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Review

Analysis of seed chain and its implication in rapeseed-mustard (*Brassica* spp.) production in India

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ABSTRACT

India is ranked third after Canada and China sharing about 11.0% of the global rapeseed-mustard production (72.41 m t) and 24.7% and 29.4% in terms of area and production, respectively, of oilseeds in India during 2018-19. Of the projected demand of 82-101 m t of oilseeds by 2030, contribution of rapeseed-mustard is projected at 16.4-20.5 m t, considering its share of 20%-25% in production. Near doubling the production of rapeseed-mustard from its current production of 9.26 m t within 10 years is a daunting challenge necessitating multi-pronged strategy. First and foremost approach would be to bridge the exploitable yield reservoir (EP II) of 57.2% in rapeseed-mustard. Seed is the technological carrier and facilitates the realization of potential of variety and crop management technologies. The present paper reviews global scenario of rapeseed-mustard production and Indian scenario of seed sector, seed systems, seed production chain, seed status and its implication in production of rapeseed-mustard. India has a very robust seed system comprising both public sector institutions and private seed companies; this system acts as a driver of growth in agriculture. Of the three seed systems prevalent in India, *viz.,* formal, informal and integrated, formal system wherein guiding principles are to maintain varietal identity, purity and to produce seed of optimal physical, physiological and phyto-sanitary quality is predominant. Seed chain of rapeseed-mustard during 2019-20 was maintained with 55 varieties comprising 35 of Indian mustard, 11 of *toria,* 5 of yellow sarson and 2 each of *gobhi sarson* and taramira. Varietal mismatches in the breeder seed production was only 5.6% during 2019-20. Breeder seed production was higher by two to three folds than the indents during the last 11 years (2009-10 to 2019-20). During the last 10 years there has been a surge in seed requirement from 2.20 lakh q to 2.64 lakh q. Seed availability during this period was always higher by 2.3%-27.8% than the requirement, except during 2016-17 when a marginal deficit (0.8%) was observed. The seed replacement rate (SRR) is above the threshold level (33% for self- and 50% for cross-pollinated crops) and varietal replacement rate (VRR) is also high as contribution of old and obsolete varieties (released up to 1993) has substantially reduced from 49.4% (2014-15) to 1.7% (2019-20) for Indian mustard; 81.1% (2014-15) to 25.1% (2019-20) for *toria* and 64.0% (2014-15) to 18.9% (2019-20) for yellow sarson. Increased availability of seed, adequate SRR with high VRR are some of the contributing factors for enhanced yield from 1143 kg/ha to 1511 kg/ha during 2008-09 to 2018-19 in rapeseed-mustard. This paper also highlights some of the issues and strategies for quality breeder seed production.

Keywords: Breeder seed, Global scenario, Rapeseed-Mustard, Seed production chain, Seed replacement rate, Seed systems, Varietal replacement rate

India is the 4th largest vegetable oil economy in the world next to USA, China and Brazil. Oilseeds in India accounted for 16.7%, 12.9% and 18.3% of the total arable land, gross and net cropped area, respectively, during 2016 (Anonymous, 2019a). There is a continuous surge in demand of edible oils even at the current level of consumption (17.7 kg/capita/annum) because of increasing population, changing food habits, improved purchasing power, etc. The demand of vegetable oils is likely to grow by about 3.5-6.0% annually over the next 10 years which translates in to total requirement of 29.0-34.0 million tonnes (m t) of oils that works out to be equivalent to 82-102 m t of oilseeds by 2030 from the level of production of 33.50 m t during 2019-20 (DRMR, 2011; NAAS, 2017; Anonymous, 2020a). Rapeseed-mustard is an important group of oilseed crops in India. It contributes 24.7% and 29.4%, respectively, to total area and production of oilseeds during 2018-19. Further, considering 20% contribution from secondary sources and 20-25% from rapeseed-mustard; the projected demand for this crop would be around 16.4-20.5 m t by 2030 from the current production of 9.26 m t. This requires multi-pronged strategies such as horizontal expansion of the crop by inter cropping in wide-spaced crops, mixed cropping and extending it to new niches; vertical enhancement in yield through continuing varietal improvement programme, realizing the exploitable yield reservoir by narrowing yield losses due to biotic and abiotic stresses, using quality inputs and adopting efficient crop management technologies. It is in the latter context, where seed comes to the forefront and mere replacement of seed may enhance crop yield up to 20%. The present paper reviews the status of the crop in the world *vis-a-vis* India and seed sector, seed systems, seed production

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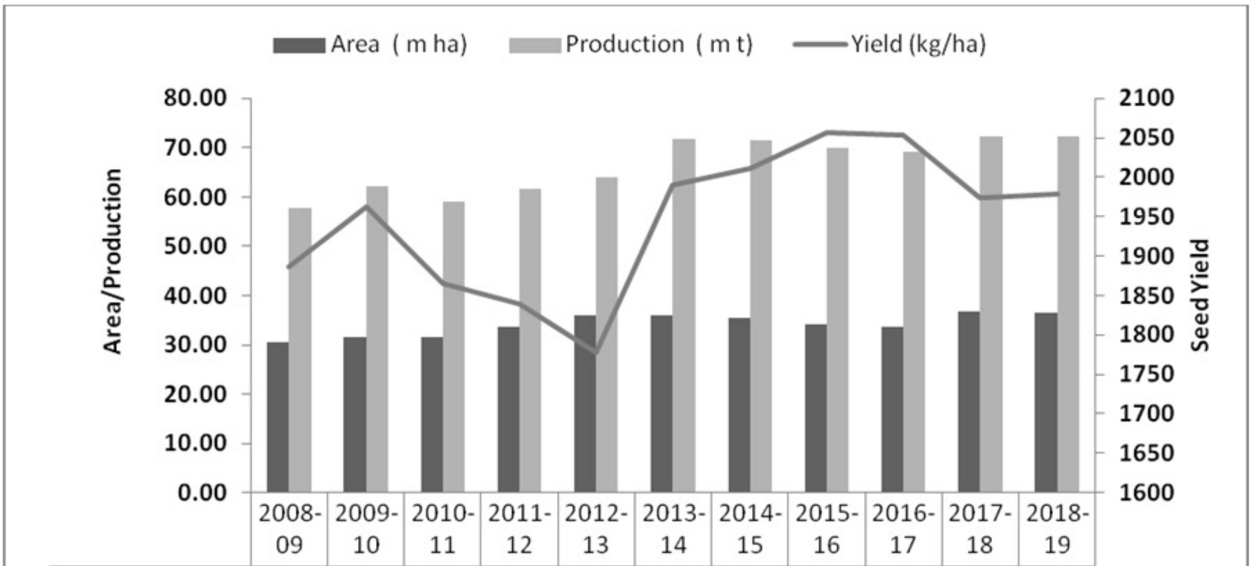
chain, seed status and its implication in production of rapeseed-mustard in India during the last 11 years.

Global scenario of rapeseed-mustard

Brassicas comprise many diverse types of plants, which are consumed as vegetables, fodder, sources of oil and condiments. The *oleiferous Brassica* species, commonly known as rapeseed-mustard are one of the economically important agricultural commodities. Rapeseed-mustard with a production of 72.41 m t, contributed 12.1% to the global oilseed production (597.27 m t) during 2018-19 (Anonymous, 2020b). These crops are grown in 67 countries in Asia, Europe, America, Africa and Australia. Rapeseed comprising colza (*Brassica napus* L.ssp. *oleifera* DC var. annua L. and turnip rape) (*Brassia rapa* L.) are extensively grown in most of the countries. Of these, about 26 countries also grow mustard consisting of (*Brassica juncea* (L.) Czern. & Coss.); black mustard (*Brassica nigra* [L.] Koch); Ethiopian mustard or *karan rai* (*Brassica carinata* A. Braun) and white mustard (*Sinapis alba* L.). In South Asian countries, India and Pakistan, Indian mustard and Ethiopia in Africa, Ethiopian mustard are predominatly grown (Chauhan *et al.,* 2013; FAOSTAT, 2018). Mustard accounted for about 17.3% and 10.3% of the global rapeseed-mustard area and production, respectively, during 2017-18 (FAOSTAT, 2018). From 2008-09 to 2018-19, the area under rapeseed-mustard in the world increased consistently from 30.59 million ha (m ha) during 2008-09 up to 36.05 m ha (2012-13), an increase of 17.8% but gradully declined thereafter up to 33.70 m ha (2016-17) but still higher by 10.2% over the base year and again increased by 19.9% during 2017-18 and 19.6% during 2018-19 (Fig.1). The production during this period ranged from 57.74 m t (2008-09) to 72.42 m t (2017-18) showing an increase of 25.4% which was marginally declined to 25.3% during 2018-19. Nevertheless, the trend was inconsistent and production peaked during 2013-14 and 2017-18 (Fig.1). Similar pattern was observed for yield (kg/ha) which ranged between 1777 (2012-13) and 2057 (2015-16) registering an increase of 15.8% but this increase was 9.0% over the base year. The yield increase during 2016-17, 2017-18 and 2018-19 over the base year (2008-09) was 8.8%, 4.6% and 4.9%, respectively. An anaysis on the basis of quinquennium (2013-14 to 2017-18) revealed that Canada, China and India together had a share of 62.7% and 55.3% in global rapeseed-mustard area and production, respectively. India ranked 3rd and 4th in area and production of rapeseed-mustard, respectively.



	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Area (m ha)	30.59	31.64	31.64	33.51	36.05	36.01	35.52	34.05	33.70	36.68	36.59
Production (m t)	57.74	62.08	59.01	61.64	64.06	71.68	71.45	70.05	69.18	72.42	72.37
Yield (kg/ha)	1887	1962	1865	1840	1777	1990	2012	2057	2053	1974	1979

Fig.1. Global trends in rapeseed-mustard area, production and yield from 2008-09 to 2018-19

European Union contributed the highest (30.9%) to production with only 19.1% share in area. The yield/ha varied from 0.54 t in Tajikistan to 3.89 t in Chile (FAOSTAT, 2018). Other countries with higher level of yield (> 3 t/ha) were Ireland (3.86 t), Belgium (3.79 t), Switzerland (3.66 t), United Kingdom & Northern Ireland (3.45 t), Denmark (3.43 t), Czechia (3.43 t), Turkey (3.30 t), Luxembourg (3.23 t), Slovenia (3.11 t), France (3.06 t) and Hungary (3.02 t). All these countires are in Europe and grow long duration winter rape (*Brassica napus*) that takes about 8-9 months from seed-to-seed and use very high dose of nitrogen fertilizer up to 250 kg/ha. Several other European contries had yield of more than 2.5 t /ha. In India, several short duration *Brassicas* are grown that take 100-150 days from seed-to-seed, i.e., about half of the duration than that of European countries with low nitrogeneous fertlilier use (60-120 kg/ha) under diverse agroecological conditions. Indian average seed yield was 1258 kg/ha as compared to global average yield of 1996 kg/ha (FAOSTAT, 2018). India also ranked 3rd after Canada and China with a share of about 11.0% in the global rapeseed-mustard production (72.41 m t) during 2018-19 (Anonymous, 2020b).

Rapeseed-mustard in India

Rapeseed-mustard in India consists of eight different species. Of theses, toria (*Brassica rapa* L. var. toria), brown sarson (*Brassica rapa* L. brown sarson), yellow sarson (*Brassica rapa* L. var. yellow sarson), gobhi sarson (*Brassica napus* L. ssp. *oleifera* DC var. annua L.) and taramira (*Eruca sativa*/vesicaria Mill.) are together termed as rapeseed; and Indian mustard (*Brassica juncea* (L.) Czern. & Coss.); black mustard (*Brassica nigra* [L.] Koch) and Ethiopian mustard or karan rai (*Brassica carinata* A. Braun) are collectively called mustard. They are grown under diverse agroclimatic conditions ranging from north-eastern/ north western hills and plains to down south under irrigated/rainfed, timely/late sown, saline soils and mixed/inter-cropping situations. In India, the major rapeseed-mustard growing states are Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, West Bengal, Assam and Gujarat accounting for 92.7% of the area and 95.8% of production during 2017-18 of which Rajasthan alone account for 36.6% and 40.9%, respectively, of the area and production (Anonymous, 2019a). Indian mustard is predominantly grown in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat. Toria is a short duration crop cultivated largely in Odisha, Assam, West Bengal and Bihar as a main crop while as a catch crop in Haryana, Madhya Pradesh, Punjab, Himachal Pradesh, Uttarakhand and western Uttar Pradesh. Yellow sarson is now mainly grown in Odisha, Assam, West Bengal, Bihar and eastern Uttar Pradesh. Brown sarson is cultivated on a limited scale in colder regions of the country like Jammu & Kashmir and Himachal Pradesh. Gobhi sarson is a longer duration crop confined only to limited areas of Punjab and Himachal Pradesh.Taramira is grown in certain drier parts of north western states like Rajasthan, Haryana and Uttar Pradesh (Chauhan *et al.,* 2013). However, area under these (brown sarson, yellow sarson and taramira) crops has been shrinking of late due to crop diversification or availability of shorter duation varieties of Indian mustard which have replaced these crops.

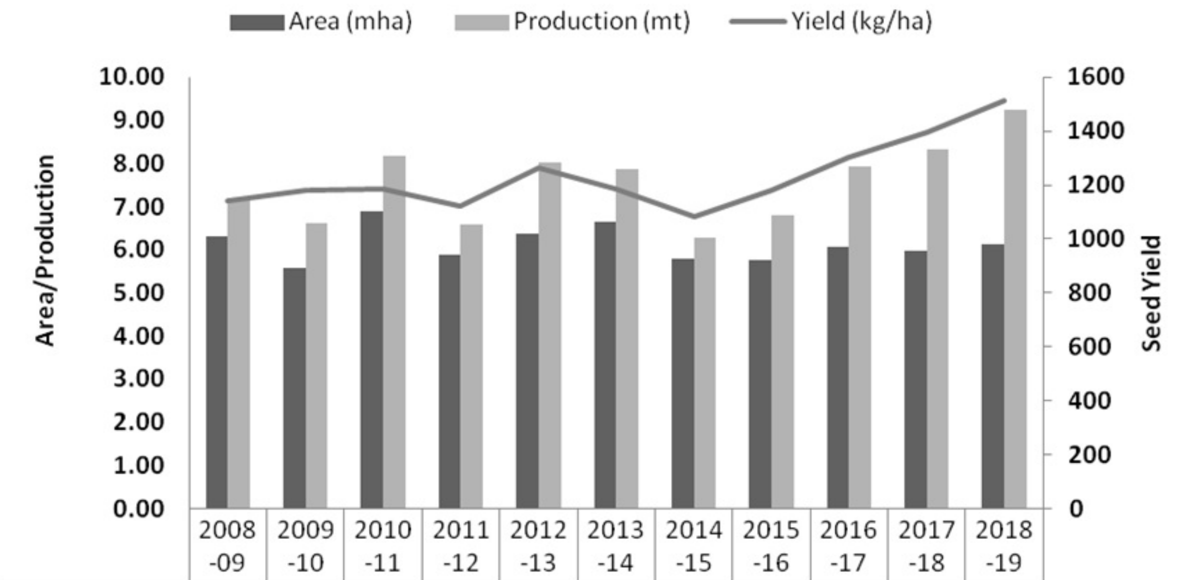
Rapeseed-mustard production in India during 2008-09 to 2018-19 increased by 28.6% (7.20 m t from 6.30 m ha in 2008-09 to 9.26 m t from 6.12 m ha during 2018-19) but area decreased by 2.9% (Anonymous, 2019a; 2020a). Yield levels showed an enhancement from 1143 to 1511 kg/ha, an increase of 32.2% during the same period. The arrea under rapeseed-mustard peaked thrice during the period, highest (6.90 m ha) in 2010-11 but showed variable and declining trend during the rest of the years ranging from 5.75 m ha during 2015-16 to 6.65 m ha during 2013-14 m ha (Fig. 2). The irrigated area during this period enhanced from 71.9 % to 76.6 % (2014-15).

Rapessed-mustard production also did not show a definite trend during this period, which increased by 13.6% during 2010-11 over the base year (2008-09), thereafter declined by 1.8% (2012-13) to 23.2% (2014-15) until 2016-17 and registered an incease of 1.7% and 13.2% during 2017-18 and 2018-19, respectively, (Fig. 2) over the highest ever achieved during 2010-11.

Indian seed sector, seed systems and supply chain

The journey of seed system/sector development started way back in 1928 with the report of Royal Commission of Agriculture. Since then over a period of 92 years, it traversed a long way with mile stones such as establishment of Central Seed Testing Laboratory at IARI, New Delhi in 1960; National Seed Corporation Ltd., New Delhi in 1963; Seed Act enactment in 1966; establishment of Tarai Development Corporation, Pantnagar and State Farms Corporation of India, New Delhi in 1969; setting up of National Commission on Agriculture in 1971; Joint Working Party and launching of National Seed Project in 1974; New Policy on Seed Development in 1988; Protection of Plant Varieties & Farmers' Rights Act in 2001; National Seed Policy in 2002; establishment of ICAR-Directorate of Seed Research, Mau (UP) in 2004; introduction of Seed Bill in parliament in 2004; launching of ICAR-Mega Seed Project during 2005-06; joining of OECD Seed Schemes by India in 2008 and presently 249 varieties of 20 crops have been enlisted for seed export under the scheme; launching of export-import policy 2009-14; Modified New Policy on Seed Development 2011; ISTA accreditation of first public sector laboratory in 2015; up gradation of ICAR-Directorate of Seed Research to ICAR-Indian Institute Seed Science, Mau in 2015; Cotton

Seeds Price (Control) Order, 2015 and Licensing and Formats for GM Technology Agreement Guidelines, Government of India in 2016 (Chauhan *et al.*, 2016; 2017). Seed Sector in India has evolved gradually from a pre-dominantly public sector holding (until the 1980's) into a multi-faceted sector with the involvement of about 600 national and multinational seed companies/firms with increasing emphasis on research and development activities besides a strong network of public sector institutions and organizations. Currently, public seed sector comprises National Agriculture Research, Education and Extension System (NAREES) having 64 ICAR Research Institutes, 6 Bureaux, 15 National Research Centres, 13 Directorates/Project Directorates, 3 Central Agricultural Universities and 5 Deemed Universities, 82 All India Coordinated and Network Projects [59 All India Coordinated, 21 Network and 2 other projects], 11 Agricultural Technology Application Research Institutes (ATARI), 716 Krishi Vigyan Kendras, 4 Central Universities with Agriculture faculty, 63 State Agricultural Universities (https://www.icar.org.in, visited on July 24, 2020), National Seed Corporation (NSC), New Delhi with 10 Regional and 66 Area offices, 16 State Seed Corporations, 25 State Seed Certification Agencies and 134 State Seed Testing Laboratories; 18 ISTA member and six (one public and five private sector) ISTA accredited laboratories. These concerted efforts have led to a vibrant and globally competitive Seed Sector in India. At present, India has a very robust seed system (production, processing, marketing and distribution) comprising both public sector institutions as well as private seed companies that guarantees food security of the country and acts as a driver of growth in agriculture.



	2008 -09	2009 -10	2010 -11	2011 -12	2012 -13	2013 -14	2014 -15	2015 -16	2016 -17	2017 -18	2018 -19
Area (mha)	6.30	5.59	6.90	5.89	6.36	6.65	5.80	5.75	6.07	5.96	6.12
Production (mt)	7.20	6.61	8.18	6.60	8.03	7.88	6.28	6.80	7.92	8.32	9.26
Yield (kg/ha)	1143	1183	1185	1121	1262	1185	1083	1183	1304	1397	1511

Fig. 2. Trends of rapeseed-mustard area, production and yield in India from 2008-09 to 2018-19

Global seed market in terms of value was about US$ 71.4 billion in 2019 with Compound Annual Growth Rate (CAGR) of 7% during 2011-18 and expected to register US $ 90.37 billion in 2024 with likely CAGR of 7.9% during 2020-24 (www.imarcgroup.com, visited on July 20, 2020). Indian seed market is the 5th largest in the world after USA, China, France and Brazil. Indian seed market (US$ 2.3-2.7 billion) had been growing at rapid rate with CAGR of 19.0% (2009-14); 8.4% (2012-16) and projected at 11% (US $ 3.0 billion) for field crops and 14.6% (US$ 700 million) for vegetable seed during 2020 (NAAS, 2018; www.ifca.org.in, visited on Feb.5, 2019). During 2017, India imported 29,456 tonnes of seeds of vegetables, flowers and field crops worth US$ 121 million of the total global import of 3.98 m t of seeds worth US$ 11,289 million and exported 33,036 tonnes of seed worth US$ 101 million against global export of 3.79 m t worth US$ 11,924 million, respectively, (International Seed Federation; https://www.worldseed.org, visited on July 30, 2019).

Seed system, a framework of institutions/farmers group organized together by their involvement or influence on the seed multiplication, processing, quality assurance and marketing of seeds, could be formal, informal or integrated. Guiding principles in the formal system are to maintain varietal identity, purity and to produce seed of optimal physical, physiological and phyto-sanitary quality. It is characterised by large scale production of seeds of officially released and notified varieties as per Section 5 of Seed Act 1966 with strict quality assurance mechanism. The formal seed system follows the three stages, viz., breeder, foundation and certified seed production. It is very well organized and systematic. The seed supply chain involves multiple stakeholders both from public and private sectors including NGOs and farmers (Fig. 3). Quality of seed and pricing are regulated as per the Seed Act (1966), Seed Rules (1968), Seed (Control) Order 1983, the legal instruments to regulate the quality of seeds available in the market and other notifications from time to time (Chauhan *et al*., 2016a; 2017; Prasad *et al*., 2017). The responsibility for seed law enforcement is vested with the State Governments. The Seed Act/Rules are applicable only to notified seeds. Labelling of seed is compulsory as per the Seed Act 1966 but certification is voluntary.

Informal seed system caters to the need of only a small scale supply of locally known varieties without any government interference in quality control. Farmers themselves produce, disseminate and access seed: directly from their own harvest; through exchange / barter among friends, neighbours, relatives; and through local grain markets. Informal system is characterized largely by a wider range of variations in seed system and flexibility. Varieties may be landraces or mixed races and may be heterogeneous or modified through on-farm breeding. The seed is of variable quality and the same general steps are involved in the local system as in the formal system (variety choice, variety testing, introduction, seed multiplication, selection, dissemination and storage) but they take place as integral parts of farmers' production systems rather than as discrete activities (Reddy *et al*., 2007). There is not always necessarily a distinction between seed and grain. Quality control is exercised by local technical knowledge, local social structures and norms.

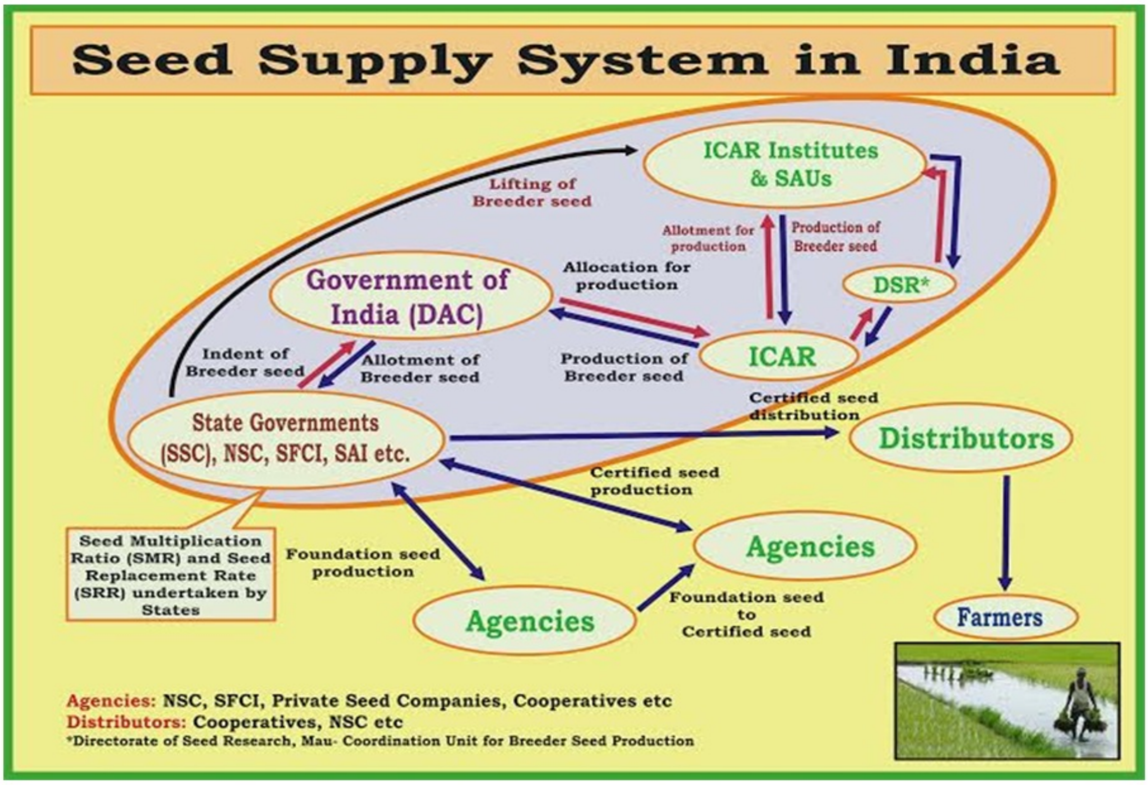


Fig.3 Existing formal seed production and supply system in India (Source: Prasad *et al.,* 2017)

In integrated system, however, a farmer will use the formal system for some crops and informal system for others. He may buy seed from the formal system once in order to obtain a particular variety and produce own seed from then onwards and share the new variety with neighbours and relatives. Community based seed production refers to production of the varieties preferred by the farmers for themselves in their own locality by organizing themselves into small groups (Fig. 4) is also a regular feature. These groups cultivate the same variety avoiding cross pollination and follow the recommended cultivation practices particularly seed selection procedures. These farmers are given the appropriate training, and supplied with good quality foundation seed for multiplication, so that they become the source of improved seed for the entire village. Each season, the farmers are supplied with foundation seed of different crops.

