to be dynamic.

The government has no clue about the quantity of oil contracted for, type of oil, price, arrival period and so on. In the absence of this vital information, New Delhi's response to edible oil trade is often kneejerk. A system of 'Import Contract Registration' will remove the opacity, make the business transparent and facilitate informed decision making for policymakers - it is a simple administrative decision with no cost involved.

Policy Action # 2: Shorten Import Credit Period: There's need to cut down the credit period for payment (to overseas suppliers) against import to 45 days maximum. Currently importers enjoy 90-120-150 days' credit which encourages overtrading and speculation. The long credit period tempts many Indian importers to indulge in over-trading. Some importers are already in a serious 'import debt trap' because of rampant overtrading. Bank loans to importers can turn into NPA anytime. Reduced credit period will automatically slow the pace of import and make the importer more responsible and accountable.

Policy Action # 3: Cooking oil under PDS: Support vulnerable sections of consumers with supply of edible oil under PDS / NFSA at subsidised and affordable rates. If it involves subsidy, so be it. This country has a recorded history of supplying edible oil through PDS until the year 2002. It must be revived. PDS and private trade supplies can co-exist; they are not in conflict and both help advance consumer interest. Edible oil consumption among the most vulnerable sections of the population is rather low and deserves to be raised. This could be done by combining the public procurement of edible oilseeds by the government and then the extracted oil could be supplied through PDS.

Policy Action # 4: Encourage Oilseed Import: Allow import of oilseeds in partial replacement of vegetable oils to gain multiple benefits. After all, vegetable oils are finished or semi-finished goods with hardly any value addition possibility. On the other hand, Oilseeds are primary raw material. Import of oilseeds in lieu of oils will (a) boost utilization of domestic idle processing capacity; (b) create more jobs and incomes; (c) result in augmented edible oil availability; and importantly, (d) make available more cake/ meal for the domestic livestock sector or for export. Oilseed import policy should be liberal with robust phyto-sanitary inspection at the borders. Tariff should be dynamic to ensure that the landed cost of imported oilseed is not below the specified MSP for domestic oilseeds.

Policy Action # 5: Modernization Fund: Consider creating 'Oilseeds Processing Industry Modernisation Fund'. Many of 15,000 oilseed crushing units and about 800 solvent extraction plants are intrinsically inefficient in terms of scale, equipment, technology and productivity. They need to be upgraded. When modernized, the industry has better chance to capture greater value with improved oil recovery. Also, it will create potential to attract Foreign Direct Investment (FDI).

Policy Action # 6: Backward linkage: There is a mistaken belief in a section of the Indian refining industry that a liberal policy of vegetable oil import is its inalienable birth right. This section of the industry thrives on import and has done nothing to advance domestic growers' interests. A policy that mandates large domestic processing industries (oil mills, refining units, solvent extraction plants) to establish backward linkages to produce and procure oilseeds is perfectly justified and the need of the hour. Importers have to mandatorily contribute to import substitution too. They must work with FPOs. Implementation details can be discussed with all the involved stakeholders.

Large processors must establish backward linkages, work with FPOs and help lift or prop domestic oilseed production. A fake narrative of 'Make in India' with some entrenched interests in the industry to continue to promote large-scale vegetable oil import must give way to 'Genuine Make in India' which is when we produce and process more oilseeds domestically.

Additional points to be considered for increased domestic vegetable oil production:

Palm oil: Much bet is being laid on the prospect of oil palm cultivation in our country as part of our self-sufficiency quest. But history tells us that nothing remarkable has happened in India's oil palm foray in the last 30 years. While the new oil palm initiative is a welcome step, let us not fool ourselves by believing that oil palm alone will solve our supply problems. We need a comprehensive review of oil palm promotion policy for sustained and sustainable growth.

Oilseeds: Strong promotional support to domestic oilseeds such as soybean, rapeseed-mustard and groundnut is the need of the hour, specifically through technological intervention. Sunflower seed and sesame seed are high-oil content oilseeds that deserve to be promoted. Our research institutions have a duty to come up with appropriate seed varieties with enhanced seed productivity, oil content, in-built resistance against biotic and abiotic factors, and other agronomic traits suitable for the ecoregions. The country's oilseeds sector deserves Policy Support, Investment Support and Research Support.

Engagement with Indonesia: From Indonesia, we import palm oil, timber and coal to name a few key commodities. Our balance of trade with Indonesia is adverse. The world's largest palm oil producer imposes export duty on palm oil and often threatens to curtail/contain exports. This makes India highly vulnerable. We need to address this risk. Let's have G-to-G dialogue with Indonesia and put pressure on them to review their export policy at least insofar as palm oil export to India is concerned. We may consider G-to-G import of palm oil from Indonesia. Counter-trade or Barter-trade may be explored too.

Finally, our policymakers must demonstrate strong 'political will' to creatively disrupt the status quo. It is debilitating. Let us design supportive policies to holistically move towards substantial self-reliance in oilseeds/vegetable oils in a time-bound manner.

(Excerpts of speech delivered by Economist, Senior Editor and Policy Commentator G. Chandrashekhar during International Conference on Vegetable Oils 2023 in Hyderabad on January 21, 2023. As a global agribusiness and commodities market specialist, he has been closely associated with the oilseeds and vegetable oil sector for over four decades. He is associated with several international institutions and provides policy inputs for the government).

Heterosis and combining ability studies under artificial epiphytotic condition for yield and its related traits in Indian mustard

DIVYA PRAKASH, B SINHA AND KARTIKEYA SRIVASTAVA*

Faculty of Agriculture, Banaras Hindu University, Varanasi - 221005, Uttar Pradesh

(Received: January 30, 2023; Revised: March 10, 2023; Accepted: April 4, 2023)

ABSTRACT

The performance of Indian mustard genotypes for eleven morpho-physiological traits was assessed. Genotypes (lines) having white rust resistance *viz.,* BioYSR, Donskaja, Heera and Basanti, were crossed with genotypes (testers) having high per se performance for yield *viz.,* Varuna, Kranti, RH749 and Giriraj in the line × tester fashion. The analysis of variance revealed significant mean sum of squares due to crosses for all traits. All traits, except area under disease progression curve and days to 50% flowering, showed both, additive and a predominance of non-additive gene action. Results suggested that heterosis breeding would lead to good result. All traits had lower levels of narrow sense heritability, as well. Predominance of non-additive gene action coupled with low heritability suggested that, selection should be practised once plant reach sufficient levels of homozygosity. Single seed descent method with large F_2 and diallel selective mating design would be preferable for obtaining superior pure lines. Additionally, all lines showed significant desirable general combining ability for disease resistance. Varuna × BioYSR was the only cross that showed significant heterosis for yield over national check, Kranti. It also revealed significant heterobeltiosis for: seeds per siliqua, number of primary branches, days to 50% flowering, AUDPC and days to maturity. This potential hybrid can be deployed with the help of cytoplasmic-genetic male sterility, or it can be utilised to obtain superior purelines through conventional breeding methods.

Keywords: GCA, Heterosis, Indian Mustard, Line×tester, SCA

The rapeseed and mustard production in India was 9.99 million tonnes in the year 2020-21, next only to, groundnut and soybean among oilseeds (DRMR, 2022). Indian mustard is a *rabi* season oleiferous Brassica crop which is affected both, by biotic as well as abiotic stresses. Paddy harvest in the month of November forces farmers to go for late sowing of mustard which have lower yields and are more vulnerable to white rust disease (Chattopadhyay *et al.,* 2011; Mubark *et al.,* 2022). White rust caused by *Albugo candida* is a major disease of Indian mustard accounting for upto 90% yield losses, in years with severe disease intensity (Lakra and Saharan, 1989). A number of exotic and few indigenous white rust resistant genotypes have been known and utilized in resistance breeding programmes with limited success though, for obtaining high yielding resistant variety. Thus, it is important to decipher combining ability of parents used in breeding programmes and nature of gene action governing inheritance of traits in crosses, to achieve success.

Line × Tester mating design is an extension of top cross which not only provides information on general and specific combining ability of parents and crosses but also estimates various types of gene effects (Kempthorne, 1957). Estimates of better parent heterosis (heterobeltiosis), mid-parent heterosis and standard heterosis, help in deployment of best hybrids (Chaurasiya *et al.,* 2022). Keeping all above in view, present investigation was planned to study magnitudes of general and specific combining ability, heterosis and gene action for white rust resistance along with, assessment of seed yield and its component traits, under late sown epiphytotic condition.

MATERIALS AND METHODS

Four white rust resistant genotypes (lines): Basanti, BioYSR, Donskaja and Heera were crossed with four genotypes (testers) namely, Varuna, Kranti, Giriraj and RH749 following the line × tester mating design, at IARI Regional Research Station, Wellington in *kharif* season of the year 2018-19. Sixteen F_1 hybrids produced were evaluated in *rabi* season of 2019-20 at agricultural research farm of Banaras Hindu University, along with parents. The texture of soil at test site was sandy loam. The genotypes were observed for 11 different morpho-physiological traits. The trial was late sown in Randomized Complete Block Design (RCBD) with three replications. Genotypes were hand sown in 2 rows of 3 m length with 30 cm inter-row spacing and manual thinning was done to achieve plant to plant distance of 10 cm. The traits *viz.,* days to 50% flowering and days to maturity were recorded as number of days taken for 50% of plants to flower, and all plants to reach physiological maturity respectively, on plot basis. Traits such as: plant height, number of primary branches,

Corresponding author's E-mail: karstav7@gmail.com

number of secondary branches, seeds per siliqua and main raceme length were recorded, based on average of five plants per plot. Plants were randomly sampled for observations, excluding those on borders. The plot yield obtained was divided by number of plants to achieve seed yield/plant, and extrapolated to per hectare for recording as seed yield/ha.

Artificial epiphytotic conditions were maintained in the experimental field. Seeds and soil were inoculated with stagheads containing oospores at the time of sowing. Inoculation with white rust sporangial suspension having sporangial load of 2×10^4 sporangia/ml at: 35, 50 and 65 days after sowing was accomplished. Frequent irrigations to maintain high moisture condition for disease development, were done. Disease scoring was done at 45, 60 and 75 days after sowing, following 0-9 scale (Williams, 1985). Area under disease progression curve was calculated using the formula:

$$AUDPC = \sum_{i=1}^{n} \frac{Y_i + Y_{i+1}}{2} \times (t_{i+1} - t_i)$$

Where, Y_i is disease level at time t_i, Y_i+1 is disease level at time t_i+1, t_i + 1- t_i is the time (in days) between two disease scores and, n is the number of dates on which white rust scores were recorded. Line × tester analysis was done following Kempthorne (1957) and, Singh and Chaudhary (1977). Mid-parent, better parent and standard heterosis were estimated by the procedure of Falconer and Mackey (1980). Standard heterosis was estimated as deviation of F_1 value from national check Kranti. Data analysis was done using the package "Agricola" (Mendiburu, 2009) and "inti" (Lozano-Islo, 2022) in R studio version 4.2.2 (R core team 2022), and TNAUSTAT (Manivannan, 2014).

RESULTS AND DISCUSSION

Analysis of variance revealed that mean squares due to parents were significant for all the traits except NPB and NSB. This showed that considerable amount of genetic variability was present in the experimental material (Lakra *et al.,* 2020). The mean squares due to crosses were significant for all the traits. The analysis of variance (Table 1) for GCA in lines revealed significant differences for all the traits except number of primary branches, number of secondary branches and test weight whereas, GCA in testers had significant differences for days to maturity, seeds/silique, seed yield/plant and seed yield/ha. Significant GCA revealed manifestation of additive gene effects for traits in the crosses. The line × tester interactions had significant SCA effects for all the traits except days to 50% flowering and days to maturity indicating, presence of non-additive gene action that can be harnessed through heterosis breeding. Thus, both, additive and non-additive gene actions contributed towards variability for traits in parents. Similar results were reported by several workers (Singh *et al.,* 2022; Neeraj *et al.,* 2021; Tirkey *et al.,* 2020; Meena *et al.,* 2015; Kumar *et al.,* 2016; Synrem *et al.,* 2015; Gami and Chauhan, 2013; Yadava *et al.,* 2012).

The higher magnitude of SCA variance (σ^2SCA) than variance due to GCA for all the traits except days to 50% flowering and days to maturity suggested the predominance of non-additive gene action that can be exploited through heterosis breeding (Table 2). The ratio of σ^2A/σ^2D was found to be less than unity for all the traits except area under disease progression curve and days to 50% flowering further indicating, involvement of non-additive gene action (Table 2). The predominance of non-additive gene action was also reported by Meena *et al.* (2015); Kumar *et al.* (2020); Synrem *et al.* (2015); Chand *et al.* (2022) and, Gami and Chauhan (2013). Average degree of dominance indicated that over-dominance (>1), explained inheritance of all traits except area under disease progression curve and days to 50% flowering for which, partial dominance (<1) was observed. This can be exploited through heterosis breeding. The observed over-dominance may be a result of dominance × dominance epistatic interactions (Bhateria *et al.,* 2006). The estimates of narrow sense heritability (h^2ns) revealed low heritability for all traits indicating, major part of variation in crosses being non-fixable in nature (Table 2). The presence of non-additive gene action coupled with low heritability indicated that, selection from segregating generations would be ineffective in improvement of these traits and, selection should be deferred till plants have high levels of homozygosity (Chand *et al.,* 2022). Thus, diallel selective mating design which employs both recurrent selection and mass selection along with, single seed descent method with large F_2 population for advancement of generations, should be followed for obtaining superior genotypes (Jensen, 1970). The variance due to crosses was partitioned into variance due to lines, testers and their interaction. The analysis revealed that contribution of lines to hybrids was higher than that of testers for all the traits except, seed yield/ha and seed yield/plant for which contribution of testers was higher. Perusal of table 2 also revealed that contribution of line × tester interaction was highest for number of primary branches (48.45%) and lowest for days to maturity (0.65%).

A perusal of Table 3 reveals that, no single genotype and no particular cross showed significant GCA and SCA effects for all the traits, respectively. Genotype BioYSR had significant desirable GCA effects for number of secondary branches, number of primary branches, area under disease progression curve, main raceme length, seed yield/plant, days to maturity and seed yield/ha whereas, Donskaja had significant desirable GCA effect for area under disease progression curve only. All the resistant lines along with Kranti showed significant GCA effects for area under disease progression curve. The crosses where high SCA effects were observed, involved all possible combinations between parents of high, low and medium combining ability. This indicated that GCA, in general, had no bearing on the SCA effects of the crosses. The high SCA effects of the crosses involving high × low general combiner parents may be due to the favourable additive effects of the good general combiner parent and epistatic effects of poor general combiner, supplementing the desirable plant attribute (Bhateria *et al.,* 2001). High SCA effects expressed by low × low crosses may be attributed to dominance × dominance type of non-allelic gene interaction, resulting in overdominance (Bhateria *et al.,* 2001). Varuna and BioYSR showed significant GCA effect for seed yield while their hybrid showed significant SCA effect with high *per se* performance.

Table 1 Analysis of variance for yield and its attributing characters in Indian mustard

Sources of variation	Parents	Crosses	Lines	Testers	Lines vs. Testers	Error
df	7	15	3	3	9	46
Characters						
AUDPC	372099.23**	23924.39**	101847.14**	6882.73	3630.69**	686.9
DFF	499.71**	121.92**	546.24**	20.74	14.21	7.17
DM	549.90**	258.07**	1266.02**	15.91*	2.8	6.01
MRL	118.68**	184.10**	682.78**	102.59	45.05**	8.26
NPB	0.21	0.57**	1.18	0.29	0.46*	0.21
NSB	0.78	2.15**	3.62	2.92	1.41**	0.39
PH	2465.24**	1888.13**	7538.61**	424.93	492.37**	98.38
SPS	26.83**	8.22**	19.87**	12.85*	2.79**	0.56
SY	681743.28**	248938.10**	434416.69*	471862.14*	112803.89**	9618.78
SYPP	6.14**	2.24**	3.91*	4.25*	1.02**	0.09
TW	0.57**	0.52**	0.79	0.69	0.37**	0.07

df; degree of freedom, AUDPC; Area under disease progression curve, DFF; Days to 50% flowering, DM; Days to maturity, MRL; Main raceme length, NPB, Number of primary branches, NSB; Number of secondary branches, PH; Plant height, SY; Seed yield/ha, SPS;Seeds/siliqua, SYPP; Seed yield/plant, TW; Test weight, ** significant at 1%, * significant at 5%

Table 2 Estimates of genetic component of variance for different characters

Characters	σ^2GCA	σ^2SCA	σ^2A	σ^2D	σ^2A/ σ^2D	Average degree of dominance	Heritability [h^2ns (%)]	Contribution (%)		
			F=1	F=1		$\sqrt{\sigma^2D/\sigma^2A}$		Lines	Testers	Interaction
AUDPC	704.64	981.26	1409.28	981.26	1.44	0.83	2.46	85.14	5.75	9.11
DFF	3.74	2.34	7.48	2.34	3.19	0.56	9.67	89.61	3.40	6.99
DM	8.86	-1.07	17.73	-1.07	-16.58	#	15.82	98.12	1.23	0.65
MRL	4.83	12.26	9.66	12.26	0.79	1.13	18.49	74.17	11.14	14.68
NPB	0.00	0.08	0.01	0.08	0.09	3.34	4.55	41.32	10.24	48.45
NSB	0.03	0.34	0.05	0.34	0.15	2.56	7.56	33.65	27.16	39.19
PH	48.46	131.33	96.93	131.33	0.74	1.16	13.85	79.85	4.50	15.65
SPS	0.19	0.74	0.38	0.74	0.51	1.40	8.17	48.36	31.26	20.38
SY	4726.88	34395.03	9453.77	34395.03	0.27	1.91	7.67	34.90	37.91	27.19
SYPP	0.04	0.31	0.09	0.31	0.27	1.91	7.67	34.90	37.91	27.19
TW	0.01	0.10	0.01	0.10	0.10	3.12	5.91	30.46	26.66	42.88

AUDPC; Area under disease progression curve, DFF; Days to 50% flowering, DM; Days to maturity, MRL; Main raceme length, NPB, Number of primary branches, NSB; Number of secondary branches, PH; Plant height, SY; Seed yield/ha, SPS; Seeds/siliqua, SYPP; Seed yield/plant, TW; Test weight, σ^2GCA; Variance due to general combining ability, σ^2SCA; Variance due to specific combining ability; σ^2A; Additive genetic variance, σ^2D; Dominance variance, F; Coefficient of Inbreeding, h^2ns; Narrow sense heritability, #; Undefined value

Table 3 Character wise estimate of general combining ability of superior parents and specific combining ability of superior cross combinations

	General combining ability of superior parents			Specific combining ability of superior cross combinations			
Character	Parents	*Per se* performance	GCA effects	Cross combinations	*Per se* performance	SCA effects	GCA effects
NSB	BioYSR	5.23	0.77 **	BioYSR × Varuna	6.9	1.05 *	H×L
	Kranti	5.3	0.56 **	Basanti × RH749	6.03	0.66 ns	L×M
SPS	Basanti	13.47	1.23 **	Donskaja × RH749	10.67	0.89 *	L×L
	Giriraj	14.5	0.77 **	Basanti × Varuna	15.23	0.86 *	H×M
	Kranti	14.33	0.6 **	Heera × Varuna	14.57	0.8 *	M×M
PH	Heera	110.2	-19.31 **	Donskaja × Giriraj	197.8	-14.7 *	L×L
	Basanti	154.93	-17.38 **	BioYSR × Kranti	159.07	-8.17 ns	M×M
NPB	BioYSR	3.87	0.31 **	BioYSR × Varuna	4.8	0.74 **	H×L
DFF	Heera	48.67	-4.35 **	BioYSR × Kranti	53	-2.56 ns	H×L
	Basanti	61	-3.02 **	Basanti × Kranti	53.67	-1.56 ns	H×M
	BioYSR	62.67	-2.69 **	Donskaja × Varuna	67.33	-1.56 ns	L×M
AUDPC	Heera	30.55	-62.82 **	Basanti × Kranti	146.68	-66.51 **	H×H
	BioYSR	20.37	-57.49 **	Heera × Giriraj	44.45	-24.88 *	L×H
	Kranti	496.3	-17.88 **	Donskaja × Giriraj	103.13	-15.11 ns	H×L
	Donskaja	35.19	-13.91 *	BioYSR × Varuna	16.67	-12.76 ns	H×M
MRL	Basanti	55.89	6.11 **	Donskaja × RH749	54.82	5.02 *	L×H
	BioYSR	65.88	3.84 **	Basanti × Giriraj	64.55	3.66 ns	H×L
	Varuna	63.27	2.35 *	BioYSR × Varuna	67.42	2.32 ns	H×H
TW	RH749	4.13	0.27 **	BioYSR × RH749	4.74	0.56 **	M×H
	Basanti	3.83	0.22 **	Basanti × Kranti	4.23	0.32 *	H×L
SYPP	Varuna	5.12	0.88 **	BioYSR × Varuna	7.25	0.88 **	H×H
	BioYSR	4.07	0.81 **	Basanti × Varuna	6.11	0.54 **	M×H
DM	Heera	105.67	-6.81 **	Donskaja × RH749	138	-1.35 ns	L×M
	BioYSR	121.67	-4.98 **	Basanti × Kranti	119.33	-1.02 ns	H×M
	Basanti	125	-3.48 **	Heera × Kranti	116.33	-0.69 ns	H×M
	Varuna	121	-1.65 *	BioYSR × RH749	118.67	-0.44 ns	H×M
SY	Varuna	1705.77	292.33 **	BioYSR × Varuna	2415.84	291.45 **	H×H
	BioYSR	1356.4	268.93 **	Basanti × Varuna	2036.61	180.75 **	M×H

NSB; Number of secondary branches, SPS; Seeds per siliqua, PH; Plant height, NPB, Number of primary branches, DFF; Days to 50% flowering, AUDPC; Area under disease progression curve, MRL; Main raceme length(cm), TW; Test weight(g), SYPP; Seed yield/plant(g), DM; Days to maturity, SY; Seed yield/ha(kg/ha), ** significant at 1%, * significant at 5%, NS=non-significant, GCA; General combining ability, SCA; Specific combining ability; H; High GCA, M; Medium GCA, L; Low GCA

Table 4 Crosses exhibiting higher estimates of heterosis (%) over mid parent (MP), better parent (BP) and national check (NC) for seed yield/ha

Crosses	*Per se* performance	Heterosis			SCA effects	GCA effects of parents	Desirable significant heterobeltiosis for other traits
		Over MP	Over BP	Over NC			
BioYSR × Varuna	2415.84	57.79 **	41.63 **	13.16 **	291.45 **	H×H	SPS, NPB, DFF, AUDPC, SYPP, DM
Basanti × Varuna	2036.61	39.96 **	19.4 **	-4.61 ns	180.75 **	M×H	NSB, DFF, AUDPC, MRL, SYPP, DM

MP; Mid parent, BP; Better parent, NC; National check (Kranti), SCA; Specific combining ability, GCA; General combining ability, H; High GCA, M; Medium GCA, NSB; Number of secondary branches, SPS; Seeds/siliqua, NPB, Number of primary branches, DFF; Days to 50% flowering, AUDPC; Area under disease progression curve, MRL; Main raceme length, SYPP; Seed yield/plant, DM; Days to maturity, ** significant at 1%, ns; non-significant

The hybrid BioYSR × Varuna also showed significant heterosis for all three estimates including standard heterosis (Check; Kranti), for seed yield (Table 4). The other hybrid Basanti × Varuna having higher SCA effects and *per se* performance for seed yield, did not show standard economic heterosis. The hybrid BioYSR × Varuna also showed heterobeltiosis for traits seeds/siliqua, number of primary branches, days to 50% flowering, area under disease progression curve, seed yield/plant and days to maturity. This potential hybrid can be utilised to obtain high yielding white rust resistant varieties through conventional breeding methods. The hybrid can also be deployed with the help of available cytoplasmic-genetic male sterility systems after conversion of parents into male sterile, maintainer and restorer lines.

ACKNOWLEDGMENTS

The first author acknowledges the financial support in the form of scholarship from ICAR and CSIR.

REFERENCES

Bhateria S, Sood S P and Pathania A 2006. Genetic analysis of quantitative traits across environments in linseed (*Linum usitatissimum* L.). *Euphytica*, **150** : 185-194.

Chattopadhyay C, Agrawal R, Kumar A, Meena R L, Faujdar K, Chakravarthy N V K, Kumar A, Goyal P, Meena P D and Shekhar C 2011. Epidemiology and development of forecasting models for White rust of *Brassica juncea* in India. *Archives of Phytopathology and Plant Protection*, **44**: 751-763.

Chaurasiya J P, Mahak Singh and Nageshwar 2022. Heterosis response and combining ability (variance and effect) analysis for seed yield and its components in Indian mustard (*Brassica juncea* L.) under timely sown condition. *Journal of Oilseeds Research*, **39**(1): 14-20.

DRMR 2022. https://www.drmr.res.in/

Gami R A and Chauhan R M 2013. Heterosis and combining ability analysis for seed yield and its attributes in Indian mustard [*Brassica juncea* L., Czern & Coss.]. *Indian Journal of Agricultural Research*, **47**: 535-539.

Jensen N F 1970. A diallel selective mating system for cereal breeding. *Crop Science*, **10** : 629-635.

Kempthorne O 1957. *An introduction to Genetic Statistics.* John Wiley and Sons, Inc., New York, pp. 545.

Kumar N, Avtar R and Singh V K 2021. Combining ability analysis in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] involving Ogura CMS system. *Electronic Journal of Plant Breeding*, **12** : 667-672.

Lakra A, Tantuway G, Tirkey A E and Srivastava K 2020. Genetic variability and trait association studies in Indian mustard (*Brassica juncea* L. Czern. & Coss). *International Journal of Current Microbiology and Applied Sciences*, **9** : 2556-63.

Lakra B S and Saharan G S 1989. Correlation of leaf and staghead infection intensities of white rust with yield and yield components of mustard. *Indian Journal of Mycology and Plant Pathology*, **19**: 279-281.

Meena H S, Kumar A, Kulshrestha S, Meena P D, Bhagirath R and Sharma A 2015. Combining ability and heterosis for seed yield and its components in Indian Mustard (*Brassica juncea* L.). *Journal of Agricultural Science and Technology*, **17**: 1861-1871.

Mendiburu D F 2021. *Agricolae: Statistical Procedures for Agricultural Research*. R package version 1.3-5, Retrieved from https://CRAN.R-project.org/package=agricolae.

Mubark T, Shakoor A, Parvez A Sheikh and Haseeb-Ur-Rehman 2022. Impact of non-monetary and low monetary inputs on yield and economics of brown sarson (*Brassica campestris* L.) under temperate hill ecology. *Journal of Oilseeds Research*, **39**(3 & 4): 249-252.

Priyamedha, Kumar A, Mahto C S and Haider Z A 2016. Combining ability and heterosis studies for oil and seed meal quality traits in Indian mustard (*Brassica juncea* L .). *Journal of Oilseed Brassica*, **7**: 156-162.

Singh M, Avtar R, Kumar N, Punia R, Pal A, Lakra N, Kumari N, Kumar D, Naruka A, Bishnoi M, Khedwal R S, Choudhary R R, Singh A, Meena R K, Dhillon A and Singh V K 2022. Genetic analysis for resistance to sclerotinia stem rot, yield and its component traits in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]. *Plants*, **11**: 671.

Singh N Yadava D K, Vasudev S, Singh R, Giri S C, Dass B, Barun S and Prabhu K V 2015. Combining ability and heterobeltiosis for yield and yield contributing traits in high quality oil Indian mustard (*Brassica juncea*) genotypes. *Indian Journal of Agricultural Sciences*, **85**: 498-503.

Singh R K and Chaudhary B D 1977. Biometrical Methods in Quantitative Genetic Analysis. Scholarly Punns, New Delhi, India, pp. 350.

Synrem G J, Rangare N R, Choudhari A K, Kumar S and Myrthong I 2015. Combining ability analysis for seed yield and component traits in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]. *Electronic Journal of Plant Breeding*, **6**: 445-453.

Tirkey A E, Girish T and Kartikeya S 2020. Identification of superior parents and cross combination for seed yield and its attributing traits in *Brassica juncea. Journal of Experimental Biology and Agricultural Sciences*, **8**: 21-29.

Williams P H 1985. White rust [*Albugo candida* (Pers. ex. Hook.) Kuntze.]. IN: Crucifer Genetics Cooperative (CRGC) Resource Book. University Wisconsin, pp USA 1-7.

Yadava D K, Singh N, Vasudev S, Singh R, Singh S, Giri S C, Dwivedi V K and Prabhu K V 2012. Combining ability and heterobeltiosis for yield and yield-contributing traits in Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Sciences*, **82**: 563-567.

Assessment of genetic diversity for yield and yield contributing traits in peanut (*Arachis hypogaea* L.)

C SUVARNA[1], K JOHN[2], M REDDI SEKHAR[1] AND P LATHA[2]

[1]Department of Genetics and Plant Breeding, S V Agricultural College, Tirupati - 517502, Andhra Pradesh

(Received: January 3, 2023; Revised: April 17, 2023; Accepted: April 28, 2023)

ABSTRACT

Thirty-three advanced breeding lines of peanut were evaluated during *kharif,* 2019 using Mahalanobis D^2 statistics for 19 characters including physiological, yield and quality traits and were grouped into nine clusters, where cluster IV was the largest containing 11 genotypes followed by cluster III and II with 8 and 7 genotypes respectively. Highest inter-cluster distance was observed between cluster VII and IX (118.10) followed by cluster V and VI (113.29) and cluster V and IX (106.42), respectively. The maximum intra-cluster distance was observed in cluster IV (31.37) followed by cluster III (20.11) and II (13.17). Hundred kernel weight contributed maximum towards genetic divergence followed by sound mature kernel (%), specific leaf area at 45 DAS, oil content and plant height. The crosses *viz.,* TCGS-2141 × TCGS-2117, Narayani × TCGS-1887, Narayani × TCGS-2117, Narayani × TCGS-2111 and TCGS-1887 × TCGS-2141 could be recommended to get desirable transgressive segregants for physiological, yield and quality traits.

Keywords: Cluster, D^2 statistics, Genetic diversity, Peanut

The cultivated groundnut or peanut (*Arachis hypogaea* L.), is an annual self-pollinated legume crop with a chromosome number of 2n = 4x = 40. It is the only nut found under the soil and designated as "wonder legume". It belongs to the family Fabaceae. It is native to South America, grown throughout the tropical and sub-tropical regions of the world between the latitudes of 40o N to 40o S. It is an important oilseed crop known for its multi-uses including edible oil production, direct human consumption as food and for animal consumption in the form of silage, haulms and oilcake. It is a rich source of high-quality oil (44-56%), protein (22-30%) on dry seed basis, carbohydrates (10-25%), vitamins (E, Z and B complex), minerals (Ca, P, Mg, Zn and Fe) and fiber (Gulluoglu *et al.,* 2016; Meena *et al.,* 2022) Being a legume it adds nitrogen (25-75 lb of nitrogen per acre per year) and organic matter to the soil (Frankow-Lindberg and Dahlin, 2013; Suthar *et al.,* 2022).

In India, peanut is cultivated in an area of 60.90 lakh hectares with production of 10.21 Mt and productivity of 1676 kg/ha (Anonymous, 2021). In an autogamous crop like peanut, the genetic divergence of the parents involved mainly decides the success of hybridization programme. Information about genetic diversity could be useful for achieving long term selection gain through breeding. The divergence analysis has a definite role to play in an efficient choice of parents. Mahalanobis D2 statistics is an effective tool in multivariate analysis for estimating relative contribution of each character towards genetic divergence and to identify best parent(s) for hybridization and to exploit maximum heterosis for improving the pod yield.

MATERIALS AND METHODS

Thirty-three advanced breeding lines of peanut were sown during *kharif,* 2019 in a Randomized Block Design (RBD) with three replications in order to study the genetic diversity (Table 1). In each replication, every genotype was sown in five rows of 5 m length with a spacing of 30 cm between rows and 10 cm between plants within a row. Need based recommended agronomic and cultural practices and plant protection measures were followed. The data was collected from five randomly selected plants of each genotype in each replication for 19 characters *viz.,* days to 50% flowering, days to maturity, SCMR at 45 DAS, SLA at 45 DAS (cm^2/g), Relative Water Content (%), plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of mature pods per plant, hundred pod weight (g), shelling per cent, hundred kernel weight (g), sound mature kernel per cent, dry haulms yield per plant (g), harvest index (%), protein content (%), oil content (%), kernel yield per plant (g) and pod yield per plant (g) except days to 50% flowering and days to maturity which were recorded on plot basis. SLA is a measure of leaf thickness and low SLA groundnut genotypes produces high dry matter under drought stress conditions (Nautiyal *et al.,* 2002). SCMR measures green colour intensity and associated with chlorophyll density in groundnut. SLA is inversely related to SCMR and they are associated with WUE. RWC is an important indicator of water status in

[2]IFT, RARS, Tirupati, Andhra Pradesh;
Corresponding author's E-mail: suvarnachintha121@ gmail.com

plants, it reflects the balance between water supply to leaf tissue and transpiration rate (Lugojan and Ciulca, 2011). The 33 genotypes included in our study were derived from the drought resistance breeding programme, so these three traits are useful to know drought tolerance among the genotypes.

The analysis of genetic divergence was carried out using Mahalanobis's D^2 statistics (1936). Grouping of genotypes into clusters was done by the Tocher's method as described by Rao (1952). The data analysis was carried out with WINDOWSTAT 9.2 software.

Table 1 List of peanut genotypes and their pedigree

Entry	Pedigree
TCGS-1880	KDG-128×NRCG-CS-425
TCGS-1885	K-6 x KDG-123
TCGS-1887	K-6 x KDG-126
TCGS-1895	K-6 x JL-776
TCGS-1896	KDG-128 x JL-776
TCGS-1897	TCGS-913x NRCG-CS-425
TCGS-1901	TAG-24 x LPG
TCGS-1911	K-6 x JL-11
TCGS-1923	K-6 x JL-11
TCGS-2104	Prasuna x TCGS-1321
TCGS-2111	Prasuna x TCGS-1321
TCGS-2117	K-6 x Bheema
TCGS-2133	Prasuna x TCGS-1321
TCGS-2135	Bheema x Prasuna
TCGS-2137	Prasuna x TCGS-1416
TCGS-2141	K-6 x ICGV-91114
TCGS-2142	K-6 x TCGS-1416
TCGS-2143	Greeshma x TCGS-1416
TCGS-2151	Rohini x 8TMV2
TCGS-2160	TAG-24 x Dharani
TCGS-2162	Greeshma x ICGV-91114
TCGS-2164	K-6 x Dharani
TCGS-2168	Greeshma x TMV-2
TCGS-2176	Narayani x Dharani
TCGS-2179	TAG-24 x TMV-2
TCGS-2185	TAG-24 x TCGS-1416
TCGS-2194	K-6 x TMV-2
TCGS-2196	Narayani xTMV-2
TCGS-2200	Greeshma x Dharani
TCGS-2210	Prasuna x Dharani
Dharani	VRI-2 x TCGP-6
Narayani	JL-24 x Ah 316/s
K-6	JL-24 x Ah 316/s

RESULTS AND DISCUSSION

Based on D^2 statistic, thirty-three genotypes of peanut were grouped into nine clusters by using Tocher's method. The distribution of genotypes into nine clusters is presented in Table 2 and Figure 1. Cluster IV is the largest cluster comprising eleven genotypes followed by Cluster III having eight genotypes, cluster II with seven genotypes, cluster I had two genotypes and remaining clusters (V, VI, VII, VIII and IX) are mono genotypic clusters. The average inter and intra-cluster D^2 and D values were furnished in Table 3 and Figure 2. The inter-cluster distance was larger than the intra-cluster distance which indicated that greater diversity was present among the genotypes of different clusters (Zaman *et al.,* 2010; Dolma *et al.,* 2010). The average intra cluster distance ranged from 0 to 31.37. The maximum intra-cluster distance was observed in cluster IV (31.37) followed by cluster III (20.11), cluster II (13.17) and cluster I (7.07). Intra-cluster distance for other clusters i.e., V, VII, VIII and IX is zero as they are solitary clusters. While, the inter-cluster D^2 values varied from 19.80 to 118.10. Highest inter-cluster distance was observed between cluster VII and IX (118.10) followed by cluster V and VI (113.29) and cluster V and IX (106.42) as compared to others, indicating greater diversity between genotypes of these clusters. Hence, elite genotypes from these diversified clusters can be used as parents for hybridization which would result in transgressive segregants for yield and yield related traits in filial generations. Crossing between such genotypes will also be helpful to create variability for desired traits and to select superior recombinants for the improvement of traits. Cluster mean values with respect to the nine clusters were presented in Table 4. Cluster VI recorded highest cluster mean values for the characters like number of primary branches per plant, number of mature pods per plant, 100-kernel weight, shelling per cent, harvest index, protein content, kernel yield and pod yield per plant followed by cluster V for specific leaf area, plant height, sound mature kernel (%), cluster IX for SCMR at 45 DAS, dry haulm yield per plant and days to 50% flowering. Cluster I, II, VII and VIII recorded highest cluster mean values for days to maturity, oil content, relative water content and 100 pod weight respectively.

The characters contributing to most of the genetic divergence should be given more importance for effective selection and choice of parents for hybridization which is desirable for genetic improvement of peanut. The number of times that each character appeared first and its relative contribution towards genetic divergence was presented in Table 5. The character hundred kernel weight was ranked first for 120 times and contributed maximum towards genetic divergence (22.73%) followed by characters like hundred pod weight, sound mature kernel per cent, specific leaf area at 45 DAS, oil content, plant height, protein content, number of primary branches per plant, harvest index, kernel yield per plant, number of secondary branches per plant, days to maturity, relative water content, dry haulms yield per plant, pod yield per plant, SPAD chlorophyll meter reading at 45 DAS and number of mature pods per plant in descending order. The character days to 50% flowering and shelling per cent showed no contribution towards genetic divergence.

Table 2 Clustering of peanut genotypes

Clusters	No. of Genotypes	Genotypes
I	2	TCGS-1911, Dharani
II	7	TCGS-1880, TCGS-2104, TCGS-2143, TCGS-2185, TCGS-2210, TCGS-2200, TCGS-2176
III	8	TCGS-1896, TCGS-2160, TCGS-2196, TCGS-2164, TCGS-2142, K-6, TCGS-2162, TCGS-1923
IV	11	TCGS-1895, TCGS-1897, TCGS-1901, TCGS-2133, TCGS-2135, TCGS-2194, TCGS-2168, TCGS-2179, TCGS-2151, TCGS-2137, TCGS-1885
V	1	Narayani
VI	1	TCGS-1887
VII	1	TCGS-2141
VIII	1	TCGS-2111
IX	1	TCGS-2117

Similar results were recorded by the earlier researchers for pod yield (Vivekananda *et al.,* 2015; Ganvit *et al.,* 2018), plant height (Bhakal and Lal, 2015), protein content (Kumar *et al.,* 2018), SLA at 60 DAS (Saritha *et al.,* 2018) and oil content (Shruti *et al.,* 2019). We also observed that cluster IX comprising of the genotype TCGS-2117 had high WUE as it recorded highest SCMR coupled with low SLA, hence it can be used as donor for drought tolerance in future breeding programme.

Based on inter cluster distances the clusters VII×IX, V×VI, V×IX, V×VIII and VI×VII were found to be divergent in decreasing order of their magnitude. Hence, genotypes of these clusters could be utilized as parents and crossing among them would result in heterotic expression for yield components. Due to wide diversity between the genotypes, superior recombinants could be obtained by involving such genotypes as parents in hybridization programme.

ACKNOWLEDGEMENT

The authors thank Acharya N.G. Ranga Agricultural University for providing financial assistance and support in the conduct of experiment at RARS, Tirupati.

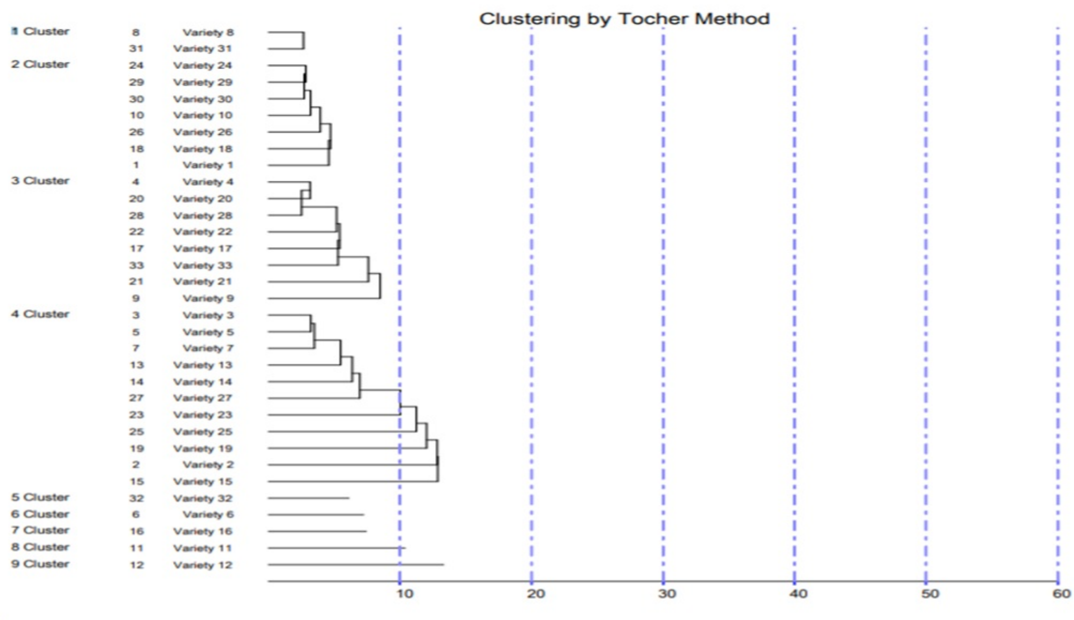

Fig. 1. Grouping of genotypes into clusters using Tocher's method

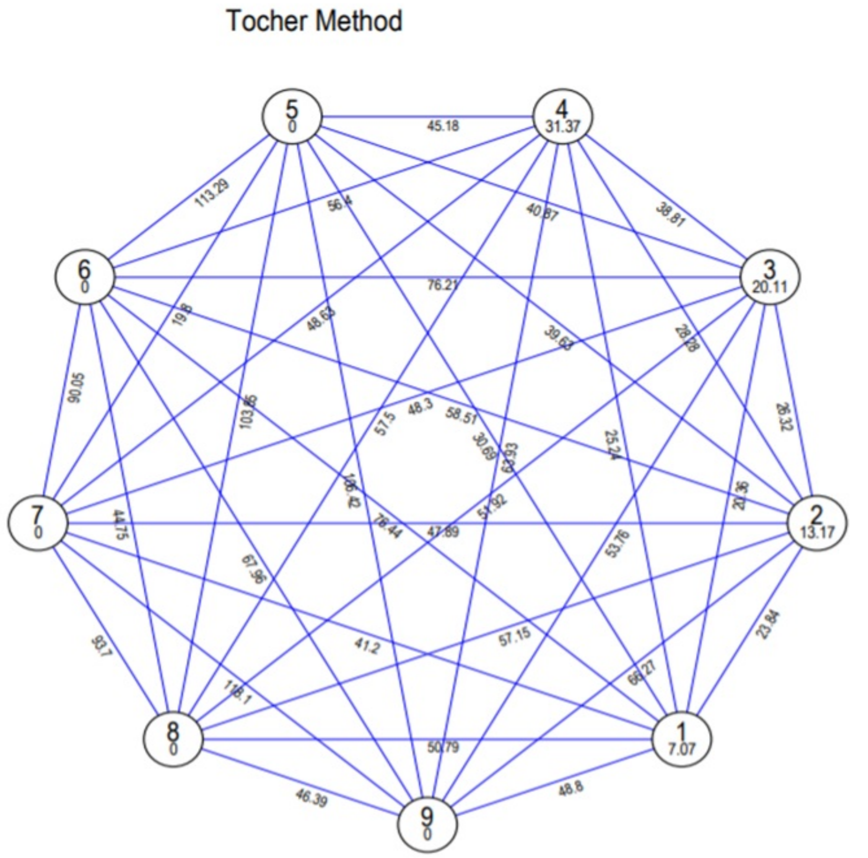

Fig. 2. Statistical intra and inter-cluster (D^2) distances among nine clusters of peanut

Table 3 Inter and Intra cluster (diagonal) average D^2 and D values (in parentheses) among 33 advanced breeding lines of peanut

Cluster	I	II	III	IV	V	VI	VII	VIII	IX
I	7.07 (2.66)	23.84 (4.88)	20.36 (4.51)	25.24 (5.02)	30.69 (5.54)	76.44 (8.74)	41.20 (6.42)	50.79 (7.13)	48.80 (6.99)
II		13.17 (3.63)	26.32 (5.13)	28.28 (5.32)	39.63 (6.30)	58.51 (7.65)	47.89 (6.92)	57.15 (7.56)	66.27 (8.14)
III			20.11 (4.48)	38.81 (6.23)	40.87 (6.39)	76.21 (8.73)	48.30 (6.95)	51.92 (7.21)	53.76 (7.33)
IV				31.37 (5.60)	45.18 (6.72)	56.40 (7.51)	48.63 (6.97)	57.50 (7.58)	63.93 (8.00)
V					0.00 (0.00)	113.29 (10.64)	19.80 (4.45)	103.85 (10.19)	106.42 (10.32)
VI						0.00 (0.00)	90.05 (9.49)	44.75 (6.69)	67.96 (8.24)
VII							0.00 (0.00)	93.70 (9.68)	118.10 (10.87)
VIII								0.00 (0.00)	46.39 (6.81)
IX									0.00 (0.00)

Table 4 Cluster means for physiological, yield attributes and quality traits in peanut

Cluster	DF	DM	SCMR	SLA	RWC	PH	NPB	NSB	NMP	100-PW	SP	100-KW	SMK	DHY	HI	PRO	OIL	KYP	PYP
I	26.83	101.67	42.25	223.84	84.69	32.87	4.40	2.50	15.97	105.33	75.00	55.83	91.00	18.90	46.56	25.55	47.33	12.63	16.60
II	27.38	95.10	42.08	258.53	88.93	37.92	5.50	1.26	15.63	119.81	79.05	48.33	84.67	20.30	45.35	25.73	47.74	13.90	17.69
III	27.71	95.67	43.07	202.12	92.82	42.25	5.13	1.84	15.26	111.04	76.33	49.13	89.83	18.35	45.22	25.57	47.60	11.80	15.39
IV	27.48	94.85	43.17	253.39	91.02	33.76	5.64	1.67	14.42	117.18	75.57	58.67	88.27	18.38	50.06	25.70	47.17	13.69	17.84
V	25.67	91.67	39.40	266.83	88.89	46.90	4.80	0.00	15.60	107.00	74.00	42.33	96.00	21.53	38.71	25.23	47.37	10.07	13.60
VI	28.67	96.67	46.80	244.33	94.94	44.03	9.93	0.00	19.13	137.33	81.33	74.67	84.33	20.27	57.29	26.10	46.10	21.50	26.27
VII	29.00	97.67	42.53	262.74	95.08	44.27	7.47	2.17	17.87	92.67	68.00	44.33	92.67	20.0	44.90	24.50	47.43	12.70	18.73
VIII	29.33	93.33	43.90	176.85	90.27	34.10	8.90	0.67	10.33	135.33	77.00	75.00	91.00	14.53	52.96	24.40	47.43	13.60	21.73
IX	29.33	95.00	47.70	162.89	84.58	41.37	4.27	1.53	10.20	125.33	80.33	74.00	86.67	25.87	39.44	25.40	45.67	11.28	13.67
Mean	27.93	95.74	43.43	227.95	90.14	39.72	6.23	1.29	14.93	116.78	76.29	58.03	89.38	19.79	46.72	25.35	47.09	13.46	17.95

DF : Days to 50% flowering; DM : Days to maturity; SCMR : SPAD chlorophyll meter reading at 45 DAS ; SLA : Specific leaf area at 45 DAS (cm^2/g);
RWC: Relative water content (%); PH : Plant height (cm); NPB : No of Primary branches per plant; NSB : No of secondary branches per plant;
NMP: No of mature pods per plant;100-PW : 100 Pod weight (g); SP: Shelling Per cent; 100-KW : 100 Kernel weight (g); SMK: Sound mature kernel (%);
DHY: Dry haulms yield per plant (g); HI : Harvest index (%); PRO: Protein content (%); OIL: Oil content (%); KYP : Kernel yield per plant (g);
PYP: Pod yield per plant (g)

Table 5 Relative contribution of various characters towards genetic diversity in peanut

Characters	No times ranked first	Contribution (%)
Days to 50% flowering	0	0
Days to maturity	2	0.38
SCMR at 45 days after sowing	1	0.19
Specific leaf area at 45 DAS (cm2 g-1)	67	12.69
Relative water content (%)	2	0.38
Plant height (cm)	32	6.06
No. of primary branches per plant	22	4.17
No. of secondary branches per plant	3	0.57
No. of mature pods per plant	1	0.19
Hundred pod weight (g)	99	18.75
Shelling per cent	0	0
Hundred kernel weight (g)	120	22.73
Sound mature kernel per cent	84	15.91
Dry haulms yield per plant	2	0.38
Harvest index (%)	7	1.33
Protein content (%)	29	5.49
Oil content (%)	46	9.28
Kernel yield per plant (g)	6	1.14
Pod yield per plant (g)	2	0.38

REFERENCES

Bhakal M and Lal G M 2015. Studies on genetic diversity in groundnut (*Arachis hypogaea* L.) germplasm. *Journal of Plant Science and Research*, **2**(2): 1-4.