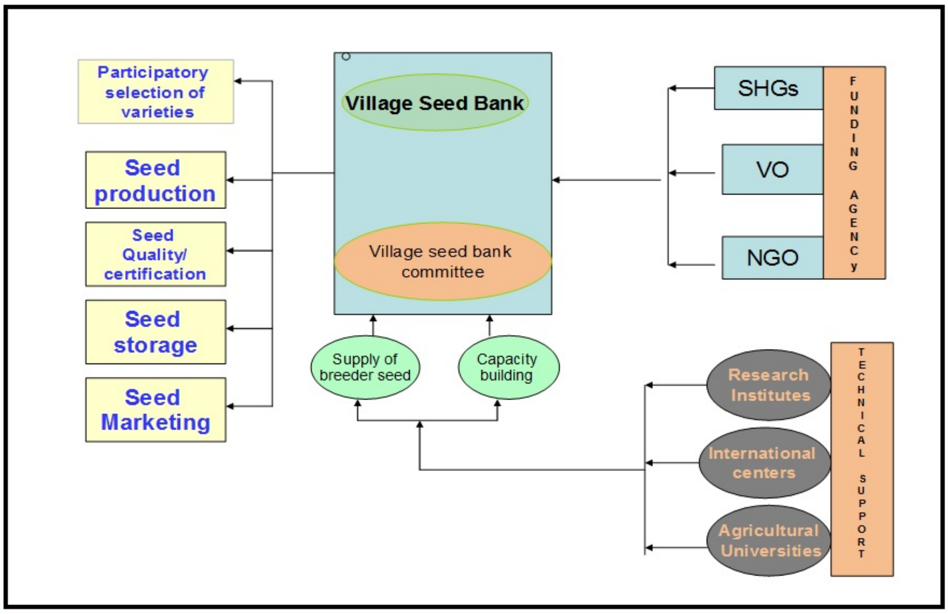


Fig. 4. An integrated seed system model: Interlinking different stakeholders (farmers, public and private organizations): Source: Chauhan *et al.* (2017)

Seed production

Seed chain: The present paper is based on analysis of formal seed production system. Seed production chain commences with the indenting of varieties for breeder seed production by the concerned stakeholders. A total of 201 varieties of rapeseed-mustard have been released during 1969-2019 of which 44 were released during the last five years and majority of them were of Indian mustard (Table 1). During this period, 4 (2 each of yellow sarson and Indian mustard) varieties have also been de-notified. Thus 197 varieties/hybrids currently qualify for formal system of seed production as per Seed Act 1966.

Varietal diversity in seed chain: During 2014-15 to 2019-20, only 27.9% to 39.6% of the varieties that are qualified for formal seed production were in the seed chain. These comprised mustard (59%-68%) and rapeseed (32%-41%). Number of varieties in the seed chain varied from 55 to 78 (Table 2).

Varietal replacement: Varietal replacement rate was assessed by analyzing breeder seed indents for the last six years (2014-15 to 2019-20) to know the trend of induction of recently released varieties and exclusion of old obsolete varieties in the seed chain. The varieties were grouped on quinquennium (5 years) basis according to their release and notification years to assess their contribution to indent of breeder seed.

The indented Indian mustard varieties for breeder seed production were 50, 50,46,43, 36 and 35 during 2014-15, 2015-16, 2016-17, 2017-18, 2018-19 and 2019-20, respectively (Table 3), and the contribution of top 5 varieties to the total indent of the crop was 69.3%, 50.7%, 38.9%, 41.2%, 42.6% and 52.2% respectively, during the corresponding period. Further, share of top 10 varieties in breeder seed varied from 58.1% during 2016-17 to 84.3% during 2014-15. Among the leading varieties in the seed chain, except for Varuna (1976), Pusa Bold (1985), Pusa Mahak (2004) and Jawahar Mustard 3 (2005), the rest were released within 10 years. The varieties, Varuna (1976) and

RH 761(2019) were the earliest and latest release in the seed chain. Contributions of varieties released during the last 10 years as per the guidelines of National Food Security Mission (NFSM), DAC&FW, Govt. of India, New Delhi to promote recently released high yielding varieties, varied from 21.2% from 21 varieties (2014-15) to 65.0% from 15 varieties (2018-19) and from 0.3% from a single variety (2015-16) to 27.8% from 16 varieties (2019-20), for the varieties released between 2009-13 and 2014-18, respectively (Table 3). Share of very old varieties (released prior to 1993 and / or for which date of notification was not available) was substantially reduced from 49.4% from 7 varieties during 2014-15 to only 1.7% from a single variety during 2019-20. The share of varieties released during the past 10 years (2009-18), to breeder seed indent varied from 44.1% in 2015-16 to 88.3% during 2019-20. The highest indent, in general, except for the year 2014-15, was for the varieties (13-21) released during 2009-13, contributing from 43.8% (2015-16) to 65.0% (2018-19). Of the 25 varieties released during 2015-19, 16 were indented for breeder seed production during 2019-20. The variety Pusa Bold was the leading variety with a share of 7.4%-30.7% to breeder seed indent until 2017-18. Thereafter, NRCHB 101, JM 3, Pusa Mahak, Pusa Mustard 25, Pusa Mustard 30 and DRMRIJ 31(Giriraj) were the leading varieties in the seed chain with a contribution of 5.9%-15.8%, 9.7%-19.1%, 5.3%-8.4%, 5.3%-10.8%, 11.1%-11.4% and 10.1%-11.6%, respectively, to the total indent.

Table 1 Varieties of rapeseed-mustard released during the last five years

Crop	2015	2016	2017	2018	2019	Total
Rapeseed						
Toria	0	2	3	3	0	8
Brown sarson	0	0	0	1	2	3
Yellow sarson	0	1	1	0	1	3
Gobhi sarson	2	0	0	0	0	2
Taramira	0	0	2	0	0	2
Mustard						
Indian mustard	5	9	2	3	6	25
Ethiopian mustard	0	1	0	0	0	1
Total	07	13	8	7	9	44

Table 2 Rapeseed-mustard varieties in seed chain during the last six years

Crop	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Rapeseed						
Toria	14	13	13	13	13	11
Brown sarson	0	0	2	0	0	0
Yellow sarson	6	6	7	6	7	5
Gobhi sarson	6	4	3	3	3	2
Taramira	2	1	2	0	2	2
Mustard						
Indian mustard	50	50	46	43	36	35
Ethiopian mustard	0	1	0	0	0	0
Total	78	75	73	65	61	55

In case of toria, 14 varieties were indented for breeder seed production during 2014-15 whereas, the number declined to 13 in the next year and remained the same until 2018-19 and further declined to 11 during 2019-20 (Table 3). Top five varieties contributed 40.4% (2016-17) to 82.5% (2019-20). Contribution of varieties released during the last 10 years (2009-18) varied from 1.1% from one variety in 2014-15 to 75.0% from five varieties in 2019-20 (Table 3). The highest indent, in general, was for the varieties (5-9) released up to 1993, ranging from 44.1% from 6 varieties (2015-16) to 81.8% from 9 varieties (2014-15) until 2018-19 (Table 3). However, the old varieties were completely replaced by those released during 2009-13 and 2014-18 and their contribution was 34.8% and 40.2%, respectively, during 2019-20. Three pre-released varieties (TS 36, TS 38 and TS 46) were also indented for breeder seed production in substantial quantity for all the six years, which should not have been the case since breeder seed could not be produced for un-notified varieties as per Seed Act 1966. The predominant varieties of toria in the seed chain were Uttara, M 27, Anuradha and Sushree contributing 9.3%-40.6%; 2.9%-16.7%; 2.9%-8.1% and 11.5%-16.2%, respectively, to the seed indent during the six years. M 27 is the oldest variety released in 1978 and Tapeswari, Tripura Toria are the latest released (2018) varieties in the seed chain during 2019-20 (Table 4). Of the eight varieties released during 2015-19, four were in seed chain during 2019-20.

Table 3 Recent trends of varietal replacement of selected rapeseed-mustard in seed chain from 2014-15 to 2019-20

Crop	Year	Indent (q)	Varieties	Up to 1993	1994-98	1999- 2003	2004-08	2009-13	2014-18	2019-23
Indian mustard	2014-15	98.5	50	7 (49.4%)***	4 (3.4%)	8 (3.0%)	10 (23.1%)	21(21.2%)	-	-
	2015-16	82.1	50	7 (21.4%)	3 (3.0%)	8 (1.0%)	9 (30.5%)	22 (43.8%)	1 (0.3%)	-
	2016-17	51.8	46	8 (27.4%)	4 (6.6%)	4 (1.5%)	9 (20.2%)	20 (42.7%)	1 (1.6%)	
	2017-18*	61.3	43	8 (21.1%)	4 (6.1%)	1 (0.08%)	9 (17.8%)	17 (52.0%)	4 (2.8%)	
	2018-19*	57.6	36	6 (14.3%)	2 (5.2%)	1 (0.5%)	6 (12.8%)	15 (65.0%)	4 (2.2%)	-
	2019-20**	59.5	35	1 (1.7%)	-	-	4 (9.9%)	13 (60.5%)	16 (27.8%)	1 (0.08%)
Toria	2014-15	18.6	14	9 (81.8%)	1 (0.3%)	2 (16.2%)	1 (0.6%)	1 (1.1%)	-	-
	2015-16	16.6	13	6 (44.1%)	1 (18.1%)	2 (21.1%)	1 (0.6%)	1 (9.2%)	2 (6.7%)	-
	2016-17	35.2	13	9 (71.3%)	-	2 (15.6%)	1 (0.1%)	1 (12.9%)	-	-
	2017-18*	12.7	13	8 (54.2%)	-	1 (3.9%)	-	1 (9.2%)	1 (40.2%)	-
	2018-19*	17.4	13	8 (54.3%)	-	1 (2.9%)	-	1 (30.0%)	3 (12.8%)	-
	2019-20**	12.4	11	5 (25.1%)	-	-	-	1 (34.8%)	4 (40.2%)	-
	2014-15	9.2	6	2 (64.0%)	-	-	-	4 (36.0%)	-	-
Yellow sarson	2015-16	6.9	6	2 (63.0%)	-	-	-	4 (37.0%)	-	-
	2016-17	11.0	7	3 (49.8%)	-	-	-	4 (50.2%)	-	-
	2017-18*	7.8	6	2 (45.3%)	-	-	-	4 (54.6%)	-	-
	2018-19*	8.6	7	1 (47.5%)	1 (1.8%)	-	-	4 (50.1%)	1 (0.6%)	-
	2019-20**	1.9	5	1 (18.9%)	-	-	-	4(81.1%)	-	-

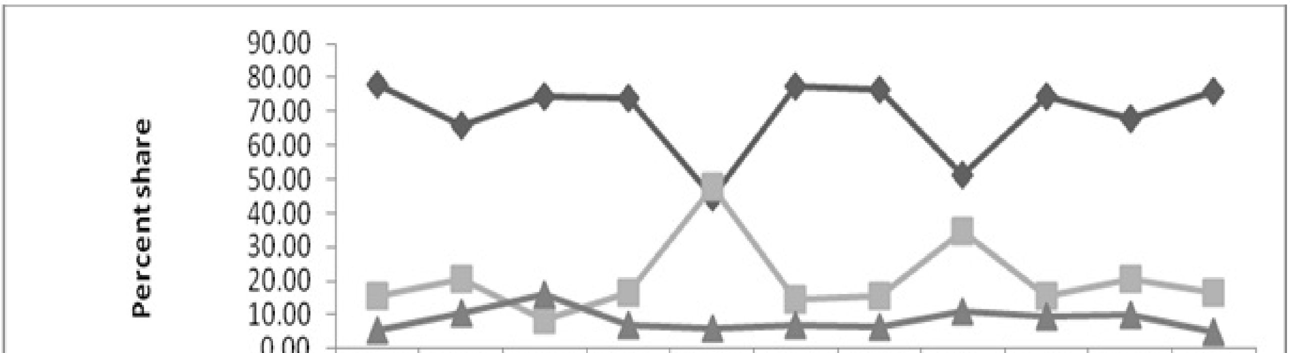
*,**Source: https://seednet.gov.in/readyrecknor/Seed_III_VI.aspx visited on 13.12.2018 and 16.11.19
***: Figures in parenthesis is the contribution of varieties to the crop indent

In yellow sarson, the number of varieties indented was highest (7) in the year 2018-19 and the lowest (5) in 2019-20 (Table 3). Top five varieties contributed from 97.1% (2015-16) to 100.0% (2019-20). Except Benoy (1982) and Jhumka (1998), all other predominant high yielding varieties in the seed chain during the last six years have been released within 10 years (Table 4). Benoy, Pitambari and Pant Pili Sarson 1 were the leading varieties with a contribution ranging from 18.9% to 62.3%, 6.0% to 51.1% and 4.9% to 29.6%, respectively. Until 2015-16, varieties developed up to 1993 were the main contributors to the seed indent with share ranging from 63.0% (2015-16) and 64.0% (2014-15). Thereafter, varieties developed during the period 2009-13 were predominant in the seed chain during 2016-17, 2017-18, 2018-19 and 2019-20 contributing 50.2%, 54.6%, 50.1% and 81.10%, respectively, to the seed indents (Table 3). Of the three varieties released during 2015-19, seed indent of only one variety was received during 2019-20 with a contribution of only 0.6%.

In gobhi sarson, six varieties and one hybrid were in the seed chain during the six years. Three to six varieties were indented for breeder seed production during the last six years. In all the years, only three varieties per year were indented except 2014-15 when 6 varieties were in the seed chain. Predominant high yielding varieties in the seed chain during the last six years were Sheetal (released in 1995) and Neelam (released in 2001) each contributing to 31.3% during 2014-15, GSC 6 (released in 2008) and Him Sarson 1(released in 2009) contributing to 38.2% and 42.5%, respectively, during 2015-16, GSC 7 (released in 2015) contributing 84.7% during 2016-17, Him Sarson and GSC 7 contributing 28.4% and 57.1%, respectively, during 2017-18, Sheetal, GSC 6 and GSC7 each contributing 33.3% during 2018-19 and GSC 7 with a contribution of 96% to the seed chain during 2019-20.

During the last six years, only two varieties of brown sarson, *viz.,* BSH 1 (released in 1975) and KBS 3 (released in 1998) were indented during 2016-17 in a small quantity (0.05 q). Similarly, only one variety of Ethiopian mustard, *viz*., Pusa Aditya (released in 2006) was indented (0.02 q) during 2015-16. But no breeder seed was produced even to meet small requirements of these varieties. Four varieties of taramira, *viz*., Karan Tara released in 1995, Narendra Tara released in 2007, Jobner Tara (RTM 1351) and Jwala Tara (RTM 1355) both released in 2017 were in the seed chain during the last six years except for 2017-18. Of these Narendra Tara was the leading variety during 2014-15 and 2015-16 with a share of 87.8% and 100.0%, respectively. Jwala Tara was the leading variety during 2017-18, 2018-19 and 2019-20 contributing to 98.0%; 96.3% and 98.1%, respectively, to the seed indent for taramira. Seed chain of rapeseed-mustard during 2019-20 was maintained with 55 varieties comprising 35 of Indian mustard, 11 of toria, 5 of yellow sarson and 2 each of gobhi sarson and taramira.

Breeder seed: Breeder seed production is demand driven. It is produced after receiving indents from interested stakeholders both from public and private sectors and is supplied to them for further multiplication in the form of foundation and certified seeds which is made available to the farmers. Analysis of indent of breeder seed for the last 11 years (2009-10 to 2019-20) showed inconsistent trend, breeder seed indent declined from 76.30q in 2009-10 to 49.28q in 2011-12 showing a reduction of 34.5%. Then the indents showed upward trend and increased by 7.4% (2017-18) to 66.9% (2014-15) over the base year and peaked during 2012-13, 2014-15 and 2018-19 with an increase of 43.8%, 66.9% and 12.1%, respectively. Rapeseed-mustard had a share of 0.25%-0.71% in the total indent for oilseeds during 2012-13 to 2018-19. Of the seven crops that comprise rapeseed-mustard, Indian mustard had the dominant share in the total breeder seed indent ranging between 44.75% during 2013-14 and 77.77% during 2009-10 (Fig.5). Toria, a short duration rapeseed crop contributed to 8.54% (2011-12) to 47.68% (2013-14) and yellow sarson, another rapeseed crop accounted for 4.91% (2019-20) to 16.11% (2011-12) of the breeder seed indent for rapeseed-mustard. Other crops (brown sarson, Ethiopian mustard, taramira and gobhi sarson) together had a small share in the breeder seed indent of rapeseed-mustard ranging between 0.39% (2017-18) and 3.6% (2010-11). During 2018-19 and 2019-20, Indian mustard, toria, yellow sarson and other crops accounted for 67.93%-75.80, 16.29%-20.52%, 4.91%-10.1% and 1.45%-3.0% of the rapeseed-mustard breeder seed indent, respectively (Fig. 5).



	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Indian mustard (%)	77.77	65.80	74.63	73.88	44.75	77.41	76.68	51.26	74.65	67.93	75.80
Toria (%)	15.29	20.31	8.54	16.75	47.68	14.58	15.47	34.84	15.43	20.52	16.29
Yellow sarson (%)	5.24	10.29	16.11	6.97	6.03	7.19	6.44	10.84	9.53	10.10	4.91

Fig.5. Share of major rapeseed-mustard crops (%) in breeder seed indents during the last 11 years (2009-10 to 2019-20)

In an earlier study, Chauhan *et al.* (2012) analyzed the trend of breeder seed indents of rapeseed-mustard during 25 years, *viz.,* from 1987-88 to 2011-12 and concluded that indent for toria was reduced from 35% during 1986-87 to 1990-91 to 15% during 2006-07 to 2011-12. On the other hand, indents for Indian mustard and yellow sarson increased, to 76% from 56% and to 8% from 4% during this period, respectively. By and large, similar trends continued during the last decade also, *viz.,* the indents during 2019-20 for Indian mustard and toria were almost similar to that of 2006-07 to 2011-12 but reduced substantially for yellow sarson to only 4.91%.

Abundant quantities of rapeseed-mustard breeder seed has been produced, always much higher than the indents. As a matter of fact, during the last 11 years, the breeder seed produced was two-three times higher than the indents (AICRPRM, 2010; 2011; 2012; 2020 and Anonymous, 2019b; 2020c). It ranged between 123.80q during 2011-12 and 304.32q during 2015-16 (Fig. 6). However, despite indent for breeder seed, no seed was produced for brown sarson during 2012-13 and 2013-14. Further, there has been no seed indent for brown sarson and Ethiopian mustard since 2016-17 and 2015-16, respectively (Table 5).

Table 4 Share of top 5 varieties to breeder seed indent of major rapeseed-mustard crops and promising varieties in seed chain from 2014-15 to 2019-20

Crop	Share	Prominent varieties (among top 5 in a year) in seed chain**
Indian mustard	38.9% (2016-17) to 69.3% (2014-15)	Jawahar Mustard 3 (2005)a, Pusa Bold (1985), Varuna (1976), Pusa Mahak (2004), NRCHB 101 (2009), Pusa Mustard 25 (2010), Raj Vijay Mustard 2 (2013), Pusa Mustard 28 (2012), DRMR IJ 31 (2013), Pusa Mustard 30 (2013), Pusa Mustard 27 (2011), Chhatisgarh Sarson (2010), RH 725 (2018),CS 60 (2018), RH 761 (2019)
Toria	40.4% (2016-17) to 82.5% (2019-20)	Uttara (2010), Anuradha (2002), M 27 (1978), PT 303 (1985), Parbati (2001), T 9 (1975), JMT 689 (1997), TL 15 (1982), Agrani (1982), Bhawani (1986), Sushree (2015), Tapeswari (2018), Raj Vijay Toria (2017), Tripura Toria (2018)
Yellow sarson	97.1% (2015-16) to 100.0% (2019-20)	Benoy (1982), Pant Pili Sarson 1 (2010), Pitambri (2010), YSH 0401 (2009), Jhumka (1998), NRCYS 05-02 (2009),

** Varieties indented at least thrice or in 2018-19/2019-20; a: Year of release

Table 5 Breeder seed indent (I) and production (P) in quintals of rapeseed-mustard during the last 11years (2009-10 to 2019-20)*

Year	Indian mustard		Ethiopian mustard		Toria		Brown sarson		Yellow sarson		Gobhi sarson		Taramira	
	I	P	I	P	I	P	I	P	I	P	I	P	I	P
2009-10	59.3	102.7	0.7	1.2	11.7	29.6	0.06	1.0	4.0	6.8	0.04	0.2	0.6	0.8
2010-11	49.7	98.5	0.7	0.2	15.3	30.5	0.1	1.0	7.8	10.0	0.7	1.5	1.2	10.9
2011-12	36.9	91.4	0.0	0.0	4.2	16.2	0.1	0.0	7.9	16.1	0.0	0.0	0.0	0.0
2012-13	81.3	150.8	0.2	0.2	18.4	42.9	0.1	0.0	7.9	13.2	0.6	3.0	1.2	1.8
2013-14	43.5	126.1	0.1	0.1	45.2	50.1	0.1	0.0	5.7	32.6	0.3	2.4	1.3	1.9
2014-15	98.5	212.5	0.0	0.0	18.6	59.2	0.0	0.0	9.2	11.4	0.3	3.7	0.8	3.6
2015-16	82.1	231.0	0.02	0.02	16.6	40.8	0.0	0.0	6.9	18.8	0.3	12.9	0.8	0.8
2016-17	51.8	174.6	0.0	0.0	35.2	38.2	0.1	0.1	11.0	26.2	1.8	9.4	1.0	0.9
2017-18	61.3	186.5	0.0	0.0	12.7	81.4	0.0	0.0	7.8	28.5	0.1	6.6	0.0	0.0
2018-19	57.6	151.9	0.0	0.0	17.4	40.8	0.0	0.0	8.6	60.5	0.2	2.1	1.1	1.1
2019-20	57.6	174.9	0.0	0.0	12.4	34.6	0.0	0.0	3.7	42.7	1.3	1.6	1.0	4.9

*Source: AICRPRM, 2010; 2011; 2012; 2020 and Anonymous, 2019b, 2020c

Seed requirement, availability and certified /quality seed distributed: Analysis of data of seed requirement and availability of certified/quality seed of rapeseed-mustard during the last 10 years (2009-10 to 2018-19) revealed that the requirement for seed of rapeseed-mustard although showed variable trend, yet, it was always higher over the base year by 0.5% (2013-14) to 20.0% (2014-15) varying from 2.20 lakh q to 2.64 lakh q (Table 6). Rapeseed-mustard quality seed distribution has been decreasing consistently since 2011-12 until 2015-16 except 2014-15. The reduction in seed distribution as compared to the base year, 2011-12, (2.56 lakh q) was 26.6%; 36.3%, 16.8%, 55.1% and 6.3%, during 2012-13; 2013-14; 2014-15; 2015-16 and 2016-17, respectively (Table 6). However, during 2017-18 seed distribution was 10.9% higher but declined during 2018-19 by 26.6% compared to that of 2011-12.'

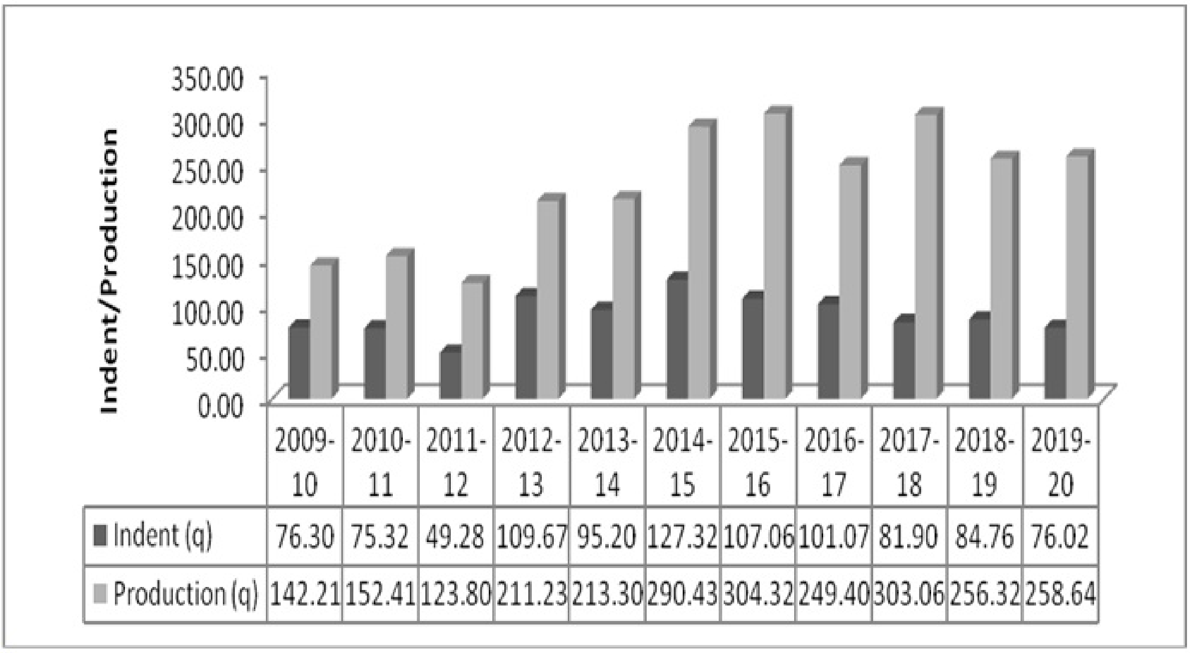


Fig. 6. Trend of breeder seed indent and production of rapeseed-mustard during the last 11years (2009-10 to 2019-20)

Implication

Enhanced seed replacement rate and yield: Seed replacement rate (SRR) is considered as an important intervention for yield enhancement in all crops as it has proven time and again that use of quality seed alone could increase yield by 20%. The ideal SRR is considered as 33% for Indian mustard, Ethiopian mustard, gobhi sarson and yellow sarson and 50% for brown sarson, toria and taramira. The SRR of rapeseed-mustard was quite variable during the last 10 years but always well above the threshold. The SRR during 2013-14 was 51.3% and during 2018-19 was 52.4% in comparison to 74.8% during 2009-10. The highest SRR (78.9%) was achieved during 2011-12 (Table 6). Concerted efforts of researchers and development personnel involved in rapeseed-mustard seed production programme have resulted in higher availability of quality seed of recently released varieties to achieve spectacular gains in SRR and VRR during the last six years. Besides high SRR, the VRR is also high as contribution of old and obsolete varieties (released up to 1993) has substantially reduced from 49.4% (2014-15) to 1.7% (2019-20) for Indian mustard, 81.1% (2014-15) to 25.1% (2019-20) for toria and 64.0% (2014-15) to 18.9% (2019-20) for yellow sarson. These two factors (SRR and VRR) contributed to increased productivity (yield) and thereby enhanced production of rapeseed-mustard during the last 11 years.

Issues and strategy

Seed chain involves several stakeholders with definite responsibility. It has mainly two activities: breeder seed production and conversion of breeder seed into downstream classes to achieve higher seed production and delivery system to the end users. All these components of seed chain need to be energised (Prasad *et al*., 2017; NAAS, 2018). The following are the issues and strategy exclusively pertaining to rapeseed-mustard seed production.

Non-notified and old varieties in the seed chain: Several pre-released varieties [three advanced breeding lines of toria, *viz.,* TS 36, TS 38 and TS 46 and two of Indian mustard

(RGN 303 and Rajendra Suphalam)] have repeatedly been indented for breeder seed production and production figures were also reported. It was inappropriate as breeder seed can only be produced for notified varieties as per Seed Act 1966. How the breeder seed production was monitored and downstream conversion has taken place for these pre-released varieties is the question that has remained unanswered. Therefore, there is an urgent need to release and notify them if their performance is acceptable as per the standards for release and notification of varieties or exclude from the formal system of seed production to maintain quality of seed. Organizations/institutes concerned should take up appropriate steps in this direction. Further, very old varieties of yellow sarson such as Jhumka and Benoy from West Bengal were observed in the seed chain with considerably higher indents despite four better varieties having been released for the region during the last five years. Therefore, there is an urgent need to have extensive efforts in showcasing, popularizing new and improved yellow sarson varieties in West Bengal to create demand for seed.

Table 6 Requirement, availability, distribution of certified/quality seed (lakh quintals) and seed replacement rate (SRR) of rapeseed-mustard during the last 10 years

Year	Requirement [R]	Availability [A]	[A-R] / R (%)	Certified/quality seed distributed	SRR (%)
2009-10	2.20	2.48	12.7	-	74.8
2010-11	2.45	2.80	14.3	-	63.6
2011-12	2.37	2.66	12.2	2.56	78.9
2012-13	2.44	2.65	8.6	1.88	57.3
2013-14	2.21	2.34	5.9	1.63	51.3
2014-15	2.64	2.70	2.3	2.13	54.6
2015-16	2.52	2.65	5.2	1.15	62.2
2016-17	2.49	2.47	-0.8	2.40	68.0
2017-18	2.31	2.55	10.4	2.84	54.9
2018-19	2.34	2.99	27.8	1.88	52.4

Quality of breeder seed: Breeder seed is the back bone of quality seed production programme. Therefore, its genetic and physical purity is of paramount importance. In view of the several cases of rejection of foundation seed plots due to questionable quality of breeder seed having been reported frequently, there is a greater concern for quality as huge cost and efforts are involved in seed production. Several stakeholders demand for having seed certification standards for breeder seed also. Therefore, there is a strong need for strengthening the maintenance breeding and nucleus seed production. It should be an effective and regular activity of the research/production centres with timely technical back stopping, capacity building programmes for stakeholder concerned and rigorous monitoring to ensure quality of breeder seed.

Irrational breeder seed indenting: Rapeseed-mustard are small seeded crops with high seed multiplication ratio (SMR) and low seed rate but very high indents were placed in all the six years. Moreover, surplus (two to three folds higher) rapeseed-mustard breeder seed have been produced than the indents. Production of such quantities of breeder seed every year is a sheer wastage of resources. Chauhan *et al*. (2016) assessed the requirement of rapeseed-mustard breeder seed for the year 2019-20 for the highest ever cropped area (7.30 m ha) and target SRR (90.9%) considering seed multiplication ratio of 1:200 and seed rate @ 5kg/ha to be 8.30 q. But area during the last five years has been hovering around 6.0 m ha. In this scenario, with this quantity of breeder seed there could be 100% SRR. Similarly, crop-wise analysis revealed that proportion of the crops in the breeder seed indent were skewed to 47.68% during 2013-14 and 34.84% during 2016-17 for toria and 16.11% for yellow sarson during 2011-12 at the expense of Indian mustard but without any contingency. Even there is no targeted SRR; it was variable to an appreciable extent. Thus, there is a need for consistently maintaining the requisite SRR. Therefore, there is an urgent need to relook into the formulation of seed rolling plan for rapeseed-mustard. Careful planning is required considering actual area, SRR and varieties while developing seed rolling plan otherwise non-notified varieties of toria/Indian mustard and obsolete varieties like Jhumka and Benoy of yellow sarson could be indented even during 2019-20.

Varietal mismatches: Despite the fact that overall breeder seed production of field crops including rapeseed-mustard, in general, was always higher than the indents, there were some varietal mismatches. Greater efforts were made in the National Seed Project during the last five years that resulted in considerable reduction in varietal mismatches from 34% to 17%. It is envisioned to further bring down the varietal mismatches to 5% in the next couple of years (Anonymous, 2020b). Further, analysis of seed chain of rapeseed-mustard revealed that varietal mismatches were reduced to 3.1% in 2017-18 in comparison to 16.7% in 2014-15 though this mismatch again increased to 6.6% during 2018-19 and reduced to 5.6% during 2019-20. During the last six years (2014-15 to 2019-20), the mismatches accounted for 3.6% to 27.9% of the total seed indent. It reduced considerably from 27.9% during 2014-15 to 3.8% during 2019-20. Such varietal mismatches caused deficit of breeder seed to the tune of 51%, 45.9%, 71.0%, 100.0%, 43.0% and 70.7%, respectively, during 2014-15, 2015-16, 2016-17, 2017-18, 2018-19 and 2019-20, for some of the indented varieties. Therefore, various breeder seed producing (BSP) centres should address this issue by proper planning, systematic and concerted efforts.

Tracking of breeder seed: Tracking of the breeder seed in the seed chain is an important issue to know its downstream conversion to foundation/certified seed or it is going directly for commercial utilization. Breeder seed production is a highly specialized and resource intensive activity. Further, non-lifting of breeder seed is also a matter of concern in almost all crops and rapeseed-mustard is not an exception. Hence liquidating such high quantity of breeder seed could also be a problem. There is a need to think of 'cooling period' for breeder seed production, in general, except for variety indented for the first time. Studies should be planned for seed quality enhancement for long term storage of breeder seed. Crop specific breeder seed banks may be created, be it in area of predominant cultivation or zone wise and, resources, thus saved, should be utilized for breeder seed production of other high volume oilseeds like groundnut and soybean.

Disparity in seed distributed and SRR: During the last decade, there has been a surge in seed requirement and abundant seed was produced. In general, barring 2016-17, seed availability was always higher than the requirement. But it is intriguing that quality seed distribution among the end use stakeholders in the seed chain, i.e to farmers, decreased. It might be due to production of seed of such varieties which were less preferred by the farmers or overproduction. Therefore, there is a need to carefully plan for demand driven seed production programme. Accordingly, breeder seed indents for such varieties should be placed with organization concerned well in advance. This necessitates that seed rolling plan should be developed in consultation with farmers / farmers producer organizations to avoid this anomaly and also offset the liquidity problem. Further, the seed distribution was also not directly linked to seed replacement rate (SRR), it was 78.9% when seed distribution was 2.56lakh q during 2011-12 while only 54.9% during 2017-18 with 2.84 lakh q quality seed was distributed. It was probably that seed was provided to the marketing agencies but could not reach the farmers, the ultimate users. In depth analysis should be carried out to sort out such anomalies.

Overall, there are no major issues with seed production chain of rapeseed-mustard. On the contrary, there is a serious concern for irrational seed indenting, over production of breeder seed and its quality and anomaly in SRR *vis-à-vis* distribution of certified/quality seed to the famers.

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REFERENCES

AICRP (Rapeseed-Mustard) 2010. *Annual Progress Report.* Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, Rajasthan.

AICRP (Rapeseed-Mustard) 2011. *Annual Progress Report.* Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, Rajasthan.

AICRP (Rapeseed-Mustard) 2012. *Annual Progress Report.* Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, Rajasthan.

AICRP (Rapeseed-Mustard) 2020. *Annual Progress Report.* Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, Rajasthan

Anonymous 2019a. Agricultural Statistics at a Glance 2018. Directorate of Economics & Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi, p. 468.

Anonymous 2019b. *Breeder Seed Review Report 2017-18.* XXII Breeder Seed Review Meeting. CCS-Haryana Agricultural University, Hisar, Haryana. 7 April 2019. p. 136.

Anonymous 2020a. *Third Advance Estimates of Production of Food Grains and Oilseeds & Commercial crops for 2019-20 as on May 15, 2020*. Agricultural Statistics Division. Directorate of Economics & Statistics. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi. (www.agricoop.nic.in).

Anonymous 2020b. Oilseeds: *World Markets and Trade. Foreign Agricultural Service,* United States Department of Agriculture. p. 39 (April 2020).

Anonymous 2020c. *Breeder Seed Review Report 2018-19.* Virtual XXIII Breeder Seed Review Meeting. Crop Science Division, Indian Council of Agricultural Research, New Delhi and Institute of Seed Science, Mau, Uttar Pradesh, 14-15 May 2020. p. 124.

Chauhan J S, Singh K H and Kumar V 2012. *Compendium of rapeseed-mustard varieties notified and breeder seed production scenario in India (2006-2012).* All India Coordinated Research Project on Rapeseed-Mustard, Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan. p.72.

Chauhan J S, Jha S K, Kumar V and Singh K H 2013. *Rapeseed-mustard production technology for different agro-ecological systems in India.* Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, Rajasthan. p.54.

Chauhan J S, Prasad S R, Pal S, Choudhury P R and Udayabhaskar K 2016. Seed production of field crops in India: Quality assurance, status, impact and way forward. *Indian Journal of Agricultural Sciences*, **86** (5): 563-579.

Chauhan J S, Prasad S R, Pal S and Choudhury P R 2017. Seed systems and supply chain of rice in India. *Journal of Rice Research*, **10** (1): 9-16.

DRMR 2011. *Vision 2030.* Directorate of Rapeseed-Mustard Research, Bharatpur 321 303, Rajasthan. p. 29.

FAOSTAT 2018. Statistics Division, Food and Agricultural Organization of United nations. www.faostat.fao.org. 15 June, 2020.

NAAS 2017. *Vegetable oil economy and production problems in India.* Strategy Paper no.7, National Academy of Agricultural Sciences. New Delhi, p. 20.

NAAS 2018. *Accelerating seed delivery systems for priming Indian farm productivity enhancement: A strategic view point.* Strategy Paper no.9, National Academy of Agricultural Sciences. New Delhi, p.22.

Prasad S R, Chauhan J S and Sripathy K V 2017. An overview of national and international seed quality assurance systems and strategies for energizing seed production chain of field crops in India. *Indian Journal of Agricultural Sciences*, **87**(3): 287-300.

Reddy R Ch, Tonapi V A, Bezkorowajnyj P G, Navi S S and Seetharama N. 2007. Seed system innovations in the semi-arid tropics of Andhra Pradesh, International Livestock Research Institute (ILRI), ICRISAT, Patancheru, Andhra Pradesh, pp. 224.

Evaluation of nutrient expert - a decision support tool through SSNM in soybean

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ABSTRACT

A field experiment was carried out during *kharif* seasons of 2017-18 and 2018-19 in AICRP on Soybean at Regional Research and Technology Transfer Station of OUAT, Bhawanipatna, Kalahandi, Odisha to evaluate the effectiveness of site specific nutrient management (SSNM) in soybean using Nutrient Expert, a decision support tool. Seven treatments comprising of T1: SSNM(NE) (25:23:19 kg $N:P_2O_5:K_2O$/ha), T2: T1-N omission (0:23:19 kg $N:P_2O_5:K_2O$/ha), T3: T1-P omission (25:0:19 kg $N:P_2O_5:K_2O$/ha), T4: T1-K omission (25:23:0 kg $N:P_2O_5:K_2O$/ha), T5: RDF (25:100:50:50kg $N:P_2O_5:K_2O:S$ /ha), T6: Farmers practice (20:20:20 kg $N:P_2O_5:K_2O$/ha) and T7: Absolute control (No fertilizer) were tried in randomized block design (RBD) with three replications. Recommended dose of fertilizer (25:100:50:50 kg $N:P_2O_5:K_2O:S$/ha) recorded maximum seed yield of soybean (1465 kg/ha) which was at par with application of fertilizer based on site specific nutrient management [SSNM (NE) 25:23:19 kg $N:P_2O_5:K_2O$/ha] with seed yield of 1352 kg/ha. Yield data from the omission plot treatments suggested that N is the most important major nutrient for enhancing the seed yield of soybean followed by P and K. There was 28.1% reduction in seed yield when N was omitted from SSNM (NE). Omission of nitrogen, phosphorus and potassium application from SSNM (NE) recorded 33.7, 25.1 and 21.7% reduction in seed yield, respectively, as compared to application of NPKS (RDF). Application of RDF earned higher gross return to an extent of 8% and 28% over SSNM (NE) and Farmers Practice, respectively, whereas, net return (₹13271/ha) and return/rupee invested (1.49) were higher in SSNM (NE).

Keywords: Nutrient expert, Omission plot, Site specific nutrient management, Soybean

Soybean [*Glycine max* (L.) Merrill.] is an important leguminous oilseed crops, popularly known as golden or miracle bean due to its high nutritive value and various uses such as human food, animal feed, cooking oil and different soy food products. It is rich in oil (18-20%) and protein (38-42%) (Pandey *et al.,* 2008). The area, production and productivity of soybean in India during 2018-19 was 10.96 m ha, 13.46 m t and 1.23 t/ha, while the world scenario was 129.3 m ha, 370.5 m t and 2.87 t/ha, respectively, during that period. Non-judicious and skewed use of chemical fertilizers leading to imbalanced nutrition has been one of the major reasons for the low yield of soybean in our country. Site-specific nutrient management (SSNM) strategies that include knowledge of crop nutrient requirement and indigenous nutrient supplies is useful for improving nutrient use efficiency, crop productivity as well as soil health.

SSNM is a plant based approach which provides the guidelines for tailoring nutrient management practices to specific field conditions through optimally supplying crops with essential nutrients as and when needed to achieve high yield and high efficiency of input use (Jangilwad *et al.,* 2019). Computer-based decision support tools are the options to address this novel cause. Nutrient Expert (NE), a decision support tool developed by International Plant Nutrition Institute (IPNI), is an easy-to-use, interactive, and computer-based decision support tool that can rapidly provide nutrient recommendations for an individual farmer's field in the presence or absence of soil testing data. NE can use experimental data but it can also estimate the required SSNM parameters using existing site information. The parameters needed in SSNM are usually measured in nutrient omission trials conducted in farmers' fields, which require at least one crop season. With NE, parameters can be estimated using proxy information, which allows farm advisors to develop fertilizer guidelines for a location without data from field trials.

The judicious and balanced fertilizer use is useful for sustaining agricultural crop productivity as well as maintaining soil quality. The varied response of the intensively grown crop like soybean grown in Vertisols to the applied nutrients reveal the potential of soil, effectiveness of nutrients added and the indigenous nutrient supplying capacity of soil. The present study was carried out to evaluate the effectiveness of SSNM in soybean using Nutrient Expert in Odisha.

MATERIALS AND METHODS

The field investigation was carried out to study the response of fertilizer recommendation through Nutrient Expert (NE) on growth and yield of soybean during the kharif season of 2017-18 and 2018-19 in AICRP on Soybean at Regional Research and Technology Transfer Station of Odisha University of Agriculture and Technology,

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Bhawanipatna, Kalahandi, Odisha. The SSNM dose was decided as per Nutrient Expert recommendation. The algorithm for calculating fertilizer requirements in NE is determined from a set of on-farm trial data using SSNM guidelines. In SSNM, the N, P and K requirements are based on the relationships between balanced uptake of nutrients at harvest and grain yield. This relationship is called internal nutrient efficiency and is predicted using the quantitative evaluation of the fertility of tropical soils (QUEFTS) model (Janssen *et al*., 1990). The fertilizer requirement for a field or location is estimated from the expected yield response to each fertilizer nutrient, which is the difference between nutrient-limited yield and attainable yield. Nutrient-limited yield is determined from nutrient omission trials in farmers' fields, i.e. when a nutrient of interest is omitted while all other nutrients are supplied in ample amounts (Dobermman *et al.,* 2004; Witt *et al.,* 2009). Attainable yield at a location is the yield obtained in a typical year using best management practices without any deficiency of nutrients. The amount of nutrients taken up by a crop is directly related to its yield so that the attainable yield indicates the total nutrient requirement and nutrient-limited yield indicates the indigenous nutrient supply. The yield response indicates nutrient deficit, which must be supplied by fertilizers. Nutrient Expert estimates the attainable yield and yield response to fertilizer from site information using decision rules developed from on-farm trials (Satyanarayan *et al.,* 2011). The omission plot technique was used in the present study wherein each major nutrient i.e., nitrogen, phosphorus and potassium was omitted and the recommended dose of N, P, K and S was applied in one treatment in order to study the response of the crop under this varied nutrient rates. The calculation of SSNM based Nutrient Expert fertilizer recommendation (25:23:19 kg $N:P_2O_5:K_2O$/ha) for soybean was done by International Plant Nutrition Institute (IPNI) based on the inputs provided. The nutrient limited yield for N, P_2O_5 and K_2O was 0.015 t/ha/kg of N applied, 0.011 t/ha/kg of P_2O_5 applied and 0.011 t/ha/kg of K_2O applied, respectively. The attainable yield of soybean was 1.0 t/ha. Yield response for the experimental site for N, P and K was 0.2 t, 0.2 t and 0.1 t/ha, respectively. Nutrient combinations comprising of T1: SSNM (NE) (25:23:19 kg $N:P_2O_5:K_2O$/ha), T2: T1-N omission (0:23:19 kg $N:P_2O_5:K_2O$/ha), T3: T1- P omission (25:0:19 kg $N:P_2O_5:K_2O$/ha), T4: T1- K omission (25:23:0 kg $N:P_2O_5:K_2O$/ha), T5: RDF (25:100:50:50kg $N:P_2O_5:K_2O:S$/ha), T6: Farmers practice (20:20:20 kg $N:P_2O_5:K_2O$/ha) and T7: Absolute control (No fertilizer) were tried in randomized block design (RBD) with three replications. The soybean variety RKS-18 was sown at a spacing of 45 cm x 7.5 cm on 25.08.2017 and 23.08.2018 during the year 2017-18 and 2018-19, respectively. The complete dose of N, P, K and S as per treatments was applied as basal. The initial composite soil samples from each site were collected, processed and analyzed for initial soil fertility status. The soil of the experimental site was black cotton soil having 6.2 pH, 0.65% O.C., low available N (120.0 kg/ha), high available P (33.2 kg/ha) and high available K (374.0 kg/ha). The rainfall received during the cropping season was 428.8 mm and 539.5 mm during the year 2017-18 and 2018-19, respectively. Observations on plant height, number of branches/plant, number of pods/plant, number of seeds/pod were recorded from randomly selected five plants. Weight of 100 seeds (seed index) was recorded from harvested seeds. Seed yield and straw yield were recorded from the net plot and converted to hectare factor. Cost of cultivation, gross return and net return were estimated per hectare taking sale price of soybean as ₹30/kg.

RESULTS AND DISCUSSION

Growth attributing characters: The data on plant height and number of branches/plant over two years of experimentation revealed significant influence of different nutrient management practices on these characters (Table 1). Considering the mean performance over two years, recommended dose of fertilizer (25:100:50:50 kg $N:P_2O_5:K_2O:S$/ha) recorded maximum plant height (35.2 cm), which was at par with SSNM(NE) i.e. 25:23:19 kg $N:P_2O_5:K_2O$/ha (34.6cm), SSNM with K omission (33.0cm) and SSNM with P omission i.e. 25:0:19 kg $N:P_2O_5:K_2O$/ha (32.6cm). The absolute control and SSNM with N omission i.e. 0:23:19 kg $N:P_2O_5:K_2O$/ha treated plots recorded significantly shorter plants (31.1 and 29.3cm, respectively) than RDF (25:100:50:50 kg $N:P_2O_5:K_2O:S$/ha). Number of branches/plant was maximum (3.5) with application of recommended dose of fertilizer (25:100:50:50 kg $N:P_2O_5:K_2O:S$/ha) which was closely followed by SSNM (NE (3.4) and RDF (3.3). Other nutrient management practices recorded significantly less number of branches/plant.

Yield attributes and yield: The number of pods/plant in soybean variety RKS-18 was significantly influenced by different nutrient management practices during both the years of study (Table 1). The recommended dose of fertilizer recorded maximum number of pods/plant (23.2) which was at par with SSNM (NE) applied plot (20.0). Maximum number of seeds/pod (2.8) was observed with application of recommended dose of fertilizer which was closely followed by SSNM (NE) (2.7) and farmers' practice i.e. (2.7). Minimum number of seeds/pod was recorded in absolute control (2.3). No significant difference was observed with respect to seed index (100 seed weight) in different nutrient management practices. However, heavier seeds having seed index of 10.99 g were obtained with application of recommended dose of fertilizer and 10.89 g with SSNM

(NE). Similar results on yield attributing parameters have been reported by Devidayal and Agarwal (1999) in sunflower.

Application of recommended dose of fertilizer (25:100:50:50 kg $N:P_2O_5:K_2O$:S/ha) recorded maximum seed yield (1465 kg/ha) which was at par with application of fertilizer based on SSNM(NE) with seed yield of 1352 kg/ha. Yield data from the omission plot treatment suggested that N is the most important major nutrient for enhancing the seed yield of soybean followed by P and K. There was 28.1% reduction in seed yield as compared to SSNM (NE) when N was omitted. Omission of nitrogen, phosphorus and potassium application recorded 33.7, 25.1 and 21.7% reduction in seed yield, respectively, than application of NPKS (RDF). The higher seed yield with the combined application of NPKS could be attributed to adequate supply of nutrients through balanced nutrient management system which helped in proper growth and yield attributes. Katkar *et al.* (2012) reported that application of NPK recorded significantly highest yield of soybean. These findings are in agreement with those of Mohapatra *et al.* (2010) and Yadav and Chandel (2010).

Table 1 Effect of SSNM practices on plant height, branches/plant, pods/plant, seeds/pod, seed index, seed and straw yield of soybean

Treatment	Plant height (cm)			No. of branches/plant			Pods/plant			No. of seeds/pod			Seed index (g)			Seed yield (kg/ha)			Straw yield (kg/ha)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T1: SSNM(NE) (25:23:19 kg $N:P_2O_5:K_2O$/ha)	36.1	33.0	34.6	3.5	3.3	3.4	21.9	18.0	20.0	2.8	2.6	2.7	11.11	10.67	10.89	1433	1270	1352	1550	1507	1528
T2: T1 – N omission (0:23:19 kg $N:P_2O_5:K_2O$/ha)	32.8	29.5	31.1	2.7	2.6	2.6	16.9	13.4	15.2	2.5	2.2	2.4	10.41	9.99	10.20	1017	927	972	1033	1013	1023
T3: T1 – P omission (25:0:19 kg $N:P_2O_5:K_2O$/ha)	34.2	31.1	32.6	2.9	2.9	2.9	17.9	14.5	16.2	2.6	2.4	2.5	10.90	10.47	10.68	1150	1047	1098	1317	1280	1298
T4: T1 – K omission (25:23:0 kg $N:P_2O_5:K_2O$/ha)	34.6	31.4	33.0	3.1	3.0	3.0	19.3	15.7	17.5	2.6	2.5	2.5	10.82	10.39	10.61	1183	1110	1147	1367	1327	1347
T5: RDF (25:100:50:50kg $N:P_2O_5:K_2O$:S /ha)	36.7	33.6	35.2	3.6	3.4	3.5	25.0	21.3	23.2	2.9	2.7	2.8	11.21	10.77	10.99	1533	1397	1465	1617	1587	1602
T6: Farmers practice (20:20:20 kg $N:P_2O_5:K_2O$/ha)	35.4	32.3	33.9	3.4	3.3	3.3	20.2	16.5	18.4	2.7	2.6	2.7	10.86	10.43	10.64	1233	1057	1145	1567	1370	1468
T7: Absolute control	30.8	27.9	29.3	2.2	2.0	2.1	14.2	9.2	11.7	2.4	2.2	2.3	10.31	9.90	10.11	867	717	792	883	823	853
SEm (±)	1.15	1.13	0.80	0.14	0.12	0.09	1.9	1.8	1.3	0.11	0.12	0.08	0.44	0.42	0.30	62.0	52.5	41.0	66.0	57.0	44.0
CD (P=0.05)	3.54	3.48	2.40	0.42	0.36	0.26	5.9	5.5	3.8	NS	NS	0.25	NS	NS	NS	191	162	119	203	177	127

Table 2 Effect of SSNM practices on gross returns (Rs./ha) , net returns (Rs./ha) and return/rupee invested in soybean

Treatment	Cost of cultivation (₹/ha)			Gross returns (₹/ha)			Net returns (₹/ha)			Return/ rupee invested		
	2017	2018	Mean	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T1: SSNM (NE) (25:23:19 kg $N:P_2O_5:K_2O$/ha)	29223	25335	27279	43000	38100	40550	13271	12765	13271	1.47	1.50	1.49
T2: T1 – N omission (0:23:19 kg $N:P_2O_5:K_2O$/ha)	28903	25010	26956	30500	27800	29150	2194	2790	2194	1.06	1.11	1.08
T3: T1 – P omission (25:0:19 kg $N:P_2O_5:K_2O$/ha)	27785	23754	25770	34500	31400	32950	7180	7646	7180	1.24	1.32	1.28
T4: T1 – K omission (25:23:0 kg $N:P_2O_5:K_2O$/ha)	28858	24737	26797	35500	33300	34400	7603	8563	7603	1.23	1.33	1.29
T5: RDF (25:100:50:50kg $N:P2O_5:K_2O$:S /ha)	34633	31608	33120	46000	41900	43950	10830	10293	10830	1.33	1.34	1.33
T6: Farmers practice (20:20:20 kg $N:P_2O_5:K_2O$/ha)	28992	25097	27044	37000	31700	34350	7306	6603	7306	1.28	1.26	1.27
T7: Absolute control	25606	21336	23471	26000	21500	23750	280	165	280	1.02	1.01	1.01
SEm (±)	-	-	-	1860	1576	1219	1219	1576	1219	0.06	0.06	0.05
CD (P=0.05)	-	-	-	5729	4855	3557	3557	4855	3557	0.20	0.19	0.13

N.B.: Cost of soybean seed = ₹ 30 per kg

The straw yield (1602 kg/ha) was significantly higher with application of recommended dose of fertilizer followed by SSNM (NE) and Farmers practice (1468 kg/ha). The maximum straw yield with RDF application may be attributed to the enhanced nutrient uptake and use efficiency of nutrients. The results are in line with the findings of Singh *et al.* (2001). It could be inferred that, the soil has the capacity to supply nutrients indigenously to some extent. The native nutrients in soil can provide nutrients to sustain the crop yield for some years which has been indicated from the yield obtained with omission of N, P and K. The supply of adequate quantity of NPK and S externally through fertilizers significantly increased the seed and straw yield of soybean.

Economics: The nutrient management practices significantly influenced the gross return, net return and return per rupee invested in soybean during both the years of study (Table 2). Application of RDF earned 8% and 28% higher gross return over SSNM (NE) and Farmers practice, respectively, whereas net return (₹13271/ha) and return/rupee invested (1.49) were higher in SSNM (NE). This was due to higher cost of cultivation in RDF (₹33120/-) as compared to ₹27279/- in SSNM (NM) and ₹ 27044/- with Farmers' practice.

From the above study, it is concluded that growing soybean with application of RDF (25:100:50:50 kg $N:P_2O_5:K_2O:S$/ha) recorded maximum seed yield (1465 kg/ha) which was at par with application of fertilizer using SSNM (NE) (25:23:19 kg $N:P_2O_5:K_2O$/ha) having seed yield of 1352 kg/ha but, net return (₹13,271/ha) and return/rupee invested (1.49) was higher with application of fertilizer based on recommendation of Nutrient Expert as SSNM. Hence application of SSNM (NE) may be suggested in soybean for higher profit and balanced fertilization.

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REFERENCES

Devidayal P and Agarwal S K 1999. Performance of sunflower (*Helianthus annuus* L.) genotypes at varying levels of nitrogen fertilization during spring season. *Journal of Oilseeds Research*, **13**: 258-259.

Dobermann A and Witt C 2004. In Dobermann, A., C. Witt and D. Dawe. (eds.), Increasing productivity of intensive rice systems through site-specific nutrient management. Enfield, NH (USA) and Los Baños (Philippines): Science Publishers, Inc., and International Rice Research Institute (IRRI), pp. 75-100.

Jangilwad M, Katkar R N, Kharche V K, Lakhe S R and Konde N M 2019. Effect of site specific nutrient management on yield and quality of soybean [*Glycine max* (L.)] in soybean in vertisols. *International Journal of Current Microbiology and Applied Sciences*, **8**(11): 2113-2118.