DES 2021. Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India, New Delhi. Agriculture Statistics at a Glance, 2020-2021.

Dolma T, Sekhar M R and Reddy K R 2010. Genetic divergence studies in groundnut (*Arachis hypogaea* L.). *Journal of Oilseeds Research*, **27**(2): 158-160.

Frankow-Lindberg B E and Dahlin A S 2013. N_2 fixation, N transfer and yield in grassland communities including a deep-rooted legume or non-legume species. *Plant Soil*, **370**: 567-581.

Ganvit R S, Jagtap P K, Patel M C and Malaviya A 2018. Genetic divergence studies for yield and its component traits in groundnut (*Arachis hypogaea* L.). *Journal of Pharmacognosy and Phytochemistry*, **7**(5): 3056-3058.

Gulluoglu L, Bakal H, Onat B, EI Sabagh A, Arioglu H 2016. Charaterization of peanut (*Arachis hypogaea* L.) seed oil and fatty acids composition under different growing season under Mediterranean environment. *Journal of Experimental Biology and Agricultural Sciences*, **4**(5S): 564-571.

Kumar J, Jain S K and Raj K N 2018. Genetic divergence in germplasm of groundnut (*Arachis hypogaea* L.). *International Journal of Current Research in Biosciences and Plant Biology*, **6**(8): 1-2.

Lugojan C and Ciulca S. 2011. Evaluation of relative water content in winter wheat. *Journal of Horticulture, Forestry and Biotechnnology.*

Mahalanobis P C 1936. On the generalized distance in statistics. *Proceedings of National Institute of Science,* India, **2**: 49-55.

Meena B 2022. Integration of bioagent, Bacillus subtilis Bbv57 and fungicides for the management of foliar diseases of groundnut (*Arachis hypogaea* L.). *Journal of Oilseeds Research*, **39**(3 & 4): 215-218.

Nautiyal P C, Nageswara Rao R C and Joshi Y C 2002. Moisture-deficit-induced changes in leaf water content, leaf carbon exchange rate and biomass production in groundnut cultivars differing in specific leaf area. *Field Crops Research*, **74**: 67-69.

Rao C R 1952. *Advanced statistical methods in biometrical research.* John Wiley and Sons Inc., New York. 236-272.

Saritha K, Vasanthi R P, Priya M S and Latha P 2018. Genetic divergence studies in groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding*, **9**(4): 1355-1361.

Shruthi K, Rao V, Girija M and Sreekanth B 2019. Genetic diversity studies in yield and its contributing traits in groundnut (*Arachis hypogaea* L.) genotypes using D2 statistics. *International Journal of Current Microbiology and Applied Sciences*, **8**(6): 32-38.

Suthar B, Pundir R S and Baldodiya V 2022. Price behaviour of groundnut (*Arachis hypogaea* L.) in major markets of India. *Journal of Oilseeds Research*, **39**(2): 134-141.

Vivekananda Y, Pramesh K and Singh N B 2015. Genetic divergence analysis in groundnut (*Arachis hypogaea* L.). *Electronic Journal of Plant Breeding*, **6**(1): 315-317.

Zaman M A, Thuhina M K, Bhuiyan M M H, Moniruzzamn M and Yousuf M N 2010. Genetic divergence in groundnut (*Arachis hypogaea* L.). *Bangladesh Journal of Plant Breeding and Genetics*, **23**(1): 45-49.

Genetic variability, heritability and character association among linseed genotypes for yield and yield attributing traits

S K CHOUDHARY[1], RAM BALAK PRASAD NIRALA[*1] AND RAMANUJ VISHAWAKARMA[2]

[1]Departmentof Plant Breeding and Genetics, Bihar Agricultural, University, Bhagalpur-813210, Bihar

(Received: January 17, 2023; Revised: April 15, 2023; Accepted: May 3, 2023)

ABSTRACT

The present investigation has been conducted to determine genetic variability, heritability, and character association among 38 linseed genotypes for yield and thirteen morphological traits at Bihar Agricultural College Sabour Farm of Bihar Agricultural University Sabour, Bhagalpur (Bihar) during the *rabi* 2020-21. Thirty-eight genotypes including four checks, namely, Sabour Tisi-1, Sabour Tisi-2, Shekhar and T-397 were evaluated in RBD design with three replications. Analysis of variance for fourteen characters indicated that there was a sufficient amount of variability among the genotypes for all the characters studied. The characters, namely, flowering period, plant height, bud fly infestation, bud blight infestation, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight and seed yield per plant exhibited high GCV, PCV and high heritability along with high genetic advance. A correlation study showed a significant and positive correlation between seed yield per plant and flowering period, flower diameter, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, seed length and 1000-seed weight, whereas, days to 50% flowering, days to 50% maturity, plant height and bud fly infestation were found to be a significant and negative correlation with seed yield per plant. However oil content had a non-significant correlation with seed yield per plant but in the positive direction. Path coefficient analysis indicated that the number of capsules per plant exhibited high and positive direct effect on seed yield per plant, while, bud fly infestation showed a moderate and negative direct effect on seed yield per plant.

Keywords: Correlation, Heritability, Linseed, Variability

Linseed (*Linum usitatissimum* L.) commonly known as flax or flaxseed, is a self-pollinated crop that belongs to the family Linaceae of the order Geraniale. It has been cultivated for several thousand years mainly for its seed oil and its high-quality stem fibre. Each part of the linseed plant is being used commercially, either directly or after processing. Linseed contains about 33 to 45 percent oil and 36 per cent crude protein in oil cake which are used commercially for several purposes. About 80 per cent of the oil produced goes to industries and is used as a drying oil for the manufacturing of stickers, linoleum, patent leather, paints, varnish, printer ink, enamels, tarpaulins and soaps. The fibre extracted from the stem is utilized to produce strong yarns, linen fabrics, linen threads and the coarser grades are used for making strings, canvas bags, quality papers etc. (Pujar, 2012; Anamika *et al.,* 2022). Linseed oil is a rich source of unsaturated fatty acids i.e. oleic acid (16-24%), linoleic acid (18-24%) and linolenic acid (33-50%) with a relatively low glucosinolate content (Flachowsky *et al.,* 1997; Minz *et al,* 2022). The knowledge of genetic variability is pre-requisite for proper selection strategies as selection depends on the existence of available genetic variability. Furthermore, selection utilizes the heritable proportion of existing variability. Hence, knowledge of heritability is essential for crop improvement. Genetic parameters like the phenotypic and genotypic coefficients of variation play important for identifying the amount of variability present within the germplasm. Heritability along with high genetic advance would be more helpful tool for the selection of the best genotypes based on the yield component characters (Kumar *et al.,* 2022). Yield is the end product of multiplicative interaction among various yield components traits which involves a perception of character association with direct and indirect effects contributed by each character on seed yield. Correlation is the measure of the mutual relationship between two variables and may help the plant breeder to understand the effect of improving one character on other characters. Correlation alone cannot provide true information about the contribution of the character towards yield.

The genotypic and phenotypic correlation coefficients must be divided into direct and indirect effects through path coefficient analysis, which is the standardized partial regression coefficient measuring the direct and indirect influence of independent variables on the dependent variable. Considering the all these facts, the present study has been proposed to assess genetic variability, heritability,

[2]Department of Entomology, Bihar Agricultural, University, Bhagalpur-813210, Bihar;
Corresponding author's E-mail: nrambalak@yahoo.co.in

and character association and path coefficients among the genotypes.

MATERIALS AND METHODS

The present investigation contains 38 genotypes of linseed obtained from AICRP on linseed Bihar Agricultural College, Sabour, Bhagalpur (Table 1). The experiment was conducted in irrigated condition at the Bihar Agricultural College Farm of Bihar Agricultural University Sabour, Bhagalpur, Bihar, laying to the Middle Gangetic Plain region of agro-climatic zone III-A of Bihar and situated at an altitude of 52.73 meters above mean sea level between 25°50' N latitude and 87°19' E longitude. The experiment was carried out under irrigated condition in randomized complete block design with three replications during Rabi 2020-21. The experimental material was sown on November 15, 2020, in two rows of each 5 m in length with 30 cm spacing between rows and about 5cm spacing between the plants. The recommended agronomical package and practices were followed to ensure a good crop. Observations were recorded on five randomly selected and tagged plants per plot and per replication for flower diameter (mm), flowering period (days), plant height (cm), number of primary branches per plant, bud fly infestation (%), bud blight infestation (%), number of capsules per plant, number of seeds per capsule, seed length (mm), 1000-seed weight (g) and seed yield per plant (g), whereas, days to 50 per cent flowering and days to 50 per cent maturity were recorded on the plot basis. The oil content of bulk seeds were estimated through Soxhlet. The mean data were subjected to statistical analysis using INDOSTAT software.

Table 1 List of genotypes with brief description

Genotypes	Parentage	Seed coat colour	Flower colour
BRLS103	BAU-06-5 × RL 26018	Brown	Blue
BRLS104	LCK 7035 × Shekhar	Brown	Light blue
BRLS105	LCK 7035 × Shekhar	Brown	Blue
BRLS106	(PKDL 71 × NL 260) × LCK 7035	Brown	Light blue
BRLS107-1	(LCK 7035 × Shekhar)	Brown	Blue
BRLS109-1	(LCK 7035 × Shekhar) × NL 260	Brown	Blue
BRLS109-2	(LCK 7035 × Shekhar) × NL 260	Brown	Blue
BRLS110-1	(RL 26018 × Shekhar) × PKDL 71	Brown	Blue
BRLS110-2	(RL 26018 × Shekhar) × PKDL 71	Brown	Blue
BRLS110-4	(RL 26018 × Shekhar) × PKDL 71	Brown	Light blue
BRLS111-2	(RL 26018 × Shekhar) × LCK 7035	Brown	Blue
BRLS112-2	LCK 7035 × RL 26018	Brown	Blue
BRLS112-3	LCK 7035 × RL 26018	Brown	Light blue
BRLS119	(LCK 7035 × Shekhar) × PKDL 71	Brown	Blue
BRLS120	(RL 26018 × Shekhar) × NL 260	Brown	Blue
BRLS121	(NL 260× Shekhar) × PKDL 71	Brown	Light blue
Priyam	BAU 2K-14 × Garima		White
Divya	BAU 1008 × Kiran	Brown	White
Rajan (LCK 1009)	Gaurav × GS-234		Dark blue
Parvati	[(EC 41628 × EC 77959) × (DPL 20 × Neelum)] × [(EC 216 × Hira) × (BR 1 × NP 440)]	Light brown	Blue
LC 2945	Not Available	Brown	Light blue
H-40	Not Available	Brown	Blue
GS-202	Not Available	Brown	Dark blue
EC322672	Not Available	Brown	White
TL99	RLC 6 × Solin	Brown	Blue
Ruchi	Garima × LCK 88062	Brown	Light blue
Kota Barani Alsi-4	Triveni × RL 1011	Brown	Blue
Uma (LCK 1101)	Polf 34 × Padmini	Brown	Blue
JRF-2	FT-889 × FT-895	Brown	White
RLC133	(NL 14 × ACC. No. 926) × LCK 9313	Brown	White
Pratap Alsi-2	-	Brown	Dark blue
RLC153	LCK-88062 × EC-1424	Brown	Light blue
UP-Type367	Local germplasm of UP	Brown	Light blue
RL15580	Pratap Alsi-1 × NL-18	Brown	Dark blue
Sabour Tisi-1	Selection from kishanganj local germplasm	Brown	Dark blue
Sabour Tisi-2	SLS 72 × Shekhar	Brown	Light blue
Shekhar	Laxmi 27 × EC 1387	Brown	Blue
T-397	T- 491 × T- 1193-1	Dark brown	Violet

The phenotypic and genotypic coefficients of variation were calculated by the method given by Burton and Devane (1953). Broad sense heritability was calculated as the ratio between genotypic variance to the total phenotypic variance as given by Lush (1940) and expressed in percentage. The expected genetic advance was estimated by the formula given by Johnson *et al.* (1955a). Genotypic and phenotypic correlations coefficients were computed between pairs of characters by the formula given by Johnson *et al.* (1955b) and Al-Jibouri *et al.* (1958). The direct and indirect paths were estimated using the formula suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variances exhibited that the mean sum of squares due to genotypes was highly significant for all the characters under study (Table 2). These results indicated that there were significant differences among the genotypes for each character. The mean performance of genotypes for fourteen characters has been given in Table 3. The highest value of phenotypic (510.09) and genotypic (487.85) variance was found for the number of capsules per plant. A little difference was found between phenotypic and genotypic variance for flower diameter, number of primary branches per plant, number of seeds per capsule, seed length, 1000-seed weight, oil content and seed yield per plant (Table 4). The highest environmental variance was found for the number of capsules per plant (22.24) followed by days to 50% maturity (18.84) (Table 4). A similar pattern of variability among the genotypes in linseed for all the characters has been reported by Kumar and Paul (2016) and Ranjanna *et al.* (2014).

The seed yield per plant was recorded in the range of 5.78g to 1.74 g with a mean seed yield of 3.29g. Sabour Tisi-2 (5.78g), BRLS 111-2 (5.65g) and BRLS 112-2 (5.23g) recorded highest seed yield per plant. Oil content was found to be in the range of 37.9 to 31.3%; Pratap Alsi-2 (37.9%), BRLS 109-1(37.8%) and BRLS 119 (37%) showed highest oil content in the study. Days to flowering ranged from 88 to 68 days, whereas plant height ranged from 113 to 52 cm. Number of capsules per plant ranged from 120 to 33 with a mean value of 67 capsules per plant. BRLS 111-2 (120), BRLS 112-2 (116) and BRLS 110-4 (108) recorded the highest number of capsules per plant. Thousand seed weight was recorded in the range of 8.87 to 4.65g with a mean value of 6.47g. BRLS111-2 (8.87g) followed by Pratap Alsi-2 (8.7) and BRLS112-2 (8.05g) showed highest thousand seed weight compared to other genotypes.

The coefficient of variation (CV) was recorded within the range of 2.09 to 14.41 for different characters (Table 4). The highest CV was recorded for seed yield per plant (14.41) followed by bud fly infestation (10.99) and bud blight infestation (10.95). The remaining characters showed lower estimates for the coefficient of variation. The result indicated that genotypes had a wide range of variation for the characters under study. The phenotypic coefficients of variation (PCV) were higher than genotypic coefficients of variation (GCV) but very close for all the characters under study (Table 5). These results indicated that the selection of character on the basis of PCV would reflect GCV very closely. High GCV and PCV were estimated for bud fly infestation, bud blight infestation, number of primary branches per plant, number of capsules per plant and seed yield per plant, respectively. These results indicated that the variability present among the genotypes is heritable in nature and also less influenced by the environment. Similar findings were reported by various workers in linseed *viz.,* Tyagi *et al.* (2014), Paul and Kumari (2014) and Dhirhi and Mehta (2019) for the seed yield per plant, number of capsules per plant and number of primary branches per plant.

The broad sense heritability comprises both additive and non-additive gene effects but narrow sense heritability includes only additive components (Johnson *et al.,* 1955b). Knowledge of the heritability of a trait an essential tool, which could be employed for the selection of the trait under specific conditions. In the present study, all the characters showed high to very high estimates of broad sense heritability except days to 50% maturity which showed medium heritability (Table 5), indicating the negligible influence of environment on these traits. High heritability showed that a large proportion of phenotypic variance is attributed to genotypic variance so the selection of these traits on the basis of phenotypic variability would be effective. These results are in accordance with the findings of Jeet *et al.* (2010), Tyagi *et al.* (2014) and Yadav and Singh (2016) for yield and yield attributing traits. Since the estimates of heritability alone were insufficient for predicting the effect of selection. Heritability along with genetic advance is more useful than heritability alone for the selection of useful genotypes. A genetic advance is an essential tool used for the selection of prominent the best-performing population. High heritability coupled with high genetic advance as per cent means were obtained for the characters *viz*., seed yield per plant, number of capsules per plant, number of primary branches per plant, number of seeds per capsule, plant height, flowering period, bud fly infestation, bud blight infestation and 1000-seed weight. These results indicated that the heritability of these traits is due to additive gene action and so the selection will be effective. Similar results were also reported by Sahu and Sahu (2016), Siddiqui *et al.* (2016), Choudhary *et al.* (2017) and Dhirhi and Mehta (2019). High heritability along with moderate genetic advance as per cent of mean were recorded for days to 50% flowering, flower diameter and seed length. High heritability coupled with low genetic advance as per cent mean was found for oil content. These results indicated the presence of non-additive gene effects in the expression of the character (Panse, 1957). Moderate heritability coupled with low genetic advance as percent mean was observed for days to 50% maturity. This finding was also supported by Yadav and Singh (2016).

Genotypic and phenotypic correlation coefficients have been computed for pairs of all the fourteen characters of linseed genotypes are presented in Table 6. The magnitude of the genotypic correlation coefficient was higher than the corresponding phenotypic correlation for most of the characters studied. A significant and positive correlation was estimated between seed yield and flowering period, flower diameter, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, seed length and 1000-seed weight (Table 5). The above finding of a significant and positive correlation between seed yield and the number of capsules per plant is supported by Rajanna *et al.* (2014), Ali *et al.* (2014), Sharma *et al.* (2016), Yadav and Singh (2016), Siddiqui *et al.* (2016), Patial *et al.* (2018) and Meena *et al.* (2020). Similarly, a significant and positive correlation for seed yield with 1000-seed weight and was reported by Meena *et al.* (2020) and for seed yield with seed length by Kumari *et al.* (2017). A significant and positive correlation between seed yield and the number of seeds per capsule was similar to the finding of Kumari *et al.* (2017) and Patial *et al.* (2018). The result of a significant and positive correlation between seed yield per plant and flower diameter was similar to the finding of Kasana *et al.* (2016) and Kumari *et al.* (2017). However, bud fly infestation, days to 50% flowering, days to 50% maturity and plant height exhibited significant and negative correlations with seed yield. A similar finding was reported by Kumari *et al.* (2017) for bud fly infestation; Patial *et al.* (2018) for days to 50% flowering; Kasana *et al.* (2016) for days to 50% maturity. Hence, the selection of genotypes having a more number of capsules and seeds and ahigh1000-seed weight would be effective in improving the seed yield per plant.

Table 2 Analysis of variances for fourteen quantitative characters in linseed

Source of variation	Degree of freedom	Days to 50% flowering	Flowering period	Flower diameter	Days to 50% maturity	Plant height	Bud fly infestation	Bud blight infestation	Number of primary Branches/ plant	Number of capsules/ plant	Number of seeds/ capsule	Seed length	1000-Seed weight	Oil content	Seed yield/ plant
Replications	2	0.104	3.219	1.089	54.377	1.125	0.759	0.625	0.022	10.734	0.432	0.046	0.022	0.87	0.178
Treatments	37	72.929**	27.174**	9.644**	89.269**	573.652**	83.617**	48.607**	2.320**	1485.802**	2.8768**	0.342**	3.475**	6.238**	3.070**
Error	74	6.252	1.804	0.266	18.845	8.986	3.787	1.022	0.065	22.245	0.162	0.013	0.026	1.314	0.224

**significant at1% level of probability

Days to 50% flowering was found to have a significant and positive correlation with days to 50% maturity and plant height. Further, this character showed a significant and negative correlation with flowering period and seed length. A similar result of the correlation between days to 50% flowering with days to maturity was reported by Ranjanna *et al.* (2014), Ali *et al.* (2014), Gul *et al.* (2016) and Patial *et al.* (2018), while, between days to 50% flowering and plant height by Chandrawati *et al.* (2017). Flower diameter showed a significant and positive correlation with seed length and 1000-seed weight. This result revealed that larger seeds were produced from the larger flower. Plant height showed a significant and positive correlation with days to 50% maturity. This character also showed a significant and negative correlation with 1000-seed weight. Bud fly infestation and bud blight infestation showed significant and negative correlations with the number of capsules per plant, which revealed that the bud fly infestation and bud blight infestation affect the formation of seeds as bud fly attacks at the bud stage which results in a smaller number of buds converted into capsules which ultimately decreases seed yield per plant. A similar result was reported by Kumari *et al.* (2017). The number of primary branches per plant exhibited a significant and positive correlation with the number of capsules per plant and the number of seeds per capsule. A significant and positive correlation between primary branches per plant and the number of capsules per plant is supported by Ali *et al.* (2014), Chandrawati *et al.* (2017) and Paul et al. (2016). The number of capsules per plant exhibited a significant and positive association with seed length and 1000-seed weight. The number of seeds per capsule exhibited a significant and positive correlation with 1000-seed weight. 1000-seed weight showed a significant and positive correlation with seed length and oil content. A similar result of the correlation between 1000-seed weight with oil content was reported by Pali and Mehta (2014) and Siddiqui *et al.* (2016).

Table 3 Mean performance of genotypes for fourteen quantitative characters in linseed

Genotypes	DF	FP	FD	DM	PH	BFI	BBI
BRLS103	77.33	15.33	27.13	115.00	71.40	22.09	16.20
BRLS104	73.67	18.00	24.57	111.33	60.40	23.74	10.38
BRLS105	75.00	22.67	23.87	105.00	60.80	16.50	6.95
BRLS106	68.67	21.67	24.07	106.67	57.93	18.08	7.41
BRLS107-1	72.67	18.67	25.73	105.00	52.33	21.54	9.40
BRLS109-1	69.67	21.00	24.67	104.00	55.93	16.56	7.97
BRLS109-2	69.00	23.67	26.07	113.33	64.40	14.60	5.42
BRLS110-1	70.33	19.33	25.13	109.67	54.40	17.33	8.52
BRLS110-2	70.67	18.33	26.73	111.00	55.80	14.90	6.03
BRLS110-4	69.00	19.67	24.93	107.00	56.87	19.37	7.98
BRLS111-2	69.00	24.00	25.43	104.00	60.57	9.25	8.66
BRLS112-2	71.00	22.00	27.13	118.33	69.07	14.56	6.86
BRLS112-3	71.33	22.00	28.13	115.67	66.67	15.38	8.03
BRLS119	70.00	16.33	25.77	117.67	65.20	17.43	6.15
BRLS120	70.67	23.67	24.07	112.00	62.37	13.49	9.13
BRLS121	71.00	18.33	25.40	110.33	69.13	9.63	9.10
Priyam	81.33	19.00	24.77	119.00	61.27	29.78	9.58
Divya	84.33	19.67	24.93	117.00	59.60	21.49	18.35
Rajan	79.67	17.67	24.77	117.33	92.73	17.08	8.17
Parvati	76.00	21.00	27.33	120.33	87.73	13.34	6.40
RLC2945	87.67	14.00	23.37	113.33	93.67	13.45	7.97
H-40	79.00	18.00	26.27	120.67	91.73	16.75	7.93
GS-202	81.33	15.00	24.27	119.67	84.40	27.23	19.59
EC322672	79.00	17.67	22.80	123.33	85.40	15.91	7.01
TL99	71.33	21.00	24.60	114.33	72.60	16.39	7.04
Ruchi	74.00	16.00	24.00	116.00	85.53	21.37	8.21
Kota Barani Alsi-4	70.00	23.33	23.13	114.33	64.60	20.97	8.36
Uma	71.67	22.67	24.87	115.67	67.47	14.63	6.45
JRF-2	77.00	19.33	21.13	120.33	113.47	13.05	16.11
RLC133	71.00	22.67	23.27	119.33	67.75	31.02	20.54
Pratap Alsi-2	72.33	22.33	28.00	115.33	78.93	13.97	6.82
RLC153	71.33	21.33	25.47	119.33	75.60	19.05	6.23
UP-Type367	80.00	22.67	23.03	116.00	79.53	21.30	9.11
RL15580	79.00	16.00	23.47	120.67	78.60	11.38	5.40
Sabour Tisi-1 (LC)	78.00	15.67	19.93	113.00	61.60	16.71	6.05
Sabour Tisi-2 (LC)	68.00	27.33	25.57	105.67	54.53	9.40	8.24
Shekhar (ZC)	68.33	19.00	23.00	121.00	60.27	27.73	16.40
T-397 (NC)	72.00	21.33	21.63	109.00	62.40	16.37	6.72
Mean	73.95	19.93	24.70	114.12	70.07	17.71	9.23
S.E. m (±)	1.44	0.78	0.30	2.51	1.73	1.12	0.58
C.D. at 5%	4.07	2.19	0.84	7.06	4.88	3.17	1.64
C.V. (%)	3.38	6.74	2.09	3.80	4.28	10.99	10.95

Table 3 (contd...)

Genotypes	PBP	CP	SC	SL	TSW	OC	SYP
BRLS103	3.13	53.30	7.17	5.21	7.74	35.43	3.06
BRLS104	4.00	39.83	7.67	4.78	5.39	34.43	2.41
BRLS105	3.67	50.43	6.40	4.70	5.54	33.51	2.52
BRLS106	3.53	58.90	7.13	4.79	5.51	35.98	2.36
BRLS107-1	3.47	50.00	6.87	5.13	7.16	35.52	3.87
BRLS109-1	3.20	74.93	8.50	5.16	6.89	37.80	3.40
BRLS109-2	3.40	83.60	5.97	5.22	7.10	35.60	3.20
BRLS110-1	3.00	56.00	7.77	5.10	7.60	36.24	2.87
BRLS110-2	3.33	76.03	7.17	5.14	7.03	32.28	3.75
BRLS110-4	5.20	108.37	7.43	5.29	7.42	35.17	4.90
BRLS111-2	6.20	120.20	9.63	5.59	8.87	34.38	5.65
BRLS112-2	5.87	115.60	9.30	5.39	8.05	34.46	5.23
BRLS112-3	2.73	95.60	8.77	5.07	7.30	35.35	4.67
BRLS119	2.40	48.17	6.67	5.58	5.45	37.03	2.17
BRLS120	2.80	98.07	7.40	5.05	7.31	34.69	4.09
BRLS121	3.27	48.37	9.60	5.11	7.14	36.24	4.32
Priyam	4.87	55.60	9.23	4.74	5.99	33.27	3.06
Divya	4.40	45.93	8.20	4.55	6.35	34.79	2.16
Rajan	4.60	82.83	9.13	5.13	6.10	33.32	3.73
Parvati	3.47	70.63	8.07	4.88	6.27	34.36	3.25
RLC2945	4.27	44.97	7.20	4.55	5.57	36.36	2.07
H-40	3.53	38.07	7.87	4.60	4.75	34.71	2.44
GS-202	3.40	52.47	9.07	4.40	5.05	31.26	1.74
EC322672	2.80	86.93	7.40	5.06	6.12	34.68	3.13
TL99	3.20	64.93	6.60	4.82	5.24	35.28	3.11
Ruchi	4.47	58.00	8.30	4.75	5.98	35.12	2.59
Kota Barani Alsi-4	4.40	55.93	7.40	4.66	5.76	34.22	3.10
Uma	3.57	54.80	7.83	4.94	6.10	36.52	3.76
JRF-2	2.93	55.77	6.73	4.49	4.65	33.54	2.06
RLC133	2.87	56.07	7.97	4.87	6.60	36.28	2.95
Pratap Alsi-2	3.13	74.93	7.47	5.36	8.70	37.97	4.32
RLC153	3.47	63.00	5.97	4.81	5.92	35.14	2.72
UP-Type367	3.20	67.07	7.93	4.75	7.76	37.91	2.34
RL15580	3.80	85.50	8.20	4.64	6.09	34.87	3.21
Sabour Tisi-1	4.00	88.70	7.70	4.32	5.00	33.47	3.57
Sabour Tisi-2	5.13	99.47	8.97	4.77	7.24	35.31	5.78
Shekhar	2.73	32.83	8.83	5.10	6.81	35.04	2.40
T-397	3.93	48.00	6.87	4.08	5.17	34.28	2.89
Mean	3.72	67.36	7.80	4.91	6.44	35.05	3.29
S.E. m (±)	0.15	2.72	0.23	0.07	0.09	0.66	0.27
C.D. at 5%	0.42	7.67	0.66	0.19	0.27	1.86	0.77
C.V. (%)	6.87	7.00	5.17	2.38	2.54	3.27	14.41

Note:DF - Days to 50% flowering; FP - Flowering period; FD - Flower diameter; DM - Days to 50%maturity; PH - Plant height; BFI - Bud fly infestation; BBI - Bud blight infestation; PBP - Number of primary branches per plant; CP - Number of capsules per plant; SC - Number of seeds per capsules; SL - Seed length; TSW - 1000-Seed weight; OC - Oil content; SYP - Seed yield per plant; LC - Local check; ZC - Zonal check; NC - National check

Table 4 Estimation of coefficient of variation, genotypic variance, phenotypic variance and environmental variance for fourteen quantitative characters in linseed

Characters	Days to 50% flowering	Flowering period	Flower diameter	Days to 50% maturity	Plant height	Bud fly infestation	Bud blight infestation	Number of primary branches/ plant	Number of capsules/ plant	Number of seeds/ capsule	Seed length	1000-Seed weight	Oil content	Seed yield/ plant
Coefficient of variation	3.38	6.74	2.09	3.80	4.28	10.99	10.95	6.87	7.00	5.17	2.38	2.54	3.27	14.41
Phenotypic variance	28.48	10.26	3.39	42.32	197.21	30.40	16.88	0.81	510.09	1.06	0.12	1.17	2.96	1.17
Genotypic variance	22.22	8.46	3.13	23.47	188.22	26.61	15.86	0.75	487.85	0.90	0.10	1.14	1.64	0.94
Environmental variance	6.25	1.80	0.27	18.84	8.99	3.79	1.02	0.06	22.24	0.16	0.01	0.02	1.31	0.22

Table 5 Estimation of GCV, PCV, H, GA and GAM for fourteen quantitative characters in linseed

Characters	Days to 50% flowering	Flowering period	Flower diameter	Days to 50% maturity	Plant height	Bud fly infestation	Bud blight infestation	Number of primary branches/ plant	Number of capsules/ plant	Number of seeds/ capsule	Seed length	1000-Seed weight	Oil content	Seed Yield/ plant
GCV	6.38	14.59	7.16	4.25	19.58	29.13	43.13	23.31	32.79	12.2	6.74	16.65	3.66	29.64
PCV	7.22	16.07	7.46	5.7	20.04	31.13	44.5	24.3	33.53	13.25	7.15	16.84	4.9	32.96
H	78.04	82.41	92.15	55.47	95.44	87.54	93.95	92	95.64	84.75	78.08	79.23	73.57	80.88
GA	8.58	5.43	3.5	7.43	27.61	9.94	7.95	1.71	44.5	1.8	0.64	2.18	1.97	1.8
GAM	11.6	27.28	14.16	6.51	39.4	56.15	86.12	46.05	66.05	23.13	13.1	33.9	5.61	54.92

Note: GCV-Genotypic coefficient of variation; PCV-Phenotypic coefficient of variation; H-Broadsense Heritability; GA-Genetic advance; GAM-Genetic advance as percent of mean

Table 6 Phenotypic and genotypic correlation coefficient between pairs of fourteen quantitative characters in linseed

	Flowering period	Flower diameter	Days to 50% maturity	Plant height	Bud fly infestation	Bud blight infestation	Primary Branches/ plant	Capsules/ plant	Seeds/ capsule	Seed length	1000-seed weight	Oil content	Seed yield/plant
Days to 50% flowering	-0.513** (-0.619)	-0.236 (-0.238)	0336* (0.534)	0.516** (0.587)	0.155 (0.182)	0.242 (0.249)	0.056 (0.050)	-0.259 (-0.284)	0.049 (0.113)	-0.451** (-0.528)	-0.336* (-0.386)	-0.214 (-0.280)	-0.423** (-0.506)
Flowering period		0.170 (0.192)	-0.268 (-0.401)	-0.329* (-0.378)	-0.209 (-0.258)	-0.151 (-0.169)	0.154 (0.172)	0.358* (0.397)	-0.018 (0.001)	0.150 (0.198)	0.374* (0.419)	0.159 (0.287)	0.415** (0.536)
Flower diameter			-0.025 (-0.66)	-0.136 (-0.152)	-0.164 (-0.184)	-0.171 (-0.174)	0.047 (0.037)	0.199 (0.201)	0.143 (0.141)	0.585** (0.648)	0.524** (0.550)	0.149 (0.225)	0.376* (0.426)
Days to 50% maturity				0.512** (0.727)	0.254 (0.323)	0.213 (0.312)	-0.242 (-0.314)	-0.136 (-0.244)	0.030 (0.083)	-0.152 (-0.173)	-0.249 (-0.334)	-0.082 (-0.245)	-0.321* (-0.462)
Plant height					-0.126 (-0.136)	0.116 (0.120)	-0.132 (-0.138)	-0.124 (-0.137)	-0.031 (-0.024)	-0.249 (-0.276)	-0.358* (-0.365)	-0.092 (-0.147)	-0.330* (-0.365)
Bud fly infestation						0.578** (0.623)	-0.134 (-0.151)	-0.458** (-0.499)	0.026 (0.029)	-0.169 (0.199)	-0.186 (-0.206)	-0.113 (-0.159)	-0.456** (-0.520)
Bud blight infestation							-0.141 (-0.169)	-0.371* (-0.365)	0.210 (0.235)	-0.176 (-0.192)	-0.055 (-0.049)	-0.152 (-0.198)	-0.314 (-0.358)
Primary branches per/plant								0.428**(0.465)	0.399*(0.445)	0.009 (0.021)	0.185 (0.200)	-0.239 (-0.317)	0.460**(0.495)
Capsules/plant									0.240 (0.270)	0.389* (0.431)	0.522** (0.539)	-0.042 (-0.085)	0.717** (0.828)
Seeds/capsule										0.146 (0.137)	0.306* (0.326)	-0.084 (-0.156)	0.373* (0.422)
Seed length											0.683** (0.733)	0.292 (0.421)	0.475** (0.536)
1000-seed weight												0.324* (0.455)	0.615** (0.705)
Oil content													0.0837 (0.057)

Note 1 : Genotypic correlation coefficients are shown under parentheses.
Note 2 : *,** significant at 5% and1% level of probability, respectively.

Table 7 Direct (digonal) and indirect phenotypic effect of different characters on seed yield in linseed

	Days to 50% flowering	Flowering period	Flower diameter	Days to 50% maturity	Plant height	Bud fly infestation	Bud blight infestation	Primary Branches/ plant	Capsules/ plant	Seeds/ capsule	Seed length	1000-Seed weight	Oil content	Seed yield/ plant
Days to 50% flowering	-0.163	-0.013	-0.025	-0.008	-0.063	-0.036	0.007	0.011	-0.090	0.009	-0.010	-0.039	-0.005	-0.424
Flowering period	0.083	0.024	0.018	0.006	0.040	0.048	-0.005	0.028	0.124	-0.003	0.003	0.044	0.004	0.415
Flower diameter	0.039	0.004	0.106	0.001	0.017	0.038	-0.005	0.008	0.069	0.025	0.012	0.061	0.003	0.377
Days to 50% maturity	-0.055	-0.007	-0.003	-0.024	-0.063	-0.059	0.007	-0.044	-0.047	0.007	-0.003	-0.029	-0.002	-0.321
Plant height	-0.084	-0.008	-0.014	-0.012	-0.122	0.029	0.004	-0.025	-0.043	-0.005	-0.005	-0.042	-0.002	-0.331
Bud fly infestation	-0.025	-0.005	-0.017	-0.006	0.015	-0.230	0.018	-0.024	-0.159	0.005	-0.004	-0.022	-0.003	-0.457
Bud blight infestation	-0.039	-0.004	-0.018	-0.005	-0.014	-0.133	0.031	-0.025	-0.129	0.036	-0.004	-0.007	-0.003	-0.315
Primary branches per plant	-0.010	0.004	0.005	0.006	0.017	0.030	-0.004	0.180	0.149	0.068	0.000	0.022	-0.005	0.461
Number of capsules per plant	0.042	0.009	0.021	0.003	0.015	0.105	-0.011	0.077	0.347	0.041	0.008	0.061	-0.001	0.718
Number of seeds per capsule	-0.008	-0.001	0.015	-0.001	0.004	-0.006	0.006	0.072	0.083	0.171	0.003	0.036	-0.002	0.373
Seed length	0.073	0.004	0.062	0.004	0.030	0.039	-0.005	0.002	0.135	0.025	0.021	0.080	0.007	0.476
1000-seed weight	0.055	0.009	0.056	0.006	0.044	0.043	-0.002	0.033	0.181	0.052	0.014	0.117	0.007	0.616
Oil content	0.035	0.004	0.016	0.002	0.011	0.026	-0.005	-0.043	-0.015	-0.014	0.006	0.038	0.023	0.084

The path coefficients were computed by using phenotypic correlation coefficients between seed yield per plant and its component traits are presented in Table 6. Direct phenotypic effects ranged from 0.023 to 0.347. The maximum direct positive effect was recorded for the number of capsules per plant (0.347) on seed yield followed by the number of primary branches per plant (0.180), number of seeds per capsule (0.171), 1000-seed weight (0.117), flower diameter (0.106), flowering period (0.024), oil content (0.023) and seed length (0.021). A similar finding was reported by Tewari *et al.* (2012), Ibrar *et al.* (2016), Sahu *et al.* (2016), Patial *et al.* (2018), Meena *et al.* (2020) for the number of capsules per plant and Ibrar *et al.* (2016) for the number of seeds per capsule and 1000-seed weight. Thus, direct selection can be done for these characters. The positive indirect effect on seed yield was found for the flowering period via days to 50% flowering (0.083), flower diameter (0.018), plant height (0.040), number of primary branches per plant (0.028), number of capsules per plant (0.124), 1000-seed weight (0.044) whereas flowering period showed the positive indirect effect on seed yield via days to 50% flowering (0.039), number of capsules per plant (0.069), number of seeds per capsule (0.025) and 1000-seed weight (0.061).The number of primary branches per plant showed a positive indirect effect on seed yield via the number of capsules per plant(0.149) and the number of seeds per capsule (0.068). The number of capsules per plant contributes positively to the seed yield indirectly via days to 50% flowering (0.042), number of primary branches per plant (0.077), number of seeds per capsule (0.041) and 1000-seed weight (0.061), however, the positive indirect contribution of seed length to seed yield showed via days to 50% flowering (0.073), flowering period (0.062) plant height (0.030), number of capsules per plant (0.135), number of seeds per capsule (0.025) and1000-seed weight (0.080). Thousand seed weight exhibited a positive indirect effect on seed yield via days to 50% flowering (0.055), flower diameter (0.056) plant height (0.044), number of primary branches per plant (0.033), number of capsules per plant (0.181) and number of seeds per capsule (0.052), while oil content showed the positive indirect effect on seed yield via days to 50% flowering (0.035) and 1000-seed weight (0.038). The highest direct negative effect was estimated for bud fly infestation (-0.230), followed by days to 50% flowering (-0.163) and plant height (-0.122) on seed yield. Similar results were reported by Kumari *et al.* (2017) for bud fly infestation. It indicated that bud fly infestation would be given priority for the direct selection of genotypes in the breeding programme.

More seed yield with a high oil percentage is the prime objective of most of the oilseed breeding programmes. It can be concluded that the yield of linseed has a positive and significant correlation with the flowering period, flower diameter, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, seed length and 1000-seed weight. However, days to 50% flowering, days to 50% maturity, plant height and bud fly infestation exhibited a significant and negative correlation with seed yield. The number of capsules per plant also had a high and positive phenotypic direct effect on seed yield. So, the number of capsules per plant, number of seeds per capsule, number of primary branches per plant and 1000-seedweight should be given due weightage in the selection of genotypes for seed yield.

The three top ranker genotypes for high seed yield *viz.,* Sabour Tisi-2, BRLS 111-2 and BRLS 112-2; and the three top ranker genotypes for oil content *viz.,* Pratap Alsi-2, BRLS 109-1 and BRLS 119 may be rewarding to use in the crossing programme for developing high seed yield and high oil content variety.

REFERENCES

Ali M F, Mekbib F and Wakjira A 2014. Morphological diversity of Ethiopian linseed (*Linum usitatissimum* L.) land race accessions and non-native cultivars. *Journal of Plant Breeding and Genetics*, **2**(3): 115-124.

Al-Jibouri H, Miller P A and Robinson H F 1958. Genotypic and environmental variances and covariances in an upland cotton crosso finter specific origin. *Agronomy Journal,* **50**(10): 633-636.

Anamika, Jain Badkul, Sharma P B, Archit Kumar Nayak, Shritama Bhuniya and Namarata Jain 2022. Influence of irrigation scheduling and fertility levels on growth, yield and economics of linseed (*Linum usitatissimum* L.) in Kymore Plateau and Satpura Hills region. *Journal of Oilseeds Research,* **39**(2): 113-116.

Burton G W and Devane E H 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal,* **45**(10): 478-481.

Chandrawati D, Singh N, Kumar R, Kumar S, Ranade S, Kumar A and Yadav H 2017. Agro-morphological traits and microsatellite markers based genetic diversity in Indian genotypes of linseed (*Linum usitatissimum* L.). *Journal of Agriculture Science and Technology,* **19**(3): 707-718.

Choudhary A K, Marker S and Rizvi A F 2017. Genetic variability and character association for seed yield in linseed (*Linum usitatissimum* L.) under rainfed conditions. *Journal of Pharmacognosy and Phytochemistry,* **6** (5): 457-460.

Dewey D R and Lu K G. 1959. A correlation and path analysis of yield components of crested wheat grass seed production. *Agronomy Journal,* **15**: 513-8.

Dhirhi N and Mehta N 2019. Estimation of genetic variability and correlation in F_2 segregating generation in linseed (*Linum usitatissimum* L.). *Plant Archives,* **19**(1): 475-484.

Flachowsky G, Langbein T, Bohme H, Schneider A and Aulrich K 1997. Effect of false flax expeller combined with short-term vitamin E supplementation in pigs feeding on the fatty acid pattern, vitamin E concentration and oxidative stability of various tissues. *Journal of Animal Physiology and Animal Nutrition,* **78**: 187-195.

Gul S, Rajper A A, Kalhoro F A, Kalhoro S A, Ali A, Shah F A and Ahmed M 2016. Screening of selected linseed (*Linum usitatissimum* L.) genotypes for yield performance in Sindh, Pakistan. *Natural Science,* **8**(2): 53.

Ibrar D, Ahmad R, Mirza M Y, Mahmood T, Khan M A and Iqbal M S 2016. Correlation and path analysis for yield and yield components in linseed (*Linum usitatissimum* L.). *Journal of Agricultural Research,* **54**(2): 153-159.

Jeet R, Singh P K, Dubey S D, Kumar A and Gautam C P N 2010. Genetic variability, heritability and genetic advance in linseed (*Linum usitatissimum* L.). *Current Advances in Agricultural Sciences*, **2**(1): 45-46.

Johnson H W, Robinson H F and Comstock R E 1955a. Estimates of genetic and environmental variability in soybeans. *Agronomy Journal*, **47** (7): 314-318.

Johnson H W, Robinson H F and Comstock R E 1955b. Genotypic and phenotypic correlations in soybeans and their implications in selection. *Agronomy Journal,* **47** (10): 477-483.

Kasana B S, Tomar R K S and Singh A K 2016. Evaluation of improved varieties of mustard on farmers' field in datia district of Madhya Pradesh. *Bhartiya Krishi Anusandhan Patrika,* **31** (1): 28-30.

Kumar N and Paul S 2016. Selection criteria of linseed genotypes for seed yield traits through correlation, path coefficient and principal component analysis. *Journal of Animal and Plant Sciences,* **26** (6): 1688-1695.

Kumar M, Patel M, Chauhan R S, Tank C and Solanki S 2022. Unravelling the G × E interactions using AMMI biplot for phenology and agro-morphological traits in linseed (*Linum usitatissimum* L.). *Journal of Oilseeds Research,* **39**(3&4): 179-190.

Kumari S, Nirala R B P, Rani N and Prasad B D 2017. Selection criteria of linseed (*Linum usitatissimum* L.) genotypes for seed yield traits through correlation and path coefficient analysis. *Journal of Oilseeds Research*, **34** (3): 166-170.

Lush J L 1940. Inter-sire correlation and regression of offspring on damsasa method of estimating heritability of characters. *Proceedings of American Society of Animal Production,* **33**: 293-301.