Janssen B H, Guiking F C T , Van der Eijk D, Smaling E M A, Wolf J and Van Reuler H 1990. A system for quantitative evaluation of the fertility of tropical soils (QUEFTS). *Geoderma*, **46**: 299-318.

Katkar R N, Sonune B A, Mohan Rao Puli and Kharche V K 2012. Effect of integrated nutrient management on productivity and soil fertility under soybean-wheat cropping system. *PKV Research Journal*, **36** (1): 17-20.

Mohapatra A K , Parida P, Pattanayak S K and Satyanarayana T 2010. Response of groundnut to balanced fertilization and omission of potassium. *Better Crops*, **7**(1): 12-15.

Pandey K, Singh K, Singh V B, Gupta M K and Yadav N S 2008. Character association and path coefficient analysis in advance breeding lines of soybean [*Glycine max* (L.), Merrill.]. *Soybean Research*, **6**:15-20.

Satyanarayana T, Majumdar K and Biradar D P 2011. New approaches and tools for site-specific nutrient management with reference to potassium. *Karnataka Journal of Agriculture Science*, **24** (1): 86-90.

Singh G, Singh H and Kolar J S 2001. Response of soybean to nitrogen, phosphorous, potassium and zinc fertilization. *Journal of Research Punjab Agriculture University*, **38**(1):16-19.

Witt C, Pasuquin J M , Pampolino M F, Buresh R J and Dobermann A 2009. A manual for the development and participatory evaluation of site-specific nutrient management for maize in tropical, favorable environments. Available at http://seap.ipni.net, pp. 30.

Yadav Rashmi and Chandel A S 2010. Effect of nitrogen and phosphorus nutrition at different physiological stages of soybean on yield and seed quality in Uttarakhand hills. *Progressive Agriculture*, **10**(2): 256-259.

Evaluation of herbicides combination for effective weed control in groundnut

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ABSTRACT

Groundnut is highly susceptible to weed infestation because of its slow growth at initial stages up to 40 DAS and the weeds interfere with pegging, pod development and harvesting of groundnut at different crop growth stages besides competing for essential resources. Yield losses due to weeds have been estimated as high as 24 to 70% in groundnut. Therefore, weeding has to be completed before pegging. Major problem in agriculture is labour shortage during the peak period of important operations like sowing, weeding and harvesting. The manual method of weed control is costly and time consuming as well as need to be repeated at frequent intervals. In this context, chemical weed control is a better supplement to conventional methods. Hence, field experiments were conducted at Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam during *kharif* 2018 and *kharif* 2019 to evaluate suitable herbicide combinations for effective weed control and reducing labour consumption in groundnut production. The experiment was laid out in a randomized complete block design replicated thrice with nine treatments. Pre-emergence application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) followed by one manual weeding at 25-30 DAS showed higher weed control efficiency (67.37 %) followed by two manual weedings at 20 and 40 DAS (61.37%) and pre-emergence application of Pendimethalin @ 1.0 kg/ha + Manual weeding at 25-30 DAS (60.30%). Significantly higher pod yield (2400 kg/ha) was recorded by pre-emergence application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) followed by one manual weeding at 25-30 DAS, whereas pre-emergence application of Pendimethalin @ 1.0 kg/ha + Manual weeding at 25-30 DAS recorded pod yield of 2067 kg/ha only which was at par with two manual weedings at 20 and 40 DAS (1967 kg/ha).

Keywords: Groundnut, Herbicide, Hand weeding, Weed Control Efficiency

Groundnut (*Arachis hypogaea* L.) which is known as the 'king' of oilseeds is highly susceptible to weed infestation because of its slow growth at initial stages up to 40 DAS. Among several constraints for low productivity in groundnut, weed menace is one of the major factors (Chaitanya *et al.,* 2012). As groundnut is grown mainly in the rainy season when the condition is more favourable for weed growth, weeds compete with the crop during entire season, especially during early stages.

Developing countries account for 96% of the global groundnut area and 92% of the global production. Asia accounts for 58% of the global groundnut area and 67% of the groundnut production with an annual growth rate of 1.28% for area, 2.0% for production and 0.71% for productivity (Anonymous, 2018). World peanut production totals 41.2 million tonnes during 2017-18 with India being the world's second largest producer after China (Anonymous, 2018).

In India, groundnut production and productivity has seen wide fluctuations in recent years, mainly due to changing rainfall patterns and stiff competition with other cash crops and availability and preference for cheaper edible oils. During the year 2017-18, there was a production of 82.17 lakh tonne of groundnut from an area of 49.08 lakh ha with a yield of 1674 kg/ha (Anonymous, 2018).

The critical period for crop-weed competition was reported to be up to 40 days after sowing and yield losses up to 57% (Pawar *et al.,* 2018) and 70% (Prasad *et al.,* 2002) have also been recorded in groundnut due to weed infestation.

Weeds are generally controlled with the conventional methods i.e. cultural manipulation either by hand weeding or hoeing. Major problem in agriculture is labour shortage during the peak period of important operations like sowing, weeding and harvesting. The manual method of weed control is costly and time consuming as well as needs to be repeated at frequent intervals. In this context, chemical weed control is a better supplement to conventional methods. This has created a scope for using herbicides in groundnut crop. Use of chemical herbicides in oilseeds is observed to be very effective in weed management and boosting the yield of groundnut (Prabhakaran *et al.,* 1996).

Therefore, an experiment was carried out at the Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam to find out the most effective and cheaper weed control method for yield improvement in groundnut.

MATERIALS AND METHODS

Field experiments were conducted at Regional Research Station, Tamil Nadu Agricultural University, Vridhachalam

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during *kharif* 2018 and *kharif* 2019 to evaluate suitable herbicide combinations for effective weed control and reducing labour consumption in groundnut production. The soil of the experimental plot was red sandy loam and slightly acidic in reaction (pH 6.8 and EC 0.20 dS/m) as well as low in available nitrogen (222 kg/ha), medium in available phosphorus (12 kg/ha) and high in available potash (323 kg/ha). The experiment comprising of nine treatments *viz.,* T1- Pendimethalin @ 1.0 kg/ha PE, T2 - Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix), T3- Pendimethalin @ 1.0 kg/ha PE + Quizalofop-p-ethyl @ 50 g/ha at 15-20 DAS, T4- Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix) + Quizalofop-p-ethyl @ 50 g/ha at 15-20 DAS, T5- Pendimethalin @ 1.0 kg/ha PE + Imazethapyr @ 75 g/ha at 15-20 DAS, T6- Pendimethalin @ 1.0 kg/ha PE + Manual weeding at 25-30 DAS, T7- Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix) + Manual weeding at 25-30 DAS, T8- Two manual weeding at 20 and 40 DAS and T9- Weedy check were laid out in a randomized block design with three replications.

The groundnut variety VRI 8 was sown at 30 x 10 cm spacing with a seed rate of 125 kg kernel/ha. The crop was fertilized with 25-50-75 kg N-P_2O_5-K_2O/ha. The pre-emergence herbicides were applied to soil on third day after sowing, while post-emergence herbicides were applied to foliage of weeds on 20 DAS. The spray fluid was used at the rate of 500 l/ha.

Total weed density of major weed species was recorded using 0.25 m^2 quadrant at 30 and 60 DAS and converted to number of weeds/m^2 area. Weed biomass was also recorded from each plot from 0.25 m^2 quadrant and computed to gram/m^2 area. At the end of cropping season, yield was recorded from net plot area and computed to kg/ha. Cost of cultivation, gross return and net return were also calculated based on the prevailing price of inputs and outputs. Benefit cost ratio was calculated on the basis of gross return divided by the cost of cultivation. The experimental data were subjected to statistical analysis using standard procedures.

RESULTS AND DISCUSSION

Weed flora: The weed flora observed in experimental plots comprised of grasses, sedges and broad leaved weeds. The dominant weeds were *Cyperus rotundus, Cynodon dactylon, Cleome viscosa, Boerhaavia diffusa, Eclipta alba, Dactyloctenium aegypteium, Vernonia cinerea, Tridax procumbens, Phyllantus niruri, Commelina benghalensis, Chenopodium album, Echinochloa* spp. and *Digitaria sanguinalis.* Occurrence of these weed flora in groundnut have been reported earlier also (Pawar *et al*., 2018).

Weed density and dry weight: The observations on weed density and weed dry matter production at 60 days after sowing (Table 1) revealed that significant difference was found among the weed control treatments. Application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) as pre-emergence herbicide on 3rd day after sowing followed by one manual weeding at 25-30 DAS recorded lower weed density of 43.8 No/m^2 as compared to pre-emergence application of Pendimethalin @ 1.0 kg/ha followed by one manual weeding at 25-30 DAS which recorded weed density of 74 No/m^2 and Pendimethalin @ 1.0 kg/ha as PE fb Imazethapyr @ 75 g/ha at 15-20 DAS (68.7 No/m^2), Two manual weeding at 20 and 40 DAS (92.7 No/m^2) and weedy check (403 No/m^2). Similar trend was observed with weed dry matter production. This result was converse to the observations made by Vaghasia *et al.* (2014) who reported that pendimethalin 1 kg/ha+ quizalofop ethyl @ 50 g/ha at 20 DAS recorded the lowest weed density and dry weight of weeds at 60 DAS. These variation may be attributed to the differences in the weed flora observed between the experimental sites.

Lower weed dry weight of 70 g/m^2 was recorded with application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) as pre-emergence herbicide on 3rd day after sowing followed by one manual weeding at 25-30 DAS as compared to pre-emergence application of Pendimethalin @ 1.0 kg/ha followed by one manual weeding at 25-30 DAS (106.2 g/m^2), application of pendimethalin @ 1.0 kg/ha as PE fb Imazethapyr @ 75 g/ha at 15-20 DAS as POE (107.74 g/m^2) and two hand weeding (140.67 g/m^2).

Weed control efficiency: Pertaining to weed control efficiency, pre-emergence application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) followed by one manual weeding at 25-30 DAS showed higher weed control efficiency (79.81%) followed by pre-emergence application of Pendimethalin @ 1.0 kg/ha + Manual weeding at 25-30 DAS (69.61 %) and pendimethalin @ 1.0 kg/ha as PE fb Imazethapyr @ 75 g/ha at 15-20 DAS as POE (68.99%) (Table 1). The probable reasons for obtaining highest weed control efficiency under treatment T7 might be due to lesser weed competition faced by groundnut crop, as pre-emergence application of pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) resulted in better weed control during initial stages of the crop growth and later the growth of weeds was checked by one hand weeding at 25-30 DAS. Maximum weed control efficiency of 80.15 % with application of pendimethalin @ 1.0 kg/ha + one hoeing 45 DAS has also been reported by Jadhav *et al*. (2015). Similarly, weed control at earlier stages of crop growth by pre-emergence application of pendimethalin and later stages by one hoeing was reported by Rao *et al.* (2011).

Yield and yield attributes: The results of pooled analysis revealed that number of pods per plant were significantly influenced by weed control treatments (Table 2) whereas 100 kernel weight and shelling (%) were not influenced by the treatments. Higher number of matured pods/plant was produced under pre-emergence application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) followed by one manual weeding at 25-30 DAS (18.40 pods/plant) where as 15.95 pods/plant was recorded with pre-emergence application of Pendimethalin @ 1.0 kg/ha + Manual weeding at 25-30 DAS and 17.40 pods/plant with two manual weedings at 20 and 40 DAS.

The results (Table 2) revealed that significant differences in groundnut pod yield due to different treatments. Significant higher pod yield of 2682 kg/ha was recorded by pre-emergence application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) followed by one manual weeding at 25-30 DAS and pod yield of 2162 kg/ha was recorded under pre-emergence application of Pendimethalin @ 1.0 kg/ha fb one manual weeding at 25-30 DAS which was at par with two manual weedings at 20 and 40 DAS (2116 kg/ha.). Shwetha *et al.,* (2016) also reported that pre-emergence spray of pendimethalin followed by post-emergence spray of imazethapyr was superior as the higher pod yield was achieved with lower cost of cultivation with these treatments. Further, pre-emergence application of pendimethalin 0.9 kg/ha supplemented with inter cultivation & hand weeding at 40 DAS was found with higher yield and economics as reported by Mathukia *et al.* (2017). The lowest pod yield of 513 kg/ha was recorded under weedy check due to significant reduction in the dry matter accumulation. Kori *et al.* (2000) and Murthy *et al.* (1992) also reported that weedy check gave lower pod yields due to increased weed competition for growth resources like moisture, nutrients and light.

Table 1 Influence of weed management practices on Weed density (WD), Weed Dry Weight (WDW) and Weed Control Efficiency (WCE) in groundnut

Treatments	WD (No./m^2)			WDW (g/m^2)			WCE (%)		
	Kharif 2018	*Kharif* 2019	Pooled	*Kharif* 2018	*Kharif* 2019	Pooled	*Kharif* 2018	*Kharif* 2019	Pooled
T1 Pendimethalin @ 1.0 kg/ha PE	186.7	342.7	264.7	245.20	294.67	269.94	29.88	15.56	22.72
T2 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix)	96.0	210.7	153.4	202.60	210.67	206.64	41.38	39.65	40.52
T3 Pendimethalin @ 1.0 kg/ha PE + Quizalofop-p-ethyl @ 50 g/ha at 15-20DAS	157.3	241.3	199.3	230.00	177.33	203.67	34.09	49.17	41.63
T4 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix) + Quizalofop-p-ethyl @ 50 g/ha at 15-20 DAS	93.3	178.7	136.0	206.13	164.00	185.07	41.00	53.02	47.01
T5 Pendimethalin @ 1.0 kg/ha PE + Imazethapyr @ 75 g/ha at 15-20 DAS	72.7	64.7	68.7	164.80	50.67	107.74	52.43	85.54	68.99
T6 Pendimethalin @ 1.0 kg/ha PE + Manual weeding at 25-30 DAS	71.3	76.7	74.0	139.07	73.33	106.20	60.31	78.91	69.61
T7 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix) + Manual weeding at 25-30 DAS	33.3	54.3	43.8	113.00	27.00	70.00	67.37	92.24	79.81
T8 Two manual weeding at 20 and 40 DAS	53.3	132.0	92.7	134.00	147.33	140.67	61.37	57.97	59.67
T9 Weedy check	356.0	450.0	403.0	349.87	666.67	508.27	0	0	0.00
SEd (±)	13.20	12.37	12.72	18.61	15.34	16.48	-	-	-
CD (P=0.05)	27.99	26.22	27.16	39.45	32.51	34.52	-	-	-

Economics: Pre-emergence application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha (ready mix) followed by one manual weeding at 25-30 DAS gave higher net return of ₹78333/ha with benefit to cost ratio (BCR) of 2.14 whereas pre-emergence application of pendimethalin @ 1.0 kg/ha followed byPOE application of Imazethapyr @ 75 g/ha at 15-20 DAS gave net return of ₹ 51673/ha with BCR of 1.81 (Table 3). These results are in conformity with the findings of Pawar *et al.* (2018) who reported that pre-emergence application of pendimethalin @ 1.5 kg a.i./ha as followed by post emergence spray of Imazethapyr @ 0.075 kg a.i./ha at 20-30 DAS was most economical. Containing weeds through two hand weeding at 20 and 40 DAS registered lower net return of ₹ 43829/ha with BCR of 1.61 due to increased cost of cultivation under manual weeding.

From the present investigation, it was concluded that pre-emergence application of Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg a.i//ha (ready mix) followed by one manual weeding at 25-30 DAS proved practically more effective and economically feasible weed management practice for groundnut considering the scarcity and cost of labourers, efficiency of weed control, yield and economics of groundnut cultivation.

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Table 2 Influence of weed management practices on yield attributes and pod yield in groundnut

Treatments	Number of matured pods/plant			100 kernel weight (g)			Shelling %			Dry pod yield (kg/ha)		
	Kharif 2018	*Kharif* 2019	Pooled	*Kharif* 2018	*Kharif* 2019	Pooled	*Kharif* 2018	*Kharif* 2019	Pooled	*Kharif* 2018	*Kharif* 2019	Pooled
T1 Pendimethalin @ 1.0 kg/ha PE	11.4	8.1	9.75	39.27	43.10	41.19	68.2	66.1	67.15	950	1690	1320
T2 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix)	12.3	12.1	12.20	41.23	43.13	42.18	71.7	72.3	72.00	1300	1889	1595
T3 Pendimethalin @ 1.0 kg/ha PE + Quizalofop-p-ethyl @ 50 g/ha at 15-20DAS	11.9	13.5	12.70	38.95	43.40	41.18	71.0	68.2	69.60	1267	1975	1621
T4 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix) + Quizalofop-p-ethyl @ 50 g/ha at 15-20 DAS	13.3	13.8	13.55	40.42	44.70	42.56	68.2	68.8	68.50	1400	1991	1696
T5 Pendimethalin @ 1.0 kg/ha PE + Imazethapyr @ 75 g/ha at 15-20 DAS	16.4	15.8	16.10	40.39	44.43	42.41	68.8	65.1	66.95	1600	2593	2097
T6 Pendimethalin @ 1.0 kg/ha PE + Manual weeding at 25-30 DAS	19.4	12.5	15.95	40.33	44.17	42.25	70.8	68.2	69.50	2067	2257	2162
T7 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix) + Manual weeding at 25-30 DAS	21.1	15.7	18.40	42.52	44.53	43.53	68.5	64.1	66.30	2400	2963	2682
T8 Two manual weedings at 20 and 40 DAS	20.5	14.3	17.40	40.19	45.17	42.68	69.9	73.8	71.85	1967	2264	2116
T9 Weedy check.	6.8	4.8	5.80	36.94	37.87	37.41	70.8	71.8	71.30	383	642	513
SEd (±)	1.16	1.16	1.18	2.93	2.20	2.54	2.61	4.19	3.47	130.8	124.4	128.4
CD (P=0.05)	2.47	2.46	2.52	NS	NS	NS	NS	NS	NS	277.3	263.8	268.8

Table 3 Influence of weed management practices on economics in groundnut

Treatments	Gross return (₹/ha)			Net return (₹/ha)			BCR		
	Kharif 2018	*Kharif* 2019	Pooled	*Kharif* 2018	*Kharif* 2019	Pooled	*Kharif* 2018	*Kharif* 2019	Pooled
T1 Pendimethalin @ 1.0 kg/ha PE	52250	92958	72604	-10219	30489	10135	0.84	1.49	1.17
T2 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix)	71500	103877	87689	7226	39603	23415	1.11	1.62	1.37
T3 Pendimethalin @ 1.0 kg/ha PE + Quizalofop-p-ethyl @ 50 g/ha at 15-20DAS	69667	108642	89155	7033	43038	25036	1.11	1.66	1.39
T4 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix) + Quizalofop-p-ethyl @ 50 g/ha at 15-20 DAS	77000	109523	93262	11571	44094	27833	1.18	1.67	1.43
T5 Pendimethalin @ 1.0 kg/ha PE + Imazethapyr @ 75 g/ha at 15-20 DAS	88000	142593	115297	24376	78969	51673	1.38	2.24	1.81
T6 Pendimethalin @ 1.0 kg/ha PE + Manual weeding at 25-30 DAS	113667	124124	118896	46323	56780	51552	1.69	1.84	1.77
T7 Pendimethalin 30 EC + Imazethapyr 2 EC @ 1.0 kg/ha PE (ready mix) + Manual weeding at 25-30 DAS	132000	162963	147482	62851	93814	78333	1.91	2.36	2.14
T8 Two manual weeding at 20 and 40 DAS	108167	124538	116353	35643	52014	43829	1.49	1.72	1.61
T9 Weedy check	21083	35309	28196	-35191	-20965	-28078	0.37	0.63	0.50

REFERENCES

Anonymous 2018. *Annual Report 2018-19,* ICAR-Directorate of Groundnut Research, Junagadh, Gujarat, India.

Chaitanya S, Shankaranarayana V and Nanjappa H V 2012. Chemical weed management in *kharif* groundnut. *Mysore Journal of Agricultural Science*, **46**(2): 315-319.

Jadhav P B, Rajesh Singh and Kamble D R 2015. Effect of weed control methods on growth and yield of groundnut. *Advance Research Journal of Crop improvement*, **6**(2): 151-157.

Kori R N, Patil S L, Salakinkoppa S R and Hunshal C S 2000. Economics of integrated weed management in irrigated groundnut. *Journal of Oilseeds Research*, **17**: 61-65.

Mathukia R K, Panara D M, Sagarka B K and Savaliya N V 2017. Effectiveness of herbicides for weed management in pre-monsoon groundnut (*Arachis hypogaea*). *Journal of Crop and Weed*, **13**(1): 175-177.

Murthy B G Agasimani C A and Babalad H B 1992. Studies on weed management in bunch groundnut. *Journal of Oilseeds Research*, **9**(2): 322-325.

Pawar S B, Mahatale P V, Thakare S S and Sawarkar S D 2018. Weed management in groundnut with tank-mix application of post emergence herbicides. *International Journal of Current Microbiology and Applied Sciences*, **6**: 2169-2173.

Prabhakaran N K, Medhiyazhagan R, Sridharan, C S and Venkutusamy R 1996. Evaluation of weed management practices in groundnut. *International Arachis Newsletter*, **16**: 53-54.

Prasad T V R, Narsimha N, Dwarakanath N and Krishnamurthy K 2002. Efficacy of oxyfluorfen for weed control in irrigated groundnut. *International Arachis Newsletter*, **2**(6-8): 4.

Rao S S, Madhav M and Reddy C R 2011. Integrated approach for weed control in rabi groundnut (*Arachis hypogaea* L). *Journal of Research ANGRAU*, **39**(1/2): 60-63.

Shwetha B N, Umesh M R and Agnal M B 2016. Post-emergence herbicides for weed management in groundnut. *Indian Journal of Weed Science*, **48**(3): 294-296.

Vaghasia P M, Bhalu V B and Kavani R H 2014. Influence of pre and post-emergence herbicides in groundnut (*Arachis hypogaea* L.). *Journal of Oilseeds Research*, **31**(1): 37-40.

Effects of altitudinal gradient and soil depth on selected soil physical properties in Hakim Gara shrub land of Harari Region (Eastern Ethiopia)

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ABSTRACT

The study was conducted to investigate the effects of altitudinal gradient and soil depth on selected soil physical properties in Hakim Gara shrub land of Harari Region of Eastern Ethiopia which is good for oilseed crops groundnut, sunflower, safflower and niger. Soil samples were collected along altitudinal gradients of the land features between 2001 and 2113 m above sea level at 0-20 and 20-40 cm depths. The soil texture was mainly loamy and loamy sand except at a few sites that had silt loamy textural class. Bulk density and particle density at different soil depths exhibited increasing trend between the range from 1.12 to 1.40 g/cm^3 and 2.35 to 2.65 g/cm^3, respectively in all sampling sites. While there was decreasing trend in total porosity between 52.12 to 46.17 %. Clay, silt and total porosity were positively correlated with altitude while sand content, bulk density and particle density were negatively correlated with altitude. Sand content, bulk density and particle density also were positively correlated with soil depth from that bulk density was significantly correlated with depth while clay, silt, and total porosity were negatively correlated with soil depth.

Keywords: Altitudinal gradient, Hakim Gara, Soil depth, Soil physical properties

The physical properties of a soil are the result of soil parent materials being acted upon by climatic factors such as rainfall and temperature and being affected by slope, direction and vegetation with the time. A change in any one of the soil-forming factors usually results in different physical properties of the resulting soil. The physical properties of soil across a landscape are very variable and influenced by topographical features, vegetation types, climate, soil type, soil properties, soil depth and parent material (Fantappie *et al*., 2011).

Altitude modifies soil moisture regimes and thus exerts control on soil properties (Phachomphon *et al*., 2010). Further, slope and surface characteristics are major topographical parameters that control movement of water, sediments and nutrients. These parameters also modify land form, soil formation, soil depth, moisture status and hence, increase biomass production and C inputs (Egli *et al*., 2009). Thin soil depths are generally characteristic of steeper slopes, resulting in poor physical properties of soil. However, higher soil moisture and hence increased biomass production in down slope positions contribute to higher soil organic carbon concentrations and stocks (Schwanghart and Jarmer, 2011). Overall, altitude modifies temperatures and precipitation and thus exerts control of the climate parameters that affect soil organic carbon formation, accumulation and decomposition. Soil properties distribution in Ethiopia varies with topography, geology, organic material and climatic factors, which have resulted in variability of soil types (Hurni *et al*., 2007; Abdel Kadir, 2006).

Oilseed crops are the third major crops after cereals and pulses in Ethiopia both in area and in production. Groundnut, sunflower, safflower and niger are the major production belts in eastern Ethiopia especially Harari region which have the most efficient resources for increasing oilseeds production in Ethiopia (FAO, 2010). Lack of access for improved and high yielding varieties in eastern Ethiopia is the main problem that hampers production of oilseed crop. Therefore, objective of the present study was to assess the suitability of soil physical properties against altitudinal gradient and soil depth in shrub land of Hakim Gara District in Harari Region of Eastern Ethiopia suitable for oilseed crops which could yield high.

MATERIALS AND METHODS

Description of the study area: Hakim Gara is located in Hakim District of Harari National Regional State, in the Eastern midlands of Ethiopia which is good for oilseed crops groundnut, sunflower, safflower and niger. The land features of the study area are relatively mountainous with good shrub vegetation coverage. Based on the topographic features and vegetation conditions of Hakim Gara Shrub land, Hakim district is believed to represent the highland shrub land areas of Harari region. Hakim Gara is found at about 1.5 km in the south eastern direction from Harar city, the administrative city of Eastern Harerghe Zone. Harar city is about 526 km far from Addis Ababa in the North-East direction (Fig. 1).

Description of the altitude: The altitude of Hakim Gara shrub land ranges from 2001 to 2113 meters above sea level (masl). All samples were collected by dividing the shrub land into three altitudinal gradients i.e. upper, middle and lower altitude between the range from 2001 to 2033, 2033 to 2064 and 2064 to 2113 masl, respectively. The mean annual rainfall of the area ranges from 636.7 to 917.9 mm and the mean monthly maximum and minimum temperatures range from 22.6 to 28.4°C and 5.1 to 16°C, respectively. The total area of the shrub land is around 50 hectares. The dominant tree species are *Juniperus procera, Lantana camara* (in Barkarkate) and *Carissa edulis* (in Agamsa), *Olea europe*, *Acacia albida, Acacia synic* (in Wangayo) and others are found in scattered manner. The shrub is mostly used for browsing, fire wood and also as sources of construction wood by the local people. According to the Soil Survey (2001) conducted in this Region, the major soil types of the area are Arenosols, Leptosols, Luvisols, Cambisols, Nitisols, Rendzinas and Regosols. In the undulating plains the dominant soil types are Nitisols, Regosols and luvisols hills. While on ridges and ridge tops occupy almost half of the regions by Leptisols, Regosols and Rendzinas. The dominant soil type of the above altitude in the study area was loamy and loamy sand except a few of them having silt loam.