Meena A K, Kulhari S, Kumar M, Koli N R, Tak Y, Meena D and Meena N 2020. Studies on genetic variability and character association in linseed (*Linum usitatissimum* L.) genotypes. *International Journal of Current Microbiology and Applied Sciences,* **9** (7): 3949-3957.

Minz A S, Ekka S, Lal H C and Mundu S 2022. Variability in *Alternaria lini* causing leaf blight disease of linseed (*Linum usitatissimum* L.). *Journal of Oilseeds Research,* **39**(3 & 4): 225-233.

Pali V and Mehta N 2014. Evaluation of oil content and fatty acid compositions of flax (*Linum usitatissimum* L.) varieties of India. *Journal of Agricultural Sciences,* **6** (9): 1916-9752.

Panse, V G 1957. Genetics or quantitative characters in relation to plant breeding. *Indian Journal of Genetics and Plant Breeding,* **17**: 318-346.

Patial R, Paul S and Sharma D 2018. Correlation and path coefficient analysis for improvement of seed yield in linseed

(*Linum usitatissimum* L.). *International Journal Current Microbiology and Applied Sciences*, **7** (3): 1853-1860.

Paul S and Kumari A 2014. Genetic variability and divergence analysis for seed yield, its component characters in linseed (*Linum usitatissimum* L.) over environments in North Western Himalayas. *Journal of Entomology and Zoology Studies,* **6** (4): 932-938.

Paul S, Kumar N and Chopra P 2016. Genetic variation and characterization of different linseed genotypes (*Linum usitatissimum* L.) for agromorphological traits. *Journal of Applied and Natural Sciences,* **9** (2): 754-762.

Pujar M S 2012. Variability analysis of linseed (*Linum usitatissimum* L.) germplasm for yield related components. *Doctoral Dissertation,* UAS, Dharwad.

Rajanna B, Biradar S A, Ajith K 2014. Correlation and pathcoefficient analysis in linseed (*Linum usitatissimum* L.). *Supplement on Genetics and Plant Breeding,* **9** (4): 1625-1628.

Sahu D and Sahu M 2016. Selection parameters for seed yield and related traits in linseed (*Linum usitatissimum* L.). *Bangladesh Journal of Botany,* **45** (3): 621-629.

Sahu G, Mishra S P, Mishra V K, Sahu T and Solanki R S 2016. Correlation and path coefficient analysis in linseed (*Linum usitatissimum* L.) genotypes under rainfed condition. *Environment and Ecology,* **34** (1A): 288-291.

Sharma D, Paul S and Patial R 2016. Correlation and path-coefficient analysis of seed yield and yield related traits of linseed (*Linum usitatissimum* L.) in mid hills of North-West Himalaya. *Supplement on Genetics and Plant Breeding,* **11** (4): 3049-3053.

Siddiqui A, Shukla S, Rastogi A, Bhargava A, Niranjan A and Lehri A 2016. Relationship among phenotypic and quality traits in indigenous and exotic accessions of linseed. *Pesquisa Agropecuária Brasileira,* **51** (12): 1964-1972.

Tewari N, Singh N and Shweta N 2012. Selection parameters for seed yield and its components in linseed (*Linum usitatissimum* L.). *Current Advances in Agricultural Sciences,* **4** (2): 149-151.

Tyagi A K, Sharma M K, Mishra S A, Kerkhi P and Chand 2014. Estimates of genetic variability, heritability and genetic advance in linseed (*Linum usitatissimum* L.) germplasm. *Progressive Agriculture,* **14**: 37-48.

Yadav S K and Singh M R 2016. Genetic variability and selection parameter for yield and its components in linseed (*Linum usitatissimum* L.). *Agriculture*, **1** (1): 24-29.

Effect of conserved soil moisture on growth and yield attributes of Taramira (*Eruca sativa* Mill.) in hot arid zone of Rajasthan

R SARANYA*, MAVJI PATIDAR, ANIL PATIDAR, S C MEENA AND DILEEP KUMAR

ICAR-Central Arid Zone Research Institute, Jodhpur-342003, Rajasthan

(Received: March 14, 2023; Revised: April 12, 2023; Accepted: May 23, 2023)

ABSTRACT

A study on the utilisation of conserved soil moisture and the effect of sowing time on the productivity of taramira (*Eruca sativa* Mill.) was conducted during *rabi* 2021-22 at ICAR-CAZRI-RRS Jaisalmer, Rajasthan. The three treatments, i.e. T_1 (sown in the last week of September) utilized conserved soil moisture with one irrigation, T_2 (sown in the last week of October) and T_3 (sown in the last week of November)- with two irrigations, was taken in this study. Yield attributes i.e. silique/branch, seed/siliqua and seed yield were significantly influenced by different treatments. The maximum silique/branch, seed/siliqua and seed yield was recorded in T_1 (34.92; 20.35; 0.95 t/ha), followed by T_2 (23.92; 17.52; 0.84 t/ha). The growth attributes like plant height, primary branches and pod length were not significantly affected by different treatments.

Keywords: Conserved soil moisture, Date of sowing, Taramira, Yield

The majority of crops in the arid region are grown under rainy conditions. Water scarcity is limiting factor in this region. The average annual rainfall in western Rajasthan (also known as the Thar desert) ranges from less than 100 mm in west of Jaisalmer to 450 mm in east of Jalore, with the majority of the area receiving between 185 to 472 mm. Over 90% of the rainfall falls between the end of June and the first week of September (Bhati *et al.,* 2017). The distribution of rainfall during critical growth stages of crops is critical for profitable cultivation. The availability of soil moisture is most important factor for growing crops in arid conditions and therefore the choice of crops is limited due to low and erratic nature of rainfall (Moharana *et al.,* 2016). Sometimes the rain received at the end of *kharif* season that is not utilized by the kharif crops and is also not sufficient for growing subsequent long-duration rabi crops but the conserved soil moisture can be utilized for short-duration *rabi* crops.

Another constraint in western Rajasthan is that most soils are light and sandy in nature. These soils are alkaline in reaction (pH 8.2 to 8.8), less fertile, and have a low water retention capacity as their organic matter lies between 0.03-0.3%. This results in crust formation, which hampers the growth of the crop. This water stress condition combined with salinity of the soil favours the root rot complex diseases in crops like chickpea, ground nut, cumin, isabgol and cluster bean etc as the pathogen is having wide host range. To overcome above said problems in arid region the crop Taramira (*Eruca sativa*) also known as "rocket salad," is chosen. It is short duration crop of the family Brassicaceae. Its oil is mainly used in industries and for culinary purpose it is mixed with mustard oil to increase the pungency (Mundiyara and Jakhar, 2017; Gandhimathy *et al.,* 2022). It is believed to have originated in the Mediterranean region and been introduced to India. In Asia, most of it is grown in India, followed by a limited area in Pakistan. The majority of land in India is in the state of Rajasthan, with small areas in Gujarat and Haryana. This crop is particularly suitable for north-western Rajasthan and can be grown in early *rabi* season utilizing the conserved soil moisture (Mundiyara and Jakhar, 2017). For improving productivity the time of sowing need to be adjusted in arid region. With this, the experiment was conducted to study the utilisation of conserved soil moisture and the effect of sowing time on its productivity.

Corresponding author's E-mail: vrsaran92 @gmail.com

MATERIALS AND METHODS

The field experiment was conducted during *rabi* 2021-22 at ICAR-CAZRI, RRS, Jaisalmer. The climatic condition of the area is hyper arid, characterized by exceptionally hot dry summers, and cold dry winters. The soil is coarse loamy sand, low in organic carbon and available nitrogen and medium in available phosphorus with pH 8.1. The average rainfall of the region is 165 mm but we received 338 mm during the year 2021. The treatment details were as follows T_1(sown during the last week of September)- utilized conserved soil moisture of (103 mm rainfall received in that month) + one irrigation at grain filling stage, T_2 (sown during the last week of October)- 1st irrigation after sowing+ 2nd irrigation at grain filling stage; T_3 (sown during last week of November)- 1st irrigation after sowing+ 2nd irrigation at grain filling stage. Taramira variety RTM -13 was sown in the plot size of 5.5 m × 4.5 m with 30 × 10 cm spacing using seed rate 5 kg/ha.

The treatments were replicated four times randomly. Observations were recorded for plant height, primary branches, siiquae/branch, pod length and seed yield.

RESULTS AND DISCUSSION

The growth and yield attributes of taramira was affected differentially by different treatments (Table 1). Plant height, primary branches and pod length were not significantly affected by different treatments. However, maximum plant height and silique/branch was recorded in T_1 (91.58 cm; 34.92) followed by T_2 (87.75 cm; 23.92) and T_3 (82.5 cm; 27.25) whereas the primary branches in T_1 and T_2 was 5.67. Yield attributes i.e., siliqua/branch and seed/siliqua were significantly influenced by different treatments. Maximum silique/branch and seed/siliqua was recorded with T_1(34.92; 20.35) followed by T_2 (23.92; 17.52). Finally, the biological yield and seed yield was significantly affected by the different treatments. The biological yield and seed yield recorded highest in T_1 (4.83 t/ha;0.95 t/ha) followed by T_2 (4.65 t/ha; 0.84 t/ha). The biological yield in T_1 and T_2 was statistically on par with each other. The increase in seed yield of first sowing was by 13.4 and 40.8 % higher over second and third sowing respectively. The result indicated that the crop sown in the last week of September (T_1), which utilised the conserved soil moisture, gave a better seed yield than other dates of sowing with two irrigations. The higher seed yield in first sowing (T_1) was due to better root development, plant growth and seed setting as a result of more availability of soil moisture. Its efficient root system helped in extracting moisture from deeper layers of soil (Jat and Jakhar, 2015). Although the effect of date of sowing on yield attributes of taramira was studied by Maliwal (1985), Singh and Rajput (1993), and Jat and Jakhar (2015), the effect of date of sowing along with the utilisation of conserved soil moisture was not studied. Therefore, our preliminary study on the effect of the utilisation of conserved soil moisture will help the researchers and farmers of arid regions take this forward in this climate change scenario.

Table 1 Effect of sowing date and conserved soil moisture on growth and yield attributes of taramira

Treatments	Plant height (cm)	Primary branch	Siliqua/ branch	Siliqua length	Seed/ siliqua	Biological yield (t/ha)	Seed yield (t/ha)
T1	91.58	5.67	34.92	3.01	20.35	4.83	0.95
T2	87.75	5.67	23.92	2.99	17.52	4.65	0.84
T3	82.5	5.75	27.25	2.87	15.95	3.06	0.68
SEm ±	NS	NS	1.76	NS	0.65	0.08	0.03
C.D. (p=0.05)	NS	NS	6.10	NS	2.25	0.3	0.09

REFERENCES

Bhati T K, Shalander K, Amare H and Whitbread A M 2017. Assessment of Agricultural Technologies for Dryland Systems in South Asia: A Case Study of Western Rajasthan, India. Patancheru 502 324. Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. 1-2 pp.

Gandhimathy B 2022. Growth and instability of oilseeds in India. *Journal of Oilseeds Research,* **39** (3& 4): 265-267.

Jat B L and Jakhar M L 2015. Character association in taramira (*Eruca sativa* L.) under three environment conditions. *International Journal of Plant Science*, **10** (1): 49-52.

Maliwal P L 1985. Effect of dates of sowing on yield and quality of taramira (*Eruca sativa* L.) varieties. *Indian Journal of Agronomy,* **30**(1): 112-113.

Moharana P C, Santra P, Singh D V, Suresh Kumar, Goyal R K, Deepesh Machiwal and Yadav O P 2016. ICAR-Central Arid Zone Research Institute, Jodhpur: Erosion Processes and Desertification in the Thar Desert of India. *Proceedings of the Indian National Science Academy*. **82**.

Mundiyara R and Jakhar M L 2017. Identify Promising Parents and Crosses of Taramira (*Eruca sativa* Mill.) for Improvement in Irrigated and Drought Conditions. *Journal of Pharmacognosy and Phytochemistry,* **6**(4): 789-795.

Singh S P and Rajput O P 1993. Seed quality and oil yield of rocket-salad (*Eruca sativa*) as influenced by date of sowing and row spacing. *Indian Journal of Agronomy,* **38**(2): 335-336.

Assessment of antioxidant activity and physical characteristics of PJTSAU released sesame seed varieties

PULLURI PRATHYUSHA[1*], THOOMATI SUPRAJA[2], BETHAPUDI ANILA KUMARI[3], NEELA RANI[4], SRINIVASA CHARY[5] AND PADMAJA[6]

[1]College of Community Science, PJTSAU, Rajendranagar-500 030, Hyderabad, Telangana

(Received: March 2, 2023; Revised: April 11, 2023; Accepted: April 28, 2023)

ABSTRACT

Sesame (*Sesamum indicum* L.) is one of the oldest annual herbs from the Pedaliaceae family. It is considered an essential crop, due to its nutritional properties of edible oil and economic viability. The oil from this seed crop has a high nutritional value such as protein and mineral content as well as an excellent source of antioxidant activity which helps in preventing chronic diseases. Due to increased health awareness, the worldwide sesame market demand is growing across the world. The physical properties of seeds can be useful for storage and processing. This knowledge plays a vital role in the preparation of the processing chain from seed to food. Due to this reason, the present study aimed to investigate the IC50 antioxidant activity as well as physical properties such as 1000 seed weight, seed size, geometric diameter, arithmetic diameter, bulk density, tapped density and porosity of among three selected sesame seed varieties (JCS 1020, Hima and Swetha) released from PJTSAU. Results concluded that the highest IC50 antioxidant activity (5.27 µg/ml) was found in JCS 1020 and Swetha sesame seed varieties. However, there was no significant difference in antioxidant activity, length, width, thickness, tapped density and arithmetic diameter of the selected PJTSAU sesame seed varieties. Among the sesame seed varieties, 1000-seed weight, bulk density and porosity showed significant differences at $p<0.05$ whereas geometric diameter had a significant difference at $p<0.01$.

Keywords: Antioxidant activity; Porosity and Bulk density, Sesame seeds, Seed size

India is one of the major producers of sesame seeds. Traditionally, Indians consume a substantial quantity of edible oils mainly as a cooking medium. Sesame seeds add a nutty taste and a delicate flavour. Roasting of sesame seeds makes the products crunchier to many Asian dishes (Anilakumar *et al.,* 2010; Kumar *et al.,* 2022). Sesame (*Sesamum indicum* L.) is an annual herb grown for its edible seeds and oil. It is also known as gingelly, til, benne seeds and it is all so called the "queen of oilseeds" due to its high resistance to oxidation and rancidity. Sesame seeds are considered a valuable food because they enhance the diet with a pleasant aroma and taste, while providing nutritional and physiological benefits (Pratyusha *et al.,* 2022). Recent studies on the antioxidant and anticancer activities of sesame seeds have greatly increased their application in health food products to protect the liver, heart and prevent tumors (Pathak *et al.,* 2014; Angel and Poonguzhalan, 2022).

Sesame seeds contain high oil content (about 50%) and protein (20-25%), with the rest consisting of mineral ash (about 6%), crude fiber (about 4.5%), oxalates (about 2.5%), and soluble carbohydrates (12.5%). Methionine and tryptophan, are two important amino acids, which are abundant in sesame proteins, whereas lysine is limiting (Johnson *et al.,* 1979). Sesame seeds are rich in vitamin B1, fiber and are an excellent source of iron (7.37 ± 0.33 mg/100g), magnesium (182.47 ± 0.50 mg/100g), calcium (440 ± 0.10 mg/100g), sodium (80 ± 0.09 mg/100g) and zinc (4.47 ± 0.19 mg/100g). Sesamin and sesamolin are the active components in sesame responsible for antioxidant activity. These two substances belong to a group of particularly beneficial fibers called lignans and have been shown to lower cholesterol in humans, prevent high blood pressure and increase vitamin E levels in animals (Cheng *et al.,* 2006). Several studies have reported that sesame oil is effective in prevention of various disorders such as hypertension, hypercholesterolemia, cancer and aging (Philip *et al.,* 2010).

Sesame is an excellent source of bioactive compounds including phytosterols, tocopherols and lignans such as sesamin, sesamolin and sesaminol, which are known to play an important role in providing stability, counter the oxidation of oil and thus exhibiting antioxidant activity (Shahidi *et al.,* 2006). The present study, aims at investigating the antioxidant activity and physical properties of three sesame seed varieties (JCS 1020, HIMA and SWETHA) released by Professor Jayashanker Telangana State Agricultural University (PJTSAU).

[2]Department of Extension Education, PGRC, College of Community Science, PJTSAU, Rajendranagar-500 030, Hyderabad, Telangana;
[3]Department of Mathematics and Statistics, Agricultural College, PJTSAU, Rajendranagar-500 030, Hyderabad, Telangana;
[*]Corresponding author's E-mail: prathyusha.pulluri95@ gmail.com

MATERIALS AND METHODS

Three seeded sesame varieties, JCS 1020, Hima and Swetha released by the PJTSAU were selected for the present study. The seeds were procured from RARS (Regional Agricultural Research Station), Polasa, Jagatiyal.

Estimation of antioxidant activity in sesame seed varieties: Antioxidant activity of the sesame samples was measured based on its DPPH radical-scavenging activity as per the method suggested by Ghani *et al.* (2018).

Physical properties of sesame seeds: Sesame seeds were analyzed for physical properties such as (a) dimensional properties and (b) gravimetric properties. The dimensional properties include: size of seeds, geometric mean diameter, and arithmetic diameter. Gravimetric properties were analyzed by 1000-seed weight, bulk density, true density and porosity according to their respective standard procedures (Mohsenin, 1980).

a) Dimensional properties:

Size of seed: For the size and shape of the sesame seed 100 seeds were randomly selected and for each individual seed length, width and thickness were measured by using a digital caliper (0.01mm).

Geometric mean diameter (Dg): The geometric diameter was calculated by using the formula.

$$Dg = (L \times W \times T)^{1/3} \text{ mm}$$

Where L, W and T are the length, width and thickness in mm, respectively.

Arithmetic diameter (Da): The arithmetic diameter was calculated by using the formula

$$Da = (LxWxT)/3$$

Gravimetric properties

Thousand Seed Weight: 1000-seed weight is highly useful for calculating the optimal seeding rate for a given crop type or variety, and it can also be used to calibrate a seed drill as well as estimate yields. Thousand seed weight was measured by counting 100 randomly selected sesame seeds and weighing them using an electronic balance having an accuracy of 0.001 g and then multiplied by 10 to give a mass of 1000 seeds.

Bulk Density (b): It was calculated for the seeds by dividing the mass of a number of seeds by its volume, which was measured by using a constant volume cylinder and expressed as g/ml.

$$\text{Bulk density} = \frac{\text{Weight of seeds}}{\text{Volume of seeds}}$$

True Density (t): Take 25 g of sound sesame seeds and weighed on the digital weighing balance and filled into the measuring cylinder in which the reference solution of kerosene or toluene was already filled. The increase in the level of liquid was measured after adding the grains. It is true density represented in g/ml.

$$\text{True density} = \frac{\text{Weight of seeds}}{\text{Volume occupied}}$$

Porosity (ε): The porosity (ε) of the bulk sesame seed was defined as the fractions of the space in the bulk grain that is not occupied by the grain. The porosity, (ε) was calculated using the formula

$$\varepsilon = \frac{(\rho b) \times 100}{\rho t}$$

Where, ρb and ρt are the bulk and true density, respectively in kg/m^3.

Statistical analysis: Statistical analysis was conducted by using SPSS (16.0 version) software and the mean scores were compared at $P \leq 0.05$ and $P \leq 0.01$ at the level of significance suggested by Nile *et al.* (1970).

RESULTS AND DISCUSSION

The selected sesame seed varieties (JCS 1020, Hima and Swetha) are white seeded category developed for the extraction of cold pressed oils for culinary purposes. Hence, the above listed parameters will be helpful for the entrepreneurs for the supply of quality material to the consumers.

Estimation of antioxidant activity in sesame seed varieties: The antioxidant activity of the sesame seed varieties were given in Figure 1. The findings showed that JCS 1020 (5.27±0.0005 µg/mL) and Swetha (5.27±0.0005 µg/mL) had higher but similar mean scores for IC50 (The IC50 value indicates the concentration of antioxidants needed to decrease the initial DPPH concentration by 50%. Thus it indicates the lower the IC50 value the higher the antioxidant activity).

However, results indicated that there were no significant differences between the antioxidant activities for all three sesame seed varieties. The lesser the IC50 value, the more effective is the substance at scavenging DPPH and this indicates a higher antioxidant activity (Vimala and Adenan, 1999).

Ruslan *et al.* (2018) reported antioxidant activity in white and black sesame seeds in different extracts (n-hexane, ethanol and methonal). The range of DPPH IC50 values of methanol extracts of white sesame seed were 8.88-44.21 and µg/mL and black sesame seeds were 24.91-141.19 µg/mL, respectively.

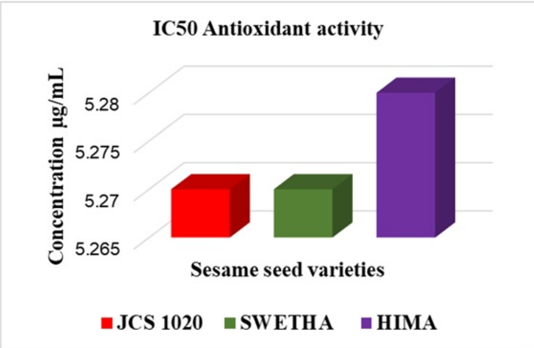

Fig. 1. Antioxidant activity in sesame seed varieties

Assessment of physical characteristics of sesame seed varieties (JCS 1020, Hima and Swetha): The physical parameters of sesame seed varieties were done by dimentional and gravimetric parameters. These are very important factors to be considered for cooking and processing. The knowledge of the physical properties of seeds helps in development of processing technology. The knowledge of the physical parameters helps to predict the pressure and loads on storage structures. Also the design of grain hoppers for processing machinery requires data on this. The physical characteristics of sesame seed varieties were presented in Table 1 and Table 2.

Physical dimensions are useful in determining aperture size in the design of seed handling machinery. The Arithmetic Mean diameter (AMD) and Geometric Mean Diameter (GMD) are dependent on the length, breadth and thickness of seeds. The AMD and GMD can be used to determine the average diameter of sesame seeds, which is useful in determining the aperture size of sieve holes (Adebowale *et al.,* 2010).

Dimensional parameters:

Length: Mean scores for the length of sesame seed varieties (JCS 1020, HIMA and SWETHA) were observed higher for HIMA (3.17±0.02mm) compared to JCS 1020 (3.05±0.04 mm) and SWETHA (3.05±0.05 mm) varieties. However, results concluded that there was no significant difference ($p<0.05$) between the length of the three sesame seed varieties.

Rizki *et al.* (2015) investigated the length in sesame seed varieties grown in the Tadla-Azilal area, Morocco. The mean length values of sesame seed varieties were identical to the present study where 3mm was reported for the varieties krakeb 1, krakeb 2, ouled zian 1, ouled yaich 2, had boumussa 1, had boumoussa 2, taghzirt 4, ibazazal 1, ouled barkat 2, ouled ayad, taghzirt 7 and taghzirt 5.

Similar findings were reported by Adebowale *et al.* (2010) in improved varieties of sesame seeds obtained from the National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, Nigeria was as follows NCRI BEN 01M (3.01mm), NGB\04\026 (2.56 mm), NCRI BEN 03L (2.40 mm), NG\SA\07\179 (2.51mm), NG\SA\07\090 (2.79 mm), NG\SA\07\095 (2.94 mm), NG\SA\07\052 (2.86 mm) and OM1 (2.85 mm).

Width: The width mean score was observed highest for JCS 1020 (1.90 ± 0.02mm) followed by HIMA (1.88 ± 0.08mm) and SWETHA (1.79 ± 0.05mm). Results indicated that there was no significant difference ($p<0.05$) between the width of the three sesame seed varieties.

The identical research study was investigated by the Adebowale *et al.* (2010) in improved varieties of sesame seeds obtained from the National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, Nigeria. NCRI BEN 01M (1.84 mm), NG\SA\07\095 (1.86 mm), NG\SA\07\106 (1.83 mm), NG\SA\07\052 (1.78 mm), NG\SA\07\137 (1.77 mm), OM1 (1.75 mm), OKENE MKT (1.76 mm) and NCRI BEN 02M (1.79 mm). The above width score was identical to the mean scores of the existing investigation.

Rizki *et al.* (2015) estimated the width in sesame seed varieties grown at the Tadla-Azilal area, Morocco. The width of the sesame seed varieties were ranged from 1.3 to 1.5mm which was lower than the present investigated sesame seed varieties (JCS 1020, HIMA and SWETHA).

Thickness: The thickness of the three sesame seed varieties were observed similar for the thickness of sesame seed varieties were observed for HIMA (0.80±0.25mm) and SWETHA (0.80±0.13mm) whereas JCS 1020 (0.79± 0.05mm) variety had a slight variation compared to HIMA and SWETHA. Results concluded that there was no significant difference ($p<0.05$) between the thickness of JCS 1020, HIMA and SWETHA.

Adebowale *et al.* (2010) was investigated the thickness in improved varieties of sesame seeds obtained from the National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, Nigeria and represented as follows NCRI NGB\04\026 (0.79mm), NCRI BEN 03L (0.76mm), NG\SA\07\179 (0.76mm), NG\SA\07\090 (0.92mm), NG\SA\07\095 (0.91mm), NG\SA\07\106 (0.97mm), NG\SA\07\052 (0.95mm), NG\SA\07\137 (2.95mm), OM1 (0.89mm), YANDEF 55 (1.65mm), OKENE MKT (0.86mm) and NCRI BEN 02M (0.88mm). Theese findings were on par with the present investigation.

The similar research study was conducted by Darvishi (2012) for the length, width and thickness in commerical sesame seed variety obtained from the Agricultural Garden of Ilam University, Iran. The length, width and thickness for sesame seed were 2.997± 0.0053mm, 1.806±0.0087mm and 0.702±0.0045mm respectively. Compared to these results, present study sesame seed varieties had more length, width and thickness.

Azeez and Morakinyo (2011) analysed the length, width and thickness in randomly picked sesame seeds from nine accessions. Among them AYK (3.07 mm) and PACH (3.15) showed similar values of length to the present study. The highest score of the width of sesame seed varieties was (IBS) 2.84 followed by AZO (2.55mm), EVA (2.51 mm) and 65-8B (2.09 mm) which were higher than the present study whereas the AYK (1.95 mm) and PACH (1.94 mm) had the similar width values with the existing study. The mean score of thickness was ranged from (1.28mm) AZO to C-K2 (0.61 mm) identical to the present investigation.

Table 1 Dimensional properties of sesame seed varieties

Sesame seed varieties	Dimensional properties				
	Length (mm)	Width (mm)	Thickness (mm)	Geometric diameter (mm)	Arithmetic diameter (mm)
JCS 1020	$3.05^a \pm 0.04$	$1.90^a \pm 0.02$	$0.79^a \pm 0.05$	$1.52^b \pm 0.001$	$1.916^a \pm 0.001$
Hima	$3.17^a \pm 0.02$	$1.88^a \pm 0.08$	$0.80^a \pm 0.25$	$1.59^c \pm 0.001$	$1.953^a \pm 0.001$
Swetha	$3.05^a \pm 0.05$	$1.79^a \pm 0.05$	$0.80^a \pm 0.13$	$1.45^a \pm 0.009$	$1.881^a \pm 0.001$
Mean	3.09	1.86	0.79	1.52	1.91
F-Value	2.570	0.995	0.36	7.95	1.180
P Value	0.156	0.424	0.965	0.001**	0.000**

Note: Values were expressed as mean standard deviation for all the three determinants. Means within the same column followed by a common letter do not significantly differ at *p<0.05, **p<0.01 level of significance.

Table 2 Gravimetric properties of sesame seed varieties

Sesame seed varieties	Gravimetric properties			
	1000 seed weight (g)	Bulk density(g/ml)	True density (g/ml)	Porosity (kgm^3)
JCS 1020	2.92b± 0.009	0.60a ± 0.007	1.04a ± 0.00	38.20c±0.69
Hima	2.90a ± 0.006	0.61b± 0.001	1.04a± 0.00	36.76b±0.14
Swetha	2.95c± 0.011	0.62c± 0.004	1.04a ± 0.00	35.73a±0.38
Mean	2.93	0.61	1.04	36.89
F-Value	8.191	7.171	0.00	7.168
P Value	0.019*	0.026*	0.00	0.026*

Note: Values were expressed as mean standard deviation for all the three determinants. Means within the same column followed by a common letter do not significantly differ at *p<0.05, **p<0.01 level of significance

Gravimetric properties:

1000-seed weight: The 1000 seed weight is a very important measure of seed quality, which is effective on sprouting, seed potential, seedling growth and plant performance (Afshari *et al.,* 2011). The 1000 seed weight showed the highest mean score for Swetha (2.95±0.011g) whereas Hima (2.90 ± 0.006g) showed the lowest mean score. Results indicated that there was a significant difference at (p<0.05) among the three sesame seed varieties with the 1000 seed weight.

Similar results were reported by Zebib *et al.* (2015) in the T-85 (2.98 ± 0.09g) sesame seed variety for 1000 seed weight.

Araujio *et al.* (2018) analysed the 1000 seed weight was reported at 90% of the maturation level in CNPA G4 cream coloured variety of sesame seed in Brazil. The 1000 seed weight was 2.6g which was lower than the sesame seed varieties of the present study.

Identical results for 1000 seed weight was investigated by Adebowale *et al.* (2010) in improved varieties of sesame seeds obtained from the National Centre for Genetic

Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, Nigeria. NCRI BEN 01M (2.68 g), NG\SA\07\095 (3.12 g), NG\SA\07\106 (3.05 g), OM1 (2.88 g), OKENE MKT (2.93g) and NCRI BEN 02M (2.71g).

Bulk density and True density: Bulk density is the weight of the material including the inter granular air space in unit volume. The bulk density and true density are important in separating and grading of seeds and it plays a significant role in drying, design of silos (a structure for storage of bulk material), separation of undesirable materials and seed purity (Aremu *et al.,* 2014; Mohsenin, 1980). The highest bulk density was noted for SWETHA (0.62 ± 0.004 g/ml) followed by HIMA (0.61 ± 0.001 g/ml) and JCS 1020 (0.60 ± 0.007 g/ml) Whereas the mean scores for the true density showed the same mean score (1.04±0.00) for all the three sesame seed varieties (JCS 1020, HIMA and SWETHA). Results concluded that there was a significant difference ($p<0.05$) between the bulk density for JCS 1020, HIMA and SWETHA whereas true density there was no significant difference at $p<0.05$ level of significance.

Janardhan *et al.* (2017) estimated the true density and bulk density in sesame seeds. The true density of sesame seeds was 1.085 g/ml which is similar to the present investigation. The bulk density for the sesame seeds was 0.592, g/ml. It was lower than the present investigation.

Porosity: Porosity is defined as the ratio of empty space of seeds to its total volume. Porosity values are also very important in the storage process. Because of an increase in voids and consequently in the amount of air in voids, the respiration velocity of materials, which are still active, increases during the storage of seeds (Rahman. 2001). The highest mean score for the porosity was observed for JCS 1020 (38.201±0.69%) whereas SWETHA (35.73±0.38%) variety scored the lowest mean value. Results indicated that there was a significant difference ($p<0.05$) between the porosity for all three sesame seed varieties.

Janardhan *et al.* (2017) estimated the porosity in sesame seeds was 45.41% and it was higher than the present study.

Geometric diameter: Mean scores for the geometric diameter maximum and minimum scores were observed in HIMA (1.59±0.001mm) and SWETHA (1.45±0.009mm) sesame seed varieties. Results showed that there was a significant difference ($p<0.01$) between the geometric diameter for JCS 1020, HIMA and SWETHA.

Similar research was investigated by Adebowalw *et al.* (2010) in improved varieties of sesame seeds obtained from the National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, Nigeria. The geometric mean diameter of sesame seed varieties was NGB\04\026 (1.50mm), NCRI BEN 03L (1.45mm), NG\SA\07\179 (1.43mm), OKENE MKT (1.52mm) and NCRI BEN 02M (1.57mm) respectively.

Arithmetic diameter: The arithmetic diameter mean score was given highest for HIMA (1.953±0.001mm) followed by JCS 1020 (1.916± 0.001mm). The lowest arithmetic diameter was observed for SWETHA (1.881±0.001mm) variety. Results stated that there was no significant difference ($p<0.01$) between the Arithmetic diameter for three sesame seed varieties (JCS 1020, HIMA and SWETHA).

Adebowalw *et al.* (2010) reported the arithmetic diameter of the improved varieties of sesame seeds were done by National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, Nigeria and reported were NCRI BEN 01M (1.91mm), NG\SA\07\095 (1.91mm) and NG\SA\07\052 (1.86mm) which were similar to the present study.

Arafa. (2007) reported the physical parameters in improved sesame seed variety (Giza 32). The physical parameters of sesame seed were reported for length (2.5±0.16 mm), width (1.65± 0.13 mm), thickness (0.94 ±0.07 mm), 1000 seed weight (10±0.00 g), bulk density (0.640±0.00 kg/m^3), geometric diameter (1.57 ±0.089 mm), arithmetic diameter (1.29± 0.087 mm).

Similar results were reported by Tunde-Akintunde and Akintunde (2004) for the arithmetic diameter was analyzed in locally available sesame seeds in Ibadan, a Western state in Nigeria. Results showed that length (2.80 0.32mm), width (1.69 0.19mm), thickness (0.82 0.10mm) and geometric diameter (1.56 0.17mm).

The present investigation on the antioxidant activity of sesame seed varieties (JCS 1020, Hima and Swetha) was found to be similar among the tree sesame seed varieties (5.27 µg/ml). The evaluated physical parameters of length (3.17± 0.02 mm), thickness (0.80± 0.25mm), geometric mean (1.59±0.001 mm) and arithmetic diameter (1.95±0.001 mm) were found high in HIMA sesame seed variety. The other physical parameters such as width (1.90±0.02 mm) and porosity (38.20±0.69 mm) were highest for JCS 1020 variety whereas 1000 seed weight (2.95± 0.011 g) and bulk density (0.62±0.00 g/ml) were scored more for SWETHA variety of sesame seed. The findings of the physical parameters were like 1000 seed weight, bulk density, porosity had significant differences at $p<0.05$ whereas the geometric mean had a significant difference at $p<0.01$ level of significance. The white colour and antioxidant activity of the selected sesame seed varieties can be tapped of antioxidant rich value-added products.

ACKNOWLEDGMENT

Sincere thanks to the Department of Foods and Nutrition, Post Graduate and Research Center, PJTSAU for providing the research work on sesame seed varieties and encouragement.

Conflict of Interest: "The authors declare no conflict of interest." The authors did not identify any personal circumstances or interest that may be perceived as inappropriately influencing the representation or interpretation of reported research results.

REFERENCES

Adebowale A A, Sanni S A and Falore O A 2010. Varietal Differences in the Physical Properties and Proximate Composition of Elite Sesame Seeds. *Libyan Agriculture Research Center Journal International,* **1**(2): 103-107.

Angel I and Poonguzhalan R 2022. Yield and nutrient uptake of sesame (*Sesamum indicum* L.) as influenced by plant growth regulators. *Journal of Oilseeds Research,* **39**(1): 55-57.

Afshari H, Eftekhari M, Faraji M, Ebadi A G and Ghanbarimalidareh A 2011. Studying the effect of 1000 grain weight on the sprouting of different species of *Salvia* L. grown in Iran. *Journal of Medicinal Plants Research,* **5**(16): 3991-3993.

Anilakumar K R, Pal A, Khanum F and Bawa A S 2010. Nutritional, medicinal and industrial uses of sesame (*Sesamum indicum* L.) seeds - An overview. *Agriculturae Conspectus Scientificus,* **75**(4): 159-168.

Arafa G K 2007. Some physical and mechanical properties of sesame seeds concerning the selection of separation unit. *Misr Journal of Agriculture Engineering,* **24**(2): 415-429.

Araujo M E V, Eloiny G, Barbosa, Felipe A, Gomes, Itamar R, Teixeira, Cristiane F, Lisboa, Rodrigo S L, Araujo, Paulo C and Correa 2018. Physical properties of sesame seeds harvested at different maturation stages and thirds of the plant. *Chilean Journal of Agricultural Research,* **78**(4): 495-502.

Aremu A K, Akinoso R and Olasoji O M 2014. Effect of storage conditions and duration on selected physical and mechanical properties of star apple fruit (*Chrysophyllum* spp). *The Journal of the Association of Professionals of Trinidad and Tobago,* **42**(1): 33-39.

Azeez and Morakinyo 2011. Genetic diversity of the seed physical dimensions in cultivated and wild relatives of sesame (*Genera sesamum* Ceratotheca). *International Journal of Plant Breeding and Genetics,* **5**(4): 369-378.

Cheng F C, Jinn T R, Hou R C, Tzen J T 2006. Neuroprotective effects of sesamin and sesamolin on gerbil brain in cerebral ischemia. *International Journal of Biomedical Science,* **2**(28): 4-8.

Darvishi H 2012. Moisture-Dependent Physical and Mechanical Properties of White Sesame Seed. *American-Eurasian Journal of Agriculture and Environmental Sciences*, **12** (2): 198-203.

Ghani N A, Channip A, Hwa P C H, Jaafar F, Yasin H M and Usman A 2018. Physicochemical properties, antioxidant capacities, and metal contents of virgin coconut oil produced by wet and dry processes. *Food Science and Nutrition.* DOI: 10.1002/fsn3.671.

Janardhan B G 2017. Thesis on studies on extraction, physico-chemical and nutritional characterization of oil from different oilseeds and it's utilization in development of fat spread. Thesis. 1-173.

Johnson L A, Suleiman T M, Lusas E W 1979. Sesame Protein: A Review and Prospectus. *Journal of American Oil Chemists Society,* **56**: 463-468.

Kumar V, Sinha S, Sinha S and Singh S N 2022. Characterization of diverse sesame (*Sesamum indicum* L.) panel through morphological and molecular marker analysis. *Journal of Oilseeds Research,* **39**(2): 77-85,

Mohsenin N N 1980. *Physical Properties of Plant and Animal Materials.* Gordon and Breach Press, New York, USA. 742 p.

Nie, Norman H, Bent, Dale H and Hull H C 1970. SPSS: Statistical package for the social sciences. ISBN 9780070465305.

Pathak N, Rai A K, Kumari R and Bhat K V 2014. Value addition in sesame: A perspective on bioactive components for enhancing utility and profitability. *Phormocognacy Reviews,* **8**: 147-55.

Philip J K, Joseph Z B, Jestina B K and Kandeh J B A 2010. Nutraceutical importance of sesame seed and oil: A review of the contribution of their lignans. *Journal of Biomedical Research*, **2**(1): 4-16.

Pratyusha C, Sinha S, Satyendra, Thakur D and Singh S N 2022. Assessment of genetic variability, correlation and path analysis in sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research,* **39**(3 & 4): 256-260.

Rahman M S 2001. Toward Prediction of Porosity in Foods during Drying: a Brief Review. *Drying Technology,* **19**(1): 1-13.

Rizki H, Kzaiber F, Elharfi M, Nablousi A and Hanine H. 2015. Chemical composition and morphological markers of 35 cultivars of sesame (*Sesamum indicum.* L) from different areas in Morocco. *International Journal of Technology Enhancements and Emerging Engineering Research,* **3**(1): 50-55.

Ruslan K, Happyniar S and Fidrianny I 2018. Antioxidant potential of two varieties of *Sesamum indicum* L. collected from Indonesia. *Journal of Taibah University Medical Science,* **13**(3): 211-218.

Shahidi F, Chandrika M, Liyana-PathiranaDana S W 2006. Antioxidative activity of the crude extract of lignan glycosides from unroasted burma black sesame meal. *Food Chemistry,* **99**(3): 478-483.

Tunde-Akintunde T Y and Akintunde B O 2004. Some Physical Properties of Sesame Seed. *Biosystems Engineering,* **88**(1): 127-129.

Vimala S and Adenan M I 1999. Malaysian tropical forest medicinal plants: a source of natural antioxidants. *Journal of Tropical Forest Production,* **5**:32-38.

Zebib H, Bultosa G and Abera S. 2015. Physico-chemical properties of sesame (*Sesamum indicum* L.) varieties grown in northern area, Ethiopia. *Agricultural Sciences,* **6**: 238-246.

Effect of blending on physicochemical properties of groundnut, palm, and sunflower oil blends

PREETI BAJPAI* AND RENU MOGRA

Department of Foods & Nutrition, Maharana Pratap University of Agril. and Technology, Udaipur-313 001, Rajasthan

(Received: May 10, 2023; Revised: June 14, 2023; Accepted: June 17, 2023)

ABSTRACT

The composition of the diet plays an important role in the management of lipid and lipoprotein concentrations in the blood. Vegetable oil plays a vital role in determining the human health due to its fatty acid composition. High intakes of saturated fatty acids (SFA) increase blood levels of total and low-density lipoprotein cholesterol (LDL-C) and accelerate the process of atherosclerosis. On the other hand, monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) have the opposite effects. According to WHO and other health agencies, nutritionally superior oil must fall in the ratio of 1:1-3:1; SFA, MUFA and PUFA, respectively, however evidences suggest that no single oil can provide the recommended dietary fat ratio. To combat this fatty acid ratio problem, blending of vegetable oils is gaining popularity in the oil industry to satisfy consumer needs. Present investigation was carried out with the objective of evaluating the effect of blending on physicochemical properties of groundnut, palm and sunflower oil blends. The physicochemical properties like specific gravity, refractive index, smoke point, moisture, and free fatty acid value, peroxide value, saponification value and iodine value of vegetable oils and its blend in ratio of 50:25:25 of groundnut oil, palm oil and sunflower oil respectively were evaluated using standard analysis methods. It was observed that blending of groundnut oil with palm oil and sunflower oil affected and improved the physicochemical properties of the oil blend.

Keywords: Blending, Fatty acid composition, Groundnut, Oil, Palm, Sunflower, Sensory characteristics

Groundnuts are rich source of oil containing about 47-50 per cent oil. Groundnut oil is one of the major edible oils in India. Hence, its blending with other less commonly consumed oils will incorporate traditionally accepted flavor. Groundnut oil is composed of mixed glycerides and contains a high proportion of unsaturated fatty acids, in particular, oleic (60 %) and linoleic (22 %). Groundnut oil with only traces of linolenic acid has excellent oxidative stability and considered as premium cooking and frying oil. In groundnut oil oleic and linoleic acid constitute 97 per cent of the fatty acids and total tocopherol is 53 mg/100g. Its flavor is more widely accepted by the consumer. Groundnut oil also lowers total cholesterol and low-density lipoprotein cholesterol, but do not lower the beneficial high-density lipoprotein cholesterol (Sander *et al.,* 2003; Suthar *et al.,* 2022).

Palm oil is the excellent fat for frying since it is a very stable oil. Good quality palm oil exhibits better oxidation characteristics than other hydrogenated vegetable oil in frying applications. Addition of palm oil to fats destined for shortening and margarine production has a beneficial effect on their polymorphic stability. Stabilizing effect of palm oil is related to increased chain length diversity of fatty acids in blends. Palm oil is the richest natural plant source of carotenoids with concentration of 500-700 ppm, which is not removed during refining, and tocotrienols, which can be used to prevent vitamin A deficiency, which is widespread in India. This gives an easily available source of vitamin E and increased stability to oil. Sunflower is a major oilseed crop. Sunflower oil contains about 13 per cent saturated fats, 27 per cent monounsaturated and 60 per cent polyunsaturated fats (Ghafoorunissa *et al.,* 2000; Nazrin *et al.,* 2022). It contains highest-level alpha tocopherol, the most active form of vitamin E. The principal uses of sunflower oil are as salad and cooking oil. It has high concentration of linoleic acid and pleasing flavor and odor, which contribute to make sunflower highly acceptable for food use. The range of oleic acid (14-34 %) and linoleic acid (44-72 %) in sunflower oil depends on varietal differences and environmental conditions during maturing period of seeds. It is used for deep-frying and as an ingredient for mayonnaise, salad dressings, and liquid margarine. Owing to the importance of fats and oil in our diet for the body and increasing concern toward health of people it becomes important to develop oil blends using non-conventional oils which possess good quality of fatty acid that is healthy for heart and also to evaluate the effect of blending on physicochemical characteristics of oil blends.

MATERIALS AND METHODS

I. Preparation of Oil Blends

a) Calculation and balancing of fatty acid composition: Available literature on fatty acid composition of groundnut,

*Corresponding author's E-mail: preetidixit07@yahoo.com

palm and sunflower was reviewed and selected for blending. Oils were mixed in such different proportions so as to achieve ideal fatty acid ratio i.e. 1: 1-3 :1 of saturated fatty acids: monounsaturated fatty acids: polyunsaturated fatty acids as suggested by SAARC Oils & Fat (Anonymous, 2005). In all, twenty-three combinations were tried and fatty acid composition was calculated. Out of twenty three calculated combinations, one combination of groundnut (G), palm (P) and sunflower oil (SfO) named as GPSfO was found to contain optimal ratio of 1: 1-3: 1 for SFA: MUFA: PUFA and selected for physicochemical evaluation.

b) Procurement of oil and preparation of oil blends: For the preparation of oil blend, refined groundnut, palm and sunflower oil were purchased in bulk from the market. Selected oil blend GPSfO was prepared in bulk by mixing groundnut, palm and sunflower oil in a pre-calculated ratio of 50:25:25 of each oil respectively. Groundnut oil is one of the most commonly used oil in Indian household having a good nutritional profile and rich aroma making it suitable for blending with other oils. Considering major contribution of groundnut oil in routine diets, it has been used as control oil in present investigation.

II. Quality Evaluation of Designed Oil Blend

Physico-chemical analysis: Physical properties *viz.,* specific gravity (AOAC, 2000), refractive index (AOAC,2000) turbidity (Sadar, 1998), viscosity (Nielsen, 2010), color values (Nielsen, 2010) were determined using standard procedures. Smoke point was measured by using digital infrared thermometer in degree centigrade.

Chemical properties: Moisture content (AOAC, 2007), Free fatty Acids, Peroxide value, iodine value and saponification value (Nielson, 2010), Iodine value (AOAC, 2000) were analyzed.

RESULTS AND DISCUSSION

Physico-Chemical analysis:

Specific gravity: Specific gravity is linearly correlated to the degree of unsaturation and chain length of fatty acid predominant in oil. Specific gravity of sunflower oil was highest (0.918) and lowest was in palm oil (0.891) whereas groundnut oil was found to have specific gravity of 0.914. Specific gravity of the designed oil blend was 0.9083. The results are closely in agreement with the finding of Chugh and Dhawan (2014) who found the specific gravity as 0.923 units of sunflower oil. Higher values for specific gravity of sunflower might be due to the presence of high amount of unsaturated fatty acids.