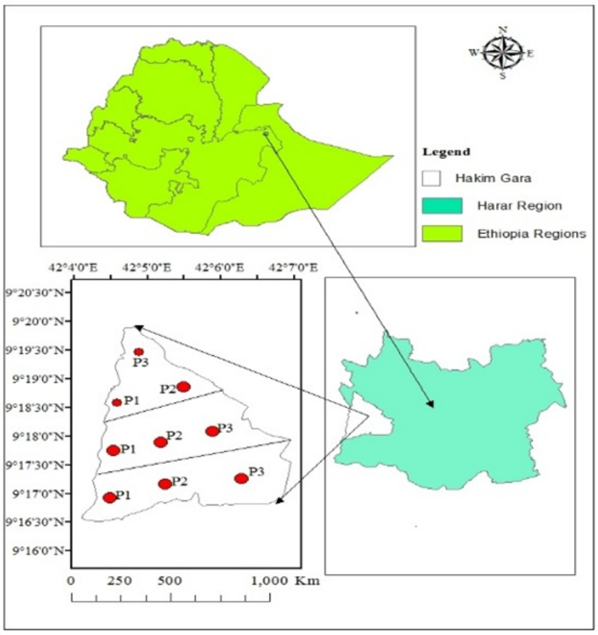

Fig. 1. Location map of the study area and soil sampling pits

Soil sampling and sites selection: Soil sampling sites were selected based on altitudinal gradients of the landscape and vegetation types i.e. tree, shrubs and herbs. The shrub land was divided into three sampling sites namely upper, middle and lower altitudinal gradients. Three soil sampling sites were selected from each altitudinal gradient. Every sampling site was geo referenced using GPS (Global Positioning System).

Soil sampling and preparation: Three soil profiles were opened at each slope gradient. Disturbed soil samples were collected from each profile at the depth of 0-20 cm and 20-40cm. A total of 18 soil samples were collected. Similarly, undisturbed soil samples were collected from each profile at the respective depth for bulk density determination. The disturbed samples were air dried and crushed to pass through 2 mm sieve for determination of soil texture and particle density. All the samples were made ready for the analysis of soil physical properties and for the determination of shrub land soil organic carbon stock.

Laboratory analysis of soil physical properties: Soil texture was determined by standard hydrometer method as described by Gee and Bauder (1986), Bulk density of soil by Blake and Hartge (1986a) method and Particle density by the pycnometer method as described by Blake and Hartge (1986b).Total porosity was estimated from the bulk and particle density values as given be low.

$$Total\ Pore\ space\ (\%) = \left(1 - \frac{BD}{PD}\right) X100$$

Statistical analysis: Statistical Package for the Social Sciences (SPSS) version 20 was used to analyze soil data by descriptive procedures and a Pearson Correlation Matrix.

RESULTS AND DISCUSSION

Soil particle size distribution: The results of particle size distribution (Table 1) indicate differences in the textural classes of the soils at the same altitude within soil depth and at different altitudes with spatial positions of the sample pits. The textural class of surface soil (0-20 cm) was silt loam for P1, P3 at lower altitude and loam for samples of P1, P2, P3 at upper altitude, P3 and P1 at middle and P2 at lower altitudes. It was loam sand for subsurface soil (20-40 cm) of P1, P3 at lower altitude and P1, P2 of upper and P2, P3 of middle altitude. Most of the textural classes of soil in the study area were classified under loam soil.

The percentage of sand composition of soil was dominant as compared to silt and clay in the Hakim Gara shrub land. This might be due to the degree of weathering, parent material and the greater shielding effect of the canopy formed by the mature shrubs and understory vegetation from the erosive energy of the falling raindrops improving the texture of the soil. In line with this, Tegenu *et al.* (2008) reported that the composition percentage of sand was the highest for soils taken from shrub or bush followed by cultivation land. Similar finding was reported by Azlan *et al.* (2012) that sand was the dominant soil particle in Pengkalan Chepa Industrial Park and southwest of Kota Bharu Township shrub and or forest soil. Sand contents showed increasing trends with soil depth in P3 at middle, in P1 and P3 at lower and upper altitudes. There were slight changes in the sand content of other sample pits with soil depth at the respective altitudes.

The silt content of soils of P1 and P3 showed decreasing trend with soil depth at lower altitude and while there was slight increase in P2. A drastic change in silt content with soil depth was recorded for soils of P3 at lower altitude. At middle altitude silt contents increased with soil depth in P1, but not much change in the silt content of soils of P2 and P3 with depth (Table 1). Changes in the silt content of the soils with depth could be attributed to change in chemical, physical and biological properties of soil by affecting the textural class of the soil in the area. At the upper altitude, silt content showed increasing trend in P2 and decreasing in P1 while no change in slit content for soils of P3 with soil depth.

The recorded clay contents of the soils (Table 1) indicate decreasing trend with soil depth in all sample pits at upper altitude and, in P1, P3 at middle altitude and P1, P2 at lower altitude. The same results of clay contents were recorded with depth in P2 at middle altitude and in P3 at lower altitude. This affected the organic carbon accumulation of soil in the sub surface layer. Clay content was positively and highly significantly ($P<0.01$) correlated with organic carbon while silt content was positively correlated with organic carbon, but not significant. Sand was negatively and significantly ($P < 0.05$) correlated with soil organic carbon (Table 2). Therefore, the influences of clay and sand are significant on soil organic carbon content of the study area.

In the study area, the composition of silt and clay particles was relatively smaller in samples from all pits as compared with sand particle. The soils in this study are characterized by high sand content and, affecting organic matter development. Higher soil organic carbon levels were observed in soil types/properties with higher contents of fine soil particles in the study area. Similar finding was reported by (Parras *et al*., 2015) who found that soils characterized by high sand content affecting organic matter development. Higher soil organic carbon levels are generally observed in soil types/properties with higher contents of fine soil clay particles.

Bulk density: Bulk density values showed increasing trend with soil depth in all the samples at the respective altitudes (Table 1).There was also a variation in bulk density value of soil along depth in all pits in the same altitude of the study area. Relatively, changes in bulk density values of soil with respective depth were higher for soils of P1 and P3 at lower and middle altitudes, respectively. The change or variation of bulk density in different altitude and the same altitude of different pits may be due to soil texture and organic matter, in the shrub land. Lower bulk density values for soils of surface layers (0-20 cm) relative to its values for that of subsurface layers (20-40 cm) in all pits at respective altitudes might be due to higher organic carbon, contents of the surface layer soils. In line with this (Whalen *et al.,* 2003) reported that soil bulk density declines with an increase in soil organic matter content of surface soil. The recorded bulk density values of soil in the study area showed increasing with soil depth while the average bulk density values along the altitude decreased from lower to middle altitude and increased from middle to upper altitude. Higher bulk density were recorded in the samples that have low organic matter and higher sand content with depth while lower bulk density was recorded in the sample that have higher soil organic matter and lower sand content in the study area.

Increasing in the bulk density values along with the depth and altitude in the study area might be due to low organic matter input, low microbial activity and plant litter input, conversion of the area to other land use like grazing land. In line with this, Mulugeta (2004) also reported that soil bulk density increased in the 0-10 and 10-20 cm layers relative to the length of time. The shrub and forest soils were changed to cultivation.

Bulk density was negatively and significantly ($P<0.01$) correlated with soil organic carbon (Table 2). Similarly, Abebayehu (2013) reported that soil organic carbon was negatively correlated with soil bulk density and sampling depth. In the study area where there was low organic carbon, high bulk density value was recorded. This is an important factor that soil organic carbon content influenced bulk density of the soil in the study area. Similar finding was recorded by Hajabbasi *et al.* (1997) wherein the higher soil organic matter/carbon content could improve soil structure, resulting in a decrease of soil bulk density.

Particle density: There were slight increasing trends in soil particle density values of most of the sample pits with soil depth at the respective altitudes, except P3 of middle altitude which showed drastic increase in particle density value (Table 1). This might be due to increasing in sand contents from 58 to 65 % with depth at that particular place. On the other hand, particle density values showed slight decrease in P1 of middle and P2 of upper altitude, whereas sand contents also decreased with depth. These findings suggest that soil particle density of the area is mostly affected by the sand fraction of the soils. In some pits (P1 at middle and P3 at upper altitude), particle density values showed decreasing trends with decreasing soil organic carbon content.

The highest ($2.65 g/cm^3$) and lowest ($2.35 g/cm^3$) particle density values were recorded for soil of P3 in 20-40 cm depth at upper altitude and for soil of P3 in 0-20 cm depth at middle altitude respectively (Tables 1). Soil Particle density was negatively and significantly correlated ($P<0.01$) with soil organic carbon (Table 2). Thus, the amount of organic matter in soil markedly affects the value of particle density. Surface soils, with higher organic matter content than the subsurface soil, usually have lower particle density than subsurface soil. The values of particle density were lower for soil of surface layer (0-20 cm) and higher in subsurface (20-40 cm).

Table 1 Some selected soil physical properties at the respective altitudes and depths

Altitude	Pit No	Depth (cm)	Particle size distribution (%) Sand	Silt	Clay	TC	BD (g/cm^3)	Mean (g/cm^3)	PD (g/cm^3)	Mean (g/cm^3)	TP (%)	Mean %
Lower (2001-2033 masl)	P1	0-20	66	18	16	SL	1.24	1.32	2.55	2.58	51.37	48.77
		20-40	74	13	13	LS	1.40		2.60		46.17	
	P2	0-20	64	14	22	L	1.23	1.25	2.56	2.58	51.95	51.55
		20-40	64	16	20	L	1.27		2.60		51.15	
	P3	0-20	66	18	16	SL	1.25	1.27	2.56	2.57	51.04	50.8
		20-40	76	8	16	LS	1.28		2.58		50.58	
Middle (2033-2064 masl)	P1	0-20	60	16	24	L	1.23	1.24	2.51	2.5	51.04	50.52
		20-40	58	22	20	L	1.25		2.50		50.00	
	P2	0-20	68	14	18	LS	1.29	1.30	2.58	2.59	50.00	49.95
		20-40	67	15	18	LS	1.30		2.59		49.9	
	P3	0-20	58	18	24	L	1.12	1.22	2.35	2.49	52.13	50.94
		20-40	65	17	18	LS	1.32		2.63		49.75	
Upper (2064-2113 masl)	P1	0-20	60	20	20	L	1.24	1.27	2.55	2.57	51.22	50.65
		20-40	64	18	18	LS	1.29		2.58		50.08	
	P2	0-20	67	13	20	L	1.25	1.26	2.55	2.54	51.08	50.6
		20-40	66	16	18	LS	1.26		2.53		50.12	
	P3	0-20	57	19	24	L	1.24	1.26	2.59	2.62	52.12	51.91
		20-40	60	19	21	L	1.28		2.65		51.70	

P = Pit, L= Loam, LS= Loamy Sand, SL= Silty Loam, TC = Textural Class, BD = Bulk Density, PD = Particle Density, TP = Total Porosity

Table 2 Pearson correlation (2-tailed) for dependent and independent variables

	Soil Physical Properties Altitude	Depth	Particle size distribution Sand	Silt	Clay	BD	PD	TP
Altitude	1							
Depth	--	1						
Sand	-.486*	.309	1					
Silt	.392	-.107	---	1				
Clay	.412	-.411	-816**	.363	1			
BD	-.144	.591**	.614**	.312	-.712**	1		
PD	-.011	.415	.376	-.208	-.418	.781**	1	
TP	.197	-.536*	-.596**	.280	.714**	-.830	-.300	1

**Correlation is significant at the 0.01 level (2- tailed); *Correlation is significant at the 0.05level (2- tailed) BD = Bulk Density, PD = Particle Density, TP = Total Porosity

Total porosity: There were slight decreasing trends in the total porosity values of the soil in all the sample pits with soil depth at the respective altitudes, except a drastic change in total porosity of soils of P1 and P3 at lower and middle altitudes, respectively (Table 1) which may be caused by texture of soil, land use system and organic matter content of the soil. The highest and the lowest total porosity values were recorded for surface soil of P3 at middle altitude and for sub surface soil of Pl at lower altitude, respectively. This may be due to relatively high litter input, well aerated soil and high root penetration in surface soil than the sub surface soil. In general, total porosity values showed decreasing trends with soil depth in all sample pits at respective altitudes. There is also slight change in total porosity between altitudes. These decreasing trends in total porosity might be due to increasing of soil bulk density values and decreasing in organic matter contents of the soil with depth. In line with this, Mulugeta (2004) reported the declining in soil total porosity and increasing in bulk density of shrub/forest soils with increasing depth.

The highest value of percent total porosity of the surface soil (0-20 cm) relative to the subsurface (20-40 cm) could be attributed to higher organic carbon in surface than that of subsurface soil. Similarly, Whalen *et al.* (2003) reported that the value of total porosity increase with an increase in soil organic matter. Total porosity values were positively and significantly ($P<0.01$) correlated with soil organic carbon contents. The samples having high percentage total porosity have high organic carbon (Table 1 and 2).

Our study has established the differences in the soil type with change in the altitude and based on these characteristic features, one can decide the oilseed crops that could suitably be grown in different regions of the study area. This study shall act as a primary basis for choosing the crops in Hakim Gara shrub land of Harari Region, Eastern Ethiopia.

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REFERENCES

Abdel Kadir 2006. Soil organic carbon and total nitrogen stocks as affected by tropical aspects and vegetation in the Bale Mountains, Ethiopia. *Geoderma*, **135**: 335-344.

Abebayehu Aticho 2013. Evaluating organic carbon storage capacity of forest soil: Case Study inKafa Zone Bita District, South-Western Ethiopia. *American-Eurasian Journal of Agriculture and Environmental Science*, **13**(1): 95-100.

Azlan A Aweng, Ibrahim E R and Noorhaidah CO 2012. Correlation between soil organic matter, total organic matter and water content with climate and depths of soil at different land use in Kelantan, Malaysia.

Blake G R and Hartge K H 1986a. Bulk Density. In: ArnoldKlute (2nd ed.), *Methods of Soil Analysis. Part-1: Physical and Mineralogical Methods.* Agronomy Series No. 9, American Society of Agronomy, Inc. and Soil Science Society of America, Inc. Publisher Madison, Wisconsin, USA, pp.364-375.

Blake G R and Hartge K H 1986b. Particle Density. In: Arnold Klute (2nd ed.), *Methods of Soil Analysis. Part-1: Physical and Mineralogical Methods.* Agronomy Series No. 9, American Society of Agronomy, Inc. and Soil Science Society of America, Inc. Publisher Madison, Wisconsin, USA, pp. 377-381.

Egli M, Sartori G, Mirabella A, Favilli F, Giaccai D and Delbos E 2009. Effect of North and South exposure on organic matter in high Alpine soils. *Geoderma*, **149**: 124-136.

FAO 2010. *Guidelines for soil description.* Food and Agriculture Organization of the Uinted Nations, Rome, Italy, 451 pp.

Fantappie M L, Abate G and Costantini E A C 2011.The influence of climate change on the soil organic carbon content in Italy from 1961 to 2008. *Geomorphology*, **135**: 343-352.

Gee G W and Bauder J W 1986. Particle size analysis. In: ArnoldKlute (2nd ed.), *Methods of Soil Analysis.* Part-1: Physical and Mineralogical Methods. Agronomy Series No.9, American Society of Agronomy, Inc. and Soil Science Society of America, Inc. Publisher Madison, Wisconsin, USA, pp. 377-381.

Hajabbasi M A, Jalalian A and Karimzadeh H R 1997. Deforestation effects on soil physical and chemical properties, Lordegan Iran. *Plant and Soil*, **190**: 301-308.

Hurni H, Amare Bantider, Herweg K, Portner B and Veit H 2007. Landscape transformation and sustainable development in Ethiopia. Background Information for a study tour through Ethiopia, 4-20 September 2006, CDE (Center for Development and Environment) University of Bern, Bern, 321 pp.

Mulugeta Lemenih 2004. Effects of land use changes on soil quality and native flora degradation and restoration in the highlands of Ethiopia: Implication for sustainable land management. Ph.D. Thesis, Swedish University of Agricultural Sciences, Uppsala.

Parras Alcántara L, Díaz Jaimes L, Lozano García B, Fernán Dez P, Moreno F and Carbonero M 2015. Organic farming has little effect on carbon stock in a Mediterranean Dehesa (Southern Spain), *Catena*, **113**: 9-17.

Phachomphon K, Dlamini P and Chaplot V 2010. Estimating carbon stocks at regional level using soil information and easily accessible auxiliary variables. *Geoderma*, **155**: 372-380.

Schwanghart W and Jarmer T 2011. Linking spatial patterns of soil organic carbon to topography. A case study from South-EasternSpain. *Geomorphology*, **126**: 252-263.

Soil Survey 2001. National WOCAT Workshop, 23-27 April 2001, Nazareth-Ethiopia. Soil and Water Conservation Team, NRDMD, MoA, Ethiopia.

Tegenu A Engda, Habitamu T, Kassahun Amy, Collick S, Tenagne Adissu, Biniyam B Ashagrie, Zelalem KTessema, AssefaDerebe, DawitSolomonandTammo S Steenhus 2008. Soil properties and fertility status dynamics of North Western Ethiopia as influenced by Land Use Changes: A Case Study of Dibanke Watershed.

Whalen M H, Watson R T, Noble I R, Bolin B, Ravindranath N H, Verardo D J, and Dokken D J 2003. Land Use, Land Use Change and Forestry. Inter-governmental Panel on Climate Change (IPCC), Special Report. Cambridge University Press, UK, pp. 375.

Evaluation of selected fungicides for the management of white rust of Indian mustard

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ABSTRACT

Field studies were conducted to evaluate the efficacy of selected fungitoxicants *viz.,* mancozeb 75 WP @ 0.2%, metalaxyl 8%+ mancozeb 64% @ 0.2%, hexaconazole 5 EC @ 0.05%, cymoxanil 8% + mancozeb 64% @ 0.1% and azoxystrobin 23% SC 0.05% as a single spray treatment at 45 DAS and each four fungicides at 60 DAS in succession of mancozeb 75 WP at 45 DAS in control of white rust disease. The experiment was carried out for two consecutive years during *rabi* 2014-15 and 2015-16 with susceptible Indian mustard cultivar Varuna. All the fungicides tested were significantly effective in reducing the disease over the check; however the level of efficacy varied among the treatments. The plots sprayed with mancozeb (0.2%) at 45 DAS followed by azoxystrobin (0.05%) at 60 DAS recorded significantly lower disease severity over the other treatments both at leaf and staghead phase with significant highest seed yield of 1906.81 kg/ha which was 42.33% higher over the check. The spray of mancozeb (0.2%) at 45 DAS followed by metalaxyl + mancozeb (0.2%) at 60 DAS was the next best treatment among combinations of two fungicidal sprays. Among single fungicidal spray treatments, spray of metalaxyl + mancozeb @ 0.2% was effective in reducing white rust at leaf and staghead phases with concomitant increase in seed yield. In general, none of the single spray treatments was found superior over the plots that received two fungicidal sprays i.e. mancozeb at 45 DAS followed by other fungicides at 60 DAS.

Keywords: Efficacy, Fungicides, Management, Indian mustard, White rust, Yield

Indian mustard [*Brassica juncea* (L.) Czern & Coss.)] is one of the major oilseeds crop cultivated in India and around the world. Being second most important edible oilseed crop in India, it is extensively grown traditionally as a pure crop as well as intercrop (mixed crop) in marginal and sub-marginal soils in the eastern, northern and north western states of India. Cool and moist climate of winter months is the major factor for luxuriant growth and productivity of mustard in these states. Despite considerable increase in productivity and production, a wide gap exists between yield potential and actual yield at farmer's field, which is largely due to biotic and abiotic stresses. Among biotic stresses, white rust disease has been reported to be most widespread and destructive fungal diseases of rapeseed-mustard throughout the world. The disease gained importance only after 1970s and for the last few years the disease has become one of the major threats to the successful cultivation of mustard crop in India. In states like Haryana, Rajasthan, Uttarkhand, Punjab, Delhi and Jammu & Kashmir prevalence of cold climate during winter months favours the faster development and spread of white rut especially under late sown conditions. White rust disease usually appears in Indian mustard at the time of flowering as shiny white to creamy yellow raised pustules on lower surface of leaves. Later on, under severe cases, white pustules may also appear on stem, inflorescence and pods. Staghead formations are quite common due to systemic infection (Meena *et al*., 2014).

White rust incited by the biotrophic oomycete pathogen Albugo candida (Pers. ex. Lev) is the serious fungal disease that causes enormous yield loss of 89.8% (Lakra and Saharan, 1989) in India due to infection at leaf phase and hypertrophy of flowers and pods. Yadav *et al.,* (2011) reported that the losses could be in the range from 17 to 34% in India. Since the established cultural methods of disease management do not provide the adequate control and the use of resistant varieties may not enjoy the agronomic preferences of farmers or not accepted in market place; hence the control of disease through the use of fungicides is economical and protecting the crops for ensuring the productivity. Early work on the chemical control of white rust is focussed on the use of copper based fungicides to control the leaf phase of disease. Vasudeva (1958) recommended the use of Bordeaux mixture for the control of white rust of crucifers. With the progress in the development of dithiocarbomates, control of white rust was attained with multiple applications of protectant fungicides. In recent days many systemic fungicides have been developed which are specifically active against perenosporales. Bhargava *et al.* (1997) found spraying of mancozeb at 45, 60 and 75 DAS + seed treatment with metalaxyl SD-35 and spraying of Ridomil MZ-72 at 20, 40 and 60 DAS significantly reduced the white rust disease and also increased the yield significantly over the check and were economical. Mehta *et al.* (1996) revealed that three sprays of Ridomil MZ-72

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(metalaxyl + mancozebmancozeb) at 0.25% at 20 days intervals starting from 40 DAS gave maximum disease control (82%), followed by seed treatment with Apron SD-35 (metalaxyl) at 2 g a.i/kg seed along with two foliar sprays of Ridomil MZ-72 at 30 days intervals. They also reported that both the treatments were also effective in reducing the staghead incidence. Two sprays of Ridomil MZ (0.25%) at 60 and 80 DAS reduced the disease indices on leaf from 62.7 to 17.1 per cent and enhanced the yield from 1052 (check) to 1842 kg/ha (Yadav, 2003). Kumar (2008) reported that severity of white rust and staghead infection was low (6.8 and 0.8% respectively) when seed treatment with Apron 35 SD followed by two foliar sprays of mancozeb. This treatment also resulted in higher seed yield (1458 kg/ha), 1000 seed weight (3.34 g) and seed oil content (41.7%). Hence, the present study was conducted to evaluate the efficacy of selected fungicides against white rust in Indian mustard.

MATERIALS AND METHODS

The field experiment was conducted at Oilseeds Research Farm, Department of Genetics and Plant breeding, CCS HAU, Hisar during *rabi* season for two consecutive years i.e., 2014-15 and 2015-16. The national susceptible mustard cultivar "Varuna" was sown during the second week of November in both the years, to ensure that foliage and flowering stage coincided with the period of maximum disease development under favourable weather conditions. The experiment was laid out in randomized block design with ten treatments replicated thrice. The crop was planted in a plot size of 5 m x 3 m, keeping row to row distance of 30 cm and plants were spaced at 10 cm apart. The manures, fertilizers, irrigations, insect control measures and other cultural operations were taken up as per the standard local recommendations.

The following treatments of fungitoxicants were imposed to test the efficacy in managing the white rust disease.T1: Single spray of mancozeb 75WP (0.2%); T2: Single spray of metalaxyl 8% + mancozeb 64% WP (0.2%); T3: Single spray of hexaconazole 5 EC (0.05%); T4: Single spray of cymoxinil 8% + mancozeb 64% (0.1%); T5: Single spray of azoxystrobin 23 % SC (0.05%); T6: T1 folowed by T2; T7: T1 followed by T3; T8: T1 followed by T4;T9: T1 followed by T5; T10: Water spray (control)

The first spray was applied at 45 DAS (with the onset of disease) and subsequent second spray was given 15 days after first spray i.e., 60 DAS, using 1000 litre of spray solution per hectare by knapsack sprayer. The plots with water spray served as check/control. The scoring on white rust severity on foliage was done 15 days after second spray (75 DAS). Twenty-five leaves sampled at random from each plot and scoring of white rust severity was done based on the leaf area covered by the pustule (%) following revised rating scale (0-6) of Conn's *et al.*, (1990); [0= No symptoms; 1= 0-5%; 2=5-10%; 3= 10-20%; 4= 20-35%; 5= 35-50%; 6= more than 50% leaf area covered by pustule].

Per cent disease index (PDI) was calculated by using the formula given by Wheeler (1969).

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Sum of all the numerical ratings}}{\text{No. of leaves examined} \times \text{maximum disease grade}} \times 100$$

The staghead incidence was also observed 15 days before harvest and per cent staghead incidence was calculated by counting the total number of plants in a plot and total number of plants showing staghead. The crop was harvested at maturity and threshed each treatment plot seperately and individual plot yield was recorded. The individual plot yield was then converted to yield per hectare. 1000 seeds were counted from a lot of the seeds drawn randomly from each treatment, weighed seperately and expressed in grams. Oil content (%) were determined by using the nuclear magnetic resonance (NMR). The analysis of all data was done using Gomez and Gomez (1984) and available online statistical sofwares (Shoeran *et al*., 1998).

RESULTS AND DISCUSSION

The spray of different fungitoxicants alone as single spray treatment or each fungicide in succession with mancozeb (0.2%) significantly reduced the white rust disease over control; however the level of efficacy varied among different treatments. The perusal of the data presented in Table 1 revealed that, the control (water spray) recorded significantly higher per cent disease intensity of 48.81% at leaf phase and 20.06% staghead incidence compared to all the fungicidal treatments.

The two fungicidal spray treatments i. e. mancozeb at 45 DAS followed by other fungicides each at 60 DAS recorded lower intensity of white rust compared to all single spray treatments. The plots sprayed with mancozeb (0.2%) at 45 DAS followed by azoxystrobin at 60 DAS recorded significantly lower % decrease of disease over control as compared to the other treatments both at leaf (85.49%) and staghead phase (78.08%) and obtained highest seed yield of 1907 kg/ha which was 42.33 % higher yield over the control (Table 2). The next best treatment was spray of mancozeb (0.2%) at 45 DAS followed by metalaxyl + mancozeb (0.2%) at 60 DAS reduced the disease up to 77.80 % and 73.66 % at leaf and staghead phase respectively with enhancement of seed yield up to 1820 kg/ha. Among the two fungicidal spray treatments, spray of mancozeb (0.2%) at 45 DAS followed by hexaconazole @ 0.05% at 60 DAS (T7) and spray of mancozeb (0.2%) at 45 DAS followed by cymoxanil + mancozeb (0.1%) at 75 DAS (T8) did not differ significantly among themselves with respect to disease severity (15.02 and 16.53), per cent staghead (10.33 and 10.90) and seed yield (1799 and 1731 kg/ha). However, these two treatments significantly reduced the disease over the control at leaf and inflorescence phases (Table 1). Although role of mancozeb in control of white rust of mustard is well documented by earlier workers (Mehta *et al*., 1996) there were no reports of use of azoxystrobin for the control of white rust. Sudisha *et al*. (2005) reported that azoxystrobin can control the downy mildew of pearl millet by significantly reducing the sporulation of *Sclerospora graminicola.* Wong and Wilcox (2001) also reported that application of azoxystrobin five days after inoculation of grapevine seedlings with *Plasmopara viticola* reduced downy mildew sporulation by 96%. Based on these observations, the effective control of white rust of Indian mustard by azoxystrobin might be attributed to reduction in sporulation of *A. candida* in the present study.