Refractive index (RI): The refractive index reflects the relationship between the speed of light in the air and in the oil. This value increases with chain length and fatty acid unsaturation and is associated to the iodine index (Ordonez-Pereda, 2005). The refractive index (RI) of fats and oils is sensitive to their composition. In fats, RI increases with increasing chain length of fatty acids in the triglycerides or with increasing unsaturation. This makes it an excellent spot test for uniformity of compositions of oils and fats. Refractive index of sunflower was found to be highest i.e. 1.479 while the lowest refractive index was observed in palm oil i.e. 1.450 among individual oils. Refractive index of designed oil blend GPSfO was 1.49, which was higher than individual oils used for blending which indicated the presence of high amount of unsaturated fatty acids. The value of refractive index for sunflower oil was 1.479, which is in agreement with the findings of Fakhri and Qadir (2011) who observed the RI of the sunflower oil to be 1.475.

Viscosity: Viscosity refers to the flow of the oil, and is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of the specific size (Topallar and Bayrak, 1998). Therefore, viscosity is closely correlated with the structural parameters of the fluid particles. The oil viscosity has a direct relationship with some chemical characteristics of the lipids, such as the degree of unsaturation and the chain length of the fatty acids that constitute the triacylglycerols (Brien, 2009). Its value increases with increasing degree of saturation and decreases with the increase in temperature (Salimon and Abdullah, 2008), also the viscosity decreases slightly with increase in the degree of unsaturation. A critical examination of data revealed that viscosity of the oils ranged from 77 cps to 33 cps at 40°C. Palm oil was highly viscous (77 cps) than other counterparts whereas sunflower oil showed lowest viscosity (33 cps). Higher viscosity of palm oil may be due to the presence of higher amount of saturated fatty acids. The results are in agreement with the findings of Fakhri and Qadir (2011) who also reported viscosity of sunflower oil as 31 cps at the temperature of 40°C. Viscosity of designed oil blend GPSfO was 38 cps at 40°C. Blending of groundnut oil with sunflower and palm oil influenced the viscosity of blended oil as it slightly increased (38 cps) when compared with individual groundnut oil (34.61 cps) and rice bran oil (33) but decreased as compared to palm oil (77 cps). Pandurangan *et al.* (2014) blended groundnut oil with rice bran oil and palm oil in proportion of 85:15 and 90:10 and reported that blended oil of groundnut and palm oil had the increased the viscosity of blended oil (59.46 cps) as compared to viscosity of groundnut oil (53.14 cps) but decreased as compared to viscosity of palm oil. Blending of groundnut oil with rice bran oil in ratio of 90:10 resulted in increase in viscosity (56.46 cps) as compared to single groundnut (53.14) and rice bran oil (46.32 cps).

Turbidity: Turbidity is the cloudiness or haziness of a fluid and is caused by large number of individual particles that are generally invisible to the naked eye, similar to smoke in air. The designed oil blend (GPSfO) was less turbid than the other individual oils used to prepare oil blend. Groundnut oil was observed to have lowest turbidity 39 NTU whereas palm oil resulted with the highest turbidity with 58 NTU among the individual oils.

Hunter color values: CIE Tristimulus Hunter color L*, a* and b* values were determined for control and experimental oils. L* values denotes the lightness of the object and it ranged between 0 (complete black) to 100 (complete white). CIE Tristimulus Hunter color a* values denotes the green-red axis of the color. Positive a* values denotes the red color while negative a* values denotes the green color. Hunter color scale b* value denotes the comparative yellow-blue axis. Positive b* values represent yellow color while negative b* values represent blue color. The color intensity is higher with the increase in the absolute values. L* values of the oil samples ranged from highest (5.1) of palm oil to lowest (2.24) of groundnut oil. Sunflower oil was found to have L* values 3.20. Minimum a* value (0.29) was recorded in sunflower oil while maximum a* value (0.59) was observed in palm oil denoting the belongingness to red axis. Minimum b* value (4.14) was recorded in sunflower oil while maximum b* value (5.14) was observed in the palm oil sample indicating a positive relationship with yellow color axis. Designed oil blend was found to have L* values 3.29, a* value 0.39 and b* value as 4.46 indicating a positive orientation with red and yellow color axis. Gulla and Waghray, (2011) reported color value of sesame + soybean (20:80) and sesame + palmolein (80:20) oil blend as 1.16 and 9.2 respectively.

Smoke point: Smoke point is used to determine purity and adulteration of oil. It is affected by free fatty acid percentage and length of carbon chain of fatty acids. Increase in percentage of free fatty acids leads to decrease in the smoke point. On the other hand, increase in length of carbon chain causes an increase in smoke point. Data presented in Table 1 reveals that the highest smoke point was observed in groundnut oil (232°C) followed by sunflower oil (230°C). Palm oil showed the lowest value at 216°C. Smoke point of the designed oil blend GPSfO was 227°C, which indicated its suitability for frying and cooking. The high smoke point prevents the isomerization and polymerization of fatty acids and also generation of free radicals at high temperature (Anonymous, 2005).

Chemical properties

Moisture content: Moisture content is directly related to shelf life of the product. Higher percent of moisture increases the chances of hydrolytic activities and thus lowers the shelf life of the oil. Moisture content was recorded maximum in sunflower oil (0.021 %), followed by that of palm oil (0.020% and minimum was recorded in groundnut oil (0.09 %). The moisture content of designed oil blend GPSfO was 0.013 percent. Chopra (2006) studied and reported moisture content of groundnut oil, sunflower oil and palm oil as 0.083 percent, 0.085 percent and 0.094 percent respectively which are higher than the values observed in the present investigation.

Free fatty acids: Free fatty acid (% FFA) content is a conventional expression of the percentage mass- fraction of total fat, related to the extent of hydrolysis and tells about the chances of rancidity of oil. According to the nature of the fat it is expressed as lauric acid for coconut, palm kernel, and similar oils, as palmitic acid for palm oil and as oleic acid for all other oils (Gunstone, 2004). Palm oil contained highest 0.47 percent of free fatty acids while sunflower oil contained lowest 0.25 percent of free fatty acids among individual oils. Groundnut oil was found to have 0.28 percent as free fatty acids. The results for the free fatty acid percent of the palm oil (0.47) was in line with the findings of Bernin and Garba (2011) who reported 0.53 percent of free fatty acid in palm oil. GPSfO oil blend had 0.23 percent of free fatty acids, which is slightly lower than values for individual oils *viz.,* groundnut oil (0.28 %), palm oil (0.47 %) and sunflower oil (0.25%). A few workers (Pandurangan *et al.,* 2014; Semwal and Arya, 2001; Padmavathy *et al.,* 2001; Sarojini and Bhawani, 1997) observed the same trends on the stability of edible oils after blending process. Low acid value, prevents the oxidation of oil resulting in decreased hydrolytic and lipolytic activities in the oil. The results indicated that the acid value which is an index of free fatty acid content due to enzymatic activity in the samples was found to be below the minimum acceptable value of 4.0 per cent recommended by the Codex Alimentarius Commission for oil seeds (Abayeh *et al.,* 1998).

Peroxide value: The peroxide value of oil is used as a measure of the extent to which rancidity reactions have occurred during storage. The best test for autoxidation (oxidative rancidity) is determination of the peroxide value. Peroxide value is also a measure of initial and primary products of lipid oxidation and used frequently in predicting quality of edible oils. The range of peroxide values for the all the oils was 0.48 to 1.78 meq/kg oil which is less than 10 meq/Kg, and therefore within the acceptable value range for fresh oil (Codex Alimentarius, 1999). Chopra (2006) observed higher peroxide value for groundnut oil as 3.42 meq/kg, for palm oil as 4.72 and for sunflower oil as 2.84 than the values observed in the present study. In the present study, peroxide value of designed oil blend GPSfO was 0.58 meq/kg which is lower than maximum limit of 10 meq/kg suggested by Codex Alimentarius Commission for oil seeds (Abayeh *et al.,* 1998) indicating the oxidative stability and good quality of the oil for human consumption.

Saponification value: Saponification value is used to determine the average molecular weight and chain length of fatty acid present in oil. Since saponification value is related to the length of the fatty acid chain, it therefore decreases with the molecular weight of the fatty acid (Cecchi, 2003). As the molecular weight and chain length of predominant fatty acid increases, saponification value decreases. Saponification value was maximum in palm oil (196 mg KOH/g) and minimum in sunflower oil (189 mg KOH/g). These observations are in concurrence with the findings of Murthi *et al.* (1987) who also found saponification value as 199 mg for palm oil. According to Fakhri and Qadir (2011) saponification value of sunflower oil was in the range of 188-194 mg KOH/g whereas saponification values for palm oil was in the range of 195-205 mg KOH/g. Higher saponification value of palm oil might be attributed to its higher palmitic acid content which is low molecular weight fatty acid and saponification value increases with the decrease in molecular weight.

Iodine Value: The iodine value is the mass of iodine in grams that is consumed by 100 g of fat or oil. This unsaturation is in the form of double bonds, which reacts with grams of a chemical substance. The higher the iodine number, the more unsaturated fatty acid bonds are present in a fat (Ziyadal and. Elhussien, 2008). Maximum iodine value (132) g was found in sunflower oil and minimum (55.11) g in palm oil. The minimum iodine value observed in palm oil in the present study might be attributed to the presence of high amount of saturated fatty acids i.e. palmitic acid. Fakhri and Qadir (2011) studied the iodine value of different oils and found iodine value of sunflower oil and palm oil to be in range of 100 -140 and 45 - 56 respectively. Chopra *et al.* (2006) reported 98.4 iodine values for groundnut oil, 121.7 iodine value for sunflower oil and 50.5 iodine value for palm oil which are in close agreement with the findings of the present study. Iodine value of designed oil blend GPSfO was found to be 96.07 which is meeting the standards set for iodine value of edible oils by Codex Alimentarius Commission (CODEX-STAN 210 -1999).

The quality and properties of the oils and blend was evaluated through this study using different physicochemical parameters. Results showed that blending influenced and improved the physico-chemical properties of oil blend GPSfO. This study will help the oil producing industry to find the most economically viable oil blends for cooking purposes, with maximum nutrition as well as desirable physico-chemical properties. Thus blending is a good choice by which we can formulate edible oils of good characteristics and ensure their quality. The food value of the oils and blends can also be predetermined to provide the safest food for consumers.

Table 1 Physicochemical properties of individual oil and its blend GPSfO

Parameters	Groundnut	Palm	Sunflower	GPSfO blend
Specific gravity (at 30°C).	0.914	0.891	0.918	0.9083
Refractive index	1.470	1.450	1.479	1.491
Viscosity cps at 40°C	34.61	77	33	38
Turbidity NTU	39	58	42	35
Smoke point (°C)	232	216	230	227
Moisture (%)	0.09 ± 0.15	0.020 ±0.05	0.021 ±0.09	0.013 ± 0.15
Free fatty acids (%)	0.28 ± 0.36	0.47 ± 0.59	0.25 ± 0.40	0.23 ± 0.35
Peroxide value meq/kg	1.78 ± 0.21	0.48 ± 0.16	0.97 ± 0.23	0.58 ± 3.60
Saponification value (mg KOH/g)	190 ± 0.43	196 ± 0.07	189 ± 0.68	197.2 ± 5.72
Iodine value	95.30 ± 0.06	55.11 ± 0.30	132 ± 0.09	96.07 ± 10.3

Values are mean ± SE of three independent determinations

REFERENCES

AOAC 2000. Official methods of analysis. 17th edition, Association of Official Agricultural Chemists, Washington.

Abayeh O J, Aina E A and Okounghae C O 1998. Oil content and oil quality characteristics of some Nigerian oil seeds. *Journal of Pure and Applied Science,* **1**: 17-23.

Anonymous 2005. *Fat and Human Diet.* SAARC Oils and Fats Today, 7(11): 12-14.

Birnin-Yauri U A and Garba S 2011. Comparative studies on some physicochemical properties of baobab, vegetable, peanut and palm oils. *Nigerian Journal of Basic and Applied Sciences,* **19**(1).

Brien R D O 2009. *Fats and Oils,* 3rd ed., CRC Press, Taylor & Francis Group. pp. 2-52.

Cecchi H M 2003. *Theoretical and Practical Foundations in Food Analysis.* Campinas: Unicamp. 13.

Chopra E 2006. Improvement in quality of rice bran oil by blending with selected edible vegetable oils. M.Sc. thesis, submitted to Chaudhary Charan Singh Haryana Agriculture University, Hisar.

Chugh B and Dhawan K 2014. Storage studies on mustard oil blends. *Journal of Food Science and Technology,* **51**(4):762-767.

Codex Alimentariu S 1999. Codex standard for named vegetable oils, CODEX STAN 210-1999, Page 1 of 16 Adopted 1999. Revisions 2001, 2003, 2009. Amendment 2005, 2011.

Fakhri N A and Qadir H K 2011. Studies on various physico-chemical characteristics of some vegetable oils. *Journal of Environmental Science and Engineering,* **5**(7).

Ghafoorunissa, Vani A, Laxmi R and Sesikeran B 2000. Effects of dietary alpha-linolenic acid from blended oils on biochemical indices of coronary heart disease in Indians. *Lipids*, **37**: 1077-1086.

Gulla S and Waghray K 2011. Effect of storage on physico-chemical characteristics and fatty acid composition of selected oil blends. *Journal of Life Sciences,* **3**(1): 35-46.

Gunstone F D 2004. *The Chemistry of Oils and Fats,* Blackwell Publishing Ltd. pp. 1-112.

Murthi T N, Sharma M, Devdhara V D, Chatarjee S and Chakraborty B K 1987. Storage stability of edible oils and their blends. *Journal of Food Science and Technology,* **24**: 84-87.

Nazrin R, Archana A and Duraimurugan P 2022. A brief insight into the insect pest of sunflower (*Helianthus annuus* L.). *Journal of Oilseeds Research,* **39**(3&4): 165-173.

Nielsen S S 2010. Rheological Principles for food analysis. *In: Food Analysis.* Springer. New York. pp.167-168.

Ordoñez-Pereda 2005. Food components and processes. *JA Lipids.* JA Food Technology, 33-49.

Padmavathy A, Siddhu A and Sundararaj P 2001. Effect of blending edible grade crude palm oil with refined groundnut or sunflower oils on storage stability and sensory attributes. *Journal of Oil Technology Association India,* **33**: 93-103.

Pandurangan M K, Murugesan S and Gajivaradhan P 2014. Physico-chemical properties of groundnut oil and their blends with other vegetable oils. *Journal of Chemical and Pharmaceutical Research,* **6**: 60-66.

Sadar M J 1998. Turbidity Science. HACH, Technical information series. Booklet No. 11, 26 pp., accessed March 25, 2002, at URL www.hach.com/ASP/ categories.asp.

Salimon J and Abdullah R 2008. Routine and innovative chemical analysis of olive oil, *Sains Malaysiana,* **37**: 379-382.

Sanders T H, CabaL Lero B, Trugo L and Finglas P 2003. *Groundnut oil.* encyclopedia of food sciences and nutrition. Editors: Academic press Ltd.., London, U.K. pp. 2967-2974.

Sarojini G and Bhavani K N. 1997. Physico-chemical properties of stored red palm (*Elaeis guineensis*) oil blends. *Journal of Oil Technology Association India,* **29**: 20-20.

Semwal A D and Arya S S 2001. Studies on the stability and some edible oils and their blends during storage. *Journal of Food Science and Technology,* **38**(5): 515-518.

Suthar B, Pundir R S and Vijay Baldodiya 2022. Price behaviour of groundnut (*Arachis hypogaea* L.) in major markets of India. *Journal of Oilseeds Research,* **39**(2): 134-141.

Topallar H and Bayrak Y 1998. The effect of temperature on the dynamic viscosity of acetone sunflower-seed oil mixtures, *Turkish Journal of Chemistry,* **22**: 361-366.

Ziyadal A K and Elhussien S A 2008. Physical and chemical characteristics of *Citrulluslanatus* Var. Colocynthoide seed oil. *Journal of Physical Science,* **19**: 69-75.

Comparative analysis of omega-3 fatty acid desaturase *FAD7A-1* chloroplastic gene in castor

KARUNASHREE, G C SHEKHAR[1], B KISAN, B V TEMBHURNE, CHANNABASAVA, ANIL JADHAV* AND S BHARATHI

College of Agriculture, University of Agricultural Sciences (UAS), Raichur-584 104, Karnataka

(Received: May 22, 2023; Revised: June 23, 2023; Accepted: June 26, 2023)

ABSTRACT

Omega-3 Polyunsaturated fatty acids (PUFAs) are characterized by the presence of a double bond, three atoms away from the terminal methyl group in their chemical structure. These fatty acids play a crucial role in promoting health benefits. Castor, known for its applications in traditional medicine and as a lubricant, has been historically employed for its pain-relieving properties and enhancement of muscle activity. In the present study the omega-3 fatty acid desaturase FAD7A-1 chloroplastic (P48619, FAD3C_RICCO) gene sequence of castor was obtained from the NCBI data base was analyzed for its diversity, amino acid composition and phylogenetic relatedness with other species harboring the gene. The phylogenetic tree of 13 aligned sequences clustered into two clusters and the amino acids varied between the species evaluated.

Keywords: Castor, *FAD7A-1* gene, Omega-3 (PUFAs), Phylogenetic tree

Fatty acid desaturase is an enzyme which removes two hydrogen atoms from a fatty acid and creates a carbon double bond of a fatty acid. Desaturation occurs to maintain and function of membranes within cells of the organisms, with the addition of one carbon double allows the membrane to maintain fluidity. Plants have many fatty acid desaturases, most of them are located in Endoplasmic reticulum and chloroplast. Chloroplast omega-3 fatty acid desaturase introduces the third double bond in the biosynthesis of 16:3 and 18:3 fatty acids, important constituents of plant membranes. It uses ferredoxin as an electron donor. These fatty acids are esterified to galactolipids, sulfolipids and phosphatidylglycerol.

In their study, Loo and Somerville (1994) examined the composition of omega-3 fatty acids in developing castor (*Ricinus communis*) seeds. They isolated cDNA (pFL1) and found significant sequence similarity to omega-3 desaturases of Brassica. The 1958-bp clone contained a 1380-bp open reading frame, encoding a protein of 52,558 D. The cDNA shared high sequence identity at the nucleotide and amino acid levels with the fad7 sequence from Arabidopsis (78% and 73%), the *B. napus* fad3 sequence (70% and 72%) compared to a cyanobacterial A12 desaturase (47% and 27%), suggesting that it encodes a plastid w-3 desaturase in castor. In the present study, the omega-3 fatty acid desaturase FAD7A-1 chloroplastic gene (P48619, FAD3C_RICCO) from castor leaves was analyzed to understand the diversity of this gene. Thirteen gene sequences obtained from NCBI were subjected to diversity, phylogenetic, and amino acid composition analysis.

[1]College of Agriculture, Bheemarayana Gudi, UAS, Raichur-584 104, Karnataka; Corresponding author's E-mail: djanil10020@gmail.com

MATERIALS AND METHODS

Sequence retrieval and BLASTp analysis: To analyse omega-3 fatty acid gene variation in castor, the gene FAD7A-1 (*Ricinus communis*) coding for the chloroplastic omega-3 fatty acid desaturase, (P48619, FAD3C_RICCO) was retrieved from the uniprot database (https://www.uniprot.org/uniprot/P48619). Simultaneously, amino acid sequence of the *FAD7A-1* was obtained in FASTA format from the same database.

The FASTA sequence was subjected to BLASTp (protein-protein blast) analysis in the National Centre for Biotechnology Information (NCBI, https://www.ncbi.nlm.nih.gov/) database against UniProtKB/Swissprot (Swissport) database (https://blast.ncbi.nlm.nih.gov/Blast.cgi). The BLASTp analysis showed 48 significant sequence alignments. However, filtering sequences based on percent identity (60-100%) against query sequence produced 13 significant sequence alignments. These aligned sequences were then retrieved in FASTA format for further studies.

Sequence analysis: Clustal Omega was used for multiple sequence alignments of the gene and protein sequences. The resulting alignments are visualized through cladograms or phylograms, depicting evolutionary relationships (http:/www.ebi.ac.uk/Tools/msa/clustalo). BioEdit, was used to determine amino acid composition by analyzing the sequence tab, selecting protein, and then exploring the amino acid composition subsections. The output included the length of the amino acid sequence, molecular weight, and the count of each of the 20 amino acids with their respective molecular weights. (http://www.mbio.ncsu.edu/

BioEdit/bioedit.html). Molecular Evolutionary Genetics Analysis (MEGA) software was employed for statistical analysis of molecular evolution and the construction of phylogenetic trees (https://megasoftware.net/).

RESULTS AND DISCUSSION

Omega-3 (ω3) fatty acids are unsaturated essential fatty acids (EFAs). The term "Omega-3" or n-3 indicates that the first double bond is located at the third carbon from the methyl end of the fatty acid. Omega-3 fatty acids are the bioactive lipids eicosapentaenoic acid (EPA) and/or docosahexaenoic acid (DHA). (Sham and Aly, 2012).

Chloroplast omega-3 fatty acid desaturase FAD7A-1 belongs to histidine box domain proteins with an amino acid length of 460 and molecular weight of 52561 daltons. This protein is involved in the biosynthesis pathway of polyunsaturated fatty acid, which is part of lipid metabolism. Chloroplast omega-3 fatty acid desaturase introduces the third double bond in the biosynthesis of 16:3 and 18:3 fatty acids, important constituent of plant membranes. It is thought to use ferredoxin as an electron donor and to act on fatty acids esterified to galactolipids, sulfolipids and phosphatidylglycerol. (https://www.uniprot.org/uniprot/P48619).

The BLASTp (protein-protein blast) analysis: The BLASTp search was carried out in NCBI database using FAD7A-1 as query sequence against Swissport data base. A total of 48 significant sequence alignments were found. However, based on E-value, query cover and percent identity (60-100%) filtering, 13 sequences (P48619.1,P48622.1, P48620.1, P46310.1, Q56VS4.1,P48618.1,P48621.1, P32291.1.P48625.1. P48624.1.P48623.1, A3F5L2.1, Q594P3.1) were selected for comparisons and the salient information of these sequences are provided in Table 1.

Multiple sequence alignment and phylogenetic analysis: Multiple sequence alignment is prerequisite to comparative genomic analyses for identification and quantification of conserved regions or functional motifs in a whole sequence family, estimation of evolutionary divergence between sequences and even for ancestral sequence profiling (Kumar and Filipski, 2007).

Multiple sequence alignment (MSA) was carried out using ClustalO software and the result is depicted in Fig 1. Similarly, phylogenetic tree of 13 aligned sequence was generated using MEGA11 using neighbor-Joining (NJ) method and depicted in Fig 2. The phylogenetic tree obtained was further fragmented into three clusters. The cluster-I comprised of seven species i.e. *Arabidopsis thaliana* (P46310.1), *Brassica napus* (P48618.1), *Arabidopsis thaliana* (P48622.1), *Ricinus communis* (P48619.1), *Helianthus annuus* (Q56VS4.1), *Sesamum indicum* (P48620.1) and *Glycine max* (P48621.1). (Fig.1, Fig.2).

Whereas, cluster-II consisting of four species namely *Vigna radiata* (P32291.1), *Glycine max* (P48625.1), *Brassica napus* (P48624.1) and *Arabidopsis thaliana* (P48623.1). The cluster-III had two accessions belongs to Sorghum bicolor (A3F5L2.1, Q594P3.1). (Fig.1, Fig.2).

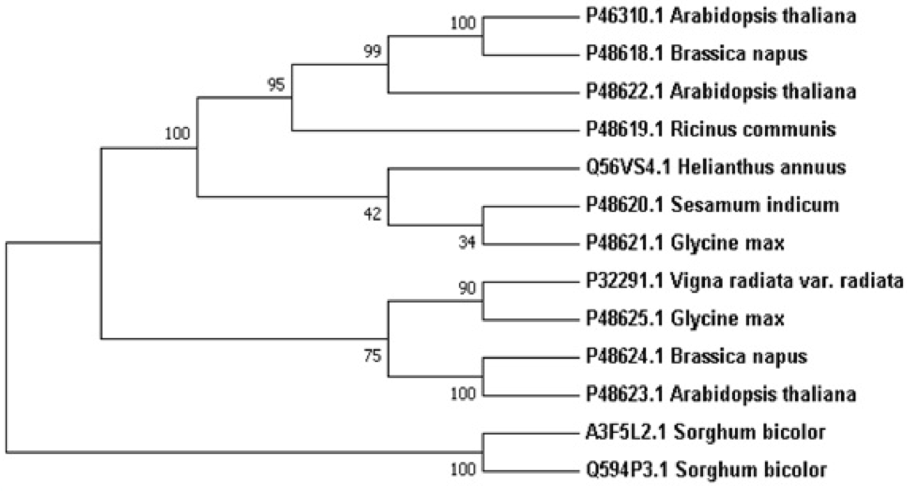

Fig. 1: Phylogenetic tree constructed based on amino acid sequence variation in *FAD7A-1* gene

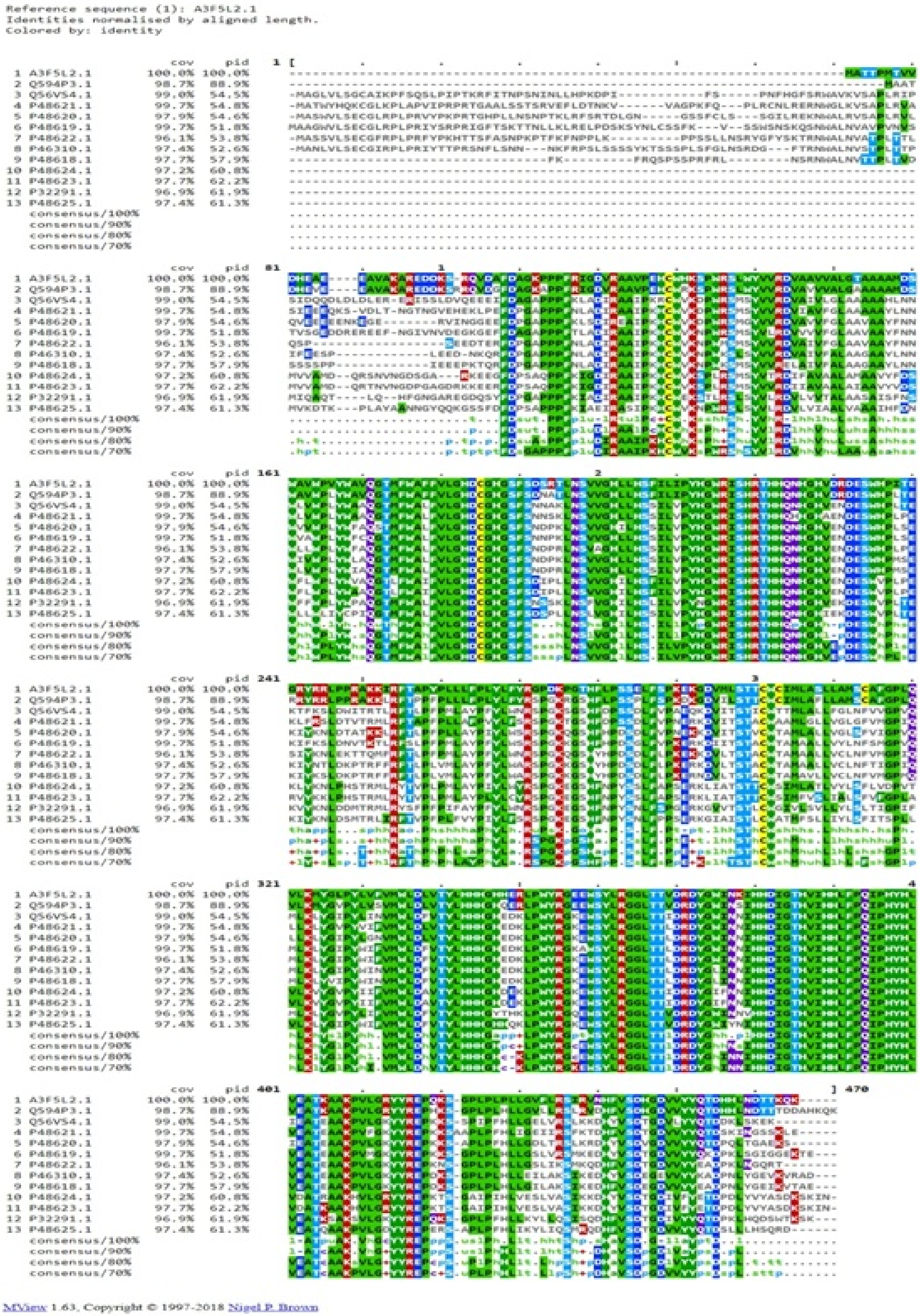

Fig. 2. Multiple sequence Alignment of *FAD7A-1* gene showing homologus sequences

Table 1 List of hits with their genbank ids obtained after BLAST search at NCBI (Blast analysis of *FAD7A-1* gene across different species)

Accession Number	Accession Description	Crop species	Accession length	Query cover (%)	E Value	Percent Identity
P48619.1	Omega-3 fatty acid desaturase, chloroplastic	*Ricinus communis*	460	100%	0.00	100%
P48622.1	Temperature sensitive sn-2 acyl-lipid omega-3 desaturase (ferredoxin)	*Arabidopsis thaliana*	435	98%	0.00	75.61%
P48620.1	Omega-3 fatty acid desaturase, chloroplastic	*Sesamum indicum*	447	98%	0.00	75.16%
P46310.1	sn-2 acyl-lipid omega-3 desaturase(ferredoxin), chloroplastic	*Arabidopsis thaliana*	446	98%	0.00	72.95%
Q56VS4.1	sn-2 acyl-lipid omega-3 desaturase(ferredoxin), chloroplastic	*Helianthus annuus*	443	97%	0.00	71.96%
P48618.1	Omega-3 fatty acid desaturase, chloroplastic	*Brassica napus*	404	91%	0.00	75.24%
P48621.1	Omega-3 fatty acid desaturase, chloroplastic	*Glycine max*	453	98%	0.00	70.80%
P32291.1	Omega-3 fatty acid desaturase, endoplasmic reticulum	*Vigna radiata*	380	77%	0.00	74.16%
P48625.1	Omega-3 fatty acid desaturase, endoplasmic reticulum	*Glycine max*	383	77%	0.00	72.83%
P48624.1	Acyl-lipid omega-3 desaturase (cytochrome b5), endoplasmic reticulum	*Brassica napus*	386	80%	0.00	70.89%
P48623.1	Acyl-lipid omega-3 desaturase (cytochrome b5), endoplasmic reticulum	*Arabidopsis thaliana*	388	81%	0.00	67.99%
A3F5L2.1	Probable fatty acid desaturase DES1: short=SbDES1 (Sorghum bicolor)	*Sorghum bicolor*	389	81%	4e-172	63.59%
Q594P3.1	Fatty acid desaturase DES3: short= Sorghum	*Sorghum bicolor*	389	81%	1e-168	67.29%

Table 2 Amino acid composition of *FAD7A-1* gene across different species

Amino Acids (%)	P.48619.1	P.48622.1	P48620.1	P48310.1	Q56VS4	P48618.1	P48621.1	P32291.1	P48625.1	P48624.1	P48623.1	A3F5L2	Q594P3
Ala	4.70	5.75	4.70	5.83	5.64	5.94	6.84	3.95	4.74	6.27	6.74	6.96	7.20
Cys	1.12	1.15	1.12	1.12	0.09	0.99	1.10	0.79	1.05	0.78	1.04	1.29	1.29
Asp	4.92	4.37	4.92	4.93	5.87	4.95	4.64	4.47	5.00	5.74	5.70	5.67	6.43
Glu	4.92	3.45	4.92	4.26	3.61	4.46	4.19	2.63	2.63	3.13	3.11	3.61	3.08
Phe	3.80	5.52	3.80	4.26	4.74	4.46	4.86	5.79	5.26	4.18	4.15	4.38	4.37
Gly	7.38	5.98	7.38	5.83	5.87	5.69	7.06	7.11	5.53	6.01	6.22	6.70	6.68
His	6.26	6.44	6.26	6.05	6.32	6.68	6.40	6.84	7.37	7.05	6.99	7.99	8.23
Ile	4.03	3.45	4.03	4.71	6.09	4.46	4.19	5.00	7.11	6.53	6.99	3.35	2.83
Lys	5.37	5.06	5.37	5.16	5.42	4.95	5.08	5.00	4.21	4.44	4.92	4.12	3.86
Leu	11.63	10.80	11.63	11.43	11.29	10.89	10.60	10.79	11.32	9.14	8.81	9.79	10.80
Met	1.12	2.53	1.12	1.57	1.58	2.23	1.55	1.58	1.58	2.09	1.81	2.32	1.80
Asn	3.80	4.60	3.80	5.16	3.61	4.21	3.53	3.16	2.63	2.61	2.33	1.29	1.29
Pro	7.38	8.74	7.38	7.62	7.22	7.92	7.28	6.32	7.11	6.53	6.74	7.22	6.68
Gln	1.79	2.07	1.79	1.12	2.26	1.49	1.77	3.42	2.89	1.31	1.30	2.06	2.06
Arg	4.92	3.91	4.92	4.48	4.29	4.46	4.86	3.68	4.21	4.44	4.66	6.19	6.94
Ser	6.94	6.90	6.94	7.40	7.22	6.68	6.62	8.42	7.89	7.57	7.25	5.41	5.91
Thr	4.25	5.29	4.25	4.71	4.51	4.21	4.86	5.00	4.21	4.70	4.15	5.15	4.37
Val	7.61	5.29	7.61	5.83	6.09	6.68	7.51	6.32	5.79	8.09	8.29	8.25	8.23
Trp	3.58	3.68	3.58	3.36	3.61	3.71	3.31	3.68	3.42	3.13	2.85	3.61	3.60
Tyr	4.47	5.06	4.47	5.16	3.84	4.95	3.75	6.05	6.05	6.27	5.96	4.64	4.37

Amino acid composition: Amino acid composition analysis was carried out using Bioedit software and results presented in Table 3. The amino acid composition of castor (Ricinus communis, P48619.1) in the present study is provided in Table 3 and it indicated that Leucine constituted the highest percentage (11.63%), followed by Valine (7.61%) Proline and Glycine (7.38%), Serine (6.94%), Histidine (6.26%) and Lysine (5.37%). Whereas, Alanine (4.70%), Cysteine (1.12%), Aspartic acid (4.92%), Glutamic acid (4.92%), Phenylalanine (3.80%), Isoleucine (4.03%), Methionine (1.12%), Aspargine (3.80%), Glutamine (1.79%), Arginine (4.92%), Threonine (4.25%), Tryptophan (3.58%) and Tyrosine (4.47%).

Loo and Somerville (1994) reported omega-3 desaturase in castor and deduced, and compared the gene sequence as well as amino acid sequences. The results suggested that the amino terminus of the predicted castor protein was having an extension similar to that of the fad7 protein but not found in the fad3 protein. This amino terminal extension is rich in the hydroxy amino acids Ser and Thr (23% of the first 78 residues), a characteristic feature of the transit peptide of plastid proteins supporting the assignment of the castor clone as a plastid desaturase. The sequence similarity between these 0-3 desaturases demonstrated the high degree of conservation between the ER and plastid forms and between the same enzymes from different species of higher plants.

As indicated in Table 2 and Figure 1, comparison of content of constituent amino acids indicated that leucine was the major amino acid in all the compared species. Oluwaniyi *et al.* (2010) studied the amino acid contents of *Clupea harengus, Scomber scombrus, Trachurus trachurus,* and Urophycis tenuis species and reported that the most abundant amino acids were glutamic acid, aspartic acid, lysine, and leucine while Suseno (2015) reported that the most abundant amino acids were glutamic acid, arginine, leucine, and lysine in tuna fish (*Thunnus* sp.). Similarly, Baki *et al.* (2015) compared the amino acid contents of natural and cultured sea bass (*Dicentrarchus labrax*) in their study, and they found that the most abundant amino acids were aspartic acid, glutamic acid, leucine, and lysine. In another study, Dogan and Ertan (2017) found that among the essential amino acids, lysine and leucine were the most abundant while aspartic acid, glutamic acid, alanine, and glycine were the predominant non-essential amino acids in the protein sequences.

The present study indicated that the selected omega-3 FAD7A-1 gene accessions were conserved across different species. The amino acid composition of this protein in castor was predominantly leucine followed by Valine, Proline, Glycine, Serine, Histidine and Lysine when compared to other crop species like sesame, brassica, soybean, Arabidopsis.

REFERENCES

Baki B, Gonener S and Kaya D, 2015, Comparison of food, amino acid and fatty acid compositions of wild and cultivated sea bass (*Dicentrarchus labrax* L., 1758). *Turkish Journal of Fisheries and Aquatic Sciences.*, **15**: 175-179.

Caleron, M., Muro Pastor, A. M., Garces, R and Martinez Force, E., 2006, Functional characterization of a plastidial omega-3 desaturase from sunflower (*Helianthus annuus*) in cyanobacteria. *Plant Physiology and Biochemistry Journal*, **44**(10): 517-525.

Dogan G and Ertan O O 2017, Determination of amino acid and fatty acid composition of goldband goatfish [*Upeneus moluccensis* (Bleeker, 1855)] fishing from the Gulf of Antalya (Turkey). *International Aquatic Research*, 313-327.

Erkan N, Selcuk A, Ozden O (2010a) Amino acid and vitamin composition of raw and cooked horse mackerel. *Food Anal Methods,* **3**:269-275.

Hall, T., Biosciences, I. and Carlsbad, C., 2011. BioEdit: an important software for molecular biology. *GERF Bulletin of Biosciences,* **2**(1): 60-61.

Johnson M, Zaretskaya I, Raytselis Y, Merezhuk Y, Mc Ginnis S and Madden T L 2008. NCBI Blast: a better web interface. *Nucleic Acids Research*, **36**: 5-9.

Li J, Liu A, Najeeb U, Zhou W, Liu H, Yan G, Gill R A, Yun X, Bai Q and Xu L 2021. *International Journal of Biological Macromolecules*, **175**: 188-198.

Loo J and Chris Somerville 1994. Plasmid omega-3 Fatty acid desaturase cDNA from (*Ricinus communis* L.). *Plant Physiology*, **105**: 443-444.

Sievers, F.and Higgins, D. G., 2014. Clustal omega. *Current Protocols in Bioinformatics*, **48**(1): 3-13.

Suseno S H, Hidayat T, Paramudhita P S, Ekawati Y and Arifianto T B 2015. Changes in nutritional composition of skipjack (*Katsuwonus pelamis*) due to frying process. *International Food Research Journal*, **22**(5): 2093.

Tamura K, Stecher G and Kumar S 2021. MEGA11: molecular evolutionary genetics analysis version 11. *Molecular Biology and Evolution*, **38**(7): 3022-3027.

Zhou X R, Singh S P and Green A G 2013. Characterisation of the FAD2 gene family from *Hiptage benghalensis:* a ricinoleic acid accumulating plant. *Phytochemistry,* **92**: 42-48.

Role of potassium, magnesium, sulphur and copper nutrients on groundnut late leaf spot disease dynamics

D R S VINEELA[1*], A K PATIBANDA[1], V PRASANNAKUMARI[1], B SREEKANTH[2] AND S K NAFEEZ UMAR[3]

[1]Department of Plant Pathology, Agricultural College, ANGRAU, Bapatla-522 101, Andhra Pradesh

(Received: March 10, 2023; Revised: June 15, 2023; Accepted: June 23, 2023)

ABSTRACT

Plant protection strategies need an effective alternative mode that reduces chemical load on environment and financial burden on farmers. Mineral nutrition, an integral part of crop production has long since proven to be a promising management strategy. Due to high specificity of host-pathogen-nutrient relationship, precise investigation has to be taken before recommendation. Among the various methods to screen infection frequency and disease tolerance with respect to applied treatments, components of resistance (incubation period, latent period, number of leaf spots, and lesion diameter) studied in hydroponically grown plants under greenhouse conditions are more appropriate than detached leaf assay as disease development of late leaf spot caused by the hemibiotroph., *Phaeoisariopsis personata* is more akin to the disease development under field conditions. Role of four nutrients i.e., Potassium, Magnesium, Sulphur and Copper deficient conditions as well as supplementation alone and in combination on groundnut late leaf spot disease incidence was compared with fungicidal check (Tebuconazole seed treatment) in terms of components of resistance and anti-oxidant enzyme activities using sand culture. Deficiency of nutrients showed higher disease incidence than control suggesting the role of nutrients in offering resistance to infection. Further it is revealed that $CuSO_4$ and combination of four nutrients were effective in delaying incubation (11.67 days, 12.33days) and latent period (16.67 days, 17.00 days) while $MgSO_4$ followed by combination of four nutrients were effective in reducing lesion number (17.65/leaf, 22.15/leaf) and diameter (0.20 and 0.27 mm) thus lowered AUDPC which showed similar antioxidant enzyme activity as fungicidal check. Nutrient supplementation though inferior to fungicidal check (14 days incubation period, 18.33 days latent period, 1.95 lesions/leaf with 0.22mm diameter), was significantly superior to control (10.33 days incubation period, 13.67 days latent period, 70.15lesions/leaf with 0.33mm diameter). Hence, application of adequate amount of nutrients improves plants growth as well as resistance to LLS infection.

Keywords: Groundnut, Nutrition, Potassium, Tikka late leaf spot disease

Plants face biotic and abiotic stress conditions from its micro-climate, of which primary component is mineral nutrition. Along with imparting plant growth, nutrients play vital role in plant health. Supplementing various plant nutrients for optimal plant health enhances disease resistance (Marshner, 2012; Suthar *et al.,* 2022). In other words, nutrition is a primary component of disease management. Biotic stress includes diseases for which using systemic chemicals after incidence of disease may not be economically viable and hence requires concrete vigilance and timely scheduled plant protection. This adds chemical load to environment and soil as well. Use of resistant genotypes often found a viable alternative as it will reduce disease incidence as well as infection frequency. The resistance of plants to diseases is mainly related to genetic composition of plant and ability of the plant to express its genetic resistance to a disease, however, is affected by mineral nutrition. Thus, mineral nutrients act directly on the pathogen, on plant growth and development, and on plant resistance mechanisms and hence the mechanisms involving nutrient induced changes in disease development are complex and multifarious.

Peanut, *Arachis hypogaea,* belongs to legume or "bean" family, is an important oil seed crop and is severely affected by a pathogen, *Phaeoisariopsis personata* (=Cercospora personata) causing late leaf spot (LLS also called 'tikka' disease) disease in majority of the groundnut growing areas. Being a major contributor to economy, groundnut with production holding 16-18 per cent of global production, India stands second after China (40%) with a production of 9.25 million tonnes from 4.88 million ha with a productivity of 1893 kg/ha (www.indiastat.com). Late leaf spot caused by *Phaeoisariopsis personata,* is prevalent mostly in *kharif* and *rabi* to certain extent and can cause losses to a tune of 50 per cent in pod and halum yield (Hegde *et al.,* 1995). As on date spraying 0.2 per cent mancozeb and 0.1 per cent carbendazim or 0.2 per cent hexaconazole or 0.1 per cent tebuconazole twice at fifteen day interval is recommended

[2]AICRP on Cotton (Crop Physiology), RARS, Lam, Guntur-522 034, Andhra Pradesh; [3]Dept. of Statistics and Computer Education, S.V. Agricultural University, ANGRAU, Tiruapti, Andhra Pradesh;
Corresponding author's E-mail: ramasrivineelaagrico@gmail.com

for management of late leaf spot disease (ANGRAU, 2018; Meena *et al.,* 2022). It is high time to employ nutrition as relationship of a nutrient *vis-a-vis* host-pathosystem decides whether the plant is tolerant or resistant to disease. So, present investigation is formulated to access impact of four nutrients, *viz.,* potassium, magnesium, sulphur and copper were studied in deficient and supplement conditions that are employed through hydroponic system as more controlled environment than detached leaf assay is necessary and components of resistance studied in hydroponically grown plants under greenhouse conditions are more appropriate. NPK fertilizer rates significantly influence progression of foliar diseases such as leaf spot and rust in groundnut (Ihejirika *et al.,* 2006). Mineral nutrition with K improves pod yield of groundnut and aids in tikka leaf spot disease management (Chandrasekhar and Narayanaswami, 1993).

MATERIALS AND METHODS

Susceptible groundnut cultivar (Kadiri 6) was grown in sand culture with nutrients applied at weekly intervals. Nutrients K, Mg, S and Cu were valuated to assess the role of nutrient deficiency and supplementation either alone or in combination of nutrients applied to soil as well as to foliage under high disease pressure. The complete Hoagland and Arnon (1950) nutrient solution was served as a check treatment. Deficiency of test nutrients was imposed by modifying nutrient composition as given by Hoagland and Arnon (1950). Supplementation of four nutrients alone and in combination were administered to plants as soil application (at root zone) and as foliar spray. Tebuconazole seed treatment and foliar spray on plants grown in nutrient solution served as a fungicidal check. Seed treatment was carried out as modification to standard recommendation owing to the procedure of early inoculation under greenhouse conditions. Three replications were maintained for each treatment. Artificial inoculation with *P. personata* conidia was first done at 20 DAS and subsequently on alternate days up to 30 DAS (six sprays) to ensure early and severe infection. Data were recorded on components of resistance *viz.,* incubation period, latent period, lesion number and diameter at regular intervals, disease severity and defoliation percent after 26 DAI. Plant analysis was done to assess the activity of anti-oxidant enzymes on infection. Total superoxide dismutase (SOD) activity was assayed using a modified NBT method (Beauchamp and Fridovich, 1971), Peroxidase (POD) activity was measured by measuring rate of dehydrogenation of guaiacol by reacting with hydrogen peroxide, catalase (CAT) activity was determined according to Aebi, 1984. The pathogen and plant parameters were studied using CRD method.

RESULTS AND DISCUSSION

Components of resistance: Incubation period, being first component of resistance was accessed and among all the treatments, fungicidal check took the highest time for first symptom appearance (14 days) while in control 10 days were required for symptom expression. In all the treatments deficient of K, Mg, Cu and S nutrients, incubation period was about 6 to 7 days. Among nutrient supplements, KNO_3 and $MgSO_4$ treatments resulted in incubation period (10 days) which was on par with control. $CuSO_4$ supplement alone gave an incubation period of 12 days which was on par with all nutrients supplements applied together (12 days).

When latent period was observed, fungicidal check took longest latent period (18 days) followed by K+Mg+Cu+S (17 days), $CuSO_4$ (17 days) and $MgSO_4$ (15 days). KNO_3 supplemented treatment took lesser time for sporulation (14 days) which was similar to control while least latent period (10 to 11 days) was observed in K, Mg, Cu and S nutrient deficient treatments (Table 1). The deficiency of nutrients reduced incubation and latent periods while supplementation of nutrients except KNO_3 delayed incubation and latent periods thus aids in reducing number of disease cycles per season and in turn disease severity.