None of the single spray treatments of fungicides against white rust was found superior over the combination sprays. Although single fungicide spray in the present investigation gave adequate control in early stages of growth it did not control the disease till the end of the crop growth and the decline in activity of fungicide might be as a result of fungicide dilution as the volume of the plant tissue increased. Among the single spray treatments, spray of metalaxyl + mancozeb @ 0.2% was found to be best with reduction of white rust by 64.54% and 69.05% at leaf and staghead phases respectively over the control with seed yield of 1601 kg/ha. The use mancozeb 75 WP and metalaxyl + mancozeb (Ridomil MZ) have been documented by various workers for the control of white rust of crucifers in India and our results corroborate with the results of earlier workers (Mehta *et al.,* 1996; Bhartaria *et al.,* 1998; Meena *et al.,* 2005). Mehta *et al.* (1996) reported that three sprays of Ridomil MZ (metalaxyl + mancozeb) at 0.25% at 20 days interval starting from 40 DAS gave maximum control of white rust. Their results also indicated that four sprays of mancozeb alone could control white rust up to 42% only; but in our study, single spray of mancozeb @ 0.2% controlled the disease up to 37.77% over check. Yadav (2003) reported that two sprays of Ridomil MZ (0.25 %) at 60 and 80 days after sowing reduced the disease indices on leaf to maximum from 62.7 % to 17.1 % and enhanced the yield. Meena *et al.* (2005) found that metalaxyl + mancozeb (Ridomil MZ) sprayed on leaves reduced the white rust intensity.

Table 1 Efficacy of selected fungicides on white rust disease of Indian mustard under field condition during rabi (2014-15 and 2015-16)

Treatment No.	Treatment details	White rust severity (PDI) at 75 DAS				White rust severity (PDI) at stag head stage			
		Rabi 2014-15	*Rabi* 2015-16	Pooled mean	% decrease over control	*Rabi* 2014-15	*Rabi* 2015-66	Pooled mean	% decrease over control
T1	Mancozeb 75WP	27.78 (31.79)*	32.97 (35.03)	30.37 (33.41	37.77	12.08 (3.47)	9.78 (3.13)	10.93 (3.30)	45.50
T2	Metalaxyl 8%+ mancozeb 64%	16.11 (23.64)	18.50 (25.45)	17.31 (24.54)	64.54	7.32 (2.70)	5.09 (2.25)	6.21 (2.48)	69.05
T3	Hexaconazole 5 EC	24.72 (29.78)	28.37 (32.17)	26.55 (30.97)	45.61	11.20 (3.35)	9.02 (3.00)	10.11 (3.17)	49.60
T4	Cymoxanil 8% + mancozeb 64%	25.56 (30.35)	31.11 (33.89)	28.34 (32.12)	41.94	12.91 (3.59)	9.76 (3.11)	11.34 (3.35)	43.48
T5	Azoxystrobin 23% SC	23.89 (29.22)	27.80 (31.79)	25.85 (30.51)	47.04	11.33 (3.36)	9.09 (3.01)	10.21 (3.18)	49.10
T6	T1 followed by T2	11.67 (19.96)	10.00 (18.41)	10.83 (19.19)	77.80	6.00 (2.44)	4.56 (2.13)	5.28 (2.29)	73.66
T7	T1 followed by T3	14.17 (22.08)	15.87 (23.41)	15.02 (22.75)	69.23	10.72 (3.27)	9.95 (3.15)	10.33 (3.21)	48.48
T8	T1 followed by T4	15.56 (23.21)	17.50 (24.65)	16.53 (23.93)	66.13	12.08 (3.47)	9.72 (3.12)	10.90 (3.29)	45.66
T9	T1 followed by T5	5.56 (13.57)	8.61 (16.93)	7.08 (15.25)	85.49	4.86 (2.20)	3.93 (1.98)	4.40 (2.09)	78.08
T10	Control	 (42.75)	51.50 (45.84)	48.81 (44.30)		21.48 (4.63)	18.63 (4.31)	20.06 (4.47)	
Mean		26.64	28.76			3.25	2.92		
CV (%)		4.36				4.93			
LSD (0.05%) (Treatment)		1.46				0.18			
LSD (0.05%) (Year)		0.65				0.08			
LSD (0.05%) (Treatment X Year)		2.06				0.25			

*Figures in the parentheses are angular transformed values

Table 2 Yield parameters of Indian mustard in different fungicide treatments under field condition during *rabi* (2014-15 and 2015-16)

Trt. No.	Treatment details	Yield (kg/ha)				Oil Content (%)			1000 seed weight (g)		
		Rabi 2014-15	*Rabi* 2015-16	Pooled mean	% increase over control	*Rabi* 2014-15	*Rabi* 2015-16	Pooled mean	*Rabi* 2014-15	*Rabi* 2015-16	Pooled mean
T1	Mancozeb 75WP	1397	1507	1452	8.37	38.57	38.37	38.47	3.77	3.90	3.83
T2	Metalaxyl 8%+ mancozeb 64%	1504	1698	1601	19.50	38.53	38.07	38.30	3.63	3.80	3.72
T3	Hexaconazole 5 EC	1540	1651	1596	19.11	38.77	38.70	38.73	3.63	3.70	3.67
T4	Cymoxanil 8% + mancozeb 64%	1487	1538	1513	12.89	38.47	38.57	38.52	3.67	3.83	3.75
T5	Azoxystrobin 23% SC	1535	1649	1592	18.83	37.73	37.50	37.62	4.00	3.90	3.95
T6	T1 followed by T2	1742	1898	1820	35.83	38.40	38.90	38.65	3.97	4.07	4.02
T7	T1 followed by T3	1754	1845	1799	34.31	38.50	38.40	38.45	3.90	3.97	3.93
T8	T1 followed by T4	1679	1782	1731	29.17	38.87	38.70	38.78	3.93	3.83	3.88
T9	T1 followed by T5	1876	1938	1907	42.33	39.00	38.93	38.97	3.97	4.23	4.10
T10	Control	1244	1436	1340		37.57	37.87	37.72	3.70	3.73	3.72
Mean		1576	1694			38.44	38.40		3.82	3.90	
CV (%)		2.46				1.79			2.92		
LSD (0.05%) (Treatment)		1634.9				38.42			3.86		
LSD (0.05%) (Year)		21.655				0.37			0.06		
LSD (0.05%) (Treatment X Year)		68.479				1.17			0.19		

Among all single spray fungicidal treatments, spray of mancozeb (0.2%) recorded significantly highest (30.37%) disease severity; however which was significantly much lesser than control (48.81%). Although single spray of azoxystrobin (0.05%) at 45 DAS was not effective in controlling the white rust, when azoxystrobin (0.05%) was given as a second spray at 60 DAS after spraying the plots with mancozeb (0.2%) at 45 DAS it was more effective in controlling the white rust. The single spray treatment of hexaconazole (0.05%) and cymoxanil + mancozeb (0.1 %) at 45 DAS did not differ significantly however both were significantly superior over the control. The oil content and 1000 seed weight did not vary significantly among the treatments (Table 2). However, Yadav (2003) have reported the role of various fungicides in control of white rust disease, 1000 seed weight (g) and oil content (%).

From this study it was concluded that, spray of mancozeb (0.2%) at 45 DAS followed by azoxystrobin (0.05%) at 60 DAS was more effective in reducing the disease severity at both leaf and staghead phases with significant increase in seed yield.

REFERENCES

Bhargava A K Sobti A K Bhargava L P and Nag A 1997. Chemical control of white rust of mustard through seed treatment-cum-spray and their economics. *Indian Phytopathology*, **50**(2): 242-245.

Conn K L, Tewari J P and Awasthi R P 1990. A disease assessment key for Alternaria black spot in rapeseed and mustard. *Canadian Plant Disease Survey*, **70**: 19-22.

Gomez K A and Gomez A A 1984. *Statistical Procedures for Agricultural Research,* Second edition, John Wiley and Sons, New York, 680 pp.

Jacobson D J, Le Febvre S M, Ojerio R S, Berwald N and Heikkinen E 1998. Persistent, systemic, asymptomatic infections of A. candida, an oomycete parasite, detected in three wild crucifer species. *Canadian Journal of Botany*, **76**: 739-750.

Kumar A 2008. Management of white rust of Indian mustard (*Brassica juncea*) in mid hills of North-Western Himalayas. *Journal of Mycolology Plant Pathology*, **38**(3): 537-541.

Lakra B S and Saharan G S 1989. Sources of resistance and effective screening techniques in *Brassica Albugo* system. *Indian Phytopathology*, **42**: 293.

Meena P D, Rathi A S, Vinod Kumar and Dhiraj Singh 2014. *Compendium of Rapeseed-Mustard Diseases: Identification and Management.* ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan, pp. 30.

Mehta N, Saharan G S, Kaushik C D and Mehta N 1996. Efficacy and economics of fungicidal management of white rust and downy mildew complex in mustard. *Indian Journal of Mycology Plant Pathology*, **26**: 243-247.

Sheoran O P, Tonk D S, Kaushik L S, Hasija R C and Pannu R S 1998. *Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications.* D S Hooda and R C Hasija (Eds.), Department of Mathematics Statistics, CCS HAU, Hisar, pp. 139-143.

Sudisha J, Amruthesh K, Deepika S A, Shetty N P, Sarosh B R and Shetty H S 2005. Comparative efficacy of strobilurin fungicides against downy mildew disease of pearl millet. *Pesticide Biochemistry and Physiology*, **81**: 188-197.

Vasudeva R S 1958. Diseases of rape seed and mustard. In: *Rapeseed and Mustard, Indian Central Oilseed Community.* Hyderabad, India, pp. 77-86.

Wheeler B E J 1969. *An Introduction to Plant Diseases.* John Wiley, London, pp. 301.

Wong F P and Wilcox W F 2001. Comparative of physical modes of action of azoxystrobin, mancozeb and metalaxyl against *Plasmapara viticola* (grapevine downy mildew). *Plant Disease,* **85**(6): 649-656.

Yadav D K, Vignesh M, Sujata V, Yadav A K, Mohapatra T and Prabhu K U 2011. Characterization of Indian mustard (*B. juncea*) indigenous germplasm line BIOYSR for white rust resistance. *Indian Journal of Plant Genetic Resource*, **24**: 400-442.

Yadav M S 2003. Efficacy of fungitoxicants in the management of Alternaria blight and white rust of mustard. *Journal of Mycology Plant Pathology*, **33**(2): 307-309.

An economic analysis of arrivals and prices of oilseed crops at APMCS of Chhattisgarh, India

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ABSTRACT

Agriculture value returns impinge upon a farmer's income, agricultural markets and marketing efficiency become critical. In the light of the Government's vision to double farmer's income by 2022, it entails an urgent need to revisit the existing market structure of the country and bring in a more competitive marketing environment. In Chhattisgarh, APMCs are responsible for the marketing of the agricultural produce. The present study was undertaken to examine the trends in arrival and prices of major commodities in selected APMCs of Chhattisgarh i.e. Jashpur, Raigarh, Saraipali, Rajim, Gariaband, Kanker, Mungeli, Kawardha, Rajnandgaon, Bhatapara, Kondagaon and Jagdalpur for 5 years from 2013-14 to 2017-18. Annual arrival of oilseeds in Chhattisgarh state were examined and observed that the soybean contributed about 94.51 % of the total arrivals of oilseeds in APMC followed by til and groundnut. It was observed that the seasonality in market arrivals and prices was quite evident in month of March, April and May. At the Mandi, no system of pricing commensurate fair average quality of the commodities. This results in inconclusive price expressions based on differentiated lots. In order to overcome this, Mandi should keep records of all the lots auctioned based on quality parameters. Procurement by MARKFED is limited only to select commodities in select pockets of Chhattisgarh state at MSP. Whereas Mandi facilitate marketing of wide range of commodities under open auction system, usually at bid prices lower than the MSP for almost all commodities.

Keywords: APMC, Arrivals and Prices, Oilseed crops

Agriculture like any other enterprise can sustain, only when it can generate net positive returns to the producer. A market is a place, where a produce is transacted and price per unit is determined, resulting in the total value that a farmer-producer fetches. Since value returns impinge upon a farmer's income, agricultural markets and marketing efficiency become critical. In the light of the Government's vision to double farmer's income by 2022, it entails an urgent need to revisit the existing market structure of the country and bring in a more-competitive marketing environment. This combined with improved levels of productivity and reduced cost of cultivation/production can drive agricultural growth, farmer's welfare, productive employment and economic prosperity in rural areas of the country. Organized wholesale marketing in the country is promoted through a network regulated markets set up under the provisions of States' Agricultural Produce Marketing (Regulation) Acts. These market structures aimed at regulation and attainment of transparency in transactions, with a view to transferring remunerative and monopolistic, falling well below the intended objectives. Further, the existing regulatory framework does not support free flow of agricultural produce; and direct interface of farmers with the processors/ exporters / bulk buyers / end users, and in sequel has let in large number of intermediaries who may or may not be adding any value along the value chain. This is neither advantageous to the farmers nor serves well interests of the consumers.

In Chhattisgarh, agricultural produce market committees (APMCs) are responsible for the marketing of the agricultural produce. There are three levels of administration which operate in Chhattisgarh and take care of the marketing of agricultural produce. The upper level of Administration is Chhattisgarh government's agricultural department, Middle level is 'Mandi' board (which works under the jurisdiction of agricultural department) and the lower level is APMC (which works under the jurisdiction of Mandi board. The agricultural minister of Chhattisgarh is the head (Chairperson) of Mandi board and there is a clear hierarchical structure to support him. At Mandi level, the Mandi Secretary is the higher authority, followed by Mandi inspectors, Accountant, Computer Operator, Bidders. APMC has 12 members, and among them 11 members represent farmers and 1 member represents the businessmen. This committee works under Mandi board. According to the rules of APMC Act, the purchasers should get registered and get license from APMC. On the basis of delivery, the produce is taken in to the Market-yard, the place of auction. A cash memo is prepared by the general commission agent or

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purchaser and one copy of memo is given to the seller with cash payment, another to market committee and one copy is kept for his own record (Mishra and Bhandari, 2013). The present study was undertaken to examine the trends in arrival and prices of major commodities in selected APMC of Chhattisgarh i.e. Jashpur, Raigarh, Saraipali, Rajim, Gariaband, Kanker, Mungeli, Kawardha, Rajnandgaon, Bhatapara, Kondagaon and Jagdalpur for 5 years from 2013-14 to 2017-18. The study also envisaged to examine the existing system of commodity marketing along with the problems related to marketing for different stakeholders such as farmers, traders and the APMCs in order to suggest alternative mechanism for better price realization of agricultural commodities by farmers.

MATERIALS AND METHODS

For the present study twelve APMC Mandi of Chhattisgarh state were selected according to highest arrival of major commodities (Table 1). Annual and monthly arrivals, minimum price, maximum price and modal price were collected from different selected Mandi for the year 2013-14 to 2017-18. The collected data from different Mandi was pooled and averaged for 5 years to get a wholesome picture of commodities *vis-a-vis* arrivals and prices. Data on minimum support price (MSP) for different commodities were obtained from CACP report. To know feedback on different aspects of the marketing and cost of cultivation of different commodities, focused group discussion (FGD) were held by the researchers in different selected Mandi and Krishi Vigyan Kendra (KVKs) of Chhattisgarh state.

RESULTS AND DISCUSSION

Annual arrival of oilseeds in Chhattisgarh state: Annual arrival of oilseeds in Chhattisgarh state, presented in Table 2, revealed that the soybean contributed about 94.51 % of the total arrivals of oilseeds in APMC followed by til and groundnut. In case of groundnut only 5.41% of the total production is traded in mandi.

Monthly arrivals and price of mustard: In order to understand the market dynamics of major commodities it is necessary to look at monthly arrival pattern in different Mandi. Table 3 and Fig. 1 provide a glimpse of arrivals and prices of mustard over the last five years. Seasonality in market arrivals and prices was quite evident in the months of March, April and May. It indicated that mustard market observed radical increase in arrival mainly in three months.

Annual arrivals and prices of mustard: Annual arrival and prices of mustard is presented in table 4. It was observed that there was a positive percentage change in arrival of mustard over the years. However, positive percentage change was observed in maximum and modal price of mustard and negative percentage change was observed in the case of minimum price of mustard. While MSP was found to have positive percentage changes over modal price of mustard.

Farmers reported that Mandi prices of mustard were not enough to meet out the expenses for cultivation. Therefore, most of the farmers are interested to sale mustard at minimum support price at PACS under govt. procurement.

Cost of production and MSP of mustard: The cost of production was estimated by interactions with farmers, which is given in Table 5. It reveals that cost of production by considering A2+FL, C2 and C3 were observed to be ₹1771/q, ₹ 2958/q and ₹3254/q, respectively. It was found that MSP was higher than cost A2+FL, C2 and C3. It was also observed that farmers got one &half times more price of mustard on cost A2+FL.

Table 1 Details of the selected Mandi

Name of mandi	Name of commodity	Agro-demotic subzones
Rajim	Paddy	Chhattisgarh Plains
Gariyaband	Maize	Chhattisgarh Plains
Kanker	Maize	Chhattisgarh Plains
Mungeli	Paddy, Arhar (Pigeon pea), Gram (Chick Pea)	Chhattisgarh Plains
Saraipali	Groundnut	Northern Hills
Jaspur	Niger	Northern Hills
Raigarh	Groundnut	Northern Hills
Kawardha	Pigeon pea, Gram (Chickpea)	Chhattisgarh Plains
Rajnadgaon	Mustard, Maize, Gram (Chickpea)	Chhattisgarh Plains
Bhatapara	Arhar (Pigeon pea), Mustard, Gram (Chick Pea), Paddy	Chhattisgarh Plains
Kondagaon	Maize	Bastar Plateau
Jagdalpur	Maize	Bastar Plateau

Table 2 Annual arrival of oilseeds in Chattisgarh State (Average of 2013-14 to 2016-17)

Crops	% to Total arrival of oilseeds	% To Total arrival of all the commodities
Soybean	94.51	1.59
Groundnut	1.40	0.02
Til	2.92	0.05
Linseed	0.52	0.01
Mustard	0.57	0.01
Sunflower	0.08	0.00
Total Arrival (Lakh Quintal)	15.39 (100)	1.68

Table 3 Monthly arrival and prices of mustard

Month	Mustard (2013-14 to 2017-18)				
	Minimum price (₹/q)	Maximum price (₹/q)	Modal price (₹/q)	Arrival (q)	Average MSP (₹/q)
April	2350	5570	3960	3046	3440
May	2500	4150	3325	2076	3440
June	2201	4071	3136	1561	3440
July	2200	4345	3272.5	1494	3440
August	2000	4115	3057.5	1009	3440
September	2300	4200	3250	986	3440
October	1500	5276	3388	957	3440
November	1500	4755	3127.5	675	3440
December	2500	4525	3512.5	320	3440
January	2200	3821	3010.5	728	3440
February	2000	5021	3510.5	647	3440
March	2400	3902	3151	2753	3440

Table 4 Market arrival and prices of mustard

Particular	2013-14	2014-15	2015-16	2016-17	2017-18	Percentage change in 2017-18 over 2013-14
Arrival (q)	1473	3691	5445	1670	4018	63.34
Minimum price (₹/q)	2550	2301	2825	2401	2375	-7.37
Maximum price (₹/q)	3355	3400	4410	5570	3791	11.50
Modal price (₹/q)	2952.5	2850.5	3617.5	3985.5	3083	4.23
MSP (₹/q)	3050	3100	3350	3700	4000	23.75

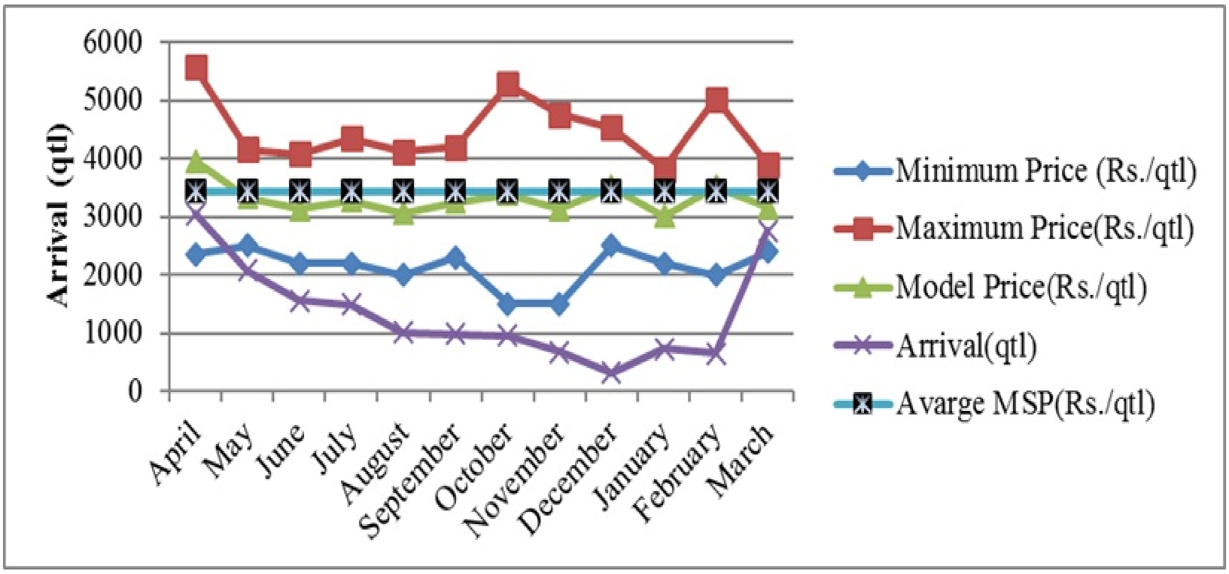

Fig. 1. Monthly arrival and price of mustard

Table 5 Cost of production and MSP of mustard (₹/q)

Particulars	A2+FL	C2	C3	MSP (2017-18)
Mustard cost of production	1771	2958	3254	4000
Mustard at 1.5 times of the cost of production	2656	4437	4881	6000

Issues related to mustard: Most of the farmers were interested to sell mustard at minimum support price at PACS. Fair average quality (FAQ) for mustard under price support are needed to be widely publicized. The quality consciousness is a long term process for which TRIFED (Tribal Cooperative Marketing Development Federation of India) can educate the mustard growers. The private traders fully exploit the poor bargaining power of the tribal farmers. Ignorance of market conditions & practices were observed among these farmers.

Monthly arrivals and price of niger: In order to understand the market dynamics of major commodities, it is necessary to look at monthly arrival pattern at different Mandis. Table 6 and Fig. 2 provide the glimpse of last five years arrivals and prices of niger in the state. Presence of seasonality in market arrivals and prices is quite evident in the months of January, February and March. It indicates that niger market observed radical increase in arrival mainly in three months.

Annual arrivals and prices of niger: The annual arrivals and prices of niger at APMC, Jashpur between 2013-14 and 2017-18 were taken for analysis to understand the changes over time of arrival and price of niger (Table 7 and Fig. 3). It revealed that annual arrival of niger declined from 22,291 q to 1412 q within this period, which was a decline of 93.66 percent. The decline in the arrival of niger could be due to lower production of niger in the state as this crop is being replaced by with other competitive crops.

The prices including minimum, maximum, Modal and MSP have seen positive changes over time period of 2013-14 to 2017-18. The percentage change of model price over MSP was notice to be negative in 2013-14 and 2014-15 while, it was positive during the remaining years.

Cost of production and MSP of niger: The cost of production was estimated by interactions with farmers and the same is given in Table 8. It reveals that the cost of production by considering A2+FL, C2 and C3 were observed to be ₹/q1850, ₹/q 2916 and ₹/q 3208, respectively. It was found that MSP higher than cost A2+FL, C2 and C3. It was also observed that farmers got one &half times more price of Niger over cost A2+FL.

Issues related to niger: Organic cultivation of Niger can be explored as export commodity. The private traders fully exploit the poor bargaining power of the tribal growers. Reasons for the disadvantaged position of the tribal producer are remote area, ignorance of market conditions and practices. They are further subjected to malpractices such as under weighing and denial of premium for quality in these transactions.

Monthly arrivals and price of groundnut: In order to understand the market dynamics of major commodities it is necessary to look at monthly arrival pattern in different Mandis. Table 9 and Fig. 4 provide a glimpse of last five years arrivals and prices of groundnut in the state. Presence of seasonality in market arrivals and prices is quite evident in months of December, January & February. It indicates that groundnut market observed radical increase in arrival mainly in three months.

Annual arrivals and prices of groundnut: Annual arrival and prices of groundnut is presented in (Table 10 and Fig. 5). It was observed that there was positive percentage change in arrival of groundnut over the years. However, negative percentage change was observed in minimum, maximum and modal price of groundnut. While MSP was found to be positive percentage changes over modal price of groundnut.

Farmers reported that mandi prices of groundnut were not enough to meet out the expenses for cultivation. Most of the farmers are not interested in growing groundnut because of this reason and the area is getting covered by other crops.

Cost of production and MSP of groundnut: The cost of production was estimated by interactions with farmers and the same is provided in Table 11. It reveals that the cost of production (₹/q) by considering A2+FL, C2 and C3 were observed to be 1700, 2427 and 2670, respectively. It was observed that MSP was higher than cost A2+FL, C2 and C3. It was also observed that farmers got one and a half times more price of Groundnut over cost A2+FL.

Monthly arrivals and price of soybean: In order to understand the market dynamics of major commodities it is necessary to look at monthly arrival pattern in different Mandi. Table 12 and Fig. 6 provide the glimpse of the arrivals and prices of soybean during the last five years in the state. Presence of seasonality in market arrivals and prices was quite evident in the months of October, November & December. It indicated that soybean market observed radical increase in arrival mainly in three months.