Lesion number was observed at 16, 21 and 26 DAI and significant differences were observed among treatments. At 16 DAI, least number of lesions were found in fungicidal check (0.50/leaf). Deficiency of the K, Mg, Cu and S nutrients resulted in lesion number on par with control (4.00/leaf). It is important to note that supplementation of selected nutrients and their combination resulted in significantly lower lesion number than that in control and respective deficient treatments indicating role of these nutrients in reducing lesion number just after pathogen inoculation. (Table 1). At 21 DAI, significantly lower lesion number was observed in fungicidal check (1.50/leaf) and all other treatments had significantly recorded higher lesion number. Lesion number in nutrient supplemented treatments i.e., combination of all nutrients together (5.40), $CuSO_4$ (5.60) and $MgSO_4$ (5.80) had significantly lower lesion number than control (31.40) and higher lesion number than fungicidal check. Lesion number in control (31.40/leaf) was on par with Mg deficient treatment (30.10/leaf) that was in turn on par with K deficient (23.50/leaf), S deficient treatment (23.50/leaf).At 26 DAI, fungicidal check continue to suppress disease significantly with least lesion number (1.95/leaf) while highest lesion number was observed in Mg deficient treatment (92.30/leaf), K deficient treatment (85.80/ leaf) followed by control (70.15/leaf). Lesion number in nutrient supplemented treatments except KNO_3 were on par with each other which had significantly lower lesion number than control and deficiency treatments yet significantly higher lesion number than fungicidal control. (i.e., $MgSO_4$ (17.65 leaf), K+Mg+Cu+S (22.15) and $CuSO_4$ (23.65/leaf).

While fungicidal check offered 79.6 per cent reduction in lesion number compared to control, nutrient supplemented treatments $MgSO_4$, K+Mg +Cu+S and $CuSO_4$ offered 48.8, 43.1, 41.1 per cent reduction in lesion number respectively while least reduction was in KNO_3 (11.9%). On the other hand, nutrient deficient treatments increased lesion number compared to control while their supplements decreased lesion number.

AUDPC was highest in Mg deficient (396.25) and K deficient treatments (348.67) followed by control (345.38), S deficient (291.24), Cu deficient (281.75) and KNO_3 supplemented treatments (245.79). Lowest AUDPC was recorded in fungicidal check (13.63) while nutrient supplemented treatments recorded lesser AUDPC than control (79.79, 89.04 and 95.46 in $MgSO_4$, K+Mg+Cu+S and $CuSO_4$, respectively).

Lesion diameter showed significant differences among treatments at 21 DAI and 26 DAI. At 21 DAI, deficient treatments showed significantly maximum lesion diameter than nutrient supplemented treatments and fungicidal check and were on par with control. Nutrient supplement treatments KNO_3, K+Mg+Cu+S, $MgSO_4$ and $CuSO_4$ (0.15, 0.15, 0.13 and 0.13mm respectively) and fungicidal check (0.10mm) recorded lesion diameter which were on par among themselves (Table 1). At 26 DAI, significantly smallest lesion diameter was observed in fungicidal check (0.20mm) and was on par with $MgSO_4$ (0.20mm). Nutrient supplementation with $CuSO_4$, K+Mg+Cu+S, KNO_3 and K deficient treatment (0.27mm) showed lesser lesion diameter than control and higher lesion diameter than fungicidal check. Maximum lesion diameter was observed in S deficient treatment (0.43mm) which was on par with Cu deficient treatment (0.37mm), Mg deficient treatment (0.37mm) which were in turn on par with control (0.33mm). $MgSO_4$ supplemented treatment resulted in 5.1 per cent reduction in lesion diameter when compared to control which was similar to fungicidal check followed by $CuSO_4$, KNO_3 and combination of four nutrients (2.5%) while nutrient deficient treatments increased lesion diameter than control.

From data on lesion number and lesion diameter, it was observed that among four test nutrients, $MgSO_4$ was effective in reducing lesion number and diameter followed by combination of four nutrients and $CuSO_4$ while their deficiencies did increase lesion number and diameter.

Disease incidence was recorded by counting number of infected leaves over total leaves. Percentage of infected leaves when enumerated showed significant differences among treatments. Among all the treatments, fungicidal check had significantly lowest per cent of infected leaves (17.2) followed by $MgSO_4$ supplemented treatments (35.7). All other treatments had higher per cent infected leaves. Treatments K+Mg+Cu+S (49.0%) and $CuSO_4$ (47.5%) showed significantly lesser infected leaves compared deficiency treatments yet significantly higher infected leaves than fungicidal check. Thus, among nutrient supplemented treatments $MgSO_4$ was effective in reducing percent infected leaves (Table 2). This indicated that number of leaves affected due to lesions whether sporulated or not, may not decrease with nutrient supplements but pathogen spread and development may be reduced further.

When per cent defoliation was recorded at 26 DAI, K deficient treatment showed 12.1 per cent defoliation followed by Mg deficient treatment (9.8%) and Cu deficient treatment (6.3%). Among nutrient supplemented treatments KNO_3 showed 2.5% defoliation while in rest of the treatments defoliation was not noticed. Thus, deficiency of nutrients also enhances defoliation of infected leaves causing more harm to the plant and nutrient supplements prevent the same besides affecting disease development.

Percent disease incidence was highest in K deficient treatment (77.7%) followed by Mg deficient treatment (72.2%) and, S and Cu deficient treatments (66.6%) which were significantly higher than control (61.1%). Nutrient supplemented treatments recorded 44.4 per cent PDI which was significantly lower than Control but higher than fungicidal check (22.2%) indicating that nutrient supplementations aid in preventing disease development due to LLS in groundnut but not as superior as chemical treatment.

Plant nutrients may affect disease susceptibility through plant metabolic changes, thereby creating a more favorable environment for disease development as nutrients aid in formation of mechanical barriers, primarily through development of thicker cell walls. Deficiencies of plant nutrients make plants vulnerable to pathogen infection and hence observed high diseases incidence than control. Okori *et al.* (2004) reported that poor host nutrition in the form of deficiency or unbalanced applications of macronutrients predisposed maize plants to grey leaf spot incited by Cercospora zeae-maydis.

K deficiency causes thin cell walls that help in earlier penetration of conidial germ tube which results in shorter incubation and latent period. K deficiency showed highest lesion number and per cent leaf area damage on inoculation with *P. personata* which may be due to accumulation of unused N that encourages pathogen infection (Graham, 1983).

Mg deficiency in present study resulted in higher disease severity compared to plants grown in complete nutrient solution which may be attributed to the accumulation of sucrose and amino acids in the leaves that create conducive environment for various disease-causing pathogens to attack (Huber and Jones, 2013).

Sulphur takes part in plant growth and development (Marschner, 2012) thus offering resistance to plant diseases due to which deficiency of S caused more disease and per cent leaf area damage.

Cu deficiency alters lipid structure in cell membrane and thereby, the plant is prone to biotic stresses (Broadley *et al.,* 2012). Based on the present investigation such alterations in the cell membrane might have resulted in shorter incubation and latent periods which accounted for more disease severity with Cu deficiency.

Deficiencies of K, S, Mg and Cu in present study resulted in significantly short incubation and latent period, higher lesion number and AUDPC than control. Some of these results were in accordance with Bledsoe *et al.* (1945) who stated that magnesium deficiency greatly increased the infection and severity of peanut leaf spot caused by *Mycosphaerella arachidicola* where disease manifestation was initiated first in the leaves with Mg deficiency. In a study on effect of nutritional deficiency on yellow sigtaoka disease of banana, the greatest AUDPC occurred in plants deficient in K, N, P, S, or Mg compared with plants with full nutrients and plants deficient Ca or B (Freitas *et al.,* 2015). In coffee, Alves *et al.* (2009) reported higher intensity of rust (*Hemileia vastatrix*) and brown eye spot (*Cercospora coffeicola*) in the leaves and fruits of plants deficient in Mg, S, N and Cu. Contrary to above observations, in the present investigation on N- deficiency didn't substantially effect disease severity probably due to poor plant growth.

As mobile regulator, K is essential in all cellular activities, reduction in lesion number and lesion diameter of LLS due to KNO_3 thrice the strength implied that adequate K helps to protect plant from metabolic stress and offers disease resistance. Mg increases tissue resistance to breakdown by enzymes thus involving in plant defence (Jones and Huber, 2007). Sulphur offers resistance to plant diseases (Marschner, 2012) by production of toxic compounds, emission of volatile component (hydrogen sulphide, dimethyl sulphide and dimethyl disulfide), and production of gluatathione, phytoalexines and glucosinolates that were against fungal infection (Haneklaus *et al.,* 2007). Combination of Mg and S ($MgSO_4$) when administered to plants through roots at thrice the strength, reduced lesion number and lesion diameter of LLS than control and the reduction was at par with fungicidal check. As reported by Marschner, (1995) and Broadley *et al.* (2012) involvement of Cu in lignification of plants and cell wall stability might have increased incubation period and latent period of *P. personata* as compared to control and similar to fungicidal check.

Anti-oxidant enzyme activity: Anti-oxidant enzyme activity (SOD, POD and CAT) analyzed at 26 DAI showed significant differences among treatments (Table 3). SOD enzyme activity was significantly highest in control and nutrient deficient treatments except for S deficient treatment (0.22 units/mg fresh weight). Significantly highest SOD activity was recorded in K deficient treatment (1.00 units/mg fresh weight) followed by control (0.95 units/mg fresh weight), Cu deficient treatment (0.86 units/mg fresh weight) and Mg deficient treatment T_3 (0.84 units/mg fresh weight). Nutrient supplemental treatments have lower SOD enzyme activity which was significantly on par with fungicidal check (0.62 units/mg fresh weight).

POD enzyme activity was significantly highest in Mg deficient treatment (0.15 units/min/gram) compared to control (0.10 units/min/gram) and Cu deficient treatment (0.08 units/min/gram) and K deficient treatment (0.07 units/min/gram). POD activity of fungicidal check (0.01 units/min/gram) was significantly least and was on par with nutrient supplemented treatments [$MgSO_4$ (0.05 units/min/gram), $CuSO_4$ (0.02 units/min/gram), K+Mg+ Cu+S (0.02 units/min/gram), KNO_3 (0.02 units/min/gram)]. CAT enzyme activity was highest in fungicidal check (2.67 H_2O_2/min/gram) and was on par with nutrient supplemental treatments KNO_3 (2.08 H_2O_2/min/gram) which was in turn on par with the nutrient supplemented treatments $MgSO_4$ (1.57 H_2O_2/min/gram), K+Mg+Cu+S (1.55 H_2O_2/min/gram). Significantly lowest CAT activity was observed in K and Mg deficient treatments and $CuSO_4$ supplemented treatment when compared to control.

It was observed that POD and CAT have inverse relationship as POD and CAT plays same role in scavenging H_2O_2: while POD enzyme activity was high correspondingly CAT enzyme activity was less and *vice-versa.*

Nutrient supplementation offers similar antioxidant enzyme activity as fungicidal check thus aiding in minimizing damage by pathogen infection and less disease incidence. SOD and CAT activities showed significant differences among nutrient supplemented treatments with P. personata. Nutreints irrespective of biotic stress, activates anti-oxidant enzyme activity in plant cells to offer tolerance from oxidative damage. At 1.5 mM Cu concentration, all antioxidant enzyme activities increased in leaves of the maize cultivar 31G98 while there were no significant changes in SOD and glutathione reductase (GR) activities in cultivar 3223 compared to the control except increased ascorbate peroxidase (APX) and POD activities. The lower Cu accumulation in leaves and higher antioxidant enzyme activities in cultivar 31G98 suggested an enhanced tolerance capacity of this cultivar to protect the plant from oxidative damage (Tanyolac *et al.,* 2007).

Copper treatments exhibited a non-significant change in the activities of CAT and APX, up to 10 mM Cu_2+, and in case of POD up to 20 mM Cu_{2+}, whereas excess Cu_{2+} in the soil led to a highly significant increase in the activities of these enzymes in wheat during early growth stages (Azooz *et al.,* 2012)

Nutrient supplementation with K, Cu, Mg and S alone or in combinations offers tolerance to disease by activating anti-oxidative enzymes. $CuSO_4$ prolonged incubation and latent periods while $MgSO_4$ reduced lesion number and lesion diameter thus lesser AUDPC values compared to control. K at higher concentration (thrice the strength) and in combination reduced disease severity as seen with Cu, Mg and S.

Increasing concentrations of K (up to 7 mmol/L) in liquid culture reduced the intensity of Phoma leaf spot (Phomatarda) (Lima *et al.,* 2010) and brown eye spot (*Cercospora coffeicola* of coffee trees, although this concentration resulted in an imbalance with other nutrients, and the over-all intensity of disease increased (Garcia *et al.,* 2003). In various studies, Cu compounds and their different combinations were found to decrease diseases like sheath blight (*Rhizoctonia solani* Kuhn.) in rice (Khaing *et al.,* 2014) and bacterial canker (*Clavibacter michiganensis* subsp. *michiganensis*) in tomato (Bastas, 2014).

Table 1 Effect of nutrient deficiencies and nutrient supplement on components of resistance of groundnut late leaf spot disease

S. No.	Treatments	Dose	Incubation Period (Days)	Latent Period (Days)	Lesion Number			Lesion Dia (mm)		
					16 DAI	21 DAI	26 DAI	21 DAI	26 DAI	AUDPC
T1	Control		10.33 c	13.67 d	4.00 abc (2.23)	31.40 a (5.68)	70.15 bc (8.400	0.25 a (1.12)	0.33 b (1.15)	342.38
T2	K -	-	6.67 d	10.67 e	6.67 a (2.76)	23.50 bc (4.89)	85.80 ab (9.31)	0.30 a (1.14)	0.27 bc (1.13)	348.67
T3	Mg -	-	6.33 d	10.67 e	6.00 a (2.64)	30.10 ab (5.58)	92.30 a (9.65)	0.27 a (1.13)	0.37 ab (1.17)	396.25
T4	S -	-	7.00 d	11.00 e	5.67 ab (2.57)	23.50 bc (4.95)	63.83 cd (8.04)	0.28 a (1.13)	0.43 a (1.20)	291.24
T5	Cu -	-	6.33 d	10.33 e	5.00 ab (2.44)	17.20 c (4.26)	73.30 abc (8.61)	0.33 a (1.15)	0.37 ab (1.17)	281.75
T6	KNO3+	Thrice the strength	10.67 c	13.67 d	3.67 abc (2.16)	20.00 c (4.58)	54.65 d (7.40)	0.15 b (1.07)	0.27 bc (1.13)	245.79
T7	MgSO4+	Thrice the strength	10.00 c	15.33 c	2.67 c (1.91)	5.80 d (2.60)	17.65 e (4.30)	0.13 b (1.06)	0.20 d (1.10)	79.79
T8	CuSO4+	Twice the strength	11.67 b	16.67 b	3.33 abc (2.08)	5.60 d (2.55)	23.65 e (4.95)	0.13 b (1.06)	0.27 bc (1.13)	95.46
T9	K, Mg, Cu, S+	Thrice the strength K, Mg, S and twice the strength Cu	12.33b	17.00 b	2.67 c (1.91)	5.40 d (2.52)	22.15 e (4.79)	0.15 b (1.07)	0.27 bc (1.13)	89.04
T10	Fungicidal check	Tebuconazole @ 0.1%	14.00 a	18.33 a	0.50 d (1.21)	1.50 e (1.58)	1.95 f (1.71)	0.10 b (1.05)	0.20 d (1.10)	13.63
	S Em (±)		0.29	0.37	0.13	0.24	0.39	0.01	0.02	
	Sed		0.42	0.52	0.18	0.33	0.55	0.02	0.02	
	CD (p=0.01)		0.87	1.09	0.37	0.70	1.15	0.04	0.05	
	CV %		5.34	4.65	9.95	10.45	9.94	2.03	2.43	

Figures in parenthesis are square root transformed values

Table 2 Effect of nutrient deficiencies and nutrient supplement on percent infected leaves, percent defoliation and groundnut late leaf spot disease incidence

S. No.	Treatments	Dose	Infected Leaves (%)	Defoliation (%)	Disease Incidence (%)
T1	Control		40.00 de (39.22)	0.00 e (0.00)	61.05 d (51.39)
T2	K -	-	62.92 b (52.58)	12.11 a (20.35)	77.70 a (61.80)
T3	Mg -	-	80.90 a (64.43)	9.79 b (18.22)	72.15 b (58.20)
T4	S -	-	55.40 bc (48.09)	0.00 e (0.00)	66.60 c (54.67)
T5	Cu -	-	64.19 b (53.31)	6.31 c (14.53)	66.60 c (54.67)
T6	KNO3+	Thrice the strength	58.96 b (50.14)	2.52 d (9.10)	44.40 e (41.77)
T7	MgSO4+	Thrice the strength	35.69 e (36.67)	0.00 e (0.00)	44.40 e (41.77)
T8	CuSO4+	Twice the strength	47.54 cd (43.57)	0.00 e (0.00)	44.40 e (41.77)
T9	K, Mg, Cu, S+	Thrice the strength K, Mg, S and twice the strength Cu	48.98 cd (44.40)	0.00 e (0.00)	44.40 e (41.77)
T10	Fungicidal check	Tebuconazole @ 0.1%	17.18 f (24.43)	0.00 e (0.00)	22.20 f (28.10)
	S Em (±)		2.12	0.29	0.93
	Sed		3.00	0.42	1.32
	CD (p=0.01)		6.31	0.87	2.76
	CV %		8.05	8.20	3.39

Figures in parenthesis are arcsine transformed values

Table 3 Effect of nutrient deficiencies and nutrient supplement on anti-oxidant enzyme activity of groundnut late leaf spot disease

S. No.	Treatments	Dose	SOD	POD	CAT
T1	Control		0.950 a (1.396)	0.100 b (1.049)	1.805 bc (1.672)
T2	K -	-	1.000 a (1.414)	0.074 bc (1.036)	0.445 d (1.201)
T3	Mg -	-	0.840 ab (1.356)	0.149 a (1.072)	0.779 d (1.332)
T4	S -	-	0.220 c (1.104)	0.068 bc (1.033)	1.449 c (1.563)
T5	Cu -	-	0.860 ab (1.363)	0.079 bc (1.039)	1.949 b (1.716)
T6	KNO3+	Thrice the strength	0.547 b (1.243)	0.021d (1.011)	2.076 ab (1.753)
T7	MgSO4+	Thrice the strength	0.600 b (1.263)	0.050 cd (1.025)	1.575 bc (1.604)
T8	CuSO4+	Twice the strength	0.623 b (1.273)	0.022 d (1.011)	0.683 d (1.297)
T9	K, Mg, Cu, S+	Thrice the strength K, Mg, S and twice the strength Cu	0.770 ab (1.329)	0.022 d (1.011)	1.546 bc (1.596)
T10	Fungicidal check	Tebuconazole @ 0.1%	0.620 b (1.271)	0.009 d (1.005)	2.671 a (1.912)
	S Em (±)		0.034	0.009	0.052
	Sed		0.048	0.013	0.074
	CD (p=0.01)		0.100	0.026	0.156
	CV %		4.496	1.492	5.798

Mean enzyme activities from three replications; Figures in parenthesis are square root transformed values

Hence by application of adequate and balanced amount of nutrients to plants improves growth as well as resistance to pathogen infection even in susceptible cultivars. The mechanism for resistance present in susceptible plants can be induced by simple inorganic chemicals (Dordas, 2008).

Supplementation of nutrients, individually or in combinations through both soil and foliar application indicated that $CuSO_4$ alone was more effective in delaying incubation period (11.67 days) and was on par with all the treatments involving nutrient supplements applied together (12.33 days), while in control it was 10.33 days. When latent period was observed, fungicidal check took longest latent period (18.33 days) followed by KNO_3+$MgSO_4$+$CuSO_4$ (17.00 days), $CuSO_4$ (16.67 days) and $MgSO_4$ (15.33 days). Lesion number in nutrient supplemented treatments except KNO_3, were on par with each other with significantly lower lesion number (in $MgSO_4$ (17.65/leaf), KNO_3+$MgSO_4$+$CuSO_4$ (22.15/leaf) and $CuSO_4$ (23.65/leaf) than control and deficiency treatments, yet significantly higher lesion number than fungicidal control (1.95/leaf). Nutrient supplementation with $CuSO_4$, KNO_3+$MgSO_4$+$CuSO_4$, KNO_3 and K deficient treatment (0.27 mm) showed significantly lesser lesion diameter than control (0.33 mm) and higher lesion diameter than fungicidal check (0.20mm). Nutrient supplemented treatments recorded 44.40 per cent PDI which was significantly lower than control (61.05%) but higher than fungicidal check (22.20%). Nutrient supplementation offers similar antioxidant enzyme activity as fungicidal check thus aiding in minimizing damage by pathogen infection and less disease incidence. It was noted that $CuSO_4$ and combination of four nutrients were effective in delaying incubation and latent period while $MgSO_4$ followed by combination of four nutrients were effective in reducing lesion number and diameter thus lowered AUDPC which showed similar antioxidant enzyme activity as fungicidal check. Hence with application of adequate amount of nutrients to plants growth as well as resistance to pathogen infection was improved even in susceptible cultivars.

REFERENCES

Aebi H 1984. Catalase in vitro. In: Methods Enzymology Academic Press, *Elsevir*, **105**: 121-126.

Alves M C, Silva F M, Pozza E A and Oliveira M S 2009. Modeling spatial variability and pattern of rust and brown eye spot in coffee agroecosystem. *Journal of Pesticide Science,* **82**: 137-148.

ANGRAU 2018. *VyavasayaPanchangam.* 2018-19.

Azooz M M, Mona F, Elhamd A, Mohamed A and Al-Fredan 2012. Biphasic effect of copper on growth, proline, lipid peroxidation and antioxidant enzyme activities of wheat (*Triticumaestivumcv.* Hasaawi) at early growing stage. *Australian Journal of Crop Science*, **6** (4): 688-694.

Bastas K K 2014. Effects on tomato bacterial canker of resistance inducers and copper compounds in greenhouse. *Journal of Agriculture and Food Sciences*, **28**: 1-10.

Bledsoe R W, Harris H C and Tisdale W B 1945. Leafspot of peanut associated with magnesium deficiency. *Plant Physiology*. **21**: 237-240.

Broadley M, Brown P, Cakmak I, Rengel Z and Zhao F 2012. Function of nutrient: micronutrients. In: Marschner P (ed) Marschner's mineral nutrition of higher plants. *Academic,* Sydney, 191-248.

Beauchamp C and Fridovich I 1971. Superoxide dismutase: Improved assays and an assay applicable to acrylamide gel. *Analytical Biochemistry*, **44**: 276-287.

Chandrasekhar V and Narayanaswami R 1993. Effect of potash and amendments on the Tikka leaf spot disease incidence of groundnut. *Journal of Potassium Research*, **9** (4): 370-374.

Dordas C 2008. Role of nutrients in controlling plant diseases in sustainable agriculture: A review. *Agronomy for Sustainable Development*, **28**: 33-46.

Freitas A S, Pozza E A, Pozza A AA, Oliveira M G F, Silva H R, Rocha H S and Galvão L R 2015. Impact of nutritional deficiency on Yellow Sigatoka of banana. *Australasian Plant Pathology,* **44** (5): 583-590.

Garcia J D, Pozza E A, Pozza A A, Souza P E, Carvalho J G and Balieiro A C 2003. Incidence and severity of the brown eye spot of coffee according to supply of potassium and calcium in nutrient solution. *Fitopatologiabrasileira*, **28**: 286 - 291.

Graham D R 1983. Effects of nutrients stress on susceptibility of plants to disease with particular reference to the trace elements. *Advances in Botanical Research*, **10**: 221-276.

Haneklaus S, Bloem E and Schnug E 2007. Sulfur and plant disease. In: Datnoff L E, Elmer W H, Huber D M (eds) *Mineral nutrition and plant disease.* The American Phytopathological Society, Saint Paul. 101-118.

Hegde V M., Subramanyam K, Gowda M V C and Prabhu T G 1995. Estimation of yield loss due to late leaf spot disease in spanish groundnut in Karnataka. Karolinska. *Journal of Agricultural Sciences*, **8**: 355-359.

Hoagland D R and Arnon D I 1950. The water-culture method for growing plants without soil. California Agricultural Experiment Station, Berkeley 32.

Huber D M and Jones J B 2013. The role of magnesium in plant disease. *Plant Soil,* **368**: 73-85.

Ihejirika G O, Nwufo M I, Oputa E, Obilo O P, Ogbebe K O and Onyia V N 2006. Effects of NPK fertilizer rates and plant population on foliar diseases, insect damage and yield of groundnut. *Journal of Plant Sciences,* **1**: 362-367.

Jones J B and Huber D M 2007. Magnesium and plant disease. In: L.E. Datnoff, W.H. Elmer, and D.M. Huber (ed.). *Mineral nutrition and plant disease.* APS Press, St. Paul, MN.

Khaing E E, Ahmad Z A M, Yun W M and Ismail M R 2014. Effects of silicon, copper and zinc applications on sheath blight disease severity on rice. *World Journal of Agricultural Research,* **2**: 309-314.

Lima L M D, Pozza E A, Torres H N, Pozza A A, Salgado M and Pfenning L H 2010. Relationship between nitrogen/potassium with Phoma spot and nutrition of coffee seedlings cultivated in nutrient solution. *Tropical Plant Pathology,* **35**: 223-228.

Marschner H 2012. *Mineral nutrition of higher plants, 3rd* edn. Academic, San Diego, 643.

Marschner H 1995. *Mineral Nutrition of Higher Plants.* San Diego, CA 92101: Academic Press Inc. 313-404.

Meena B 2022. Integration of bioagent, Bacillus subtilis Bbv57 and fungicides for the management of foliar diseases of groundnut (*Arachis hypogaea* L.). *Journal of Oilseeds Research*, **39**(3 & 4): 215-218.

Okori P, Patrick R, Rubaihayo E A and Dixelius C 2004. Interactive effects of host, pathogen and mineral nutrition on grey leaf spot epidemics in Uganda. *European Journal of Plant Pathology*, **110**: 119-128.

Suthar B, Pundir R S and Vijay B 2022. Price behaviour of groundnut (*Arachis hypogaea* L.) in major markets of India. *Journal of Oilseeds Research*, **39**(2): 134-141.

Tanyolac D, Ekmekc Y and Unalan S 2007. Changes in photochemical and antioxidant enzyme activities in maize (*Zea mays* L.) leaves exposed to excess copper. *Chemosphere*, **67**: 89-98.

Bioefficacy of some new insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.)

AKSHAY KUMAR SINGH PRATIHAR[1], M M SUNDRIA[2], SHALINI PANDEY[2*] AND RAHUL BHARDWAJ[2]

[1]College of Agriculture, Agriculture University, Jodhpur-342 304, Rajasthan

(Received: May 17, 2023; Revised: June 21, 2023; Accepted: June 23, 2023)

ABSTRACT

A field experiment was conducted to evaluate the efficacy of different insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.) at Research Farm, Agricultural Research Station, Mandor, Jodhpur during *rabi*, 2021-22. The experiment consists of ten treatments including untreated control and laid out in randomized block design with three replications. Treatments used in the experiment were dimethoate 30 EC @ 875 ml/ha, thiamethoxam 25 WG @ 100 g/ha, acetamiprid 20 SP @ 50 g/ha, buprofezin 25 SC @ 1000 ml/ha, chlorpyriphos 20 EC @ 500 ml/ha, cyantraniliprole 10.26 OD @ 600 ml/ha, diafenthiuron 50 WP @ 600 g/ha, imidacloprid 17.8 SL @ 100 ml/ha and quinalphos 25 EC @ 1000 ml/ha. Among these treatments imidacloprid 17.8 SL @ 100 ml/ha was found most effective followed by thiamethoxam 25 WG and dimethoate 30 EC while diafenthiuron 50 WP @600 g/ha and chlorpyriphos 20 EC @ 500 ml/ha were reported as least effective treatments. The maximum yield (3861 kg/ha) was recorded in the plot treated with imidacloprid 17.8 SL @ 100 ml/ha followed by thiamethoxam 25 WG (3444 kg/ha) and dimethoate 30 EC (3194 kg/ha). Further, maximum net profit (₹2,00,290/ha.) and highest B: C ratio were obtained from imidacloprid 17.8 SL @ 100 ml/ha treated plots while minimum was obtained in chlorpyriphos 20 EC (2.71:1) treated plots.

Keywords: Bioefficacy, Comparative economics, Insecticides, Lipaphis erysimi, Mustard

India is the 4th largest oilseeds producer in the world. Mustard is one of the major oilseed crops of India with second largest acreage after soybean. The mustard growing areas in India are experiencing the vast diversity in the agro-climatic conditions (Gandhimathy *et al.*, 2022). Therefore, many abiotic and biotic factors affect the yield and productivity of the crop, in which insect pests are one of them. In India, about 50 insect species have been found infesting rapeseed and mustard and about a dozen species are considered as major pests (Sharma and Singh, 2010; Chaurasiya *et al.*, 2022). Among them, mustard aphid (Lipaphis erysimi) is the key pest in all the mustard growing regions of the country. Nymphs and adults of the mustard aphid suck cell sap from the leaves, inflorescences and immature pods resulting into very poor pod setting and yield. On the other hand, aphid produces a good amount of honey dew which facilitates the growth of the fungus that makes the leaves and pods appear dirty black (Awasthi, 2002). It may cause a yield loss upto 95% in favorable conditions (Singh *et al.,* 2020) and can reduce 5-6% oil content (Shylesha *et al.*, 2006). Among the different management practices, farmers generally rely on chemical insecticides to overcome aphid's problems in India so far (Sarwar *et al.*, 2003). Looking to the increasing incidence of mustard aphid under changing climatic conditions of western Rajasthan, it is necessary to evaluate the bio-efficacy of available chemicals against mustard aphid.

[2]Agricultural Research Station, Mandor, Jodhpur-342 304, Rajasthan;*Corresponding author's E-mail: pandeyshalini80@gmail.com

MATERIALS AND METHODS

Experimental details: The present experiment was laid out in randomized block design with three replications to identify the effectiveness of insecticides against *L. erysimi* in mustard at Research Farm, Agricultural Research Station, Mandor, Jodhpur during *Rabi*, 2021-22. The crop variety, NRCHB-101 was sown in plot size of 4 m x 3 m with row to row and plant to plant distance of 30 cm and 10 cm, respectively. During experiment, the average temperature varied from 13.50 to 27.60°C and average relative humidity from 43.00 to 80.15%.

The tested treatments included, dimethoate 30 EC @ 875 ml/ha, thiamethoxam 25 WG @ 100 g/ha, acetamiprid 20 SP @ 50 g/ha, buprofezin 25 SC @ 1000 ml/ha, chlorpyriphos 20 EC @ 500 ml/ha, cyantraniliprole 10.26 OD @ 600 ml/ha, diafenthiuron 50 WP @ 600 g/ha, imidacloprid 17.8 SL @ 100 ml/ha, quinalphos 25 EC @ 1000 ml/ha and untreated control. The pest population was regularly monitored and the tested insecticides were applied at 11th SMW (76 days after sowing) with the help of Knapsack sprayer. The spray was done when the aphid population was sufficiently build up. There was no application of second spray due to environmental conditions which were responsible for falling down of aphid population.

Observations recorded: The population was counted from 10 cm top portion of the terminal shoot from five randomly selected plants from each plot. The data obtained just before treatment and one, three, seven and ten days after the spray were taken into consideration to find out the per cent reduction in the population which was determined using the Henderson and Tilton (1955) equation:

Where,

$$\text{Per cent reduction in pest population} = 1 - \frac{T_a \times C_b}{T_b \times C_a} \times 100$$

T_a = Population in treated plots after treatment
T_b = Population in treated plots before treatment
C_a = Population in untreated plots after treatment
C_b = Population in untreated plots before treatment

The seed yield was also recorded from each plot and converted into kg/ha. The statistical analysis (analysis of variance) was carried out by transforming the data of per cent reduction into angular transformation values. The comparative economics of different treatments against aphid in mustard was also worked out.

RESULTS AND DISCUSSION

Effect of insecticides on per cent reduction of mustard aphid population: Maximum aphid reduction (93.15%) was recorded in imidacloprid 17.8 SL treated plots followed by thiamethoxam 25 WG (85.55%) and dimethoate 30 EC (82.86%) which were found to be statistically on par with each other. Diafenthiuron 50 WP (60.85%) was found least effective among all the treatments (Table 1). Similarly, Dotasara *et al.* (2017) and Khedkar *et al.* (2012) also reported that imidacloprid 17.8 was found most effective against mustard aphid.

Effectiveness of insecticide on the seed yield of mustard: The maximum seed yield (3861 kg/ha) was recorded in the plot treated with imidacloprid 17.8 SL followed by thiamethoxam 25 WG (3444 kg/ha) and dimethoate 30 EC (3194 kg/ha) (Table 1). The minimum seed yield was obtained in the untreated control (1778 kg/ha) followed by chlorpyriphos 20 EC (1944 kg/ha) and diafenthiuron 50 WP (2222 kg/ha). The present findings are corroborating with the earlier results of Khedkar *et al.* (2012) and Patel *et al.* (2017) who reported increase in the seed yield by 55.66 and 51.13 per cent from the plots treated with imidacloprid 17.8 SL followed by thiamethoxam (54.31 and 39.60), respectively in comparison to the control.

Comparative economics of different treatments against aphid, *L. erysimi* in mustard: Maximum net profit was observed in the imidacloprid 17.8 SL (₹2,00,290/ha) treated plots followed by thiamethoxam 25 WG (₹1,75,353/ha) while the minimum net profit (₹85,190/ ha) was recorded in chlorpyriphos 20 EC treated plots. Likewise, the highest benefit-cost ratio (6.38:1) was recorded in the imidacloprid 17.8 SL treated plots followed by thiamethoxam 25 WG (5.60:1) whereas the minimum B:C ratio (2.71:1) was recorded in chlorpyriphos 20 EC treated plots (Table 2). These results are corroborating with the findings of Khedkar *et al.* (2012) who reported highest net realization from the treatment of imidacloprid followed by thiamethoxam against mustard aphid.

Table 1 Efficacy of some new insecticides against aphid, *Lipaphis erysimi* (Kalt.) in mustard

Treatment	PTP Aphid	Mean per cent population reduction of aphid				Overall Mean	Yield (kg/ha)
		1 DAS	3 DAS	7 DAS	10 DAS		
Dimethoate 30 EC @ 875 ml/ha	86.20	84.91 (67.24)	90.14 (71.88)	87.03 (69.16)	69.36 (56.41)	82.86 (65.61)	3194
Thiamethoxam 25 WG @ 100 g/ha	88.40	88.60 (70.93)	91.09 (73.17)	88.09 (70.18)	74.40 (59.62)	85.55 (67.79)	3444
Acetamiprid 20 SP @ 50 g/ha	91.80	77.64 (61.91)	83.60 (66.81)	76.59 (61.38)	61.94 (51.98)	74.94 (59.99)	3028
Buprofezin 25 SC @ 1000 ml/ha	91.40	79.76 (63.45)	84.90 (67.17)	76.61 (61.42)	35.38 (36.49)	69.16 (56.30)	2583
Chlorpyriphos 20 EC @ 500 ml/ha	90.20	71.17 (57.63)	80.08 (64.08)	63.79 (53.27)	14.74 (20.92)	57.44 (49.37)	1944
Cyantraniliprole 10.26 OD @ 600 ml/ha	88.87	77.89 (62.02)	81.23 (64.83)	76.39 (61.00)	48.79 (44.30)	71.08 (57.54)	2694
Diafenthiuron 50 WP @ 600 g/ha	86.40	65.47 (54.07)	81.14 (64.44)	71.14 (57.88)	25.65 (29.95)	60.85 (51.28)	2222
Imidacloprid 17.8 SL @ 100 ml/ha	92.67	97.46 (81.48)	95.31 (79.20)	94.64 (78.01)	85.20 (67.17)	93.15 (75.17)	3861
Quinalphos 25 EC @ 1000 ml/ha	83.93	81.46 (64.95)	89.03 (71.12)	79.73 (63.64)	39.91 (39.18)	72.53 (58.40)	2833
Untreated Control	86.47	-	-	-	-	-	1778
SEm±		2.69	3.51	3.03	2.97	1.84	3.36
CD @5%		8.01	10.42	9.01	8.83	5.46	9.99

Figures in parentheses are angular transformation values, DAS = Days after spray; PTP = Pre-treatment population

Table 2 Comparative economics of some new insecticides against aphid, *Lipaphis erysimi* (Kalt.) in mustard

Treatment	Yield (kg/ha)	Gross return (₹/ha)	Total expenditure (₹/ha)	Net profit (₹/ha)	B:C ratio
Dimethoate 30 EC @ 875 ml/ha	3194	191640	31996	159644	4.99:1
Thiamethoxam 25 WG @ 100 g/ha	3444	206640	31288	175353	5.60:1
Acetamiprid 20 SP @ 50 g/ha	3028	181680	31325	150355	4.80:1
Buprofezin 25 SC @ 1000 ml/ha	2583	154980	31915	123065	3.86:1
Chlorpyriphos 20 EC @ 500 ml/ha	1944	116640	31450	85190	2.71:1
Cyantraniliprole 10.26 OD @ 600 ml/ha	2694	161640	37860	123780	3.27:1
Diafenthiuron 50 WP @ 600 g/ha	2222	133320	33600	99720	2.97:1
Imidacloprid 17.8 SL @ 100 ml/ha	3861	231660	31370	200290	6.38:1
Quinalphos 25 EC @ 1000 ml/ha	2833	169980	32080	137900	4.30:1
Untreated Control	1778	106680	30450	76230	2.50:1

Cost of insecticides: Dimethoate 30 EC @ ₹ 910/lit.; Thiamethoxam 25 WG @ ₹ 875/kg; Acetamiprid 20 SP @ ₹ 2500/kg; Buprofezin 25 SC @ ₹ 715/lit.; Chlorpyriphos 20 EC @ ₹ 500/lit.; Cyantraniliprole 10.26 OD @ ₹ 11,100/lit.; Diafenthiuron 50 WP @ ₹ 4,000/kg; Imidacloprid 17.8 SL @ ₹ 1,700/lit.; Quinalphos 25 EC @ ₹ 880/lit.; Labour charges @ ₹ 250/labour/day (3 labour/spray/ha)

Among the different tested treatments imidacloprid 17.8 SL @ 100 ml/ha was found most effective treatment due to highest per cent reduction in aphid population, maximum seed yield, maximum net profit and highest benefit-cost ratio followed by thiamethoxam 25 WG and dimethoate 30 EC against aphid, *L. erysimi* in mustard.

ACKNOWLEDGEMENTS

The authors are highly thankful to the Zonal Director Research, Agricultural Research Station, Mandor, Jodhpur and Dean, College of Agriculture, Jodhpur, for providing necessary facilities to conduct the research work.

REFERENCES

Awasthi V B 2002. *Introduction to general and applied entomology,* pp. 266-271, Scientific publisher, Jodhpur (India).

Chaurasiya J P, Mahak Singh and Nageshwar 2022. Heterosis response and combining ability (variance and effect) analysis for seed yield and its components in Indian mustard (*Brassica juncea* L.) under timely sown condition. *Journal of Oilseeds Research,* **39**(1): 14-20.

Dotasara S K, Agrawal N, Singh N and Swami D 2017. Efficacy of some newer insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.) in cauliflower. *Journal of Entomology and Zoology Studies,* **5**(2): 654-656.

Gandhimathy B 2022. Growth and instability of oilseeds in India. *Journal of Oilseeds Research,* **39**(3&4): 265-267.

Henderson C F and Tilton E W 1955. Tests with acaricides against the brow wheat mite. *Journal of Economic Entomology,* **48**: 157-161.

Khedkar A A, Bharpoda T M, Patel M G and Patel C K 2012. Efficacy of different chemical insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.) infesting mustard. AGRES - *An International e-Journal,* **1**(1): 53-64.

Patel S, Yadav S K and Singh C P 2017. Bio-efficacy of insecticides against *Lipaphis erysimi* (Kalt.) in mustard ecosystem. *Journal of Entomology and Zoology Studies,* **5**(2): 1247-1250.

Sarwar M, Ahmad N, Siddiqui Q H, Rajpal A A and Toufiq M 2003. Efficacy of different chemicals on canola strain rainbow (*Brassica napus* L.) for aphid's control. *Asian Journal of Plant Sciences*, **2**(11): 831-833.

Sharma P and Singh Y P 2010. Directorate of Rapeseed-Mustard Research, Indian Council of Agriculture Research, Sewar, 321303, Bharatpur (Rajasthan). *Annals National Language Journal,* **1**: 47-51.

Shylesha A N, Thakur A N S, Pathak K A, Rao K R, Saikia K and Surose S 2006. Integrated management of insect pest of crops in north eastern hill region, pp. 50. Technical Bulletin No. 19. ICAR RC for NEH Region, Umiam,.

Singh D K, Singh R, Singh M and Prakash H G 2020. Biointensive IPM module for management of mustard aphid. *Journal of Oilseed Research,* **37** (Special Issue) : 217-218.

Identification of resistant source for leaf webber/capsule borer, *Antigastra catalaunalis* Duponchel (Lepidoptera: Crambidae) in sesame

T BOOPATHI*, K T RAMYA AND A L RATHNAKUMAR

ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Telangana

(Received: March 17, 2023; Revised: May 22, 2023; Accepted: May 30, 2023)

ABSTRACT

The incidence of the leaf webber/capsule borer, *Antigastra catalaunalis* Duponchel (Lepidoptera: Crambidae) is common during vegetative, flowering and pod formation stages of sesame during two seasons. The sesame genotypes (n=60) were screened for *A. catalaunalis* during two season 1 and 2. In season 1, four genotypes, SES-K-20-2010, SES-K-20-3002, SES-K-20-1062 and SES-K-20-2022 were found free from *A. catalaunalis* incidence. The sesame genotypes (n=60) graded for *A. catalaunalis* as highly resistant (15 genotypes), resistant (12 genotypes), moderately resistant (15 genotypes), susceptible (6 genotypes) and highly susceptible (12 genotypes) based on incidence. In season 2, none of genotype was found free from *A. catalaunalis* incidence. The sesame genotypes (n=60) graded for *A. catalaunalis* as highly resistant (1 genotype), resistant (17 genotypes), moderately resistant (28 genotypes), susceptible (13 genotypes) and highly susceptible (1 genotype) based on incidence. To summarize, 16 genotypes were highly resistant to *A. catalaunalis* and the resistant genotypes can be used as donor in future breeding programmes.

Keywords: Genotypes, Incidence, Leaf webber, Population, Reaction, Sesame

Sesame (*Sesamum indicum* L.) has earned a poetic label 'Queen of Oilseeds' due to high quality polyunsaturated stable fatty acid, which restrains oxidative rancidity. It has other nutritional and medicinal benefits like anti-cancer, anti-diabetic, anti-inflammatory, and regulates cholesterol (Sasipriya *et al.,* 2022). The present growth rate of domestic oilseed production is not sufficient to fulfil the rising demand. Under such circumstances, serious research efforts are required to enhance the production and productivity using latest breeding tools to mine and utilize the germplasm with desired traits. Biotic stresses are a major constraint for increasing the production and productivity of this crop (Sangeetha *et al.,* 2022). Insect pests are responsible for quantitative and qualitative yield reduction in sesame (Muzaffar *et al.,* 2002).

In India, the damage due to insect pests is also one of the major factors causing low productivity in sesame (Biswas *et al.,* 2001). The leaf webber/capsule borer (*Antigastra catalaunalis* Duponchel), leafhopper (*Orosius albicinctus* Distant), gall fly (*Asphondylia sesami* Felt), whitefly and mirid bug are a major constraint for increasing the production and productivity of this crop (Boopathi and Sujatha, 2022). *Antigastra catalaunalis* is a major insect pest and incidence was severe on late sowing sesame (100%) compared to early sowing (73.3%, Ahirwar *et al.,* 2009; Karuppaiah and Nadarajan, 2013). Chaudhry *et al.* (1989) reported that *A. catalaunalis* which caused 15-20% damage at vegetative phase and 10-15% at productive phase. *A. catalaunalis* is a key insect pest of sesame and causing economical loss to an extent of 43.1% (Gupta *et al.,* 2002). The high occurrence of the two pests, the high incidence of *A. catalaunalis* in Uganda (Egonyu *et al.,* 2005). Mean percentage of infested plants was >80% and approximately 50% of the capsules were seriously affected (Simoglou *et al.,* 2017). Yield losses were >50%, due to direct insect damage and premature opening of the infested capsules (Simoglou *et al.,* 2017).

Unfortunately, there are very few control strategies for management of the biotic stresses. Researchers are probably working on more eco-friendly management methods, such as plant resistance. Host plant resistance (HPR) offers a low-cost, practical, long term solution for maintaining lower insect pests and reducing crop losses in association with natural enemies. HPR can be a suitable method for pest control within integrated pest management strategies. There is an urgent need to use indigenous sesame germplasm/advanced breeding lines to build genomic resources to discover genetic variants for genetic enhancement of sesame especially for control of A. catalaunalis. Therefore, the project is aimed to identify sources of resistance to *A. catalaunalis.* This information will be utilized in the resistance breeding programmes.

MATERIALS AND METHODS

The present study was carried out in the research farm of ICAR-Indian Institute of Oilseeds Research, Rajendranagar, and Hyderabad, Telangana, India at an altitude of 540 m, 17º 19'17" N latitude and 78º 24'51" E

*Corresponding author's E-mail: boopathiars@gmail.com

longitude and has a tropical agro-climate. For the two seasons (2021 and 2022), field experiments were conducted in 60 advanced breeding lines of sesame in randomized block design (RBD) with three replication. The net plot size was 2 × 5 m with spacing of 40 × 30 cm row to row and plant to plant, respectively. All the recommended agricultural practices were followed in raising the crop. No plant protection measure was taken throughout the crop season. Observation on the incidence of *A. catalaunalis* was recorded at weekly intervals starting from initial appearance to final disappearance or up to harvest. Observations on the incidence were recorded from 10 randomly selected plants by counting number of infested capsules. Observation of leaves, flowers and pods' damage was recorded from the 10 selected plants per replication. The percent damage was determined at each stage of crops. The performance of genotypes against *A. catalaunalis* was done using 0-9 scoring methodology (Table 1) to categorise the entries into either susceptible or resistant (Gupta, 2004). The percentage of damage per cultivar was used for analysis of variance. Means were separated using Fisher's protected Least Significant Difference test, at 5% probability level. All statistical analyzes were performed using SPSS software (Version 26.0, IBM Corporation, Armonk, NY, USA).