Table 6 Monthly arrival and prices of niger

Month	Arrival (q)	Minimum price (₹/q)	Maximum price (₹/q)	Modal price (₹/q)
April	1410	2500	3600	3050
May	1095	2500	3600	3050
Jun	2241	2500	3600	3050
July	3696	2500	3600	3050
August	3610	2500	4500	3500
September	5140	2500	4500	3500
October	6675	2500	4050	3275
November	6435	2700	4050	3375
December	5786	2500	4800	3650
January	10995	2500	4500	3500
Febuary	6868	2500	4050	3275
March	10206	2500	4500	3500

Table 7 Market arrival and prices of niger

Particular	2013-14	2014-15	2015-16	2016-17	2017-18	Per change in 2017-18 over 2013-14
Arrival (q)	22291	25270	11447	3737	1412	-93.66
Minimum price (₹/q)	2500	2500	3600	3500	4000	60
Maximum price (₹/q)	3500	4500	4500	4800	4100	17.14
Modal price (₹/q)	3000	3500	4050	4150	4050	35
MSP (₹/q)	3500	3600	3650	3825	4050	15.71

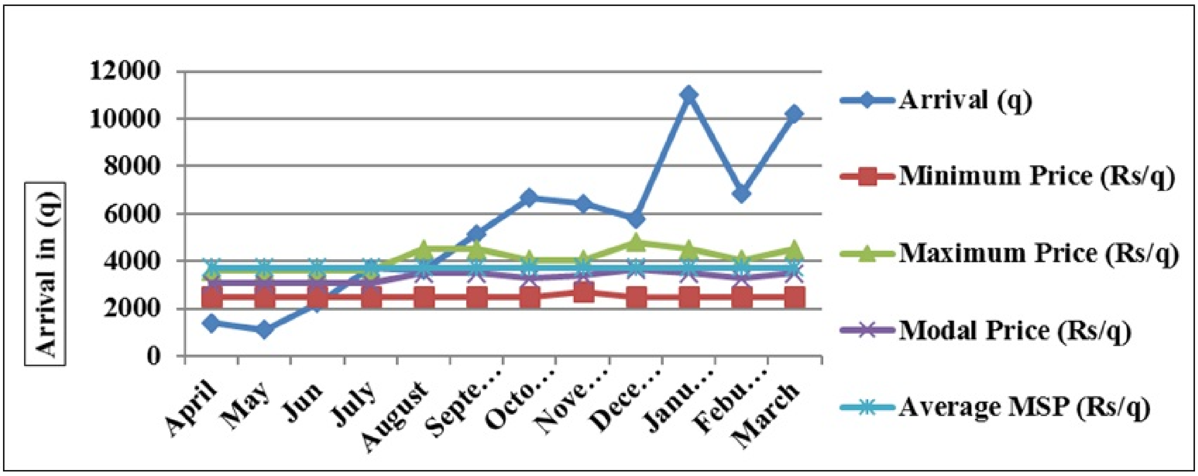

Fig. 2. Monthly arrival and price of niger

Table 8 Cost of Production and MSP of Niger (₹/q)

Particulars	A2+FL	C2	C3	MSP (2017-18)
Niger cost of production	1850	2916	3208	4050
1.5 times of the cost of production	2775	4374	4812	6075

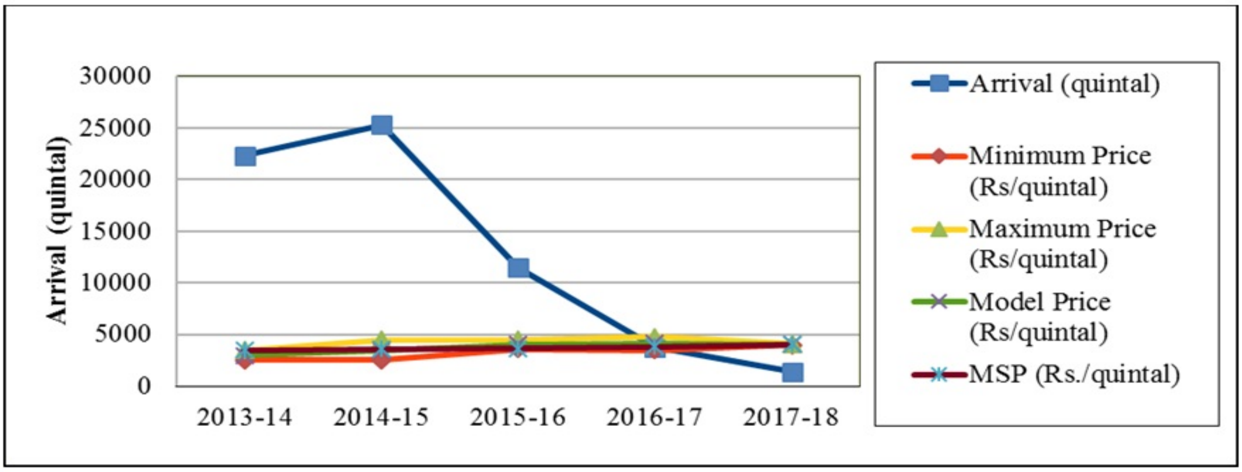

Fig. 3. Annual arrival and prices of niger

Table 9 Monthly arrival and prices of groundnut

Month	Arrival (q)	Minimum price (₹/q)	Maximum price (₹/q)	Modal price (₹/q)	Average MSP (₹/q)
April	0	0	0	0	4140
May	370	2500	4000	3250	4140
June	1891	2500	4000	3250	4140
July	838	2500	3000	2750	4140
August	1271	2000	3600	2800	4140
September	2020	1500	3000	2250	4140
October	1230	1200	4600	2900	4140
November	2055	1800	4795	3297	4140
December	1005	2000	4716	3358	4140
January	344	3000	5254	4127	4140
February	150	3000	4000	3500	4140
March	367	2150	4000	3075	4140

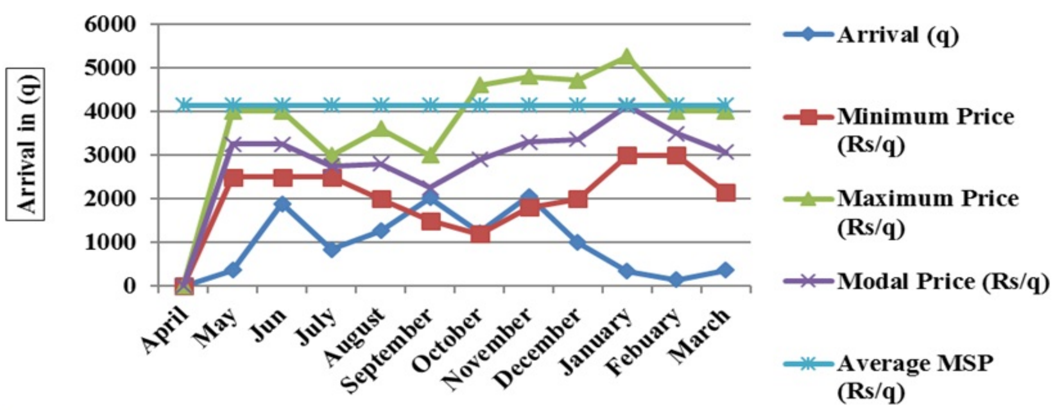

Fig. 4. Monthly arrivals and prices of groundnut

Table10 Market arrival and prices of groundnut

Particular	2013-14	2014-15	2015-16	2016-17	2017-18	Per change in 2017-18 over 2013-14
Arrival (q)	2180	1816	3119	1864	2607	19.58
Minimum price(₹/q)	4200	4150	5000	5500	3821	-9.02
Maximum price(₹/q)	8600	7000	9254	8200	6300	-26.74
Modal price(₹/q)	6400	5575	7127	6850	5060.5	-20.93
MSP (₹/q)	4000	4000	4030	4220	4450	11.25

Table 11 Cost of production and MSP of groundnut (₹/q)

Particulars	A2+FL	C2	C3	MSP (2017-18)
Groundnut cost of production	1700	2427	2670	4450
1.5 times of the cost of production	2550	3640	4005	6675

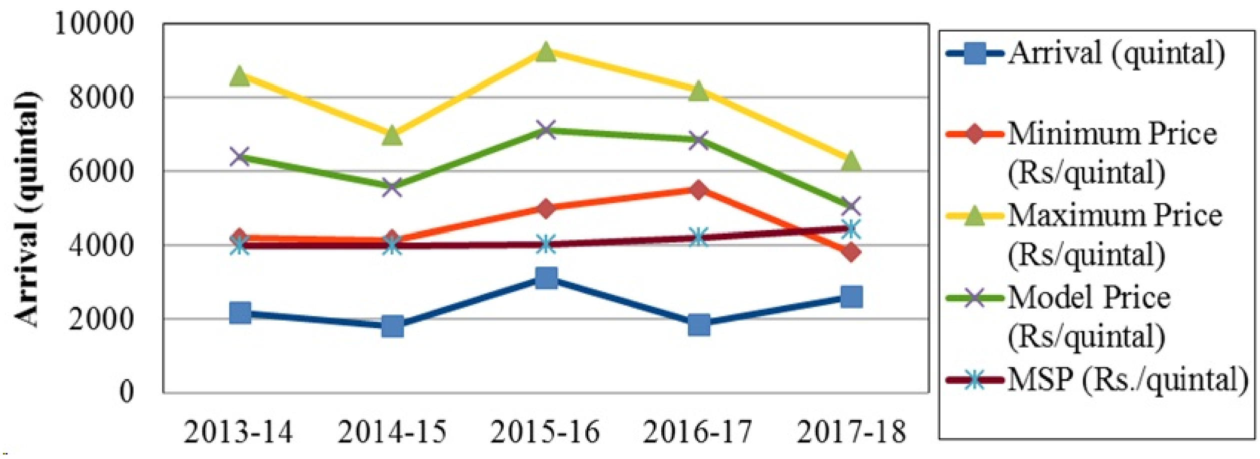

Fig. 5. Annual arrival and prices of groundnut

Table 12 Monthly arrival and price of soybean (2013-14 to 2017-18)

Month	Minimum price (₹/q)	Maximum price (₹/q)	Modal price (₹/q	Average MSP (₹/q)	Arrival ('00 q)
April	2100	4421	3260.5	2709	752.8
May	1650	5501	3575.5	2709	894.31
June	1806	4225	3015.5	2709	622.41
July	1500	4000	2750	2709	917.72
August	2000	3900	2950	2709	631.63
September	1650	3526	2588	2709	475.69
October	310	4050	2180	2709	2158.57
November	1300	3700	2500	2709	4792.63
December	1300	3840	2570	2709	2498.75
January	800	3780	2290	2709	1366.35
February	1971	3800	2885.5	2709	739.13
March	1500	4070	2785	2709	489.94

Annual arrivals and prices of soybean: Annual arrival and prices of soybean is presented in (Table 12 and Fig. 7). It was observed that there was a negative percentage change in arrival of soybean over the years. It was also observed that the negative percentage change was observed in minimum, maximum and modal price of soybean. MSP was found to be more or less equal to the modal price.

Farmers reported that Mandi prices of soybean were not enough to meet out the expenses for cultivation. Most of the farmers were interested to sell Soybean at minimum support price at PACS.

Cost of production and MSP of soybean: The cost of production was estimated by interaction with farmers and the same is given in Table 14. It revealed that the cost of production (in ₹/q) by considering A2+FL, C2 and C3 were observed to be 1831, 2682 and 2950 respectively. It was found that MSP was higher than cost A2 + FL, C2 and C3. It was also observed that farmers got one and a half times more price of Soybean when compared to A2 + FL cost.

To conclude, our study indicated that at present prices are not based on the fair average quality of commodities that arrived at Mandi not PACS which resulted in inconclusive price expressions based on differentiated lots. In order to overcome this, Mandi should keep records of all the lots auctioned based on quality parameters. Procurement by MARKFED is limited only to select commodities like maize in select pockets of this state at MSP. Whereas Mandi facilitate marketing of wide range of commodities under open auction system, usually at bid prices lower than the MSP for almost all commodities. Most of the farmers were interested in selling mustard at minimum support price at PACS. Fair average quality (FAQ) for niger under price support are needed to be widely publicized. The quality consciousness is a long term process for which TRIFED can educate the niger growers. The private traders fully exploit the poor bargaining power of the tribal farmers. Ignorance of market conditions & practices were observed among the tribal farmers. They are further subjected to malpractices such as under weighing & denial of premium for quality in these transactions.

Table 13 Annual arrival and price of soybean

Particular	2013-14	2014-15	2015-16	2016-17	2017-18	% change in 2017-18 over 2013-14
Arrival ('00 q)	8492.3	3171.34	1572.42	1763.83	1649.19	80.58
Minimum price (₹/q)	1600	1911	1950	1650	1500	-6.25
Maximum price (₹/q)	4021	4441	4000	3990	3892	-3.21
Modal price (₹/q)	2810.5	3176	2975	2820	2696	-4.07
MSP (₹/q)	2560	2560	2600	2775	3050	19.14

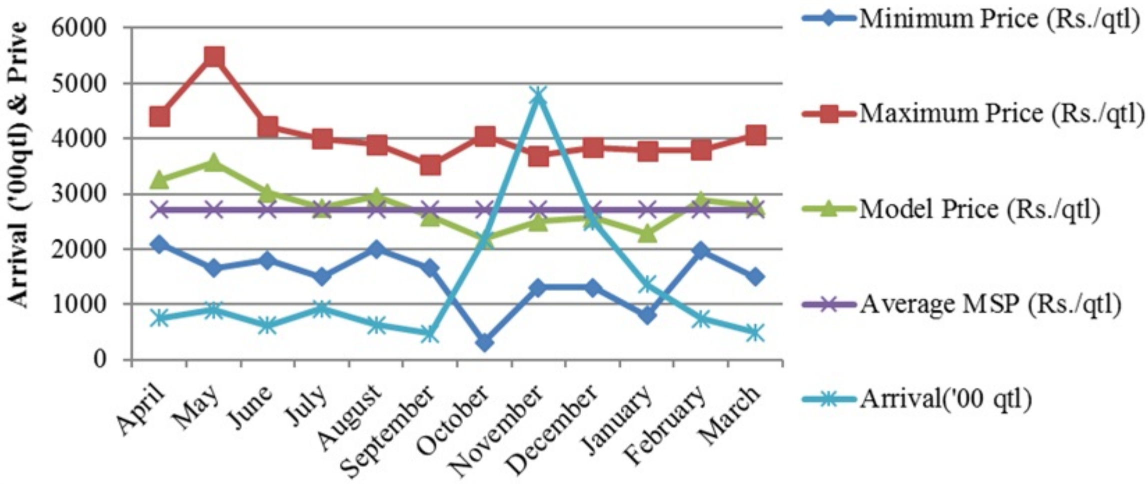

Fig. 6. Monthly arrival and price of soybean (2013-14 to 2017-18)

Table 14 Cost of production and MSP of soybean (₹/q)

Particulars	A2+FL	C2	C3	MSP (2017-18)
Soya bean cost of production	1831	2682	2950	3050
1.5 times of the cost of production	2746	4023	4425	4575

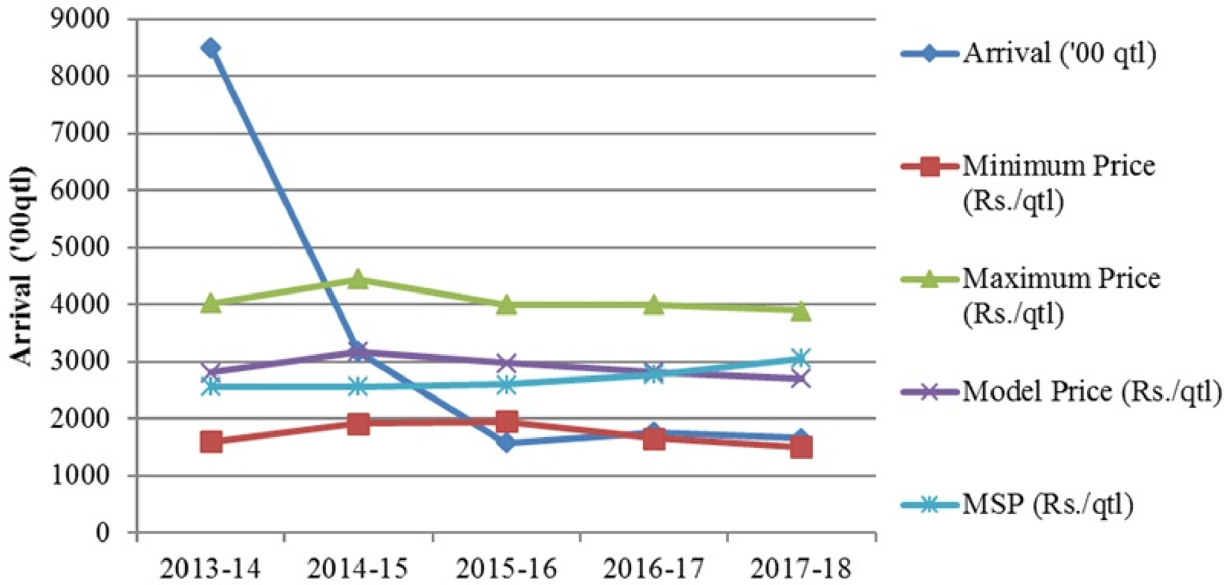

Fig. 7. Annual arrival and price of soybean

REFERENCES

Chatterjee S and Kapur D 2016. *Understanding Price Variation in Agricultural Commodities in India: MSP, Government Procurement and Agriculture Markets.* India Policy Forum. National Council of Applied Economic Research, New Delhi, pp. 1-25.

Gauraha A K and Joshi S K 2018. Quantum of subsidies in Agriculture and Allied Sectors in Chhattisgarh project report funded by Chhattisgarh State Planning Commission govt. of Chhattisgarh.

Kiran B R and Vadivelu A 2013. Problems and Prospects of Agricultural Marketing in India: An Overview. *International Journal of Agricultural and Food Science*, **3**(3): 108-118.

Kumar Ranjit, Sanjiv Kumar and P C Meena 2018 smart Micro-Mandi: For Better Price Relegation and Reduced Market Riskes. For the Small holdest, Polocy Brief April 2018 (No. 01), ICAR-National Academy of Agricultural Research Management, Hyderabad.

Mishra Srijit 2008. Risks, farmers' suicides and agrarian crisis in India: Is there a way out. *Indian Journal of Agricultural Economics*, **63**(1): 39-54.

Mishra A K and P Bhandari 2013. A study of financial status of Chhattisgarh mandis (APMC). *International Journal Scientific and Engineering Research*, **12**: 637-643.

Pandey N 2018. Agro-Economic Alerts, Aiding the Future of India's Farmers and Agriculture, Centre for Management in Agriculture (CMA), Indian Institute of Management Ahmedabad, pp. 7.

Pavithra S and Gracy C P 2018. Innovations in agricultural marketing: a case study of e-tendering system in Karnataka, India. *Agricultural Economics Research Review*, **31**(1): 53-64.

Roy A 2008. Dynamics of Spot and Future Markets in Indian Wheat Market: Issues and Implications. Indian Institute of Management, Ahmedabad, pp. 31.

Productivity potential and profitability of whole package technology in oilseed crops

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ABSTRACT

The productivity of oilseed crops in India is low due to rainfed cultivation, small operational land holdings, lack of varietal replacement (groundnut and sesame), losses due to biotic and abiotic stresses and low adoption of agronomic practices and other improved technologies. There is a potential to increase productivity of oilseeds by using best production practices and right combination of inputs at right time. Several technologies were developed by the All India Coordinated Research Projects (AICRP) on oilseed crops that can significantly increase the productivity of oilseeds. Realizing the importance of extending these technologies to farmers, frontline demonstrations (FLDs) were conducted. Data from a total of 24,035 FLDs conducted on whole package technology over an area of 9727 ha in nine oilseed crops in different agro-ecological situations of the country during 2014-15 to 2018-19 were analyzed in this paper. The results showed increased yield, gross monetary returns and additional net returns with improved technologies (IT) as compared to farmers' practices. The benefit cost ratio was also higher indicating the profitability of improved technology. In order to speed up the adoption of improved technologies by farmers, there is a need to provide timely access to key inputs like, quality seeds of high yielding cultivars and availability of agro-chemicals in time at village level. There is also a need to forge required partnerships involving extension agencies, state departments of agriculture and input agencies in educating the farmers on the impact of improved technologies, organizing exposure visits to model farms and ensuring timely availability of quality inputs to enhance oilseed productivity and profitability.

Keywords: Benefit cost ratio, Frontline demonstrations, Improved technology, Oilseeds

Oilseeds cultivation is a source of livelihood to 14 million farmers and one million people are involved in processing of oilseeds and oils in India (Hegde and Venkattakumar, 2007). Majority of farmers had small and marginal land holding cultivating oilseed crops under rainfed and resource constraint conditions. In India, annual oilseeds comprising nine oilseed crops are grown over an area of 25.50 m. ha with a production of 32.26 m. t and productivity of around 1265 kg/ha (Malhotra *et al.*, 2020). Even though India ranks first in production of castor, safflower and sesame, second in groundnut and linseed, third in rapeseed-mustard, fourth in sunflower and fifth in soybean, the productivity of oilseeds as a whole in India is low except in case of castor. The major constraints for low productivity of oilseed crops are rainfed cultivation, small operational land holdings, lack of varietal replacement (groundnut and sesame), losses due to biotic stresses (Rabindra *et al*., 2007) and abiotic stresses and low adoption of agronomic practices (Rathore *et al*., 2019) and other improved technologies. There is a potential to increase production of oilseeds by using best production practices and right combination of inputs at right time (Kumar and Chauhan, 2007).

Several technologies and management options have been developed by the All India Coordinated Research Projects (AICRP) on oilseed crops, that can significantly increase the productivity of oilseeds, but farmers had low to medium level of knowledge on improved technologies (Chauhan *et al*., 2013) and adoption of technologies by farmers has been far less than anticipated (Bairathi *et al.,* 2013, Mandavkar *et al.,* 2013 and Asiwal *et al.,* 2013). Realizing the importance of extending improved technologies in oilseed crops to farmers, frontline demonstrations (FLDs) were conducted. Field demonstrations conducted under the close supervision of the scientists of the National Agricultural Research and Education System (NARES) for the first time, before being passed onto the main stream extension system of the State Departments of Agriculture are called frontline demonstrations. The major objective of FLDs is to show the productivity potential and profitability of improved technologies *vis-à-vis* farmers' practices under real farm situations. The present study was conducted to assess the impact of FLDs in increasing the productivity and profitability of oilseeds in farmers' fields.

MATERIALS AND METHODS

FLDs were conducted through All India Coordinated Research Projects (AICRP) on oilseeds, KVKs and NGOs. The data from FLDs conducted on nine oilseed crops at various locations in India during 2014-15 to 2018-19 were considered for analysis. A total of 24,035 FLDs were

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conducted on whole package technology over an area of 9727 ha on nine oilseed crops in different agro-ecological situations of the country. The improved technology (IT) i.e., whole package, using recommended and latest cultivar for the region, maintaining optimum plant population through optimum spacing and recommended seed rate, nutrient management and pest management. The IT was demonstrated on 0.40 ha plot in comparison with farmers' practice (FP) in order to provide farmers an opportunity to compare, evaluate and choose themselves the best practice based on their own criteria. The details of IT and the area covered under FLDs for each crop are presented in Table 1. The data on seed yield, cost of cultivation and gross monetary returns were collected from the IT plots and FP plots by the respective AICRP centres over the years. The data were pooled, averaged (weighted averages) and presented.

Yield advantage: Yield advantage was the extent of gain in seed yield in IT plot over FP plot. It was estimated by the following formula.

$I_{fp} = \Sigma\ (Y_{it} - Y_{fp}/Y_{fp}) \times 100$

where I_{fp} = Improvement in seed yield over FP (%);
Y_{it} = Yield in IT plot (kg/ha);
Y_{fpi} = Yield in FP plot (kg/ha)

For assessing the economic advantage, partial budgeting technique (Birthal, 2003) was used and additional net returns (ANR) and benefit cost ratio (B:C ratio) of the demonstrations were estimated. The technology is economically feasible, if the profits are higher compared to those of farmer's practice. This could be represented as:

TR (I) - TR (F) > TC (I) -TC (F)
ΔR (I) > ΔC (F)
TR = $\Sigma\ P_i{*}Y_i$
TC = $\Sigma\ P_j{*}X_j$

Where

TR (F) = Total returns from farmers' practice plot
TC (F) = Total cost recorded in farmers' practice plot
ΔR (I) = Change in the revenue due to improved technology
ΔC (F) = Change in the revenue due to farmers' practice
TR (I) = Total monetary returns from the improved technology plot
TC (I) = Total cost recorded in improved technology plot
P_i = Price of the i^{th} output (i =1,...,n)
Y_i = quantity of the i^{th} output (i = 1,...,n)
P_j = Price of the j^{th} input (j = 1,...,n)
X_j = Quantity of the j^{th} input (j = 1,..,n)

Output of FLDs: The immediate gain to the farmers due to adoption of improved technology in FLD plot. It was estimated by the following formula:

Output of FLDs = $\Sigma\ X_i{*}Y_i$

X_i = Additional net returns accrued to the i^{th} farmer (i = 1…n) and Yi = Area covered by FLDs in i^{th} farmers field (i = 1…n).

RESULTS AND DISCUSSION

Productivity potential of improved technologies: The Frontline Demonstrations (FLDs) conducted over the years, across the locations in nine oilseed crops indicated an overall seed yield improvement of 24.52% with improved technology (IT) of whole package (1513 kg/ha) as compared to farmers' practice (FP, 1215 kg/ha). Similarly, Chavan et al. (2019), reported significant increase in the average yields in demonstration plots of groundnut and niger. Singh *et al.* (2014), reported an increase in productivity due to adoption of interventions like use of high yielding varieties, seed treatment, fertilizer application and plant protection measure in oilseeds.

The crop-wise yield data (Fig. 1) indicated that highest improvement in seed yield (82.3%) was observed in niger with IT (403 kg/ha) as compared to FP (221 kg/ha) followed by linseed (53.9%) with IT (583 kg/ha) under *utera* conditions as compared to farmers' practice (379 kg/ha). In soybean, the overall seed yield improvement was 28.3% with IT (1672 kg/ha) as compared to FP (1303 kg/ha). In rapeseed-mustard, under irrigated conditions, the seed yield improvement was 18.8 % with IT (1988 kg/ha) as compared to FP (1673 kg/ha), whereas under rainfed conditions it was 30.7% with IT (1110 kg/ha) as compared to FP (849 kg/ha). In *rabi* groundnut, mostly grown under irrigated conditions, the seed yield was 23.2% higher in IT (2603 kg/ha) as compared to FP (2112 kg/ha). In sesame, 43.1% improvement in seed yield was observed with IT (558 kg/ha) as compared to FP (390 kg/ha). In castor, FLDs conducted under irrigated conditions during *kharif* in Gujarat, Rajasthan and Haryana gave 19.5% higher seed yield with IT (3711 kg/ha) as compared to FP (3104 kg/ha). In sunflower, the seed yield was higher by 20% each in both *rabi* and *kharif* seasons. In safflower, 49.4% improvement in seed yield was observed with IT (1081) as compared to FP (724 kg/ha) under irrigated conditions (Table 2). In all the crops, the seed yield was higher with IT as compared to FP, similar results were reported by Jatav *et al.* (2019) in soybean, Meena *et al.* (2019) in groundnut, Thakur *et al.* (2019) in linseed, Kumar *et al.* (2018) in soybean, Rai *et al.* (2018), Chhodavadia *et al.* (2016) in sesame, Samuel *et al.* (2017) and Padmaiah *et al.* (2010) in castor, Sharma *et al.* (2017), Kushwah *et al.* (2016), Kasana *et al.* (2016) and Biswas *et al.* (2016) in rapeseed mustard, Bhargava *et al.* (2019), Patil *et al.* (2018) and Naveen *et al.* (2017) in groundnut and niger, and Bairwa *et al.* (2016), Kasana *et al.* (2016), Venkattakumar *et al.* (2012) and Padmaiah *et al.* (2009) in sunflower.