Table 1 Methodology for categorising the reaction of sesame genotypes to *A. catalaunalis* based on percent mean damage

Percent incidence	Grade	Category
0-10%	1	Highly resistant
11-20%	3	Resistant
21-30%	5	Moderately resistant
31-40%	7	Susceptible
>40%	9	Highly susceptible

RESULTS AND DISCUSSION

The incidence of the *A. catalaunalis* is common during vegetative, flowering and pod formation stages of sesame during two seasons (Fig. 1). The sesame genotypes (n=60) were screened for *A. catalaunalis* during two season 1 and 2 (Fig. 2). In season 1, percent incidence of *A. catalaunalis* varied from 0 to 43.4 (Fig. 2a). Four genotypes, SES-K-20-2010, SES-K-20-3002, SES-K-20-1062 and SES-K-20-2022 were found free from *A. catalaunalis* incidence. The highest *A. catalaunalis* incidence was noted in CT-51 (41.5%) and GT 10 (43.4%). The sesame genotypes (n=60) graded for *A. catalaunalis* as highly resistant (15 genotypes), resistant (12 genotypes), moderately resistant (15 genotypes), susceptible (6 genotypes) and highly susceptible (12 genotypes) based on incidence (Table 2).

Table 2 Reaction of sesame genotypes to Antigastra catalaunalis under open field conditions during season 1 (2021)

Category	Percent leaf webber incidence	Number of sesame genotypes	Genotypes
Highly resistant	0-10%	15	SES-K-20-2010, SES-K-20-3002, SES-K-20-1062, SES-K-20-2022, Lathua Local, RT-372, IIOS-1102, SES-K-20-1060, SES-3-19-3014, SES-S-19-1013, IC-16239, CT-23, SES-S-19-1037, SES-K-20-2013 and Julang Sesame
Resistant	11-20%	12	SES-K-20-2024, SES-K-20-2017, SEL-S-2018-1003, SES-K-20-1064, ISWG-20-05, SES-K-20-1045, SES-K-20-2023, SES-K-20-1055, SES-K-20-1056, SES-K-20-1051, IIOS-1101 and SES-K-20-2009
Moderately resistant	21-30%	15	SES-K-20-2027, SES-K-20-2016, SEL-S-2018-1002, SES-K-20-1063, SES-K-20-2025, SES-K-20-2012, SES-K-20-2026, Long Knog-2, SES-K-20-2021, SES-K-20-2018, SEL-S-2018-1010, SES-K-20-2020, IIOS-1103, SES-K-20-3007 and SES-K-20-2014
Susceptible	31-40%	6	SES-K-20-1058, SES-K-20-2019, Long Knog-1, SES-K-20-2015, IIOS-3103 and CT-55
Highly susceptible	>40%	12	SES-K-20-1050, SES-K-20-1059, SES-K-20-1054, SES-K-20-2008, SES-K-20-2001, SES-K-20-1061, SES-K-20-1057, SES-K-20-2011, SES-K-20-1072, SES-K-20-1052, CT-51 and GT 10
Total	-	60	-

Table 3 Reaction of sesame genotypes to Antigastra catalaunalis under open field conditions during season 1 (2022)

Category	Percent leaf webber incidence	Number of sesame genotypes	Genotypes
Highly resistant	0-10%	1	SES-K-20-2016
Resistant	11-20%	17	SES-K-20-1056, SES-3-19-3014, SES-K-20-1063, SES-S-19-1013, SES-K-20-1050, SES-K-20-1057, Julang sesame, Long knog-1, Long knog-2, SES-K-20-1072, SES-K-20-2021, SES-K-20-2022, SES-K-20-2027, RT-372, SES-K-20-1058, IC-16239, SES-K-20-2023
Moderately resistant	21-30%	28	IIOS-1103, SEL-S-2018-1002, SES-K-20-1052, SES-K-20-1054, SES-K-20-1059, SES-K-20-2001, SES-K-20-2011, SES-K-20-2012, SES-K-20-2019, CT-51, Lathua local, SES-K-20-3007, SES-K-20-2010, SES-K-20-2013, SES-K-20-1061, SES-K-20-1064, SES-K-20-2026, IIOS-1101, IIOS-1102, SEL-S-2018-1003, SEL-S-2018-1010, SES-K-20-1055, SES-K-20-1060, SES-K-20-2008, SES-K-20-2014, CT-55, SES-K-20-2024, GT-10
Susceptible	31-40%	13	SES-K-20-2015, SES-K-20-2017, SES-K-20-2018, CT-23, SES-K-20-3002, SES-K-20-1062, SES-K-20-2025, ISWG-20-05, SES-S-19-1037, SES-K-20-1051, SES-K-20-2020, IIOS-20-3013, SES-K-20-1045
Highly susceptible	>40%	1	SES-K-20-2009
Total	-	60	-

Fig. 1. Leaf webber, Antigastra catalaunalis and its damage symptoms

In season 2, percent incidence of *A. catalaunalis* varied from 8.0 to 44.0 (Fig. 2b). None of genotype was found free from *A. catalaunalis* incidence. The lowest and highest *A. catalaunalis* incidence was noted in SES-K-20-2016 (8%) and SES-K-20-2009 (44.0%), respectively. The sesame genotypes (n=60) graded for *A. catalaunalis* as highly resistant (1 genotype), resistant (17 genotypes), moderately resistant (28 genotypes), susceptible (13 genotypes) and highly susceptible (1 genotype) based on incidence (Table 3). The genotypes SI 250, UMA and ES 22 exhibiting resistance at the vegetative stage as well as at the pod maturation stage (Gupta 2004) and CST 2001-3 showing tolerance to *A. catalaunalis* were reported by All India Co-ordinated Research Project (S&N) (2003). The results are in concordance with Singh (2002). Earlier, Karuppaiah and Nadarajan (2011) reported that SI 250 and UMA genotypes were found resistant, and ES 22 was highly resistant. Ranganatha *et al.* (2013) reported the use tolerant varieties like tolerant varieties *viz.*; RT-46, RT-54, RT-103, RT-125, Usha, Swetha Til, Tapi, Pragati, TMV-3, Shekhar, Tarun, Amrit, Gujarat Til-3, TKG-306, Hima, PKV-NT-11, TKG-55, TKG-21, TKG-22 and JTS-8 for management of *A. catalaunalis.*

To summarize, 16 genotypes such as SES-K-20-2010, SES-K-20-3002, SES-K-20-1062, SES-K-20-2022, Lathua Local, RT-372, IIOS-1102, SES-K-20-1060, SES-3-19-3014, SES-S-19-1013, IC-16239, CT-23, SES-S-19-1037, SES-K-20-2013, Julang Sesame and SES-K-20-2016 were highly resistant to *A. catalaunalis* and the resistant genotypes can be used as donor in future breeding programmes. However, further research is suggested to identify the DNA markers for resistance, mapping, QTL analysis and transfer of resistant genes/map segments using a backcross breeding approach coupled with marker assisted selection and also to study the genetic inheritance of resistance.

ACKNOWLEDGEMENT

The first author gratefully acknowledges the Director, ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Telangana, India for funding this study.

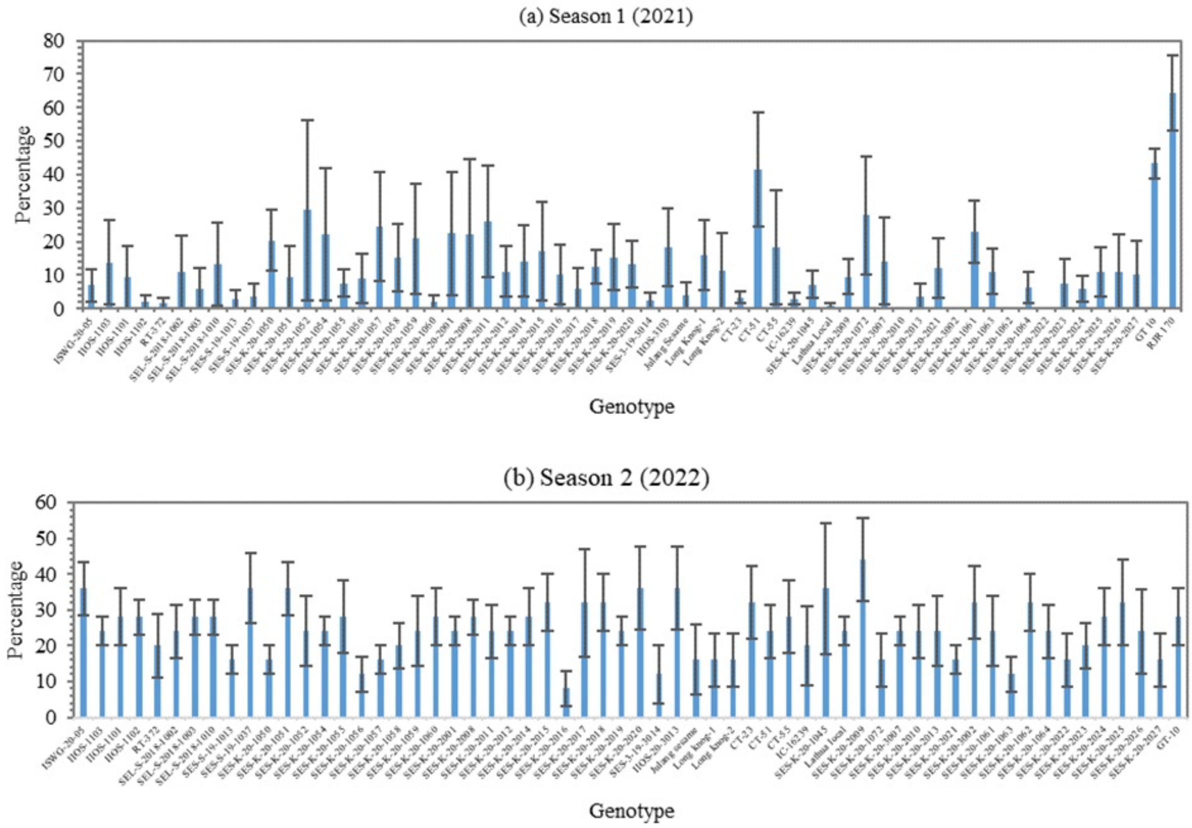

Fig. 2. Reaction of sesame genotypes to *Antigastra catalaunalis* during (a) season 1 (2021) and (b) season 2 (2022)

REFERENCES

Ahirwar R M, Banerjee S and Gupta M P 2009. Seasonal incidence of insect pests of sesame in relation to abiotic factors. *Annals of Plant Protection Science,* **17**(2): 351-356.

All India Co-ordinated Research Project (S&N) 2003. *Annual progress report. 2002-2003.* All India Co-ordinated Research project on Sesame and Niger (ICAR). Jawaharlal Nehru Agricultural University Campus, Jabalpur.

Biswas G C, Kabir S M H and Das G P 2001. Insect pest of sesamum (*Sesamum indicum* Linn.) in Bangladesh, their succession and natural enemies. *Indian Journal of Entomology,* **63**: 117-124.

Boopathi T and Sujatha M 2022. Emerging insect pests of sesame under changing climate scenario. Vikaspedia, India Development Gateway, Ministry of Electronics and Information Technology, Government of India, India. doi: https://vikaspedia.in/agriculture/crop-production/integrated-pest-managment/ipm-for-oilseeds/ipm-strategies-for-sesame/emerging-insect-pests-of-sesame-under-changing-climate-scenario.

Chaudhry, A.H., Oad, B.R. and Mehring, K. 1989. Highlights of Improvement Research on Oilseed Crops in Sindh. Oilseed Section, Agriculture Resource Institute, Tandojam, Pakistan.

Egonyu J, J.P. Egonyu, S. Kyamanywa, W. Anyanga and C. K. Ssekabembe. 2005. Review of pests and diseases of sesame in Uganda. In: *African Crop Science Conference Proceedings,* 7: 1411-1416.

Gupta, M.P., Rai, H.S. and Chourasia, S.K. (2002). Incidence and avoidable loss due to leaf roller/capsules borer, *Antigastra catalaunalis* Dup. in sesame. *Annals of Plant Protection Science,* **10**: 202-206.

Gupta M P 2004. Field screening of sesame germplasm against leaf roller and pod borer, *Antigastra catalaunalis* (Dup). *Indian Journal of Plant Protection,* **32**: 42-44.

Karuppaiah V, Nadarajan L. 2013. Host plant resistance against sesame leaf webber and capsule borer, *Antigastra catalaunalis* Duponchel (Pyraustidae: Lepidoptera). *African Journal of Agricultural Research,* **8**(37): 4674-4680.

Karuppaiah V and Nadarajan L 2011. Evaluation of sesame genotypes for resistance to sesame leaf roller and capsule borer, *Antigastra catalaunalis* Duponchel (Pyraustidae: Lepidoptera). *Archives of Phytopathology and Plant Protection,* **44** (9): 882-887.

Muzaffar A T, Rab D K, Maqsood A R and Imtiaz A N 2002. Insect pests associated with sesame at Tando Jam. *Pakistan Journal of Applied Science,* **2**(7): 723-726.

Ranganatha A R G, Jyotishi A, Deshmukh M R, Bisen R, Panday A K, Gupta K N, Jain S and Paroha S 2013. *Improved Technology for Maximizing Production of Sesame.* All India Coordinated Research Project on Sesame and Niger, Indian Council of Agricultural Research, JNKVV Campus, Jabalpur, Madhya Pradesh, India. 28p.

Sangeetha A, Gayathry G and Baskaran R 2022. Exploration of Bacillus species and AMF in the management of sesame root rot (*Macrophomina phseaolina*) and leaf blight (*Alternaria sesame*). *Journal of Oilseeds Research*, **39**(3 & 4): 219-224.

Sasipriya S, Parimala K, Eswari K B and Balram M 2022. Studies on genetic variability in sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research,* **39**(2): 142-145.

Simoglou K B, Anastasiades A I, Baixeras J and Roditakis E 2017. First report of *Antigastra catalaunalis* on sesame in Greece. *Entomologia Hellenica,* **26** (2017): 6-12.

Evaluation of efficacy of different concentrations of newer insecticides against thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) infesting castor

F K CHAUDHARY, M K CHANDARAGI*, D N TEJANI, L D PARMAR,
G P GANGWAR, A L JAT, A M PATEL AND J R PATEL

Centre for Oilseeds Research, S.D. Agricultural University, Sardarkrushinagar-385506, Gujarat

(Received: February 15, 2023; Revised: April 27, 2023; Accepted: May 3, 2023)

ABSTRACT

Field experiment was conducted at Centre for Oilseeds Research, S.D. Agricultural University, Sardarkrushinagar, Gujarat India during 2018-2019, 2019-2020, 2020-21 and 2021-22 to evaluate the efficacy of three newer insecticides (acetamiprid 20 SP, clothianidin 50 WDG, flonicamid 50 WG) with different concentrations (lower, normal and higher dose) against thrips (*Scirtothrips dorsalis*) infesting castor. Based on pooled analysis of four years data, mean population of thrips were found lower in plots treated with flonicamid 50 WG @ 0.019% (36.35 thrips/tender spike/plant), flonicamid 50 WG @ 0.015% (37.57 thrips/tender spike/plant) followed by flonicamid 50 WG @ 0.011% (39.16 thrips/tender spike/plant) and acetamiprid 20 SP @ 0.004% at its normal dose recorded 40.02 thrips/tender spike/plant which are at par with each other. The treatments acetamiprid 20 SP @ 0.005% and clothianidin 50 WDG @ 0.031% observed 40.21 and 40.58 thrips/tender spike/plant, respectively. Maximum seed yield of castor was realized from the acetamiprid 20 SP @ 0.005% treated plots (2284 kg/ha) followed by flonicamid 50 WG @ 0.019% (2220 kg/ha) and flonicamid 50 WG @ 0.015% (2148 kg/ha), which were at par with each other, whereas the lowest seed yield was recorded in control (1910 kg/ha). The maximum net gain (₹24945/ha) and benefit-cost ratio (1:11.50) was obtained with application of acetamiprid 20 SP @ 0.005% followed by acetamiprid 20 SP @ 0.004 % (₹6245/ha and 1:3.09) and flonicamid 50 WG (₹16622/ha and 1:2.84).

Keywords: Evaluation, Efficacy, Insecticides, Thrips, Castor

Castor, *Ricinus communis* L. is considered as one of the most remunerative crop in the world with a high seed oil content. India accounts for nearly 66.5 and 82.9 per cent of world's castor area and production. The current castor production in the country is 15.25 lakh tonnes from 8.63 lakh hectares with a productivity of 1767 kg/ha (DES, 2022). Castor oil and its derivatives are utilized in medicine, agriculture, textile and paper industry, plastics engineering, rubber and pharmaceuticals. One of the major constraints to get higher productivity in castor is the damage caused by insect pests. As of now, more than 100 insect pests are reported on castor and among them sucking insects and foliage feeders are of economic importance (Basappa and Lingappa, 2001; Senthil Kumar and Duraimurugan, 2022). Castor is damaged by an array of insect pests such as semilooper, *Achaea janata;* tobacco caterpillar, *Spodoptera litura;* shoot and capsule borer, *Conogethes punctiferalis;* leafhopper, *Empoasca flavescens;* thrips, *Scirtothrips dorsalis* and whitefly, *Trialeurodes ricini.* It is estimated that yield of castor reduced by 17.2 to 63.3 percent due to the insect pests during *kharif* (Lakshminarayanana and Duraimurugan, 2014; Bharathi and Duraimurugan, 2022). Among the list of insect pests reported to attack on castor, thrips assumed major status. They are tiny pinkish nymph and black adult with fringed wings, have been found to feed on both upper and lower leaf surfaces, resulting in crinkling of the terminal leaves with a silvery appearance. Severe infestation causes poor growth of plants, withering of emerging spikes, poor capsule setting and drying of the newly formed capsules. Therefore, the present investigations on efficacy of different concentrations of newer insecticides were evaluated against thrips in castor.

MATERIALS AND METHODS

Field experiment was undertaken during *kharif* 2018-19, 2019-20 2020-21 and 2021-21 at Centre for Oilseeds Research, S.D. Agricultural University, Sardarkrushinagar, Gujarat. The trials were laid out in a randomized block design at spacing of 90 cm x 60 cm with plot size of 6.00 m × 5.60 m. The castor hybrid, SKP 84 was sown as per recommended agronomic package of practices, except plant protection measures. The nine insecticidal treatments consist of acetamiprid 20 SP @ 0.003%, acetamiprid 20 SP @ 0.004%, acetamiprid 20 SP @ 0.005%, clothianidin 50 WDG @ 0.019%, clothianidin 50 WDG @ 0.025%, clothianidin 50 WDG @ 0.031%, flonicamid 50 WG @ 0.011%, flonicamid 50 WG @ 0.015% and flonicamid 50 WG @ 0.019% were evaluated against thrips. First spray

*Corresponding author's E-mail: mallu3731@sdau.edu.in

was applied at initiation of thrips on tender spike and second spray was applied at fifteen days after first spray. The observations on thrips population recorded on number of thrips per tender spike per plant from 10 randomly selected tender spike before and three, seven and fourteen days after each spray. Castor seed yield (kg/ha) was recorded in all the plots and protection cost benefit (C:B) ratio was worked out finally. Percent reduction over control was recorded according formula given by Henderson and Tilton (1955).

$$PRC = 1 - \left(\frac{\text{n in control PTC x n in treated in after treatment}}{\text{n in control after treatment x n in treated before treatment}} \right) x100$$

RESULTS AND DISCUSSION

Efficacy on thrips population: The results presented in Tables 1 to 4 revealed that there are significant differences among treatments over the control. The pretreatment counts of thrips were non-significant among treatments indicated uniform population of thrips in experimental plot during 2018-19, 2019-20 2020-21 and 2021-21, respectively.

2018-19: The pooled result of two sprays revealed that acetamiprid 20 SP @ 0.003% (1.5 ml/10 l) recorded lowest thrips (24.65/ tender spike/ plant) followed by flonicamid 50WG @ 0.015 % (3 g/10 l) (24.81 tender spike/plant) and clothianidin 50 WDG @ 0.019% (24.91 thrips/tender spike/ plant) The thrips incidence in rest of the treatments ranged between 24.88 to 25.36 number/ tender spike/plant.

2019-20: The pooled result revealed that acetamiprid 20 SP @ 0.003% recorded significantly minimum thrips (34.12 thrips/tender spike/ plant) population found at par with acetamiprid 20 SP @ 0.004% (34.65 thrips/tender spike/plant). However, significantly maximum population was observed in control (52.48 thrips/tender spike/plant).

2020-21: The pooled mean of two sprays revealed that flonicamid 50 WP @ 0.019% recorded significantly lowest thrips (25.57 thrips/ tender spike/plant) and performed statistically at par with flonicamid 50 WP @ 0.015% (26.09 thrips/tender spike/ plant). Remaining treatments recorded the thrips population from 26.28 to 27.39 thrips/tender spike/plant. While, control plot recorded significantly maximum thrips (45.40 thrips/tender spike/ plant).

2021-22: The results of pooled mean of two sprays revealed that flonicamid 50 WDG @ 0.019 % recorded minimum of 59.57 thrips/tender spike/plant followed by flonicamid 50 WDG @ 0.015% (63.96 thrips/tender spike/plant). Population of other treatments varied from 69.31 to 77.99 thrips/tender spike/plant. The untreated plot recorded maximum thrips (91.56 thrips/tender spike/ plant).

The pooled results over four years (Table 5) and spray revealed significant differences in terms of population of thrips and yield was recorded. Flonicamid 50 WDG @ 0.019% (3.8 g/10 l) recorded significantly minimum thrips (36.45 thrips/tender spike/plant) followed flonicamid 50 WG @ 0.015% (37.57 thrips/tender spike/plant), flonicamid 50 WG @ 0.011% (39.16 thrips/tender spike/plant), acetamiprid 20 SP @ 0.004% (40.02 thrips/tender spike/ plant), acetamiprid 20 SP @ 0.005%(40.21 thrips/tender spike/plant), acetamiprid 20 SP @ 0.003% (40.31 thrips/tender spike/plant), clothianidin 50 WDG @ 0.031% (40.56 thrips/tender spike/plant), Clothianidin 50 WDG @ 0.025% (41.33 thrips/tender spike/plant) and clothianidin 50 WDG @ 0.019% (41.41 thrips/tender spike/plant) performed better in terms of reduced number of thrips population. The untreated control plot recorded significantly maximum population of thrips (56.32 thrips/tender spike/plant). These findings are in agreement with Duraimurugan and Alivelu (2017) who revealed that mean reduction in thrips population over untreated control was maximum in clothianidin 50WG @ 25 g a.i./ha (95.1%) followed by dimethoate (89.4%), acetamiprid 20SP @ 20 g a.i./ha (86.6%), profenofos 50EC @ 250 g a.i./ha (78.9%), flonicamid 50WG @ 50 g a.i./ha (78.2%) and thiamethoxam 25WG @ 50 g a.i./ha (74.7%), respectively. Efficacy on castor seed yield and economics: The results presented in Tables 6 and 7 revealed that there are significant differences in seed yield and economics among treatments over the control.

2018-19: Treatment clothianidin 50 WDG @ 0.025% recorded maximum seed yield of 2585 kg/ ha followed by acetamiprid 20 SP @ 0.005% (2512 kg/ha) and flonicamid 50 WG @ 0.019% (2379 kg/ha).

2019-20: The treatment flonicamid 50 WDG @ 0.011% recorded numerically higher seed yield (1988 kg/ha) followed by acetamiprid 20 SP @ 0.005% (1928 kg/ha) and flonicamid 50 WG @ 0.019% (1838 kg/ha)

2020-21: Significantly maximum yield (2864 kg/ ha) was recorded in acetamiprid 20SP @ 0.005% followed by flonicamid 50 WG @ 0.019% (2811 kg/ha) and flonicamid 50 WG @ 0.015% (2514 kg/ha)

2021-22: The yield of insecticidal treatments including control ranged from 1493 to 1960 kg/ha and. Higher seed yield was recorded in flonicamid 50 WDG @ 0.015% (1960 kg/ha) followed by acetamiprid 20 SP @ 0.004 % (1874 kg/ha) flonicamid 50 WG @ 0.011% (1871 kg/ha).

Effect of insecticides on yield of castor revealed that acetamiprid 20 SP @ 0.005% recorded maximum yield (2284 kg/ha) followed by flonicamid 50 WDG @ 0.019% (2220 kg/ha) while, control recorded lowest yield (1910 kg/ha.). Maximum net realization and net gain (Table 7) were obtained in the plot treated with acetamiprid 20 SP 0.005% @ 2.5 g/10 L (₹27115.0/ha and ₹24945.0/ha) followed by flonicamid 50 WG 0.019% @ 3.8 g/10 l (₹22475.0/ha and ₹16622.0/ha). The highest PCBR was noticed in acetamiprid 20 SP 0.005% @ 2.5 g/10 L (1: 11.50). These research findings are in conformity with Duraimurugan and Alivelu (2017) who revealed that highest castor seed yield was recorded in clothianidin (1116 kg/ha), acetamiprid (1012 kg/ha) and flonicamid (886 kg/ha). Higher net returns and benefit-cost ratio was reported in clothianidin (₹16068/ha and 1.70) and acetamiprid (₹13548/ha and 1.62). Further, the efficacy of clothianidin and acetamiprid treatments provided higher seed yield in mungbean as reported by Singh *et al.* (2016) and Kavita *et al.* (2014). The effectiveness of flonicamid 50 WG acetamiprid 20 SP in minimizing of thrips population in bt cotton as reported by Meghana *et al.* (2018). Similarly, the influence of clothianidin 50% WDG and acetamiprid 20 SP to get seed yield and highest cost benefit ratio has been reported by Patil *et al.* (2007), Deosarkar *et al.* (2011), Ghosal *et al.* (2013) and Patil *et al.* (2016) therefore, supporting the present findings.

Table 1 Effect of newer insecticides against thrips in castor (2018-19)

Treatments	Dose (g/10L)	Mean population of thrips (No./ tender spike/ plant)												PRC
		1st spray				2nd spray				PTC	1st spray	2nd spray	Pooled mean	
		PTC	3 DAT	7 DAT	14 DAT	PTC	3 DAT	7 DAT	14 DAT					
Acetamiprid 20 SP @ 0.003%	1.5	29.97	19.07ab	20.57a	29.53ab	29.53	19.20ab	24.00ab	35.53a	29.75	23.06ab	26.24a	24.65a	21.57
Acetamiprid 20 SP @ 0.004%	2	30.80	20.77b	20.33a	28.37a	28.37	19.10a	23.80a	36.93ab	29.58	23.16ab	26.61ab	24.88a	20.38
Acetamiprid 20 SP @ 0.005%	2.5	31.87	19.50ab	20.60a	30.67b	30.67	19.43abc	24.67abc	37.30ab	31.27	23.59b	27.13bcd	25.36a	23.22
Clothianidin 50 WDG @ 0.019%	3.8	30.37	19.70ab	18.40a	30.70b	30.70	19.87a	23.90a	36.87ab	30.53	22.93ab	26.88abc	24.91a	22.79
Clothianidin 50 WDG @ 0.025%	5	30.90	18.70ab	19.30a	30.80b	30.80	20.67abc	24.23abc	37.00ab	30.85	22.93ab	27.30bcd	25.12a	22.93
Clothianidin 50 WDG @ 0.031%	6.2	30.77	18.97ab	19.30a	30.97b	30.97	20.83d	25.70d	36.97ab	30.87	23.08ab	27.83d	25.46a	21.94
Flonicamid 50 WG @ 0.011%	2.2	31.40	18.97ab	19.13a	31.23b	31.23	20.80abc	24.33abc	37.13ab	31.32	23.11ab	27.42bcd	25.27a	23.63
Flonicamid 50 WG @ 0.015%	3	32.33	17.47a	19.37a	29.63ab	29.63	20.37bcd	24.93bcd	37.10ab	30.98	22.16a	27.47bcd	24.81a	24.19
Flonicamid 50 WG @ 0.019%	3.8	33.17	17.50a	19.43a	30.83b	30.83	20.73cd	25.17cd	37.27ab	32.00	22.59ab	27.72cd	25.16a	25.59
Control	-	32.50	34.37c	34.73b	35.30c	35.30	35.67e	36.60e	38.20b	33.90	34.80c	36.82e	35.81b	00.00
S. Em. ±		0.78	0.73	0.71	0.61	0.61	0.46	0.29	0.62	0.50	0.40	0.27	0.24	-
C.D. at 5%		NS	2.18	2.10	1.82	1.82	1.36	0.85	1.84	NS	1.11	0.77	0.67	-
C.V. (%)		4.32	6.20	5.81	3.45	3.45	3.65	1.93	2.90	3.92	4.93	2.92	3.91	-

*Treatment mean with common super script letters are not significant by DNMRT at 5% level of significance, PTC: Pre-Treatment Count; DAT: Days After Treatment; PRC: Per cent Reduction over Control

Table 2 Effect of newer insecticides against thrips in castor (2019-20)

Treatments	Dose (g/10L)	Mean population of thrips (No./ tender spike/ plant)												PRC	Yield (kg/ha)
		1st spray				2nd spray				PTC	1st spray	2nd spray	Pooled mean		
		PTC	3 DAT	7 DAT	14 DAT	PTC	3 DAT	7 DAT	14 DAT						
Acetamiprid 20 SP @ 0.003%	1.5	35.60	25.03a	27.50a	42.00a	42.00	27.90a	31.07a	51.23a	38.80	31.51a	36.73a	34.12a	25.07	1807a
Acetamiprid 20 SP @ 0.004%	2	36.00	25.00a	27.57a	43.67ab	43.67	27.9a	31.07a	52.67ab	39.83	32.08ab	37.22ab	34.65ab	25.89	1786a
Acetamiprid 20 SP @ 0.005%	2.5	37.70	25.67sb	28.20abc	43.60ab	43.60	27.90a	31.03a	53.53ab	40.65	32.49bc	37.49ab	34.99bc	26.67	1928a
Clothianidin 50 WDG @ 0.019%	3.8	38.23	26.73b	29.10bc	42.00a	42.00	28.30a	31.50a	52.63ab	40.12	32.61bc	37.48ab	35.04bcd	25.57	1797a
Clothianidin 50 WDG @ 0.025%	5	38.07	25.87ab	27.93ab	44.07b	44.07	27.77a	31.20a	54.83b	41.07	32.62bc	37.93b	35.28bcd	26.82	1536a
Clothianidin 50 WDG @ 0.031%	6.2	37.90	26.07ab	28.67abc	43.47ab	43.47	27.87a	31.20a	54.57b	40.68	32.74bcd	37.88b	35.31bcd	26.06	1738a
Flonicamid 50 WG @ 0.011%	2.2	38.87	27.13b	29.60c	44.30b	44.30	27.80a	31.33a	54.63b	41.58	33.68d	37.92b	35.80d	26.66	1988a
Flonicamid 50 WG @ 0.015%	3	38.30	27.07b	29.60c	43.10ab	43.10	27.67a	31.07a	54.10ab	40.70	33.26cd	37.61ab	35.44bcd	25.82	1765a
Flonicamid 50 WG @ 0.019%	3.8	38.37	26.37ab	28.80abc	43.97b	43.97	27.67a	31.40a	54.87b	41.17	33.05bcd	37.98b	35.51cd	26.51	1838a
Control	-	37.60	41.47c	48.13d	51.83c	51.83	54.43b	57.47b	61.57c	44.72	47.14e	57.82c	52.48e	00.00	1469a
S. Em. ±		0.85	0.51	0.43	0.59	0.59	0.31	0.24	0.88	0.52	0.30	0.32	0.24	-	202.76
C.D. at 5%		NS	1.53	1.29	1.76	1.76	0.93	0.72	2.61	NS	0.84	0.90	0.67	-	602.16
C.V. (%)		3.90	3.22	2.47	2.33	2.33	1.78	1.24	2.80	3.10	2.63	2.43	2.79	-	19.89

*Treatment mean with common super script letters are not significant by DNMRT at 5% level of significance, PTC: Pre-Treatment Count; DAT: Days After Treatment; PRC: Per cent Reduction over Control

Table 3 Effect of newer insecticides against thrips in castor (2020-21)

Treatments	Dose (g/10L)	Mean population of thrips (No./ tender spike/ plant)												PRC	Yield (kg/ha)
		1st spray				2nd spray				PTC	1st spray	2nd spray	Pooled mean		
		PTC	3 DAT	7 DAT	14 DAT	PTC	3 DAT	7 DAT	14 DAT						
Acetamiprid 20 SP @ 0.003%	1.5	26.23	17.90cd	22.20de	30.97a	30.07	32.67c	22.30a	37.83a	28.15	23.69cd	30.93d	27.31f	31.33	2067a
Acetamiprid 20 SP @ 0.004%	2	25.37	16.30b	21.43bc	31.07a	30.43	31.53c	22.50a	37.67a	27.90	22.93ab	30.57d	26.75de	32.14	2153a
Acetamiprid 20 SP @ 0.005%	2.5	25.47	16.13b	21.17a	31.60a	30.77	31.80c	22.03a	37.70a	28.12	22.97ab	30.51cd	26.74cd	32.70	2864a
Clothianidin 50 WDG @ 0.019%	3.8	26.07	18.20d	21.97bcde	31.50a	30.73	31.93c	22.60a	38.13a	28.40	23.89d	30.89d	27.39f	31.74	2329a
Clothianidin 50 WDG @ 0.025%	5	25.97	17.07bc	22.33e	31.10a	30.20	32.80c	22.63a	38.20a	28.08	23.50cd	31.21d	27.36f	31.06	2280a
Clothianidin 50 WDG @ 0.031%	6.2	26.07	16.37b	21.70abcd	31.93a	31.10	32.67c	22.77a	38.13a	28.58	23.33bc	31.19d	27.26ef	32.49	2482a
Flonicamid 50 WG @ 0.011%	2.2	26.53	16.53b	21.20a	30.83a	30.00	28.20b	22.97a	37.93a	28.27	22.85ab	29.70bc	26.28bc	34.20	2425a
Flonicamid 50 WG @ 0.015%	3	26.03	14.53a	22.03cde	31.20a	30.37	28.47b	22.40a	37.93a	28.20	22.59a	29.60b	26.09ab	34.51	2514a
Flonicamid 50 WG @ 0.019%	3.8	26.57	13.97a	21.50abc	31.87a	31.57	25.53a	22.80a	37.73a	29.07	22.45a	28.69a	25.57a	37.75	2811a
Control	-	25.90	28.57e	33.43f	39.03b	38.37	81.40d	43.50b	46.47b	32.13	33.68e	57.12e	45.40g	00.00	2766a
S. Em. ±		0.45	0.30	0.18	0.33	0.30	0.54	0.28	0.24	0.27	0.16	0.22	0.14	-	254.57
C.D. at 5%		NS	0.90	0.53	0.99	0.90	1.60	0.83	0.72	NS	0.45	0.61	0.39	-	756.03
C.V. (%)		3.00	3.00	1.35	1.80	1.68	2.61	1.96	1.09	2.32	2.01	1.98	2.07	-	17.86

*Treatment mean with common super script letters are not significant by DNMRT at 5% level of significance PTC: Pre-Treatment Count; DAT: Days After Treatment; PRC: Per cent Reduction over Control

Table 4 Effect of newer insecticides against thrips in castor (2021-22)

Treatments	Dose (g/10L)	Mean population of thrips (No./ tender spike/ plant)												PRC	Yield (kg/ha)
		1st spray				2nd spray				PTC	1st spray	2nd spray	Pooled mean		
		PTC	3 DAT	7 DAT	14 DAT	PTC	3 DAT	7 DAT	14 DAT						
Acetamiprid 20 SP @ 0.003%	1.5	62.63	59.47c	55.30e	95.37a	91.27	76.60de	73.03ef	91.17ab	76.95	70.05e	80.27d	75.16de	15.05	1575a
Acetamiprid 20 SP @ 0.004%	2	63.23	58.30c	52.03de	95.10a	89.27	76.47d	68.43d	92.46abc	76.25	68.48cde	79.12d	73.80d	15.82	1874a
Acetamiprid 20 SP @ 0.005%	2.5	62.40	54.13ab	44.47ab	96.93a	88.67	79.27e	70.80de	98.48abc	75.53	65.18ab	82.85de	74.01d	14.78	1834a
Clothianidin 50 WDG @ 0.019%	3.8	62.87	58.50c	54.37e	96.13a	93.87	83.53f	78.77h	96.61abc	78.37	69.67de	86.30ef	77.99f	13.45	1493a
Clothianidin 50 WDG @ 0.025%	5	62.10	54.00ab	47.87bc	99.43a	97.00	84.67f	77.00gh	102.54bc	79.55	67.10bc	88.07f	77.59ef	15.18	1549a
Clothianidin 50 WDG @ 0.031%	6.2	62.47	52.80a	44.07a	96.13a	94.73	83.03f	75.23fg	94.60abc	78.60	64.33a	84.29ef	74.31d	17.77	1829a
Flonicamid 50 WG @ 0.011%	2.2	63.77	59.03c	55.40e	94.47a	97.20	60.57c	56.33c	90.08a	80.48	69.63de	68.99c	69.31c	25.10	1871a
Flonicamid 50 WG @ 0.015%	3	64.27	56.40bc	49.90cd	96.27a	91.13	41.57b	36.80b	102.79bc	77.70	67.52cd	60.39b	63.96b	28.41	1960a
Flonicamid 50 WG @ 0.019%	3.8	64.10	53.03ab	43.13a	95.83a	94.87	32.53a	28.97a	103.92c	79.48	64.00a	55.14a	59.57a	34.82	1852a
Control	-	62.60	71.00d	78.63f	96.10a	96.67	97.90g	102.47i	103.28c	79.63	81.91f	101.22g	91.56g	00.00	1520a
S. Em. ±		0.72	1.08	1.11	1.58	5.25	0.88	0.69	3.51	2.65	0.74	1.23	0.73	-	212.37
C.D. at 5%		NS	3.21	3.28	4.69	15.58	2.60	2.05	10.42	NS	2.06	3.44	2.01	-	630.72
C.V. (%)		1.98	3.25	3.65	2.84	9.72	2.12	1.79	6.23	8.29	3.21	4.68	4.17	-	21.19

*Treatment mean with common super script letters are not significant by DNMRT at 5% level of significance, PTC: Pre-Treatment Count; DAT: Days After Treatment; PRC: Per cent Reduction over Control (Henderson Tilton Formula)

Table 5 Effect of newer insecticides against thrips in castor (pooled)

Treatment	Dose (g/10L)	Mean population of thrips (No./ tender spike/ plant)					
		PTC	2018-19	2019-20	2020-21	2021-22	Pooled
Acetamiprid 20 SP @ 0.003%	1.5	43.42	24.65a	34.12a	27.31f	75.16de	40.31a
Acetamiprid 20 SP @ 0.004%	2	43.39	24.88a	34.65ab	26.75de	73.80d	40.02a
Acetamiprid 20 SP @ 0.005%	2.5	43.89	25.36a	34.99bc	26.74cd	74.01d	40.21a
Clothianidin 50 WDG @ 0.019%	3.8	44.35	24.91a	35.04bcd	27.39f	77.99f	41.41a
Clothianidin 50 WDG @ 0.025%	5	44.89	25.12a	35.28bcd	27.36f	77.59ef	41.33a
Clothianidin 50 WDG @ 0.031%	6.2	44.68	25.46a	35.31bcd	27.26ef	74.31d	40.58a
Flonicamid 50 WG @ 0.011%	2.2	45.41	25.27a	35.80d	26.28bc	69.31c	39.16a
Flonicamid 50 WG @ 0.015%	3	44.40	24.81a	35.44bcd	26.09ab	63.96b	37.57a
Flonicamid 50 WG @ 0.019%	3.8	45.43	25.16a	35.51cd	25.57a	59.57a	36.45a
Control	-	47.60	35.81b	52.48e	45.40g	91.56g	56.32b
S. Em. ±		0.66	0.24	0.24	0.14	0.73	1.60
C.D. at 5%		1.83	0.67	0.67	0.39	2.01	4.64
C.V. (%)		7.55	3.91	2.79	2.07	4.17	4.23

*Treatment mean with common super script letters are not significant by DNMRT at 5% level of significance; PTC: Pre-Treatment Count

Table 6 Effect of newer insecticides on yield of castor (pooled)

Treatments	Dose (g/10L)	Yield (kg/ ha)				
		2018-19	2019-20	2020-21	2021-22	pooled
Acetamiprid 20 SP @ 0.003%	1.5	2213	1807	2067	1575	1915
Acetamiprid 20 SP @ 0.004%	2	2281	1786	2153	1874	2024
Acetamiprid 20 SP @ 0.005%	2.5	2512	1928	2864	1834	2284
Clothianidin 50 WDG @ 0.019%	3.8	2330	1797	2329	1493	1987
Clothianidin 50 WDG @ 0.025%	5	2585	1536	2280	1549	1988
Clothianidin 50 WDG @ 0.031%	6.2	2284	1738	2482	1829	2083
Flonicamid 50 WG @ 0.011%	2.2	1980	1988	2425	1871	2066
Flonicamid 50 WG @ 0.015%	3	2353	1765	2514	1960	2148
Flonicamid 50 WG @ 0.019%	3.8	2379	1838	2811	1852	2220
Control	-	1886	1469	1766	1520	1910
S. Em. ±		243.44	202.76	254.57	212.37	114.64
C.D. at 5%		722.99	602.16	756.03	630.72	321.01
C.V. (%)		18.49	19.89	17.86	21.19	19.25

*Treatment mean with common super script letters are not significant by DNMRT at 5% level of significance

Table 7 Economics of newer insecticides against thrips in castor

Tr. No.	Treatment	Conc. (%)	Qty. of material required for 2 sprays (L or kg/ha)	Cost of material (₹/ha)	Labour cost (₹)	Total cost of treatment	Yield (kg/ha)	Gross realization (₹/ha)	Net realization over control (₹/ha)	Net gain (₹/ha)	PCBR
T1	Acetamiprid 20 SP	0.003	0.150	450	1420	1870	1915	138837.5	362.5	-1507.5	1: -0.81
T2	Acetamiprid 20 SP	0.004	0.200	600	1420	2020	2024	146740.0	8265.0	6245.0	1: 3.09
T3	Acetamiprid 20 SP	0.005	0.250	750	1420	2170	2284	165590.0	27115.0	24945.0	1: 11.50
T4	Clothianidin 50 WDG	0.019	0.380	7790	1420	9210	1987	144057.5	5582.5	-3627.5	1: -0.40
T5	Clothianidin 50 WDG	0.025	0.500	10250	1420	11670	1988	144130.0	5655.0	-6015.0	1: -0.52
T6	Clothianidin 50 WDG	0.031	0.620	12710	1420	14130	2083	151017.5	12542.5	-1587.5	1: -0.11
T7	Flonicamid 50 WG	0.011	0.220	2567	1420	3987	2066	149785.0	11310.0	7323.0	1: 1.84
T8	Flonicamid 50 WG	0.015	0.300	3500	1420	4920	2148	155730.0	17255.0	12335.0	1: 2.51
T9	Flonicamid 50 WG	0.019	0.380	4433	1420	5853	2220	160950.0	22475.0	16622.0	1: 2.84
T10	Untreated control	-	-	-	-	-	1910	138475.0	-	-	-

Castor seed: ₹ 72.5/kg
Labours required: 2/day/ha
Labour cost: ₹ 355/day
Acetamiprid 20 SP: ₹ 3000/kg
Clothianidin 50 WDG: ₹ 20,500/kg
Flonicamid 50 WG: ₹ 11,667/kg

REFERENCES

Basappa H and Lingappa S 2001. Studies on damage potential of *Achaea janata* at different phenological states of castor. *Indian Journal of Plant Protection,* **29**: 17-24.

Bharathi E and Duraimurugan P 2022. Pathogenicity of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium* (Nomuraea) *rileyi* against castor hairy caterpillar, *Euproctis fraterna* (Lepidoptera: Lymantriidae). *Journal of Oilseeds Research,* **39**(1): 58-60.

Deosarkar D B, Zanwar P R and Shelke L T 2011. Clothianidin: a promising new molecule for the management of sucking pests of transgenic cotton. *Proceedings of World Cotton Research Conference on Technologies for Prosperity,* Renaissance Convention Centre, Mumbai, India. 135 pp.

DES 2022 Normal estimates of area, production and yield of selected principal crops. Directorate of Economics and Statistics, Agricultural Statistics Division, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare Government of India, pp 38.

Duraimurugan P and Alivelu K 2017. Field efficacy of newer insecticides against sucking insect pests in castor. *Indian Journal of Plant Protection,* **45**(3): 1-5

Ghosal A Chatterjee M L and Bhattacharyya A 2013. Bio efficacy of neonicotinoids against *Aphis gossypii* Glover of okra. *Journal of Crop and Weed,* **9** :181-184.

Henderson C F and Tilton E W 1955. Tests with acaricides against the brow wheat mite. *Journal of Economic Entomology,* **48**: 157-161.

Kavita B M, Purohit M S and Kitturmath M G 2014. Bio-efficacy of different insecticides on insect pest complex and effect on the yield and economics of mungbean, *Vigna radiata* (L.) Wilczek. *Trends in Biosciences,* **7**: 1075-1077.

Lakshminarayan M and Duraimurugan P 2014. Assessment of avoidable yield losses due to insect pests in castor (*Ricinus communis* L.). *Journal of Oilseeds Research*, **31**: 140-144.

Meghana, Jagginavar S B and Sunitha N D 2018. Efficacy of Insecticides and Bio Pesticides against Sucking Insect Pests on Bt Cotton. *International Journal of Current Microbiology and Applied Sciences*, **7**(6): 2872-2883.

Patil S B, Udideri S S, Naik K L, Rachappa V, Nimbal F and Guruprasad G S 2007. DANTOP: A promising new molecule for the management of cotton sap feeding insects. *Karnataka Journal of Agricultural Sciences,* **20**: 47-50.

Patil S D, Padhye A P and Katare S 2016. Efficacy of insecticidal seed treatment against pests of wheat. *International Journal of Plant Protection,* **9**: 372-380.

Senthil Kumar M and Duraimurugan P 2022. Population dynamics of insect pest and natural enemies of castor (*Ricinus communis* L.) under different intercrops. *Journal of Oilseeds Research,* **39**(2): 130-133.

Singh P S, Mishra H and Singh S K 2016. Evaluation of certain newer insecticides against the insect pests of mungbean, *Vigna radiata* (L.) Wilczek. *Journal of Experimental Zoology India,* **19**: 367-372.

Analysis of impact of frontline demonstrations on adoption of improved technologies of oilseed crops

GARIKAMUKKALA ASHA LATHA SRI, G D S KUMAR[1*] AND M A KHAN

College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur-492012, Chhattisgarh

(Received: March 31, 2023; Revised: June 20, 2023; Accepted: June 22, 2023)

ABSTRACT

The major objective of frontline demonstrations (FLDs) is to demonstrate the productivity potential and profitability of improved technologies in farmers' fields. It is based on the principles of learning by doing and seeing is believing. It is assumed that the demonstrations will aid in increasing the adoption of improved technologies by the farmers and result in reducing the yield gaps at field level. The present study was conducted during the year 2021-22 in eight villages of the Prakasam and Raipur districts of Andhra Pradesh and Chhattisgarh states, respectively with the objective to assess the impact of FLDs in terms of adoption of improved technologies by FLD and non-FLD farmers. The data were collected from a total of 160 FLD and non-FLDs farmers cultivating oilseed crops. Adoption index was estimated and it was found that FLD farmers had high adoption index as compared to non-FLD farmers indicating higher adoption levels among FLD farmers.

Keywords: Adoption index, Frontline demonstrations, Improved Technologies, Oilseeds

Oilseeds as a commodity group are next only to food grains in acreage accounting for 14.28% of the gross cropped area, production, and value and form an essential part of the human diet. Rapeseed-mustard, groundnut, soybean, sunflower, sesame, safflower, and niger are the major sources of edible oils (Shenoi, 2003; Gandhimathy, 2022). The area under major oilseeds was 266.7 lakh ha. The country recorded the highest-ever production of 361 lakh t of oilseeds during the year 2020-21 (DES, 2021). India is one of the world's top producers and consumers of vegetable oils and occupy 12% of the global area and contributes to 7% of production with only 57% of global productivity (FAO, 2021). The productivity of oilseeds is low due to various reasons such as the cultivation of oilseeds under rainfed conditions, resource-poor soils with very less nutrient management, and non-adoption of improved technologies by farmers. In order to meet the growing domestic demand for edible oils, India spent more than 1.40 lakh crore to import edible oils during 2021-22. Based on the current trends, limited scope exists for the expansion of the area under oilseeds, and the increase in oilseed production will have to mainly come from productivity gains made possible by the use of new technology.

Oilseed crops are grown in Andhra Pradesh on an area of 8.53 lakh ha with a production of 31.65 lakh t (Department of Agriculture, Andhra Pradesh, 2021). Oilseed crops are grown in Chhattisgarh over an area of 0.79 lakh with a production of 0.40 lakh t (Directorate of Agriculture, Chhattisgarh, 2021). The oilseed crops in these states have low productivity.

[1]ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad-500 030, Telangana; [*]Corresponding author's E-mail: gd.satishkumar@icar.gov.in

Frontline demonstrations (FLDs) are one of the crucial technology transfer programmes to show the profitability and productivity potential of improved technologies in farmers' fields (Thakur *et al.,* 2022). FLDs have been conducted by various AICRP and voluntary centres for the past many years in oilseed crops and significant yield gaps between improved technology and farmers' practice fields were reported. FLDs on oilseed crops were conducted by various AICRP oilseeds during 2014-15 to 2018-19 to show the productivity potential and profitability of improved technologies (IT). A total of 24,035 demonstrations were conducted on the whole package which included recommended cultivar, optimum seed rate, and spacing, fertilizer management, and need-based plant protection as compared to farmers' practices (Afzal *et al.,* 2013). The lack of essential inputs, labor-intensive technologies, the need for further investment, and unprofitable crop pricing, aside from the characteristics of individual farmers affect their adoption behaviour. It was estimated that a 31.4% yield gap was observed between FLDs and national productivity as reported by Kumar *et al.* (2014). It is essential to bridge the yield gaps for increasing the production of oilseed crops. To bridge the yield gaps, the adoption of improved technologies is critical, and therefore, it is essential to understand the adoption level of farmers. The present study was conducted in the year 2021-2022 to assess the impact of FLDs in the adoption of improved technologies by FLD and non-FLD farmers and the influence of farmers characteristics in adoption of improved technologies.

MATERIALS AND METHODS

Two states, Andhra Pradesh and Chhattisgarh, where FLDs were conducted by REEDS, a voluntary centre, and AICRP-safflower, Raipur centre, respectively were selected for the study. Based on the highest number of FLDs conducted, one district from each state and two mandals from each district were selected. From each selected mandal, two villages were selected thus, making a total of eight villages. Thamballapale and Burujupalle villages from Giddalur mandal, Nallaguntla and Kistampalle villages from Komarolu mandal in Prakasam district of Andhra Pradesh, and Baktara and Mungi villages from Arang block and Pachari and Math villages from Tilda blocks in Raipur district of Chhattisgarh were selected for the study. From each selected village, 10 each of FLD and non-FLD farmers were randomly selected making a total of 160 respondents. Farmers' characteristics influencing the adoption process were finalized in discussion with experts and the data were collected through a semi-structured, pre-tested interview schedule by personal interview of the respondents. For quantifying the data, each practice was given a score of one for non-adopted, two for partially adopted, and three for fully adopted. The respondents were classified into three categories based on the mean (X) and standard deviation (S.D.) and adoption was calculated with the help of a scale developed by Sengupta (1967) and it was calculated by using the adoption index formula given below.

$$\text{Adoption index (A.I)} = \frac{\text{Total score obtained by farmer}}{\text{Maximum score}} \times 100$$

The data were analyzed by using statistical tools such as frequency, percentage, mean, standard deviation and correlation coefficient.

The relationship between the farmers' characteristics and adoption of oilseed crop production technologies was estimated using pearsons correlation.

RESULTS AND DISCUSSION

Out of the total FLD farmers, 15.0%, 12.5%, 2.5%, and 70.0% of farmers conducted FLDs on castor, sunflower, safflower, and sesame crops, respectively. Among non-FLD farmers, 13.7%, 8.75%, 2.5%, and 75.0% farmers cultivated castor, sunflower, safflower, and sesame crops, respectively. The data presented in table 1 indicated that in castor crop among the FLD farmers, adoption index was more with cultivar (91.6%) followed by spacing (88.8%), management of diseases (86.1%), seed rate (83.3%), number of irrigations (80.5%), time of sowing (75.0%), management of insect-pests (72.2 %), whereas the adoption index was 69.4% each for application of farm yard manure (FYM), application of fertilizers (NP) and time of harvesting, 66.6% for weed management and interculture, 63.8% each for application of P fertilize and use of herbicides. Among non-FLD farmers, the adoption index was more for optimum time of sowing (87.8%) and spacing (87.8%) followed by management of insect-pests (78.7%), optimum number of irrigations (72.7%), whereas the adoption index was 69.6% for seed rate and time of harvesting, 66.6% each for application of basal dose of fertilizers, weed management and interculture and 63.6% for management of diseases.

In sunflower crop, among FLD farmers, highest adoption index was observed for timely sowing and optimum spacing (86.6% each) followed by 83.3% each for optimum seed rate, application of basal dose of fertilizers and management of diseases, 80% each for use of recommended cultivar, application of FYM and optimum number of irrigations, 76.6% each for seed treatment and management of insect-pests, 73.3% for correct stage of harvesting the crop, 70% each for weed management and interculture and 66.6% for use of herbicides. Whereas among non-FLD, high adoption index was observed for timely sowing, seed rate, optimum number of irrigations, and optimum time of harvesting with 76.1% each followed by spacing (71.4%), weed management and interculture (66.6% each), 61.9% for management of insect-pests and application of N and K as basal dose.

In safflower crop, FLD farmers had high adoption index for optimum spacing and management of diseases (100% each) followed by timely sowing (83.3%) and 66.6% for adoption of recommended variety, seed rate, seed treatment, application of FYM, application of basal dose of N, P, K, weed management and interculture, management of insect-pests and optimum time of harvesting. Among non-FLD farmers, highest adoption index was found for optimum seed rate, timely sowing, optimum spacing, application of basal dose of N and K fertilizers, weed management and interculture and optimum time of of harvesting (66.6% each) followed by 50% for seed treatment.

In sesame crop, FLD farmers had high adoption index for timely sowing (92.2%) followed by seed treatment (91.6%), application of phosphorus (91.0%), use of recommended variety, optimum seed rate and application of N fertilizers, management of insect-pests (89.8%), application of FYM (89.2%), optimum time of harvesting (88.6%), weed management and interculture (86.9% each). Among non-FLD Farmers, adoption index was more for seed treatment (77.9%) followed by optimum time of sowing (76.2%) and application of FYM (69.1%) (Table 1). These findings are similar to that of Verma *et al.* (2017).

Table 1 Distribution of respondents (%) according to their adoption level

Practice	FLD farmers				non-FLD farmers			
	Castor (n = 12)	Sunflower (n = 10)	Safflower (n = 02)	Sesame (n = 56)	Castor (n = 11)	sunflower (n = 07)	Safflower (n = 02)	Sesame (n = 60)
Recommended cultivar	91.6	80.0	66.6	90.4	45.4	33.3	33.3	42.5
Use of optimum seed rate	83.3	83.3	66.6	90.4	69.6	76.1	66.6	42.5
Optimum time of sowing	75.0	86.6	83.3	92.2	87.8	76.1	66.6	76.2
Seed treatment	58.3	76.6	66.6	91.6	39.3	38.0	50.0	77.9
Recommended spacing	88.8	86.6	100	84.5	87.8	71.4	66.6	41.6
Application of farm yard manure (FYM)	69.4	80.0	66.6	89.2	48.4	47.6	33.3	69.1
Management of fertilizers (basal dose)								
Nitrogen	69.4	83.3	66.6	90.4	66.6	61.9	66.6	68.3
Phosphorus	63.8	83.3	66.6	91.0	66.6	57.1	50.0	64.1
Potassium	69.4	83.3	66.6	86.9	66.6	61.9	66.6	69.1
Management of fertilizers (split application)								
Nitrogen (first split)	52.7	60.0	66.6	85.1	33.3	33.3	33.3	42.0
Nitrogen (second split)	55.5	76.6	66.6	80.3	33.3	33.3	33.3	36.2
Optimum number of irrigations	80.5	80.0	66.6	86.3	72.7	76.1	66.6	69.1
Weed management and interculture	66.6	70.0	66.6	86.9	66.6	66.6	66.6	66.2
Weed management by herbicides	63.8	66.6	66.6	76.7	36.3	33.3	33.3	36.6
Plant protection measures								
Management of insect pests	72.2	76.6	66.6	89.8	78.7	61.9	50.0	65.8
Management of diseases	86.1	83.3	100	84.5	63.6	47.6	33.3	56.2
Optimum time of harvesting	69.4	73.3	66.6	88.6	69.6	76.1	66.6	69.1

The mean adoption score for FLD farmers was 82.8 as compared to 58.0 for non- FLD farmers indicating the impact of conducting of FLDs on adoption of improved technologies by farmers. Majority of FLD farmers (53.7%) were in medium level of adoption category, followed by a low (23.7%) and high (22.5%). Similar findings were reported by Gorfad *et al.* (2018). In the case of non-FLD farmers, majority (62.5%) were in medium level of adoption category followed by a low (26.3%) and high (11.5%). These findings were in line with the finding of Sipai *et al.* (2017) and Rathod *et al.* (2012).

Table 2 Distribution of respondents according to adoption level

Adoption Level	Number and percent	
	FLD	Non-FLD
Low	19 (23.7)	21 (26.3)
Medium	43 (53.8)	50 (62.5)
High	18 (22.3)	9 (11.2)

FLD farmers mean score= 82.8, SD = 11.3;
Non-FLD farmers mean score = 58.0, SD = 5.6

To find out the influence of farmers characteristics and adoption level regarding oilseed crop production technology, the correlation was worked out, the findings are presented in table 3.

Table 3 Correlation between farmers' characteristics and adoption

Farmers' Characteristics	Correlation coefficient (r)	
	FLDs	non-FLDs
Age	-0.284*	0.048 NS
Education	0.503**	0.267*
Land holding	0.281*	0.196 NS
Size of family	0.110 NS	0.101 NS
Annual income	0.237*	0.347**
Farming experience	-0.116 NS	0.018 NS
Innovativeness	0.468**	0.364**
Social participation	0.558**	0.176 NS
Mass media exposure	0.210 NS	0.253*
Extension participation	0.287**	0.171 NS
Farmers perception on conduct of FLDs	0.433**	0.275*

** = r is significant at the 0.01 level;
* = r is significant at the 0.05 level (2-tailed)

The correlation coefficient (r) between farmers' characteristics of FLD and non-FLD farmers and adoption level regarding oilseed crop production technology revealed that FLD farmer's education, land holding, annual income, innovativeness, social participation, extension participation, farmers perception on conduct of FLDs were positive and significantly related, whereas age was negative and significantly related to adoption level. Among non-FLD farmers education, annual income, innovativeness, mass media exposure, and farmers perception on conduct of FLDs were positive and significantly related to adoption level. The psychological characteristics of farmers such as innovativeness, social participation, mass media exposure, and extension participation were important for increasing the adoption level and higher yields of oilseed crops.

Identifying farmers with significant characteristics and nurturing them in further developing the characteristics through various modes will result in higher adoption levels and realizing higher yields and reducing the yield gaps. The findings are similar to that reported by Hadiya *et al.* (2016) and Chand *et al.* (2011).

The study clearly indicated the impact of FLDs resulting in higher adoption level among FLD farmers compared to non-FLD farmers'. Further, the study identified the critical farmers' characteristics, which may influence the farmers decision to adopt improved technologies of oilseed crops. Pragmatic mechanisms had to be developed to improve the conduct of FLDs for enhancing the adoption levels and the farmers need to be nurtured in developing the characteristics, which influenced the adoption process.

REFERENCES

Afzal Ahmad, Guru Prem and Ramesh Kumar 2013. Impact of frontline demonstrations on Indian mustard through improved technologies. *Indian Research Journal of Extension Education,* **13**: 117 - 119.

Chand S and Meena K C 2011. Correlates of adoption of groundnut production technology by the farmers. *Indian Research Journal of Extension Education,* **19**: 125-127.

Directorate of Agriculture, Andhra Pradesh 2021. *Season and crop report 2019-2020.* Accessed on 1-9-2021.

DES 2021. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India. https://eands.dacnet.nic.in/, assessed in 2021.

Directorate of Agriculture, Chhattisgarh- Raipur 2021. Agriculture Development and Farmer Welfare and Bio-Technology Department. http://agriportal.cg.nic.in/agridept/AgriEn/Default.aspx, Accessed on 1-9-2021.

Food and Agriculture Organization 2021. https://www.fao.org/statistics/en/.

Gandhimathy B 2022. Growth and instability of oilseeds in India. *Journal of Oilseeds Research,* **39**(3 & 4): 265-267.

Gorfad P S, Chovatia J V and Kalsariya B N, 2018. Adoption of improved groundnut production technology by groundnut growers. *Gujarat Journal of Extension Education,* **29**: 2.

Hadiya B, Deshmukh G and Bariya M, 2016. Adoption of recommended practices of *kharif* groundnut growers in Saurashtra zone of Gujarat. *Indian Research Journal of Extension Education,* **14**: 3.

Indian Council of Food and Agriculture 2021. Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India. https://www.icfa.org.in/. Accessed on 2020.

Kumar G D S, Padmaiah M and Ramana Rao S V, 2014. Frontline demonstrations on need based plant protection in oilseeds: impact in enhancing productivity and profitability under farmers' conditions. *Indian Journal of Plant Protection,* **42**(2): 105-109.

Kumar A, Rathod M K and Kalantri L B, 2012. Behaviour of farmers in adoption of recommended technology for soybean. Indian Research Journal of Extension Education, *Special issue,* (II): 223-227.

Verma S, Bajpai D and Shrivastava A K, 2017. Knowledge and adoption index of chickpea production technology among the small farmers of Hoshangabad district. *Plant Archives,* **17**: 2. 1419-1420

Sengupta T 1967. A simple adoption scale used for farmers for high yielding programme of rice. Indian Journal of Extension Education, 3:107-115.

Shenoi P V 2003. Oilseed Production, Processing and Trade: A Policy Framework, Department of Economics Analysis and Research; NABARD, Mumbai.

Sipai S A, Vegad N M and Zala M B, 2017. Adoption of sesamum growers about sesamum cultivation practices. *Gujarat Journal of Extension Education,* **28**(1): 40-42.

Thakur S, Shiv Ratan and M K Nayak 2022. Dissemination and impact assessment of improved technology and scientific interventions through front line demonstrations among sesame farmers of Tikamgarh, Bundelkhand Region in Madhya Pradesh. *Journal of Oilseeds Research,* **39**(3&4): 253-255.

Genetic variability studies for yield and yield attributes in Indian mustard (*Brassica juncea* L.)

VINAYAKUMAR ARAGI*, B P MARUTHI PRASAD AND B R PATIL[2]

Department of Genetics and Plant Breeding, University of Agril. Sciences, Dharwad- 580001, Karnataka

(Received: May 08, 2023; Revised: June 13, 2023; Accepted: June 22, 2023)

ABSTRACT

Mustard (*Brassica juncea* L.) cultivation was largely confined to northern India, although climate change paved the way for crop introduction to southern parts of the country. This fall, an investigation was conducted to evaluate 68 Indian mustard genotypes in the Main Agricultural Research Station, Dharwad (University of Agricultural Sciences, Dharwad) in *rabi* 2018-19. The objective of the present study is to study the genetic variability for yield and yield attributes in Indian mustard. The results of genetic variability study indicated that significant genotypic variation in key traits such as secondary branches, racemes per plant, economic yield, biological yield, harvest index, seed yield, seeds per siliqua, siliqua length, number of siliqua per raceme, and oil yield. Traits like days to 50% flowering, days to maturity, and oil content exhibited low variation. Additionally, traits with high heritability, including plant height, primary branches, racemes per plant, and several yield-related parameters, showed substantial genetic advance, suggesting the potential for effective selection and rapid improvement in these characteristics.

Keywords: *Brassica juncea,* Genetic variability, Phenotypic coefficient, Raceme, Siliqua

In contemporary agriculture, oilseed cultivation has transformed into a commercial profession, driven by favorable remuneration rates. This shift aligns with the increasing demand for oilseeds and their products, making them integral to our daily diet amidst evolving lifestyles and a growing population. Rapeseed-mustard, ranking second only to groundnut, holds a pivotal role in India's oil economy, contributing significantly with a share of approximately 27.8% in total oilseed production (Anonymous, 2018). Belonging to the Brassicaceae family, Indian mustard, with a chromosome number of 2n=36, is a natural amphidiploid derived from *Brassica rapa* (2n = 20) and *Brassica nigra* (2n = 16) (Chaurasiya *et al.,* 2022). While predominantly autogamous in pollination, there is a notable degree of cross-pollination (5 - 18%) observed (Labana and Banga, 1984).

Mustard thrives in tropical and temperate zones, requiring cool, dry conditions for optimal growth, with temperatures between 18°C to 25°C, low humidity, and minimal rain during flowering. Mustard varieties naturally contain erucic acid, a 22-carbon monogenic carboxylic acid, identified after extensive nutritional investigations as a significant component of a high-quality diet. Meeting the demand for high-yielding varieties is urgent. Mustard oil, with 37% to 48% oil content, along with protein content ranging from 24% to 30% and 35% to 40% in whole seed and meal, respectively (Vikram, 1979), is suitable for culinary and flavoring purposes. Additionally, immature mustard plant leaves serve as a good source of sulfur and minerals.

Mustard is predominantly cultivated in northern regions of India, has expanded to non-traditional regions in the east, west, and south. Numerous mustard genotypes exhibit diverse yield potential, adaptability to different climates, and varied responses to diseases, insects, and pests. Genetic variability is crucial for effective crop improvement. The success of breeding programs relies on the extent of variability and the intensity of selection. Statistics provide various analytical techniques to assess available variability in crops. Genotypic and phenotypic coefficients of variation are essential for assessing variability in the studied material and play a crucial role in improving existing cultivars and identifying superior genotypes. Distinguishing between genetic and non-genetic components of variation is vital for breeders. The selection of genetically diverse parents for hybridization is a key aspect of crop improvement programs to generate desirable segregants.

The experimental material comprised 68 varieties of *Brassica juncea* to assess the variation. The field experiment was conducted at the Botany Garden, College of Agriculture, Dharwad, during *rabi* 2018-19 to assess the variation. Each plot consisted of four rows of 40 plants. Inter and intra row spacing was kept 40×15 cm, respectively. The recommended agronomic practices were adopted to maintain good crop conditions. Observations on genotypes were recorded on five randomly selected plants from each plot in all the three replications for different characters like days to 50% flowering, days to maturity,

Corresponding author's E-mail: aragivinay@gmail.com

plant height (cm), number of primary branches per plant, number of secondary branches per plant, 1000-seed weight (g), number of seeds per siliqua, siliqua length (cm), number of siliqua per raceme, economic yield (g), biological yield (g), seed yield (kg/ha), harvest index (%), number of racemes per plant, oil content (%) and oil yield (kg/ha). Genotypic and phenotypic variances were computed according to the method suggested by Johnson *et al.* (1955). Genotypic and phenotypic coefficient of variation (GCV and PCV) were estimated based on formulae given by Burton and Devane (1953) and heritability and genetic advance as per cent mean were calculated according to Allard (1960). The phenotype of a variety is a sum of the environment and underlying genotype. Since the environment varies greatly temporally and spatially, in this connection, an investigation was made to assess the performance of *Brassica juncea* genotypes *rabi* 2019-2020. A simple Randomized Complete Block Design (RCBD) was laid out to carry out the experiments. The data pertaining to 16 characters was recorded. The ANOVA technique was used to assess the variance.

Genotypes vary significantly with respect to the selected 16 characters. Prior to the ANOVA. The result of ANOVA with genotypes as a source of variation for all the characters was found to be statistically significant, which reflected the existence of sufficient variability among the genotypes. The source of variation was found statistically significant for days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of racemes per plant, number of siliqua per raceme, siliqua length (cm), seeds per siliqua, oil content (%), biological yield (g), economic yield (g), harvest index (%), 1,000-seed weight (g), seed yield (kg/ha), oil yield (kg/ha) (Table 1).

The mean performance of Indian mustard genotypes is presented in Table 2. The results pertaining to PCV, GCV, and heritability in as percent of mean (GAM) for yield and attributes is presented in Table 3. The 68 genotypes studied in this experiment exhibited notable higher GCV values for traits including the number of secondary branches per plant, the number of racemes per plant, economic yield, biological yield, harvest index, seed yield, siliqua length, number of siliqua per raceme, and oil yield. These findings align with previous research by Kumar *et al.* (2011), Singh *et al.* (2011), Kumar *et al.* (2013) and Singh *et al.* (2020).

The phenotypic coefficient of variance was moderate for plant height, number of siliqua per raceme, number of seeds per siliqua, siliqua length and 1000 seed weight. The phenotypic coefficient of variance was low for characters like days to 50% flowering, days to maturity, plant height and oil content.

Table 1 Analysis of variance for 16 characters in the active germplasm of Indian mustard

Source of variation	df	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	1,000-seed weight (g)	Number of seeds/siliqua	Siliqua length (cm)
Replication	2	8.49	41.30	247.29	0.09	0.33	0.17	2.03	0.36
Treatments	67	10.69**	54.24**	421.05**	0.35**	1.85**	0.56**	4.62**	0.89**
Error	134	4.70	25.38	92.25	0.14	1.09	0.08	1.59	0.14
Mean		34.94	34.94	87.23	167.22	4.97	11.15	4.37	13.80
CD @ 5 %		3.50	3.50	8.14	15.51	0.61	1.68	0.44	2.04
CV (%)		6.21	6.21	5.78	5.74	7.54	9.35	6.27	9.14

Source of variation	df	No. of siliqua/raceme	Economic yield (g)	Biological yield (g)	Seed yield (kg/ha)	Harvest index (%)	No. of racemes/ plant	Oil content (%)	Oil yield (kg/ha)
Replication	2	3.30	0.34	40.57	3661.32	7.39	7.92	5.58	1139.48
Treatments	67	23.19**	15.523**	145.69**	67342.29**	148.96**	26.03**	8.50**	9914.72**
Error	134	1.34	1.03	14.43	2519.24	17.76	2.82	2.43	497.87
Mean		23.77	23.77	7.89	32.91	509.32	24.75	15.55	38.37
CD @ 5 %		1.87	1.87	1.64	6.13	81.05	6.81	2.71	2.52
CV (%)		4.88	4.88	12.89	11.54	9.85	17.03	10.81	4.06

* Significant at 0.05 probability level and ** Significant at 0.01 probability level.

Traits such as days to 50% flowering, days to maturity, plant height, the number of primary branches per plant, the number of siliqua per raceme, the number of seeds per siliqua, siliqua length, 1000 seed weight, and oil content exhibited low magnitude for Genotypic coefficient of variance. These findings align with previous studies by Baradaran *et al.* (2007) and Ghosh and Gulati (2001).

Table 2 Mean values of germplasm lines of Indian mustard for quantitative traits

Genotypes	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
KMR(E) 16-1	39	83	166	5	10	4	14	6	23	8	24	569	33	15	39	221.2
PRE -2013-19	37	83	174	6	10	4	16	6	22	11	28	579	39	16	37	211.9
TM 2776	33	87	167	5	11	4	14	7	24	9	29	657	31	11	39	256.8
DRMR 4005	36	90	181	4	13	4	14	5	21	6	23	528	25	14	39	206.5
TM-210	35	89	165	5	11	5	13	5	23	10	27	539	35	13	39	209
TM-267-1	35	76	170	5	11	4	15	5	21	10	28	435	37	13	38	166.4
TM-136	34	86	172	5	11	4	13	5	20	8	19	635	45	13	39	248.7
TM-138-1	36	82	177	5	11	5	15	5	22	10	27	734	38	12	38	282
Doddasaasive	36	86	170	5	11	4	14	6	23	8	27	675	30	12	37	250
NRCHB 101	35	87	177	5	10	4	15	6	20	5	27	425	17	14	40	168.1
PRE-2015-1	35	86	173	5	12	4	14	6	22	5	25	288	22	15	39	112.4
NDRE 8-14-1	38	90	178	5	11	4	12	6	23	4	24	279	15	13	39	109.4
Pusa Mustard 25 (NC)	36	91	176	5	11	4	16	5	22	6	27	384	23	19	39	150.1
NRCHB 101 (LR)	36	92	178	5	11	4	13	5	23	7	23	382	34	15	38	144.8
DRMRIJ 16-51	35	89	168	5	11	5	14	5	23	5	24	393	23	13	39	154.9
RH 1590	37	88	157	5	11	4	13	5	24	6	22	262	25	18	39	103.2
RH 1656	33	91	172	5	11	5	16	5	25	5	20	470	26	20	38	177
KMR (E) 17-1	35	84	136	5	12	5	14	5	24	5	27	300	17	13	37	109.7
NPJ-209	36	89	164	5	11	5	12	5	23	5	26	392	20	24	37	146.6
RRN 921	35	85	148	4	12	4	17	6	28	7	28	521	24	20	37	190.8
TM 277	36	88	147	5	11	4	15	7	27	10	34	721	30	19	36	259.1
PRE-2013-3	36	94	150	6	11	4	12	6	23	9	38	619	23	15	37	229.8
JD 6 (ZC)	38	91	157	5	11	4	13	7	23	7	38	517	18	13	36	185.3
DRMRCI 106	35	90	166	5	12	4	14	5	32	9	34	726	30	16	38	278.7
DRMR 2017-14	35	89	170	5	11	4	15	5	25	12	38	760	32	14	36	272.8
KMR (E) 17-2	35	86	170	5	11	4	13	6	26	8	28	651	30	16	37	239.1
Filler (JD 6)	35	85	159	5	11	4	12	6	28	10	31	768	32	18	36	277.3
CAU-RM1	35	90	166	5	12	4	14	6	29	8	39	555	21	20	36	198.4
NPJ-210	36	89	155	5	11	4	15	6	24	5	32	415	16	18	37	152.1
SVJ-104	34	92	188	5	10	4	14	5	25	5	37	364	14	15	37	134
RH 1650	33	88	176	5	11	4	16	6	23	5	30	377	15	16	38	144
DRMRCI 98	35	93	178	5	10	5	14	6	18	8	21	420	38	20	37	154.6
SVJ-68	34	93	177	5	11	5	13	6	19	8	30	454	26	15	38	174.3
6IJ0401 (Hybrid)	38	94	169	6	11	4	15	5	22	7	25	362	26	14	39	141.2
DRMRCI-59	35	97	177	5	11	5	16	5	23	6	23	263	27	15	39	103.7
PRE-2013-10	35	89	170	5	11	4	13	5	24	7	27	316	26	16	39	123.6
NPJ-202	34	87	177	5	11	4	15	5	27	5	35	323	16	13	37	120.5
NPJ-201	38	86	169	6	11	5	13	5	22	5	37	381	15	14	39	149.5
NIMH-23 (Hybrid)	34	80	164	5	10	4	15	6	26	7	35	477	20	13	40	189.1
RH 1573	35	80	191	5	12	4	15	6	24	10	34	582	29	12	40	233.8
KMR(E) 16-2	33	80	167	5	11	4	13	6	27	8	43	604	19	12	35	212.4
DRMRCI-58	35	83	165	4	13	5	14	6	27	6	37	704	16	11	38	265.4
TM117	37	95	157	5	11	5	15	5	25	5	41	561	13	13	42	234.4
TM143	33	88	136	5	12	5	15	6	26	9	37	566	24	11	40	226.1
TM106-1	34	92	147	5	11	4	15	6	22	9	37	456	25	15	43	197.9
TM106	33	88	159	5	11	5	14	6	19	9	37	699	23	14	39	271.9
TM204	36	89	166	5	11	4	13	5	20	6	38	723	16	15	40	286.9
TPM-1	32	90	161	5	11	4	13	6	22	8	34	682	22	17	37	254
TM-230	36	90	147	5	11	4	12	6	22	6	39	383	16	21	36	138.3
TM-209	33	88	166	5	11	4	16	6	24	11	37	269	29	15	41	109.2
TM-108	32	83	188	5	11	4	13	5	23	6	35	309	18	19	39	120.1
TM-217	37	82	181	5	11	4	12	5	23	6	31	417	19	15	40	165.4
TM-267	33	79	172	5	11	5	14	5	27	11	38	410	28	13	39	159.6
TM-267-2	36	84	189	5	11	5	14	5	23	9	41	430	23	19	35	150.2
TM-266	33	84	178	5	12	4	14	5	28	13	47	300	27	19	41	122.5
SANAA SASIVE	36	81	176	5	12	5	12	6	27	9	46	488	20	14	39	188.8
Pusa Mustard 26	30	82	170	4	11	5	13	5	23	10	40	364	25	13	39	141.9
Pusa Mustard 30	35	92	176	5	14	5	12	6	26	8	40	445	21	23	38	171.7
Pusa Mustard 28	35	93	164	5	13	5	13	6	31	9	42	597	20	19	40	235.8
PusaMahak	35	89	172	5	13	5	15	6	24	7	42	732	18	17	40	291
Pusa Mustard 27	31	90	164	4	11	5	12	6	26	9	44	649	20	16	41	267
PusaAgrani	35	87	170	4	12	4	12	6	27	8	34	533	23	13	40	211.1
PusaTarak	41	84	148	5	10	5	12	5	27	11	37	678	31	16	39	267.2
PusaJagannath	37	83	176	5	10	5	14	6	23	14	45	636	31	13	40	255.1
PusaKranti	34	82	159	5	12	5	12	6	26	8	39	680	20	16	38	257.7
Ashirwad	32	88	143	5	10	5	15	6	22	13	37	785	34	20	41	318.5
Vardhan	35	86	161	5	11	5	13	6	18	10	37	569	28	18	36	205.5
T-9	31.67	86.33	169	5.8	9.13	4.3	12.09	5.53	20.09	9.39	34.12	474.4	27.78	17.66	35.92	170.2

X_1= Days to 50% flowering; X_5= No. of secondary branches/plant; X_9= No. of siliqua/raceme; X_{13}= Harvest index (%)
X_2= Days to maturity; X_6= 1,000-seed weight (g); X_{10}= Economic yield (g); X_{14}= No. of racemes/plant
X_3= Plant height (cm); X_7= Seeds/siliqua (No.); X_{11}= Biological yield (g); X_{15}= Oil content (%)
X_4= No. of primary branches/plant; X_8= Siliqua length (cm); X_{12}= Seed yield (kg/ha); X_{16}= Oil yield (kg/ha)

Table 3 Estimation of genetic parameters in respect of growth, yield and yield related characters in germplasm lines in Indian mustard

Character	Mean	Range		GCV (%)	PCV (%)	h2 (%)	GAM (%)
		Minimum	Maximum				
Days to 50% flowering	34.94	30.00	40.67	4.04	7.41	29.8	4.54
Days to maturity	87.23	75.67	96.67	3.56	6.78	27.5	3.84
Plant height (cm)	167.22	136.28	190.70	6.26	8.50	54.3	9.50
No. of primary branches/plant	4.97	4.34	5.80	5.28	9.21	32.8	6.23
No. of secondary branches/plant	11.15	9.13	13.93	4.52	10.38	19	4.06
1,000-seed weight (g)	4.37	3.50	5.39	8.77	10.78	66.1	14.68
No. of seeds/siliqua	13.80	11.59	17.09	7.28	11.68	38.8	9.34
Siliqua length (cm)	5.59	4.60	6.83	8.93	11.14	64.3	14.75
No. of siliqua/raceme	23.77	18.18	31.55	11.35	12.36	84.4	21.48
Economic yield (g)	7.89	3.71	14.22	27.85	30.69	82.4	52.07
Biological yield (g)	32.91	18.80	47.37	20.10	23.18	75.2	35.90
Seed yield (kg/ha)	509.32	262.00	785.21	28.86	30.50	89.6	56.26
Harvest index (%)	24.75	13.19	44.77	26.72	31.69	71.1	46.43
No. of racemes/plant	15.55	10.52	23.70	17.88	20.89	73.3	31.53
Oil content (%)	38.37	34.98	43.34	3.71	5.50	45.4	5.15
Oil yield (kg/ha)	195.23	103.17	318.54	28.70	30.89	86.3	54.92

Traits such as plant height, number of primary branches per plant, the number of siliqua per raceme, the number of seeds per siliqua, siliqua length, and 1000 seed weight displayed low genotypic coefficient of variation (GCV) but moderate or high phenotypic coefficient of variation (PCV), signifying a notable influence of the environment on these traits. Conversely, high values of both PCV and GCV for other traits indicate the substantial inherent variability within those specific characteristics.

The heritability in the broad sense was found to be at a moderate level for traits such as days to maturity, the number of secondary branches per plant, and days to 50% flowering, suggesting a moderate environmental influence on these characteristics. These findings align with previous studies conducted by Yadav *et al.* (1985), Nagaraja (1990), and Gangapur (2008).

Traits including plant height, the number of primary branches per plant, the number of racemes per plant, siliqua length, the number of seeds per siliqua, 1000 seed weight, economic yield, biological yield, seed yield, oil content, and oil yield exhibited high heritability, indicating limited environmental influence. Therefore, selection is expected to be effective for these traits, as supported by studies conducted by Pant and Singh (2001), Singh (2004), and Kumar and Mishra (2006). It's worth noting that heritability estimates in the broad sense, while informative, may not solely determine the effectiveness of selection for a trait, as their interpretation is influenced by their interaction with the environment, as acknowledged by Johnson *et al.* (1955). In the set of genotypes, only broad-sense heritability can be estimated. Hence, broad-sense heritability values are considered for the estimation of the predicted response to selection. Thus, genetic advance as per cent mean is the reliable tool for estimating the gain for the character over the generations. The genetic advance as per cent mean was found to be high for traits such as number of siliqua per raceme, biological yield, seed yield, harvest index, oil content, oil yield, days to 50% flowering, days to maturity and plant height. This showed the possibility of rapid improvement in these characteristics. Similar results were observed by Khulbe *et al.* (2000), Somu (2001), Singh (2004) and Dawar *et al.* (2018).

Genetic advance as per cent mean was moderate for siliqua length and 1000 seed weight while it was low for number of secondary branches per plant, number seeds per siliqua and number of racemes per plant. These results were in agreement with Mondal and Khajuria (2000) and Mahla *et al.* (2003). These findings are in agreement with Dawar *et al.* (2018). Thus, rapid improvement is possible in these traits with high GAM. Moderate to high genetic advance coupled with high heritability indicated that selection could be useful in these characters.

The variance analysis of Indian mustard seed yield and related components revealed significant genotypic variation, indicating diversity among genotypes. Phenotypic coefficient of variation (PCV) was notably high for key traits, such as secondary branches, racemes per plant, economic yield, biological yield, harvest index, seed yield, seeds per siliqua, siliqua length, number of siliqua per raceme, and oil yield. In contrast, traits like days to 50% flowering, days to maturity, and oil content exhibited low PCV and genotypic coefficients of variance.

Traits with high heritability included plant height, primary branches, racemes per plant, siliqua length, seeds per siliqua, 1000 seed weight, economic yield, biological yield, seed yield, oil content, and oil yield. Additionally, several traits, such as number of siliqua per raceme, biological yield, seed yield, harvest index, oil content, oil yield, days to 50% flowering, days to maturity, and plant height, showed a high genetic advance as a percentage of the mean. For seed yield, oil content, oil yield, plant height, and biological yield, the combination of high PCV and GCV coupled with high heritability and significant genetic advances suggests the potential for selecting superior genotypes using these traits.

ACKNOWLEDGEMENT

Authors are thankful to University of Agricultural Sciences, Dharwad for providing Land and other logistic facilities for smooth conduct of experiment.

REFERENCES

Anonymous 2018. Annual report, Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, 321303, Rajasthan, India.

Allard R W 1960. *Principles of Plant Breeding.* John Wiley and Sons, Inc., New York.

Baradan R, Majidi E, Darvish F and Azizi M 2007. Study of correlation and path coefficient analysis between yield and yield components in rapeseed (*Brassica napus* L.). *Iranian J.,* **12**(4): 811-819.

Burton G W and Devane D E 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material 1. *Agronomy Journal,* **45**(10): 478-481.

Chaurasiya J P, Singh M, Nageshwar 2022. Heterosis response and combining ability (variance and effect) analysis for seed yield and its components in Indian mustard (*Brassica juncea* L.). *Journal of Oilseeds Research*, **39**(1): 14-20.

Dawar S, Kumar N and Mishra S P 2018. Genetic variability, correlation and path coefficient analysis in the Indian mustard (*Brassica juncea* L. Czern and Coss) varieties grown in Chitrakoot, India. *International Journal of Current Microbiology and Applied Sciences*, **7**(3): 883-890.

Gangapur D R 2008. Studies on genetic variability in the Indian mustard (*Brassica juncea* L. Czern and Coss) germplasm and its suitability to northern Karnataka. M. Sc. (Agri.) Thesis, Unic. Agric. Sci. Dharwad, Karnataka (India).

Ghosh S K and Gulati S C 2001. Genetic variability and association of yield components in Indian mustard (*Brassica juncea* L.). *Crop Research (Hisar)*, **21**(3): 345-349.

Johnson H W, Robinson H F, Comstock R E 1955. Estimates of genetic and environmental variability in soybeans 1. *Agronomy Journal*, **47**(7):314-8.

Khulbe R K, Pant D P, Naveen S 2000. Variability, heritability and genetic advance in Indian mustard [*Brassica juncea* (L.) Czern & Coss]. *Crop Research (Hisar)*, **20**(3):551-2.

Kumar H, Anubha M K, Lal J P 2016. Morphological and molecular characterization of *Brassica rapa* ssp yellow sarson mutants. *Journal of Oilseed Brassica*, **1**(1):1-6.

Kumar B, Pandey A, Singh S K 2013. Genetic diversity for agro-morphological and oil quality traits in Indian mustard (*Brassica juncea* L. Czern & Coss). *The Bioscan*, **8**(3):771-5.

Kumar S and Mishra M N 2006. Genetic variation and association analysis in Indian mustard (*Brassica juncea* (L.) Czern. and Coss.) and *Brassica campestris* L. variety *toria. Crop Research*, **31**(3): 391-393.

Labana K S and Banga S S 1984. Floral biology in Indian mustard (*Brassica juncea* (L.) Coss). *Genetica Agraria*, **38**(2).

Mahla H R, Jambhulkar S J, Yadav D K and Sharma R 2003. Genetic variability, correlation and path analysis in Indian mustard [*Brassica juncea* (L) Czern. and Coss.]. *Indian Journal of Genetics and Plant Breeding*, **63**(2): 171-172.

Mondal S K and Khajuria, M R 2000. Genetic analysis for yield attributes in mustard. *Environment and Ecology*, **18**(1):1-5.

Nagaraja T E 1990. Genetic variability study in rapeseed (*Brassica compestris* L.) and mustard (*Brassica juncea* (L.) Czern and Coss). Doctoral dissertation, University of Agriculture Science, Banglore, India. 140.

Pant S C, Singh P, Kumar R, Mishra S, Singh S P, Mishra S 2002. Correlation and path analysis in Indian mustard. *Plant Archives*, **2**(2):207-11.

Patel J R, Saiyad A T, Patel P J, Prajapati K P, Patel B K 2020. Correlation and path analysis in relation to seed yield and its components in Indian mustard (*Brassica juncea* L. Czern and Coss). *Journal of Oilseeds Research*, **37** (Special Issue):13-14.

Singh M, Tomar A, Mishra C N, Srivastava S B 2016. Genetic parameters and character association studies in Indian mustard. *Journal of Oilseed Brassica*, **1**(1):35-8.

Singh B 2004. Character association and path analysis under dry land condition in Indian mustard (*Brassica juncea* L.). *Cruciferae Newsl,* **25**:99-100.

Singh M, Singh R, Chaurasiya J P, Yadav K 2020. Genetic parameter and character association studies in Indian mustard (*Brassica juncea* L. Czern & Coss). *Journal of Oilseeds Research,* **37** (Special Issue): 65-66.

Somu, G 2001. Genetic divergence in Indian mustard (*Brassica juncea* L. Czern and Coss.). M. Sc. (Agri.) Thesis, Univ. Agric. Sci. Bangalore, Karnataka (India).

Vikram S 1979. Current status of oilseed research in India. *Research Development Newsltr,* C: 11- 44.

Yadav N, Kumar P R, Behi R K 1985. Genetic variability and selection indices in Brown Sarson. *Cruciferae Newsletter,* **10**(2):62-5.

A Brief Report on
International Conference on
Vegetable Oils 2023 (ICVO 2023)
'Research, Trade, Value chain and Policy'

conducted between January 17-21, 2023 at Hyderabad, India

Globally four crops *viz.*, oil palm, soybean, rapeseed and sunflower account for majority of the edible oils produced and consumed. Of late, there has been a perceptible crisis in production and supply of these oils. Palm oil accounts for ~40% of the supply of the four top most popular edible oils in the world, the other being soybean oil, rapeseed (canola) oil and sunflower oil. Global palm oil production slumped in 2020-21 due to migrant labour issues on plantations across Southeast Asia. Drought slashed Canada's harvest of canola in 2021 and Europe also suffered crop damage, which reduced oil supplies during 2022. Vegetable oil shortage is a major concern for India as well. The domestic oilseeds production is not meeting the pace of increase in domestic demand for household and industrial needs. The *per capita* consumption of vegetable oils is rising continuously surpassing 18.7 kg/year in 2020-21. During the last two decades, edible oil consumption has increased at a compounded annual growth rate of 4.3% and is expected to continue. Besides, demand projections on the trend of expenditure and price of food items suggest that the demand for edible oil in the country will be 29.02 and 40.89 million tonnes for 2025 and 2050, respectively. Under this challenging situation, there is a necessity to build convergence and co-operation among all the national and international stakeholders and agencies involved in production, procurement, aggregation, processing, and marketing of vegetable oils to develop a strategic roadmap to address all the issues plaguing vegetable oil economy. In this backdrop, Indian Council of Agricultural Research, ICAR-Indian Institute of Oilseeds Research (IIOR), and Indian Society of Oilseeds Research (ISOR) in collaboration with ICRISAT, other sister ICAR institutes and the societies engaged with vegetable oil research jointly organized the **"International Conference on Vegetable Oils 2023 (ICVO 2023): Research, Trade, Value Addition and Policy"** during January 17- 21, 2023 at Hyderabad, India. The conference was a convergent point for priority persuasion and provided a platform to deliberate on research strategies, infrastructure developmental needs, trade and value chain ecosystems, and policy perspective to promote increased vegetable oil production on short-, medium- and long-term basis at global as well as national levels.

The conference was inaugurated by Dr. Mangala Rai, Former secretary, DARE and DG, ICAR. In welcome address, Dr. Sanjeev Gupta ADG (Oilseeds & Pulses), ICAR recalled how technology mission on oilseeds has ushered yellow revolution and tripled the oilseed production in the country. Chief Guest, Dr. Mangala Rai highlighted the importance of human resource development and technology development for boosting the secondary agriculture. Sh. Annasaheb Shankar Jolle, Member of Parliament and Chairman, Karnataka Oilseeds Federation, Dr. Dwijendra Mathur, MD, Fare Labs, Sh. Meenesh Shah, Chairman, NDDB, Dr. Neeraja Prabhakar, VC, Sri Konda Laxman Horticultural University, are the guests of honour. Dr. R.K. Mathur, Director, ICAR-Indian Institute of oilseeds research and Dr. M. Sujatha, Organising Secretary also graced the occasion.

Sh. Annasaheb Shenker Jolle said that there is a need to develop short duration and high yielding oilseeds varieties to make India, Atma Nirbhar in oilseeds. Dr Mathur said that there is a huge potential for micro edible oils from micro algae as a healthy alternative. Sh. Meenesh shah asserted that production of quality oilseeds, effective extension, support from oil cooperatives and forward linkages in oilseeds are the major steps required for boosting the oilseed production. Dr. Neeraja Prabhakar, VC reiterated that for a given area, oil palm yields more oil when compared to oilseed crops.

The speakers in the inaugural session expressed their wishes that during the conference, issues related to research, trade, value chain and policy ecosystems will be deliberated and a road map will be prepared for increasing vegetable oil production in the country. Twenty four farmers from Andhra Pradesh, Gujarat, Karnataka Rajasthan and Telangana were felicitated on the event for their innovative practices and securing higher oilseed yields. Three publications including a Souvenir of ICVO were released by the dignitaries. Fifty ISOR members were awarded as 'ISOR fellow' for their contribution in oilseeds.

The conference was attended by 480 participants representing all the stakeholders in vegetable oil value chain and among them 21 were from outside India. The conference was organized under 5 themes viz., Frontier Science for Improving Crop Productivity, Enabling Environment: Improved Agronomy for Enhancing Production, Value Addition and Quality Improvement, Expanding Horizons, and Policy. In each of these themes, there were plenary lectures followed by invited lectures that covered major areas of research. Apart from this main conference activity, considering the importance of the topics and the crops, eight satellite symposia were held which focused on discussions and lectures that covered different aspects of research challenges, emerging technologies, and opportunities available so that strategic roadmaps in alignment with the national needs could be developed. These satellite symposia delved on 1. Post-Harvest Systems in Vegetable Oils, 2. Prospects for Bio-Diesel production from TBOs, industrial and other oilseed crops and crop residues, 3. Seed Systems for Oilseeds, 4. Niche Oilseed Crops, 5. Groundnut: Peanut research and industry needs, 6. Rapeseed-Mustard, 7. Soybean, and 8. Oil Palm. Each of the technical sessions was chaired and co-chaired by eminent personalities who have made significant contributions in the respective areas and the invited speakers presented the latest developments in the specific fields. Thus the conference covered a gamut of topics that encompassed all aspects of vegetable oil production, processing, value chain, and policy issues. In all there were about 37 broad areas covered and the technical session included 5 keynote lectures, 106 invited lectures, 5 panel discussions, and over 100 rapid presentations made by the participants whose extended summaries were chosen for crisp oral presentations. In addition to these technical sessions, there were over 300 poster presentations and a technical exhibition having more than 50 stalls was also organized in which both public and private organizations participated and showcased the latest developments in technology and value chain of vegetable oils in the country.

The deliberations during the technical sessions and satellite symposia led to concrete recommendations that covered all aspects of the entire value chain of vegetable oils. These recommendations would form a foundation for strategic roadmap development. The main recommendations made included:

RESEARCH FRONT

Crop Improvement through Frontier Science

Genetic Improvement of Oilseed Crops: Exploitation of Genetic Resources

- Exploitation of plant genetic resources has been minimal in oil crops and needs to be increased harnessing modern techniques and tools.
- Heterotic gene pools need to be developed and exploited for heterosis breeding in oil crops.
- Alien introgression has proved to be a useful strategy but requires sustained efforts and financial supports for a long time for its adoption in oilseed crops.
- Polyploidy as a breeding tool has huge potential, and can be attempted in diploid oil crops.
- Recreating *Helianthus annuus* and developing synthetic *Brassicas* to overcome the genetic bottleneck and narrow genetic base is a priority research area.
- Establishing evolutionary plant breeding nurseries at environmental analogues mimicking climatic conditions predicted for 2050 should be taken up.
- Domestication of some of the wild oil-producing plants to enhance crop diversity and resilience is to be looked into.
- Development of new phenotyping methods using drone technology and the latest phenomics tools should be taken up to improve efficiency of breeding programmes.
- Farmers' varieties are very valuable for many reasons and the research institutions involved in the oilseeds need to handhold and promote farmer varieties as per the regulatory process.
- The traditional varieties of oilseeds could be revisited in the present scenario of climate change to expand the bio diversity of other local cultivars available with the local communities.
- The best genotypes / cultivars available in the gene banks to be identified for the rainfed ecosystem through explorative research.

Translational Biotechnology for Enhancing Productivity and Production in Vegetable Oil Crops

- Gene identification, development of robust and efficient regeneration and transformation methods for exploiting the power of the genome editing technologies for enhancing the crop productivity in oilseeds to be given top priority.
- The emerging technological convergence; *viz.*, artificial intelligence, deep learning, machine learning, etc.; and their utility in diverse fields need to be exploited.

- The integrated pest management strategy is to be adopted to promote congenial condition for the survival, breeding, and population build-up of natural enemies of the pests, predators that enables not only holistic context for insect and pest control but also ensures better ecological services and associated benefits. To achieve this, the enabling policy environments at global, national, and regional levels are required and such alliance is to be taken up.
- Advanced computational and automated data-recording approaches coupled with high throughput genotyping facility are to be adopted in oilseed crops for robust, accurate and high throughput phenotyping.

Enabling Environment: Improved Agronomy for Enhancing Production

- There is an urgent need to design and adopt efficient and eco-friendly oilseed crop based systems by following principles of Regenerative Agriculture (zero hunger- zero carbon) for providing food and nutritional security.
- Intensify research on location specific Conservation Agriculture and potential of ecosystem services for oilseed based cropping systems.
- Utilization of Rice –fallows for profitable oilseed production and lower carbon foot print has to be worked out.
- Integration of Precision Agricultural practices including micro-irrigation, farm mechanization is the need of the hour for cost reduction and to improve the input use efficiency and enhancing the productivity of oilseed crops.
- There is a need to intensify research and application of the nano-based solutions for oilseed production, processing and value addition.
- Moisture conservation has to be adopted through rainwater harvesting, water storage, micro irrigation and management of undulations in fields.
- Soil test-based nutrient application and climate-smart technologies should be adopted to improve soil health, nutrient use efficiency, and yield.
- Integrated nutrient management and use of secondary fertilizers, organic fertilizers should be promoted.
- Mechanization of land preparation, weeding, harvesting, and post-harvest management for small farms can be explored to reduce labour costs and increase efficiency.
- Ensuring good irrigated areas for cultivation can lead to substantial oilseed coverage, productivity, and production.
- Drones should be explored to accelerate delivery of optimal doses of pesticides.

VALUE ADDITION AND SECONDARY AGRICULTURE

- Secondary agriculture along with higher productivity should be given adequate importance in research programmes.
- Increasing the shelf life of agri-produce, processing of agri-waste into value added products to be pursued
- Development and improvement of value chain for oilseeds and allied products is to be given priority.
- Active collaborations between public & private sectors and among ICAR & CSIR institutes need to be fostered for realizing the benefits of value addition and value chain development.
- Technologies for value addition and by-product utilization for better profitability from a system approach to be promoted for better adoption.
- Value added products profile in groundnut and soybean to be expanded and emphasis be given for plant-based proteins.
- Due consideration be given for valorization of oils, such as extraction of lecithin from soybean and sunflower, which have good export potential.

- The entire value chain from producers, processors and traders to be developed for better linkages that catalyses increased production of vegetable oils.
- Industry support is essentially required for popularization of high oleic cultivars of groundnut, sunflower and safflower and premium food grade varieties of soybean (consumed without processing) and ensure quality and safety during oil extraction.

EXPANDING HORIZONS AND EXTENSION ACTIVITIES

- Area expansion under annual oilseeds cultivation should be the top priority. Financial support given by DA & FW for Mustard, Sunflower and Soybean has to be extended to other niche oilseed crops.
- Venturing towards area expansion (especially soybean and mustard) crops should be on agro-eco region approach and the target area should be explored in non-traditional areas with matching technology / institutional support for production and marketing.
- The national target of additional 2 million ha for oilseed cultivation can be achieved through intercropping or utilizing fallow lands (Rice/potato/turmeric fallows).
- Intensification of system of chickpea-mustard, toria-wheat, castor-red gram is to be taken up.
- Selection of suitable oilseed crops based on scientific mapping of the area is important and this should form the basis of area expansion of oilseeds in traditional and non-traditional areas. The expansion based on GIS modelling and mapping, could preferably be through contract farming.
- Commercialization and popularization of latest released varieties/hybrids through seed hubs and market support will enhance farmer's income and motivate the farmers to go for oilseeds cultivation.
- The ground level monitoring of oilseed cultivation and feedback from farmers to be strengthened.
- Timely transfer of technology and knowledge dissemination using ICTs will help the farmers' to adopt latest technologies.
- Agri-startups, Cooperatives and FPOs for oilseeds to be emphasised. FPO's should be promoted in oilseed sector and provided with awareness of market outlook, commodity intelligence and government policies. Custom hiring centers for agricultural machinery and machines for value addition in oilseeds should be created by FPOs.
- Development of value chains in oil crops and strengthening the role of FPOs to be prioritized.
- Sustainable and profitable Agroforestry models have to be developed to take TBOs forward.
- Enormous potential of oil production from algae and spirulina needs to be tapped to supplement the production from oilseeds.

POLICY RELATED ISSUES

- Regularization of markets and providing better MSP is important for profitable cultivation of oilseeds.
- Government commodity commercial intelligence market research desk to be established which can guide and recommend about global and national markets.
- Recognizing oil palm as a plantation crop and captive plantations by palm oil processors to be encouraged.
- Unutilized/uncultivated northeastern land can be encouraged for oil palm cultivation.
- An Authority/National board for research and development in oilseed crops and oil palm to be established to support the edible oil programme.
- A 0.5% Cess can be imposed on vegetable oil imports to support oilseed farmers and also the research and developmental activities.
- Emphasis should be laid in promoting organic farming in select oilseed crops considering their importance that has vintage value both at the domestic and international market.

- Contract farming needs to be promoted with mutually acceptable terms and conditions for achieving higher productivity through increased farm level technical efficiency.
- Creative disruption is warranted by way of diversification and area expansion in the IGP.
- Providing incentives for oilseeds farmers is warranted in the newer eco-regions to boost area expansion.
- On the processing front, the processing units need updated technology for increased efficiency of oil recovery and a one-time grant or modernization fund may be provided.
- There is a need to impose quantitative restrictions on import of edible oil since the excessive, speculation driven, unrestrained vegetable oil imports tend to suppress domestic oilseed prices. Measures to impose annual ceiling on import volume; close monitoring of import; quarterly reviews; dynamic tariffs are the important parameters to be considered.
- The policy should permit import of oilseeds (instead of oils) in specific oilseed crops to enhance the capacity utilization of the processing sector.
- Credit period to be reduced (not exceeding 50 days) and this would provide an impetus to the domestic oilseeds farmers.
- Backward integration by setting up processing facilities especially in backward areas/ non-traditional areas with a view to improve processing activities besides reducing the length of supply chain and thereby reduce the cost of processing in the value chain.
- High skewness of the per capita consumption of edible oils in the country could be addressed by supplying edible oils under PDS to protect the vulnerable sections of the society.
- Intellectual Property of the Plant Genetic resources to be documented properly and they need to be fast tracked based on the needs and aspirations of the industry and clientele preferably through Public Private Partnership research and/or Contact Research to foster developing technologies at a faster pace.
- An exclusive platform for value chains of oilseeds produced under Organic Ecosystem needs to be developed to tap the high value market.
- Technology(ies) emanating from the oilseed crops should have a greater shelf life so that it can insulate the domestic production
- A suitable policy should be evolved for rationalization of the import of edible oils
- For improving the efficiency of the oilseeds processing industry, modernization of the processing industry is warranted for increased oil recovery.
- In the light of the nutritional benefits, measures should be initiated to increase the production of coconut oil in the country especially the virgin oil.
- The four pillars *viz.,* Technology, Infrastructure, Price incentive and Strengthening of institutions at the grass roots would pave way for giving a fillip to the domestic production of vegetable oils and therefore an appropriate non-distortive policy overlaying these needs is to be evolved.

POST-HARVEST SYSTEMS IN VEGETABLE OILS

- The potential to harness the Specialty Foods (value added products) from edible oils in the food industry by modification through blending and Inter-esterification, as demonstrated by experiments in CFTRI, Mysore needs to be explored.
- The processing technology showcased by FARE Labs *w.r.t* Automation of Ghani processor over traditional 'Kohlu' in Mustard oil extraction had improved the production efficiency up to 30% without losing the pungency and this needs to be adopted widely.
- Establishing the quality infrastructure in Testing and Analysis Laboratory in the country to be prioritized to tap the huge export market for quality edible oils and their value added by-products.
- Application of 'Duplex Real Time PCR' technique developed by FARE Labs is to be adopted to efficiently detect GM components in soya seeds in the value addition chain for edible products.

- Valorisation of palm oil wastes in to value added products is to be explored since the country has potential area of 2.8 mha for oil palm cultivation.
- The potential scope of recovering 6-7% edible oil additionally by adopting scientific method of oil extraction in cotton seed cake compared to the traditional extraction methods is to be adopted.
- Alfa Laval Company is to be involved in designing and manufacturing suitable machines for oilseeds based industries.
- Network to be created for improving the value chain and economy of coconut growers.
- Enzymatic degumming, use of quality bleachers and membrane filtration were the solutions developed by 'Ricela group of companies' for improving the quality rice bran oil is to be adopted for improved efficiency.
- Proficiency testing, i.e., testing and calibration, to be established properly for accurate measurement of quality parameters of vegetable oils and oil based products.

PROSPECTS FOR BIO-DIESEL PRODUCTION FROM TBOS, INDUSTRIAL AND OTHER OILSEED CROPS AND CROP RESIDUES

- Potential of non-edible oilseed crops for biodiesel production and the opportunity to blend biodiesel to reduce carbon dioxide emissions needs to be emphasized
- Use of green wastelands should be explored for growing energy-rich crops.
- Farming community should be involved in the creation of feedstock supply chains, focusing on the development of robust supply chain models for biomass in India similar to the cooperative dairy model.
- The potential of TBOs and the need to promote different species of TBOs for biodiesel production, with crops such as castor and *Camelina* as intercrops, in different eco-systems of Chhattisgarh plains is to be exploited.
- ICAR-IIOR should investigate the use of biomass for bioenergy as an economic activity in villages, and stressed the importance of addressing national mission and objectives with respect to biodiesel production.
- Need for a long-term strategy to utilize biomass for biodiesel production at the farm level must be emphasized.

SEED SYSTEM FOR OILSEEDS

- Quality seed production along with establishment of seed storage infrastructure facilities assume priority for *rabi* and summer crops of soybean and groundnut and other oilseeds.
- Harrington’s thumb rule and Bradford’s metronome rule must be strictly applied in seed storage and seed vigour, viability and longevity maintenance.
- Participatory seed production and involvement of FPOs in seed production need to be encouraged to ensure quality seed availability to farmers.
- Indian participation in the Organization for Economic Co-operation and Development (OECD) scheme is important for promoting international seed trade of India.
- OECD organization has been invited to conduct a meeting in India and the organization must encourage participation of neighboring countries of India in OECD scheme which will support the international seed trade of India.
- Seed Replacement Ratio (SRR) and Varietal Replacement Rate (VRR) of oilseed crops need to be increased by releasing more varieties and hybrids with higher seed yield and oil yield potential as well as through effective seed supply chain of the new cultivars.
- Knowledge empowerment of stake holder of oilseed crops with respect to seed production, seed quality maintenance, crop production, oil extraction and marketing is need of the hour to attain self-sustainability in vegetable oil sector

- Government schemes and credit support in the form of seed production, purchase and transport subsidy and insurance to seed producers are required for all the states to ensure the quality seed availability and affordability to oilseed growers
- Seed industry can be strengthened by government by recognizing and protecting research outcome, implementing seed traceability system, sharing germplasm, incentivizing the seed industry and creation of localized seed processing and storage facilities,
- Implementation of systematic seed collection procedure during proper season, utilization of scientific seed storage method, establishment and maintenance of seed orchards of Tree borne oilseed (TBO) crops with pollen dilution zone are important to ensure the availability of genetically pure high quality TBOs seeds to farmers
- Establishment of field standards and seed standards for all the TBO crops as per the requirement of Indian Minimum Seed Certification Standard (IMSCS) is need of the hour to bring the TBO crops under seed legislation and seed quality maintenance
- "Seed cubes" technology of TNAU need to be effectively utilized for aerial sowing of TBO crops and establishment of TBO crops orchard/forest.

Sensitization of Consumers

- The Ministry of Health and Consumer Affairs has a definite role to sensitize the public through social media to reduce the per capita consumption of edible oils which is high and encourage use of animal fats like desi ghee, to reduce the need for vegetable oils.

CROP SPECIFIC RECOMMENDATIONS

Rapeseed-mustard

- Testing labs for quality to be strengthened
- There is a great opportunity in NE states for area expansion which needs to be tapped. To achieve this short duration varieties of Indian mustard should be bred and tested and the number of FLDs must be increased.
- Toria breeding programme needs to be strengthened.
- Farmers should be motivated to follow resource conservation technology.
- There is a need to develop suitable agronomic solutions for management of Orobanche.
- Customized fertilizer kits should be designed and distributed to farmers for enhancement of productivity of rapeseed-mustard.
- Painted bug and frost are becoming newer threats to rapeseed-mustard. So, there is a need to address this issue.
- Nano fertilizer and pesticide formulations need to be developed for their applications through drone.
- There is a need to develop accelerated breeding facilities to address the newer and major issues.
- Glucosinolate content in seed need to be reduced without affecting its content in other plant parts through genome editing technologies with the help of public private partnership.
- Hybrid technology with high yield potential coupled with resistance to white rust to be popularized among farmers.

Groundnut

- Policy guidelines are required for high oleic acid value chain development to ensure genetic purity as this will contribute to enhance export-oriented and quality groundnut production in India.
- Research must be prioritized on aflatoxin, drought and leaf spot resistance and increase in the yield levels of groundnut.
- Self-sufficiency in oilseeds can be achieved with the collective effort of the breeding programme as well as good agronomic practices.

- Mechanization of groundnut production including digging and threshing is an immediate need to enhance the profitability of the peanut production.

Soybean

- Area expansion through developing target region specific cultivars, extension and education to new farmers, and policy initiatives like incentives to farmers in non-traditional area.
- Educating farmers about rainwater management and better land configuration for mitigating drought and waterlogging situations
- Development of specialty soybean, value addition and popularization of soybean food products for further enhancing food uses of soybean.

Oil Palm

- Development of new varieties/ planting material with high oil yield and dwarfness should be prioritized.
- Oil palm package of practices and technologies must be popularized and ICAR-IIOPR recommended best management practices are to be adopted by growers.
- Seed gardens need to be established in different oil palm growing states to attain self-sufficiency in good quality planting material.
- Sensor based micro irrigation should be developed and popularized to enhance the water use efficiency.
- Oil palm based product development and utilization of waste and subsidiary industries should be simultaneously developed / promoted.
- Promotion and encouragement of cultivation of annual oilseeds in oil palm as intercrops to support edible oils production *per se*.
- Oil palm should be treated as a plantation crop and a separate corpus fund for oil palm needs to be created
- Area expansion targets needs to be met with co-operation and co-ordination of all the stakeholders.
- Efforts should be made on war footing basis to increase the area under oil palm so that the domestic availability would increase and there could be sizeable reduction in the import of palm oil in the country
- Steps may be taken to plant new oil palm hybrids in forthcoming area expansion programmes.
- While importing tenera hybrids from other countries for commercial cultivation, bench marks for different traits need to be fixed for the mother palms.
- Early establishment of processing mills need to be prioritized for smooth and successful launch of area expansion programme in new areas.
- Cropping system approach needs to be promoted for ensuring profitability and sustainability of the system.
- Oil palm being a heavy feeder of nutrients, precision nutrient management techniques like fertigation based on soil and leaf nutrient analysis needs to be popularized.
- Land resource inventory of Oil Palm plantations may be maintained by entrepreneurs and State Horticulture and Agriculture Departments by using advanced techniques like remote sensing and GIS.
- Emphasis should be given to promote ancillary industries through value addition to generate by-products during oil palm production and processing.

Sunflower

- Emphasis should be given on best management practices in sunflower for increasing the productivity.
- Different hybrids as per the local requirements of LGP and other climatic conditions, cropping systems, etc. should be developed to take this crop as a contingent and replacement crop.
- Efforts should be increased to gain back the lost area in traditional areas.
- Pre-breeding should be a priority research to harness useful traits such as resistance to abiotic and biotic stresses.

Sesame & Niger

- The research on pre-breeding for diversification of primary gene pool and genetic enhancement in sesame and niger should be intensified and strengthened.
- Research on developing high yielding sesame varieties suitable for different agro-climatic regions needs to be given high priority.
- Concerted efforts to be made to understand and manage phyllody disease in sesame.
- Mechanization of sesame cultivation by developing appropriate cultivars and crop geometry may be looked into.
- Research should focus on breaking the barriers of low productivity in niger through identification of promising genotypes from available gemplasm.
- Efforts should be made to overcome self-incompatibility in niger.
- The research on control of dodders (*Cuscuta* sp.) in niger must be strengthened in order to develop effective remedy.

Safflower

- Supply of quality seeds, contract farming and popularization of mechanization especially mini combine harvester at village level needs to be carried out.
- Greater research thrust needs to be given on pre-breeding and broadening of genetic base for increasing the productivity.
- The research on value addition of safflower petals, cakes and seed meals and establishment of oil extraction units and marketing facilities may be initiated.

Castor

- Research focus needs to be given on castor breeding for new and emerging situations like high density planting, inter cropping, late *kharif* or *rabi* seasons under rainfed areas.
- Concerted efforts to be made for developing new plant types with short duration and multiple pest and disease resistance genotypes for enhancing area and production in castor.
- Basic research on genetic mechanisms and environmental interactions on sex expression in castor needs to be focussed.

Linseed

- Focussed approach on nutrient management and breeding needs to be given for increasing the yield attributing traits especially seed number, size and oil content in linseed.

Niche Oilseed Crops

- The vast potential of growing the niche oilseed crops in non-traditional areas has to be explored through appropriate linkages with development departments and required production and processing in these areas be ensured.
- The research on developing innovative post-harvest management technologies may be strengthened.
- More funding may be provided for research on marker-assisted selection in niche oilseed crops of India for selecting important traits in crop breeding.

Tree Borne Oilseeds

- There is a need to strengthen the research on tree borne oilseeds and algal oils to meet the industrial demands.
- Contribution from tree borne oilseed crops can be increased from the present 0.5 mt to 2.0 mt by engaging labour during the season for collecting the produce.
- Modernization of extraction units and more particularly for cotton seed and rice bran for improving the extraction efficiency.

Prepared by V. Dinesh Kumar, Programme Committee Convener, ICVO 2023, Vice-President, ISOR and Editor, JOR; GDS Kumar, General Secretary, ISOR; P. Duraimurugan, Associate Editor, JOR; Ravi K Mathur, Director, ICAR-IIOR and Executive Organizing Secretary, ICVO 2023; M. Sujatha, Organizing Secretary, ICVO 2023 and Sanjeev Gupta, President, ISOR. Compiled and edited from the proceedings prepared by the rapporteurs and convenors of different technical sessions and satellite symposia of ICVO 2023.

INDIAN SOCIETY OF OILSEEDS RESEARCH

Instructions to Authors for Preparation of Manuscript for Journal of Oilseeds Research

Prospective author(s) are advised to consult **Issue No. 27(1) June, 2010 of the Journal of Oilseeds Research** and get acquainted with the minor details of the format and style of the Journal. Meticulous compliance with the instructions given below will help quick handling of the manuscript by the reviewers, editor and printers. **Manuscripts are considered for publication in the Journal only from members of the ISOR.**

General

Full-length articles, short communications, book reviews and review articles are published in the Journal. Review articles and book reviews are published usually by invitation. Full length articles and short communications should report results of original investigations in oilseeds, oil bearing plants and relevant fields of science. Choice of submitting the paper(s) either as full length paper or short communication rests with the authors. The Editor(s) or Reviewer(s) will examine their suitability or otherwise only in that specific category. Each article should be written in English correctly, clearly, objectively and concisely. All the statements made in the manuscript should be clear, unambiguous, and to the point. Plagiarism is a crime and therefore, no part of the previously published material can be reproduced exactly without prior permission from the original publisher or author(s) as deemed essential and the responsibility of this solely rests on the authors. Also, authors shall be solely responsible for the authenticity of the results published as well as the inferences drawn thereof. Telegraphic languages should be avoided. The data should be reported in a coherent sequence. Use active voice. Active voice is clear, unambiguous and takes less space. Use past tense while reporting results. Do not repeat ideas in different forms of sentences. Avoid superfluous sentences such as `it is interesting to note that', `it is evident from the table that' or `it may be concluded that' etc. Use % for percent, %age for percentage, / for per, @ for at the rate of hr for hours, sec for seconds. Indicate date as 21 January 2010 (no commas anywhere). Spell out the standard abbreviations when first mentioned eg. Net assimilation rate (NAR), general combining ability (GCA), genetic advance (GA), total bright leaf equivalents (TBLE), mean sum of squares (MSS).

Manuscript

Language of the Journal is English. Generally, the length of an article should not exceed 3,000 words in the case of full-length article and 750 words in the case of short communication. However completeness of information is more important. Each half-page table or illustration should be taken as equivalent to 200 words. It is desirable to submit manuscript in the form of soft copy either as an e-mail attachment to editorisor@gmail.com (preferred because of ease in handling during review process) or in a **compact disk (CD) (in MS Word document; double line space; Times New Roman; font size 12).** In exceptional cases, where the typed manuscript is being submitted as hard copy, typing must be done only on one side of the paper, leaving sufficient margin, at least 4 cm on the left hand side and 3 cm on the other three sides. Faded typewriter ribbon should not be used. Double space typing is essential throughout the manuscript, right from the **Title** through **References** (except tables), foot note etc. Typed manuscript complete in all respects, is to be submitted to the Editor, Journal of Oilseeds Research, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030. Every page of the manuscript, including the title page, references, tables, etc. should be numbered. Punctuation marks help to show the meanings of words by grouping them into sentences, clauses, and phrases and in other ways. These marks should be used in proper manner if the reader of a paper is to understand exactly the intended meaning. Receipt of the manuscript (in the form of either soft or hard copy) will be acknowledged by the editorial office of the Society, giving a manuscript number which should be quoted in all subsequent correspondence regarding that particular article.

Full-length Articles

Organization of the Manuscript

Before reading the instructions given below, the author(s) would better have a close look at the latest issue of the Journal.

Full-length article comprises the following sections.

(a) Short title
(b) Title
(c) Author/Authors
(d) Institution and Address with PIN (postal) code
(e) Abstract (along with key words)
(f) Introduction
(g) Materials and Methods
(h) Results and Discussion
(i) Acknowledgments (if any)
(j) References
(k) Tables and figures (if any)

Guidelines for each section are as follows:

All these headings or matter thereof should start from left hand side of the margin, without any indent.

Short Title

A shortened title (approximately of 30 characters) set in capital letters should convey the main theme of the paper.

Title

Except for prepositions, conjunctions, pronouns and articles, the first letter of each word should be in capital letter. The title should be short and should contain key words and phrases to indicate the contents of the paper and be attractive. Jargons and telegraphic words should be avoided. In many cases, actual reading of the paper may depend on the attractiveness of the title.

Author/Authors

The name(s) of author(s) should be typed in capital letters a little below the title, starting from the left margin. Put an asterisk on the name of the corresponding author. **Give the Email ID of the corresponding author** as a footnote.

Institution and Address

This matter will come below the name(s) of the author(s). Name of the Laboratory/Department, followed by the name of the Institution/Organization/University where the work reported in the paper was carried out shall come below the name(s) of author(s). Complete postal address, which should include city/town, district, and state, followed by PIN (postal) code is to be furnished. In case any author has left the above address, this should be indicated as a footnote.

Abstract

The paragraph should start with the word Abstract (in bold font). The abstract should comprise brief and factual summary or salient points of the contents and the conclusions of the investigation reported in the paper and should refer to any new information therein. As the abstract is an independent entity, it should be able to convey the gist of the paper in a concise manner. It will be seen by many more people than will read the paper. The abstract, as concise as possible, should not exceed 250 words in length. Everything that is important in the paper must be reflected in the abstract. It should provide to the reader very briefly the rationale, objectives or hypothesis, methods, results and conclusions of the study described in the paper. In the abstract, do not deflect the reader with promises such as 'will be discussed' or 'will be explained'. Also do not include reference, figure or table citation. At first mention in the abstract, give complete scientific name for plants and other organisms, the full names of chemicals and the description of soil order/series. Any such names or descriptions from the abstract need not be repeated in the text. It must be remembered that the abstracting journals place a great emphasis on the abstract in the selection of papers for abstracting. If properly prepared, they may reproduce it verbatim.

"Key words" should, follow separately after the last sentence of the abstract. "Key words" indicate the most important materials, operations, or ideas covered in the paper. Key words are used in indexing the articles.

Introduction (To be typed as side-heading, starting from the left-hand margin, a few spaces below the key words)

This section is meant to introduce the subject of the paper. Introduction should be short, concise and indicate the objectives and scope of the investigation. To orient readers, give a brief reference to previous concepts and research. Limit literature references to essential information. When new references are available, do not use old references unless it is of historical importance or a landmark in that field. Emphasis should be given among other things on citing the literature on work done under Indian conditions. Introduction must include: (a) a brief statement of the problem, justifying the need for doing the work or the hypothesis on which the work is based, (b) the findings of others that will be further developed or challenged, and (c) an explanation of the approach to be followed and the objectives of the research described in the paper. If the methods employed in the paper are new, it must be indicated in the introduction section.

Materials and methods (To be typed as side-heading, starting from the left-hand margin, a few spaces below the introduction)

This part of the text should comprise the materials used in the investigation, methods of experiment and analysis adopted. This portion should be self-explanatory and have the requisite information needed for understanding and assessing the results reported subsequently. Enough details should be provided in this section to allow a competent scientist to repeat the experiments, mentally or in fact. The geographical position of soil site or soils used in the experiment or site of field trial should be identified clearly with the help of coordinates (latitude & longitude) and invariably proper classification according to Soil Taxonomy (USDA), must be indicated to the level of Great-group, Suborder or Order as far as possible. Specify the period during which the experiment(s) was conducted. Send the article after completion of the experiment(s) not after a gap of 5 years. Instead of kharif and rabi use rainy and winter season respectively. Please give invariably the botanical names for local crop names like raya, bajra moong, cholam etc. Botanical and zoological names should confirm to the international rules. Give authorities. Go through some of our recent issues and find out the correct names. Give latest correct names from authentic source. For materials, give the appropriate technical specifications and quantities and source or method of preparation. Should a product be identified by trade name, add the name and location of the manufacturer or a major distributor in parenthesis after the first mention of the product. For the name of plant protection chemicals, give popular scientific names (first letter small), not trade names (When trade name is given in addition, capitalize the first letter of the name). Known methods of analysis should be indicated by referring to the original source, avoiding detailed description. Any new technique developed and followed should be described in fair detail. When some specially procured or proprietary materials are used, give their pertinent chemical and physical properties. References for the methods used in the study should be cited. If the techniques are widely familiar, use only their names in that case.

Results and Discussion (To be typed as a side-heading, a few spaces below the matter on "Materials and Methods")

This section should discuss the salient points of observation and critical interpretation thereof in past tense. This should not be descriptive and mere recital of the data presented in the tables and diagrams. Unnecessary details must be avoided but at the same time significant findings and special features should be highlighted. For systematic discussion, this section may be divided into sub-sections under side-heading and/or paragraph side heading. Relate the results to your objectives. While discussing the results, give particular attention to the problem, question or hypothesis presented in the introduction. Explain the principles, relationships, and generalizations that can be supported by the results. Point out any exceptions. Explain how the results relate to previous findings, support, contradict or simply add as data. Use the Discussion section to focus on the meaning of your findings rather than recapitulating them. Scientific speculation is encouraged but it should be reasonable and firmly founded in observations. When results differ from previous results, possible explanations should be given. Controversial issues should be discussed clearly. References to published work should be cited in the text by the name(s) of author(s) as follows: Mukherjee and Mitra (1942) have shown or It has been shown (Mukherjee and Mitra, 1942)..... If there are more than two authors, this should be indicated by et al. after the surname of the first author, e.g., Mukherjee et al. (1938).

Always conclude the article by clearly crystallizing the summary of the results obtained along with their implications in solution of the practical problems or contribution to the advancement of the scientific knowledge.

Acknowledgments (To be typed as given above, as a side-heading, well below the concluding portion of Conclusions)

The author(s) may place on record the help, and cooperation, or financial help received from any source, person or organization. This should be very brief, and omitted, if not necessary.

References (To be typed as above, as side heading below Acknowledgement)

The list of references must include all published work referred to in the text. Type with double line spacing. Do not cite anonymous as author; instead cite the name of the institute, publisher, or editor. References should be arranged alphabetically according to the surnames of the individual authors or first authors. Two or more references by the same author are to be cited chronologically; two or more in the same year by the letters a, b, c, etc. All individually authored articles precede those in which the individual is the first or joint author. Every reference cited in the article should be included in the list of References. This needs rigorous checking of each reference. Names of authors should not be capitalized.

The reference citation should follow the order: author(s), year of publication, title of the paper, periodical (title in full, no abbreviations, italics or underlined), volume (bold or double underlining), starting and ending pages of the paper. Reference to a book includes authors(s), year, title (first letter of each word except preposition, conjunction, and pronouns in capitals and underlined), the edition (if other than first), the publisher, city of publication. If necessary, particular page numbers should be mentioned in the last. Year of publication cited in the text should be checked with that given under References. Year, volume number and page number of each periodical cited under "References" must be checked with the original source. The list of references should be typed as follows:

Rao C R 1968. *Advances in Statistical Methods in Biometrical Research*, pp.40-45, John Wiley & Sons, New York.

Kanwar J S and Raychaudhuri S P 1971. *Review of Soil Research in India*, pp 30-36. Indian Society of Soil Science, New Delhi.

Mukherjee J N 1953. The need for delineating the basic soil and climatic regions of importance to the plant industry. *Journal of the Indian Society of Soil Science*, **1** : 1-6.

Khan S K, Mohanty S K and Chalam A B, 1986. Integrated management of organic manure and fertilizer nitrogen for rice. *Journal of the Indian Society of Soil Science*, **34** : 505-509.

Bijay-Singh and Yadvinder-Singh 1997. Green manuring and biological N fixation: North Indian perspective. In: Kanwar J S and Katyal J C (Ed.) *Plant Nutrient Needs, Supply, Efficiency and Policy Issues 2000-2025.* National Academy of Agricultural Sciences, New Delhi, India, pp.29-44.

Singh S, Pahuja S S and Malik R K 1992. Herbicidal control of water hyacinth and its effect on chemical composition of water *(in) Proceedings of Annual Weed Science Conference*, held during 3-4 March 1992 by the Indian Society of Weed Science, at Chaurdhary Charan Singh Haryana Agricultural University, Hisar, 127p.

AICRP on Soybean 1992. *Proceedings of 23rd Annual Workshop of All-India Co-ordinated Research Project on Soybean*, held during 7-9 May 1992 at University of Agricultural Sciences, Bangalore, Karnataka, National Research Centre for Soybean, Indore, pp.48.

Devakumar C. 1986. Identification of nitrification retarding principles in neem (*Azadirachta indica* A.Juss.) seeds. Ph D Thesis, Indian Agricultural Research Institute, New Delhi.

Reference to unpublished work should normally be avoided and if unavoidable it may be mentioned only in the text.

Short Communication

Conceptually short communication is a first report on new concept, ideas and methodology which the author(s) would wish to share with the scientific community and that the detailed paper would follow. Short Communication is akin to an advance booking for the report on the findings. Short communications may include short but trend-setting reports of field or laboratory observation(s), preliminary results of long-term projects, or new techniques or those matters on which enough information to warrant its publication as a full length article has still not been generated but the results need to be shared immediately with the scientific community. The style is less formal as compared with the "full-length" article. In the short communications, the sections on abstract, materials and methods, results and discussion, and conclusion are omitted; but the material is put concisely in the same sequence but without formal sections. The other instructions are the same as in the case of the full-length articles.

Tables

Tables should not form more than 20% of the text. Each table should be typed on separate sheet and should have on the top a table number (in Arabic numerals *viz*. 1, 2, 3 etc.) and a caption or title which should be short, but sufficiently explanatory of the data included in the table. Information in the table should never duplicate that in the text and vice versa. Symbols (asterisks, daggers, etc. or small letters, *viz*., a, b, etc.) should be used to indicate footnotes to tables. Maximum size of table acceptable is what can be conveniently composed within one full printed page of the journal. Over-sized tables will be rejected out-right. Such tables may be suitably split into two or more small tables.

The data in tables should be corrected to minimum place of decimal so as to make it more meaningful. Do not use full stop with CD, SEm$\pm$, NS (not C.D., S.E.m$\pm$, N.S.). Do not put cross-rules inside the table. Tables should be numbered consecutively and their approximate positions indicated in the margin of the manuscript. Tables should not be inserted in the body of the text. Type each table on a separate sheet. Do not use capital letters for the tabular headings, do not underline the words and do not use a full-stop at the end of the heading. All the tables should be tagged with the main body of the text i.e. after references.

Figures

Figures include diagrams and photographs. Laser print outs of line diagrams are acceptable while dot-matrix print outs will be rejected. Alternatively, each illustration can be drawn on white art card or tracing cloth/ paper, using proper stencil. The lines should be bold and of uniform thickness. The numbers and letterings must be stenciled; free-hand drawing will not be accepted. Size of the illustrations as well as numbers, and letterings should be sufficiently large to stand suitable reduction in size. Overall size of the illustrations should be such that on reduction, the size will be the width of single or double column of the printed page of the Journal. Legends, if any, should be included within the illustration. Each illustration should have a number followed by a caption typed/ typeset well below the illustration.

Title of the article and name(s) of the author(s) should be written sufficiently below the caption. The photographs (black and white) should have a glossy finish with sharp contrast between the light and the dark areas. Colour photographs/ figures are not normally accepted. One set of the original figures must be submitted along with the manuscript, while the second set can be photocopy. The illustrations should be numbered consecutively in the order in which they are mentioned in the text. The position of each figure should be indicated in the margin of the text. The photographs should be securely enclosed with the manuscript after placing them in hard board pouches so that there may not be any crack or fold. Photographs should preferably be 8.5 cm or 17 cm wide or double the size. The captions for all the illustrations (including photographs) should be typed on a separate sheet of paper and placed after the tables.

Expression of Plant Nutrients on Elemental Basis

The amounts and proportions of nutrient elements must be expressed in elemental forms e.g. for ion uptake or in other ways as needed for theoretical purposes. In expressing doses of nitrogen, phosphatic, and potassic fertilizers also these should be in the form of N, P and K, respectively. While these should be expressed in terms of kg/ha for field experiments, for pot culture studies the unit should be in mg/kg soil.

SI Units and Symbols

SI Units (System International d 'Unities or International System of Units) should be used. The SI contains three classes of units: (i) base units, (ii) derived units, and (iii) supplementary units. To denote multiples and sub-multiples of units, standard abbreviations are to be used. Clark's Tables: Science Data Book by Orient Longman, New Delhi (1982) may be consulted.

Some of these units along with the corresponding symbols are reproduced for the sake of convenience.

Names and Symbols of SI Units

Physical Symbol for SI Unit Symbol Remarks quantity physical quantity for SI Unit

Primary Units					
length	l		time	t	
metre	m		second	s	
mass	m		electric current	I	
kilogram	kg		ampere	A	
Secondary Units					
plane angle	radian	rad	Solid angle	steradian	sr
Unit Symbols					
centimetre	cm		microgram	µg	
cubic centimetre	cm^3		micron	µm	
cubic metre	m^3		micronmol	µmol	
day	d		milligram	mg	
decisiemens	dS		millilitre	mL	
degree-Celsium	°C [=(F-32)x0.556]		minute	min	

gram	g	nanometre	nm
hectare	ha	newton	N
hour	h	pascal	Pa
joule J	(= 10^7 erg or 4.19 cal.)	second	s
kelvin	K (= °C + 273)	square centimetre	cm^2
kilogram	kg	square kilometre	km^2
kilometre	km	tonne	t
litre	L	watt	W
megagram	Mg		

Some applications along with symbols

adsorption energy	J/mol (=cal/molx4.19)	leaf area	m^2/kg
cation exchange capacity	cmol (p+)/kg (=m.e./100 g)	nutrient content in plants (drymatter basis)	µg/g, mg/g or g/kg
Electrolytic conductivity	dS/m (=mmhos/cm)	root density or root length density	m/m^3
evapotranspiration rate	m^3/m^2/s or m/s	soil bulk density	Mg/m^3 (=g/cm^3)
heat flux	W/m^2	specific heat	J/kg/K
gas diffusion	g/m^2/s or m^3/m^2/s or m/s	specific surface area of soil	m^2/kg
water flow	kg/m^2/s (or) $m^3$$m^2$s (or) m/s	thermal conductivity	W/m/K
gas diffusivity	m^2/s	transpiration rate	mg/m^2/s
hydraulic conductivity ion uptake	m/s	water content of soil	kg/kg or m^3/m^3
(Per kg of dry plant material)	mol/kg	water tension	kPa (or) MPa

While giving the SI units the first letter should not be in capital i.e cm, not Cm; kg not Kg. There should not be a full stop at the end of the abbreviation: cm, not cm. kg, not kg.; ha, not ha.

In reporting the data, dimensional units, viz., M (mass), L (length), and T (time) should be used as shown under some applications above. Some examples are: 120 kg N/ha; 5 t/ha; 4 dS/m etc.

Special Instructions

I. In a series or range of measurements, mention the unit only at the end, e.g. 2 to 6 cm2, 3, 6, and 9 cm, etc. Similarly use cm2, cm3 instead of sq cm and cu m.

II. Any unfamiliar abbreviation must be identified fully (in parenthesis).

III. A sentence should not begin with an abbreviation.

IV. Numeral should be used whenever it is followed by a unit measure or its abbreviations, e.g., 1 g, 3 m, 5 h, 6 months, etc. Otherwise, words should be used for numbers one to nine and numerals for larger ones except in a series of numbers when numerals should be used for all in the series.

V. Do not abbreviate litre to` l' or tonne to `t'. Instead, spell out.

VI. Before the paper is sent, check carefully all data and text for factual, grammatical and typographical errors.

VII. Do not forget to attach the original signed copy of `Article Certificate' (without any alteration, overwriting or pasting) signed by all authors.

VIII. On revision, please answer all the referees' comments point-wise, indicating the modifications made by you on a separate sheet in duplicate.

IX. If you do not agree with some comments of the referee, modify the article to the extent possible. Give reasons (2 copies on a separate sheet) for your disagreement, with full justification (the article would be examined again).

X. Rupees should be given as per the new symbol approved by Govt. of India.

Details of the peer review process

Manuscripts are received mainly through e-mails and in rare cases, where the authors do not have internet access, hard copies of the manuscripts may be received and processed. Only after the peer review the manuscripts are accepted for publication. So there is no assured publication on submission. The major steps followed during the peer review process are provided below.

Step 1. *Receipt of manuscript and acknowledgement*: Once the manuscript is received, the contents will be reviewed by the editor/associate editors to assess the scope of the article for publishing in JOR. If found within the scope of the journal, a Manuscript (MS) number is assigned and the same will be intimated to the authors. If the MS is not within the scope and mandate of JOR, then the article will be rejected and the same is communicated to the authors.

Step 2. *Assigning and sending MS to referees*: Suitable referees will be selected from the panel of experts and the MS (soft copy) will be sent to them for their comments - a standard format of evaluation is provided to the referees for evaluation along with the standard format of the journal articles and the referees will be given 4-5 week time to give their comments. If the comments are not received, reminders will be sent to the referees for expediting the reviewing process and in case there is still no response, the MS will be sent to alternate referees.

Step 3. *Communication of referee comments to authors for revision*: Once the referee comments and MS (with suggestions/ corrections) are received from the referees, depending on the suggestions, the same will be communicated to the authors with a request to attend to the comments. Authors will be given stipulated time to respond and based on their request, additional time will be given for attending to all the changes as suggested by referees. If the referees suggest no changes and recommend the MS for publication, then the same will be communicated to the authors and the MS will be taken up for editing purpose for publishing. In case the referees suggest that the article cannot be accepted for JOR, then the same will be communicated to the authors with proper rationale and logic as opined by the referees as well as by the editors.

Step 4. *Sending the revised MS to referees*: Once the authors send the revised version of the articles, depending on the case (like if major revisions were suggested by referees) the corrected MS will be sent to the referees (who had reviewed the article in the first instance) for their comments and further suggestions regarding the acceptability of publication. If only minor revisions had been suggested by referees, then the editors would look into the issues and decide take a call.

Step 5. *Sending the MS to authors for further revision*: In case referees suggest further modifications, then the same will be communicated to the authors with a request to incorporate the suggested changes. If the referees suggest acceptance of the MS for publication, then the MS will be accepted for publication in the journal and the same will be communicated to the authors. Rarely, at this stage also MS would be rejected if the referees are not satisfied with the modifications and the reasoning provided by the authors.

Step 6. *Second time revised articles received from authors and decision taken*: In case the second time revised article satisfies all the queries raised by referees, then the MS will be accepted and if not satisfied the article will be rejected. The accepted MS will be taken for editing process where emphasis will be given to the language, content flow and format of the article.

Then the journal issue will be slated for printing and also the pdf version of the journal issue will be hosted on journal webpage.

Important Instructions

- Data on field experiments have to be at least for a period of 2-3 years
- Papers on pot experiments will be considered for publication only as short communications
- Giving coefficient of variation in the case of field experiments Standard error in the case of laboratory determination is mandatory. For rigorous statistical treatment, journals like Journal of Agricultural Science Cambridge, Experimental Agriculture and Soil Use and Management should serve as eye openers.

SPECIAL ANNOUNCEMENT

In a recently conducted Executive Committee meeting of the Indian Society of Oilseeds Research, it was decided to increase the scope of the Journal of Oilseeds Research by accommodating vibrant aspects of scientific communication. It has been felt that, the horizon of scientific reporting could be expanded by including the following types of articles in addition to the Research Articles, Shor Communications and Review Articles that are being published in the journal as of now.

Research accounts (not exceeding 4000 words, with cited references preferably limited to about 40-50 in number): These are the articles that provide an overview of the research work carried out in the author(s)' laboratory, and be based on a body of their published work. The articles must provide appropriate background to the area in a brief introduction so that it could place the author(s)' work in a proper perspective. This could be published from persons who have pursued a research area for a substantial period dotted with publications and thus research account will provide an overall idea of the progress that has been witnessed in the chosen area of research. In this account, author(s) could also narrate the work of others if that had influenced the course of work in authors' lab.

Correspondence (not exceeding 600 words): This includes letters and technical comments that are of general interest to scientists, on the articles or communications published in Journal of Oilseeds Research within the previous four issues. These letters may be reviewed and edited by the editorial committee before publishing.

Technical notes (less than 1500 words and one or two display items): This type of communication may include technical advances such as new methods, protocols or modifications of the existing methods that help in better output or advances in instrumentation.

News (not exceeding 750 words): This type of communication can cover important scientific events or any other news of interest to scientists in general and vegetable oil research in particular.

Meeting reports (less than 1500 words): It can deal with highlights/technical contents of a conference/ symposium/discussion-meeting, etc. conveying to readers the significance of important advances. Reports must

Meeting reports should avoid merely listing brief accounts of topics discussed, and must convey to readers the significance of an important advance. It could also include the major recommendations or strategic plans worked out.

Research News (not exceeding 2000 words and 3 display items): These should provide a semi-technical account of recently published advances or important findings that could be adopted in vegetable oil research.

Opinion (less than 1200 words): These articles may present views on issues related to science and scientific activity.

Commentary (less than 2000 words): This type of articles are expected to be expository essays on issues related directly or indirectly to research and other stake holders involved in vegetable oil sector.

Book reviews (not exceeding 1500 words): Books that provide a clear in depth knowledge on oilseeds or oil yielding plants, production, processing, marketing, etc. may be reviewed critically and the utility of such books could be highlighted.

Historical commentary/notes (limited to about 3000 words): These articles may inform readers about interesting aspects of personalities or institutions of science or about watershed events in the history/development of science. Illustrations and photographs are welcome. Brief items will also be considered.

Education point (limited to about 2000 words): Such articles could highlight the material(s) available in oilseeds to explain different concepts of genetics, plant breeding and modern agriculture practices.

Note that the references and all other formats of reporting shall remain same as it is for the regular articles and as given in Instructions to Authors

o0o

Printed & Published by The Indian Society of Oilseeds Research,
ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad-500030, India
Ph: (040) 24598113 / 24598170; Fax: (040) 24017969
Web site: http://www.isor.org.in; E-mail: oilseedsociety@gmail.com