Table 1 Technologies demonstrated and area covered under FLDs in different seasons and situations (2014-15 to 2018-19)

Crop	Season	Technology demonstrated	Area (ha)
Soybean	*Kharif*	Varieties: JS 95 60, VLBhatt 201, VLS 77, MAUS 158, JS 93 05, JS 20 34, MAUS 162, Hara soy, VLS 59, JS 20 29, Dsb-21, PUSA 97 12, KDS 344, JS 97 52, RKS 45, GJS 3, RKS 18, NRC 37, SL 958, Basra, DSb 19, Him soy, BSS2, KDS 726, MACS 1188, MACS 1460, Palam soy, VLS 47, MACS 1281, JS 20 98, MAUS 612, recommended seed rate and spacing, seed treatment with bio inoculants (Rhizobium), S nutrition and application of SSP and need based plant protection	2042
Rapeseed and Mustard	*Rabi* -Irrigated	Varieties: Giriraj, NRCHB101, RH 725, RH 406, RH 749, PM 30, DRMR 1165-40, RB 50, RGN 73, PM 28, CS 58, Maya, Urvashi, GDM 4, GM 3, RVM 2, JM 3, RSPN 25, PBR 357 and PR 20, recommended seed rate and spacing, seed treatment, thinning, S nutrition, painted bug management and club root management	1757
	Rabi -Rainfed	Varieties: RGN 229, RGN 298, NRCHB 101, DRMR 150-35, Shivani, PPS 1, YSH 401, GSC 7, PT 508, PHT 1, Uttara, TS 38, TS 36, Shalimar sarson-1, 2, 3, RTM 1351, RTM 1355, recommended seed rate and spacing, S nutrition, thinning and need based plant protection	974
Groundnut	*Rabi*	Varieties: Dharani, G-2-52, GJG-9, GJG-17, GJG-32, K-9, JL-776, TKG bold, Phule unnati, LGN-1, UG-5, RHRG-6083, TG37 A, VRI-8, TMV-13, Devi, Pratap Raj Mungphali, KCG-6, KDG-128, RG559-3, GG-3, TG-51, recommended seed rate and spacing, seed treatment with PGPR, SSP, application of gypsum once in three years and need based plant protection	213
	Kharif	K9, TG37 A, GJG 22, GJG 20, TMV -2, JL 776, GJG-32, VRI 8, recommended seed rate and spacing, seed treatment with PGPR, SSP, application of gypsum once in three years and need based plant protection	537
Sesame	*Kharif*	Varieties: Smarak, Shubra, CUMS 17, JLT- 408, JCL-1020, AKT-101, PKVNT-11, GT-3, GT-4, GT-5, GT 10, RT 203, , RT-346, RT-351, Pragati (MT-75), Tarun, Savitri, TKG-306, TKG 308, HT-2, LT-8, VRI-2 JTS-8, Swetha Til, YLM-66, DS-5, DSS-9, recommended seed rate and spacing, line sowing, thinning, weed management, fertilizer management and need based plant protection	396
Linseed	*Kharif* - Irrigated	Varieties: PKV NL-260, Suyog, J-23, JLS-9, RL- 914, Shekhar, Garima, PKDL-41, JLS 66,79 & 95, RLC 133,138,143 and 148, Kota Barni Alsi 4, Pratap Alsi, recommended seed rate and spacing, soil test based fertilization and bud fly management	444
	Kharif - Rainfed	NDL-2002, Jawahar linseed-66, Shekar, Padmini, Kiran, JLS 66,79 & 95, RLC 133,138,143&148, Kota Barni Alsi 4, recommended seed rate and spacing, soil test based fertilization and bud fly management	583
	Utera	Deepika, Meera, weed management and need based plant protection	121
Castor	*Rabi*	Hybrids:GCH-7, ICH-66, DCH-77, DCH-519, PCH-111, recommended seed rate and spacing, S nutritiion and need based plant protection	53
	Kharif-irrigated	Hybrids: GCH-7, GCH-8, GCH-9, DCH-77, YRCH-1, YRCH-2, PCH-111, recommended seed rate and spacing, S nutrition and sucking pest management	249
	Kharif-rainfed	Hybrids: GCH-7, ICH-66, DCH-77, DCH-519, YRCH-1, YRCH-2, recommended seed rate and spacing, S nutrition and gray mold management	252
Sunflower	*Rabi*	Hybrids: RFSH-1887, RFSH-130, NDSH-1012, PSH-996, PSH-1962, CO-2, DRSH-1, LSFH-171, KBSH-53, KBSH-78, thinning, S nutrition, foliar application of B, soil test based fertilizer application and need based plant protection	662
	Kharif		163
Safflower	*Rabi*-irrigated	Safflower hybrid: DSH-185, varieties: ISH- 764, PKV pink, AKS 207, PBNS-12, SSF-708, NARI-57, optimum spacing, RDF, thinning, need based plant protection and mechanical harvesting	106
	Rabi-rainfed		939
Niger	*Kharif*	Varieties: JNS-28, JNS-30, Phule Vaitaran, Phule Karala, Pooja-1, Birsa Niger-3, Birsa nagar-9, Utkal Niger- 150, DNS-4, DNS- 9, KBN-1, Guj. Niger-1, Guj. Niger-2, JNC-3 and JNC-30, IPGN 76, KGN-2, JNS-9, line sowing, optimum time of sowing, cuscuta management and weed management, need based plant protection and timely harvesting	230
		Total	9727

Profitability of improved technologies: The data on economics of FLDs over the years, across locations in nine oilseeds crops (Table 3) showed that even though the cost of cultivation (CoC) increased by 10.7% in IT, the gross monetary returns (GMR) increased by 27.3% with additional net returns (ANR) of ₹9841/ha as compared to FP. The benefit cost ratio (BCR) was also superior in IT (2.40) as compared to FP (2.09) indicating the profitability of IT (Table 2). Increased GMR, ANR and higher BC ratios were reported with IT by Dutta, 2016 in rapeseed-mustard and Kumar *et al.* (2014) with improved plant protection technologies in oilseeds. In *rabi* groundnut, highest ANR of ₹ 20320/ha over and above FP was accrued with IT. Even though the CoC with IT increased by a meagre five per cent as compared to FP, the GMR increased by 25% with IT and the B:C ratio was 2.59 as compared to FP (2.19). The increase in CoC ranged from four per cent each in safflower and *kharif* groundnut to 49% in niger, whereas, the GMR increased by 11.6% in safflower to 85.7% in niger with IT as compared to FP. The ANR ranged from ₹ 2135/ha in safflower under rainfed conditions to ₹ 20320/ha in *rabi* groundnut with IT. The BC ratio ranged from 1.40 in rainfed safflower to 3.58 in irrigated castor with IT as compared to 1.3 to 3.15 with FP respectively (Table 2).

Output of adoption of FLDs: The output of conducting FLDs on oilseeds was immediate monetary gain to farmers due to increase in seed yield due to adoption of improved technology. The crop-wise consolidated monetary returns accrued to farmers over the locations are presented in Table 3. All the FLD farmers during 2014-15 to 2118-19 obtained ANR of 9.57 crores using IT as compared to their own practices.

Exploitable yield reservoir: The FLDs on whole package technology under real farm situations indicated huge yield gap-I (24.53%) and yield gap II (31.45%). If the yield gaps I and II are bridged through complete adoption of the whole package by all the farmers, oil seed production could be increased to 36.6 and 38.6 m t respectively, without increasing the area under oilseeds.

Farmers need to be educated through various means for adoption of improved technologies of oilseeds to reduce the yield gaps and achieve the expected production. The higher profitability in term of gross monetary returns will eventually lead the farmers to discontinue old technologies and adoption of improved technologies.

Table 2 Productivity potential and profitability of whole package technology in oilseeds (2014-15 to 2018-19)

Crop	CoC (₹/ha)		Increase over FP (%)	GMR (₹/ha)		Increase over FP (%)	ANR (₹/ha)	B:C ratio	
	IT	FP		IT	FP			IT	FP
Soybean	26046	22990	13.29	56210	43162	30.23	9992	2.16	1.88
Rapeseed and Mustard (I)	26687	25135	6.17	77013	64705	19.02	10757	2.89	2.57
(RF)	16935	14837	14.14	45499	34965	30.13	8436	2.69	2.36
Groundnut (R)	44143	41887	5.39	114405	91830	24.58	20320	2.59	2.19
(K)	45328	43510	4.18	97428	79095	23.18	16516	2.15	1.82
Sesame (K)	19479	15923	22.33	46459	31436	47.79	11467	2.39	1.97
Linseed (I)	24541	17593	39.49	64453	40692	58.39	16813	2.63	2.31
(RF)	13575	11301	20.12	35299	24554	43.76	8471	2.60	2.17
(U)	10913	8204	33.02	22305	13914	60.31	5682	2.04	1.70
Castor (R)	32038	30719	4.29	80499	65935	22.09	13245	2.51	2.15
(K-I)	37635	35887	4.87	134847	113221	19.10	19877	3.58	3.15
(K-RF)	15886	14072	12.89	42737	27735	54.09	13189	2.69	1.97
Sunflower (R)	25400	23560	7.81	55656	44918	23.91	8898	2.19	1.91
(K)	29201	26973	8.26	49129	38298	28.28	8602	1.68	1.42
Safflower (R-I)	18199	14578	24.84	41144	26258	56.69	11264	2.26	1.8
R-RF)	20042	19266	4.03	27959	25048	11.62	2135	1.4	1.3
Niger (K)	9764	6552	49.02	22432	12079	85.71	7142	2.3	1.84
Total/mean	24451	22084	10.72	58672	46078	27.33	9841	2.40	2.09

I = irrigated; RF = rainfed; R = *Rabi* season; K = *kharif* season; RI = *rabi* irrigated; R-RF = *rabi* rainfed; IT = Improved technology (whole package, which included cultivar recommended for the region, optimum seed rate and spacing, recommended fertilizer application and management of pests and diseases); FP = Farmers practice; B:C ratio = Benefit cost ratio

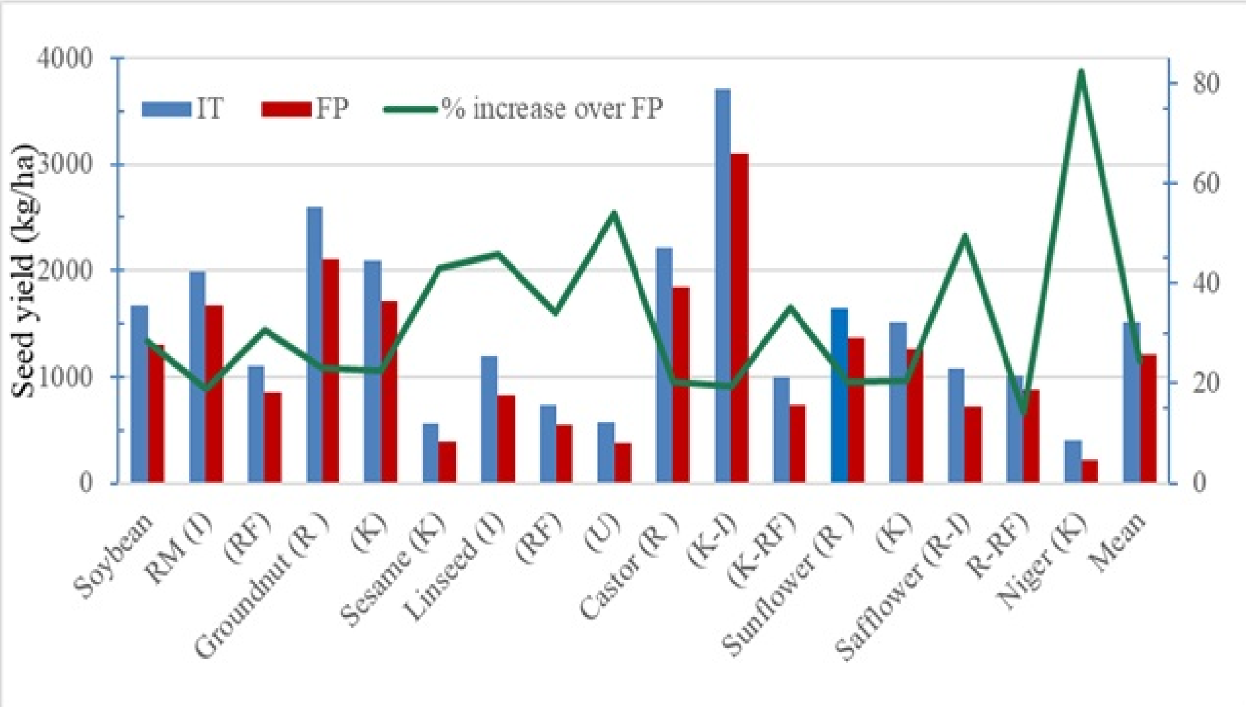

Fig. 1. Productivity potential of whole package technology in oilseeds (2014-15 to 2018-19)

Table 3 Output of FLDs conducted during 2014-15 to 2018-19

Crop	Yield increase over FP (%)	ANR (₹/ha)	Area under FLDs (ha)	ANR with adoption of technology (₹ in lakhs)
Soybean	28.3	9992	2042	203.9
Rapeseed and Mustard (I)	18.8	10757	1757	189.0
(RF)	30.7	8436	974	82.1
Groundnut (R)	23.2	20320	213	43.2
(K)	22.4	16516	537	88.7
Sesame (K)	43.1	11467	396	45.3
Linseed (I)	45.8	16813	444	74.6
(RF)	34	8471	583	49.4
(U)	53.9	5682	121	7.3
Castor (R)	20.16	13245	53	7.0
(K-I)	19.55	19877	249	4.9
(K-RF)	35.05	13189	252	33.2
Sunflower (R)	20.2	8898	662	58.9
(K)	20.6	8602	163	13.9
Safflower (R-I)	49.4	11264	106	11.9
R-RF)	14	2135	939	20.0
Niger (K)	82.3	7142	230	16.4
Total/mean	24.52	9841	9727	957.4

ANR = additional net returns

Table 4 Exploitable yield reservoir available based on the FLDs conducting during 2014-15 to 2018-19

Crop	Season	Yield gap-I (%)	Crop average yield (kg/ha)*	Yield gap-II (%)	Crop average production ('000 t)*	Expected production ('000 t)	
						EP-I	EP-II
Soybean	*Kharif*	28.3	1027	62.7	11344.8	14557.5	18461.1
Rapeseed and Mustard	Irrigated	18.8	1265	57.1	7564.6	8988.9	11885.6
	Rainfed	30.7	1265	-	-	-	-
Groundnut	*Rabi*	23.2	1953	33.2	1487.4	1833.1	1982.0
	Kharif	22.4	1474	42.4	6076.4	7436.9	8653.0
Sesame	*Kharif*	43.1	468	19.3	792.9	1134.5	946.1
Linseed	Irrigated	45.9	533	125.0	160.9	234.7	362.1
	Rainfed	34.0	533	37.6	160.9	215.6	221.4
	Utera	53.8	533	9.4	160.9	247.5	176.1
Castor	*Rabi*	20.1					
	Kharif-irrigated	19.6	1699	118.4	1548.5	1851.3	3382.3
	Kharif-rainfed	35.0					
Sunflower	*Rabi*	20.2	772	114.2	182.9	219.8	391.6
	Kharif	20.7	648	134.3	104.2	125.7	244.1
Safflower	*Rabi*-irrigated	49.3	556	94.3	63.1	94.2	122.6
	Rabi-rainfed	14.0	556	81.3	63.1	71.9	114.4
Niger	*Kharif*	82.3	328	22.9	74.2	135.4	91.3
Mean		24.5	1151	31.5	29399.8	36610.6	38646.3

Yield gap-1 = Difference in yield of IT and FP expressed in per cent; Yield gap II = Difference in yield of IT and state average yield expressed in per cent;
EP-1= Exploitable yield, if yield gap-I is bridged; EP-I1= Exploitable yield, if yield gap-II is bridged

Despite the fact, that the demonstrated improved technology was found promising and the farmers would like to continue with the new technology, even after withdrawal of FLDs, the access to key inputs like, quality seeds of high yielding cultivars and availability of agro-chemicals in time at village level is a major hindrance for enhancing the adoption levels. Therefore, the input support mechanism needs to be developed at grass-root level. In order to speed up the dissemination of improved technologies in oilseeds, there is a need to forge necessary partnerships involving extension agencies, state department of agriculture and input agencies. A multi-pronged strategy of educating the farmers on the impact of improved technologies, exposure visits to model farms and ensuring timely availability of quality inputs (chemicals and biological) will go a long way in enhancing the productivity of oilseeds.

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REFERENCES

Asiwal B L, Singh S, and Sharma N K 2013. Adoption Gap and Constraints in Adoption of Improved Mustard Production Technology in Semi-Arid Region of Rajasthan. *Indian Journal of Extension Education and Rural Development*, **21**:105-108.

Bairathi R, Verma A K, and Patodiya R S 2013. Dissemination of Improved Technology of Mustard through Frontline Demonstrations. *Indian Journal of Extension Education and Rural Development*, **21**: 141-145.

Bairwa R K, Dhaka B L, and Meena G S 2016. Enhancing Mustard Production through Frontline Demonstration. *Bhartiya Krishi Anusandhan Patrika*, **31**(3): 235-237.

Bhargava M K, Singh P, Kumar P, and Singh S 2019. Impact of front Line Demonstration on Productivity of Groundnut in Farmers Fields of Shivpuri District of Madhya Pradesh. *International Journal of Agriculture Sciences*, **11**(1): 7715-7716.

Birthal P S 2003. Economic Potential of Biological Substitutes for Agrochemicals, *Policy Paper, 18.* National Centre for Agricultural Economics and Policy Research, New Delhi.

Biswas B, Sarkar S, Sahoo S K, Das R, Das S K, and Singh D. 2016. Yield gap and economic utility evaluation of improved technologies in rapeseed-mustard cultivation: an analysis of front line demonstrations in West Bengal. *Ecology, Environment and Conservation*, **22**(3): 1279-1284.

Chauhan P S, Bareth L S, Ranawat Y, and Meena N R 2013. Knowledge Level of Farmers According to their Personal Attributes under FLDs Regarding Soybean Production Technologies. *Indian Journal of Extension Education and Rural Development*, **21**: 188-192.

Chavan S, Shinde V, Mahale M, and Patil S 2019. Impact of Frontline Demonstrations on Oilseed Crops in Konkan Region of Maharashtra. *Indian Research Journal of Extension Education*, **19**(2): 70-76.

Chhodavadia H C, Dudhat A S, and Patel J V 2016. Impact of Frontline Demonstration on Summer Sesame Growers. *International Journal of Agriculture Sciences*, **8**(25): 1514-1515.

Dutta A 2016. Impact of Improved Technologies on Productivity and Profitability of Rapeseed-Mustard Production at Farm Level in West Bengal, India. *SAARC Journal of Agriculture*, **14**(2): 126-136.

Hegde D M and Venkattakumar R 2007. Development of oilseeds - a step towards self-sufficiency in India. *Souvenir of All India Convention on Oilseeds, Oil trade and Industry,* Nagpur, pp. 41-48.

Jatav H, Sharma R P, Tomar D S, and Suryawanshi D K 2019. Impact of soybean production technology dissemination through front line demonstrations in Malwa region of M.P. *Journal of Krishi Vigyan*, **7**(2): 149-152.

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 G D S, Padmaiah M and Rao S V R 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 S and Chauhan S 2007. Production performance and total factor productivity growth of oilseeds in India. In: *Changing Global Vegetable Oil Scenario: Issues and Challenges before India,* Hegde D M (Ed.), Indian Society of Oilseeds Research, Hyderabad. pp. 239-246.

Kumar S, Srivastava Y C and Stephen A J 2018. Impact of frontline demonstration on indian mustard through improved technology. *Indian Journal of Extension Education*, **54**(2): 226-230.

Kushwah S, Kumar S, and Singh A K 2016. Adoption of improved late sown mustard cultivation practices in Bihar. *Indian Journal of Extension Education*, **52**(3-4): 153-156.

Malhotra S K, Thakur Shubha and Barik A 2020. Current production and future requirement of edible oil in the country. In: *Souvenir of National Seminar on Technological Innovations in Oilseed Crops for Enhancing Productivity, Profitability and Nutritional Security*, pp. 15-21.

Mandavkar P M, Talathi M S, Mahadik R P and Sawant P A 2013. Farmer's knowledge and correlates of oilseed production technology. *Indian Journal of Extension Education and Rural Development*, **21**: 15-19.

Meena R L, Jat B L and Babita D 2019. Status of collar rot in groundnut and impact of demonstrations on its management in Dausa District of Rajasthan. *International Journal of Agriculture Sciences*, **11**(22): 9199-9201.

Naveen N E, Chaitanya H S, Patil S U, and Dhananjaya B 2017. Impact of front line demonstration on productivity of groundnut in farmers fields of coastal Karnataka Udupi District. *International Journal of Agriculture Sciences*, **9**(37): 4561-4562.

Padmaiah M, Rao S V R and Ramanjaneyulu G V 2009. Adoption behavior of fld and non-fld farmers of sunflower. *Indian Journal of Extension Education*, **45**(3-4): 97-101.

Padmaiah M, Venkattakumar R, Singh I, Solanki S S and Sarada C 2010. Castor frontline demonstrations in Jodhpur District of Rajasthan: An impact study. *Indian Journal of Extension Education*, **46**(1-2): 86-91.

Patil S, Mahale M, Chavan S and Shinde V 2018. Impact of frontline demonstrations on oilseed crops in Konkan Region of Maharashtra. *Indian Research Journal of Extension Education*, **18**(4): 36-42.

Rabindra R J, Sunil Joshi and Veenakumari K 2007. Biological control of insect pests of oilseeds in India. In: *Changing Global Vegetable Oil Scenario: Issues and Challenges before India,* Hegde D M (Ed.), Indian Society of Oilseeds Research, Hyderabad, pp. 101-142.

Rai A K, Khajuria S, Lata K, Rajkumar and Jadav J K 2018. Study on yield gap and prioritization of castor production constraints for semi-arid region in Gujarat. *Indian Journal of Extension Education*, **54**(2): 162-167.

Rathore S S, Shekhawat K, Singh R K, Upadhyay P K and Singh V K 2019. Best management practices for doubling oilseed productivity: aiming India for self-reliance in edible oil. *Indian Journal of Agricultural Sciences*, **89**(8): 1225-1231.

Samuel G, Saritha K, Satyanarayana M, and Spandana Bhatt P 2017. Popularization of castor (PCH 111) among the small farmers of Mahabubnagar District of Telangana through frontline demonstration. *International Journal of Agricultural Science and Research*, **7**(4): 771-774.

Sharma R, Bhati D S and Sharma S K 2017. Impact of frontline demonstrations on rapeseed mustard growers. *Journal of Progressive Agriculture*, **8**(1): 115-118.

Singh A K, Singh K C, Singh Y P, and Singh D K 2014. Impact of frontline demonstration on adoption of improved practices of oilseed crops. *Indian Research Journal of Extension Education*, **15**(3): 75-77.

Thakur S, Mirjha P R, and Nag S K 2019. Assessment of high yielding varieties and agro-techniques of linseed through front line demonstration. *International Journal of Agriculture Sciences*, **11**(23): 9245-9247.

Venkattakumar R, Padmaiah M, Sarada C, Mahajan A M, Moon M K, and Deshmukh S N 2012. Impact of sunflower frontline demonstrations in Akola District of Maharashtra. *Indian Journal of Extension Education*, **48**(1-2): 6-11.

Deciphering genotype × environment interactions by AMMI method for yield and component traits in linseed (*Linum usitatissimum* L.)

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ABSTRACT

In the present study, additive main effects and multiplicative interactions (AMMI) biplot analyses were used to identify stable genotypes for number of bolls/plant, seeds/boll, seed yield/plant and oil content to dissect GEI in linseed. Trials were conducted in randomized complete block design (RCBD) with two replications over three consecutive years, 2016-17, 2017-18 and 2018-19. ANOVA analysis revealed genotype and G×E interaction effects contributed significant sum of square for number of bolls/plant (96.50% and 0.30%); seeds/boll (74.01% and 4.24%); seed yield/ plant (94.06% and 1.57%) and oil content (92.06% mainly genotype effect). The dissection of GE interaction for all the traits was mostly explained by the first and second principal component axis (IPCA1 and IPCA2). Results of genotype's stability in AMMI1 and AMMI2 biplot analyses showed differential response with some exceptions that indicated the different sets of genes and effect of environment on the cumulative expression of traits under study. The AMMI2 biplot graphs showed similar environmental response for number of bolls/plant, seeds/boll, seed yield/plant and oil content as in case of AMMI1 analysis. The Simultaneous stability index (SSI) statistic fully corresponded with the results of the AMMI1 biplot models for all the traits of top ranked genotypes across the environments. The linseed genotypes identified for yield and stability could be advocated for varietal recommendation and further use in hybridization program in semi-arid conditions.

Keywords: AMMI biplot analysis, G x E interaction, IPCA1, IPCA2, Linseed, Oil content

Linseed or flax (*Linum usitatissimum* L. 2n= 30, x=15) an important oilseed crop belonging to the family Linaceae and the tribe Lineae which comprise of approximately 230 species, is the only species of this family with economic importance (Tadesse *et al*., 2010). Flax and linseed are two phenotypically different species of cultivated linseed documented. Flax type plants are generally taller and have smaller number of branches while linseed types are often shorter, have more branches and produce more seeds. The flax types are commercially grown for the extraction of fibres, whereas the linseed is meant for the extraction of oil from seeds (Diederichsen and Ulrich, 2009). It has two separate centres of origin, linseed type originated in south west Asia while fibre type originated in Mediterranean region (Vavilov, 1951). Approximately 20% of the total linseed oil produced is used as edible oil and the remaining 80% for industrial purpose. Linseed oil is an excellent drying oil used in manufacturing paints, inks, varnishes and other wood treatments, waterproof fabrics, oil cloth, soap, linoleum, putty and pharmaceuticals etc. So, the crop is grown for fibre, oil or both seed and oil, but recently it has gained a new interest in the emerging market of functional food due to higher content of digestible proteins and lignans in seeds and high content of alpha linolenic acid (ALA), an essential Omega-3 fatty acid in its oil which constitute up to and nutraceutical properties have paved the way for its diversified uses and value addition in various forms. Recent advances in neuro-biology have established it as the best herbal source of Omega-3 fatty acids, which helps in regulating the nervous system (Anonymous, 2005).

India ranks second in the world after Canada with respect to area and third in production. It is largely grown in temperate regions and to some extent on subtropical and tropical highlands under favorable growing conditions of warm moist climate and well-drained medium heavy soils (Worku *et al*., 2015). In India linseed is mostly grown as oilseed crop on approximate area of 3.2 lakh ha with production of 1.74 lakh metric tons (FAO STAT, 2018). It is cultivated in the temperate and sub-tropical environments as rainfed crop in the states of Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Maharashtra, Rajasthan, Bihar, Odisha, Jharkhand, Karnataka and Assam that account for more than 97% of the total linseed area. The average yield of 544 kg/ha was found very low compared to world average yield of 927 kg/ha and highest average yield of 1497 kg/ha in Canada (FAOSTAT, 2018). Low productivity might be associated with the narrow genetic base and non-availability of high yielding varieties, cultivation in marginal lands and vulnerability to biotic and abiotic stresses. Hence, with increased demand there is an urgent need of varieties with high yield potential. Development of high yielding varieties requires the assessment of existing genetic variability for yield and its component characters before planning for an

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appropriate breeding strategy for genetic improvement. There is need of diverse genotypes so that genetic improvement over existing linseed varieties can be achieved.

Stability is one of the important criteria in breeding methodologies and this issue can be addressed by phenotypic expression of traits in concerned environment (Rad *et al.,* 2013). Phenotypic variation is highly dependent on the environments. Explaining such variations is biased upwardly by the fact that all genotypes don't react in the same way in two environments as they do not have exactly the same conditions (Neisse *et al.,* 2018). If the performance of genotype changes in different environments, then the interaction of the genotype with environment is an important aspect in crop improvement program. Therefore, combined analysis of any variance can measure genotype environment interaction (GEI) and identify prime component, though it is not sufficient to declare the GEI effectiveness. Several statistical methods have been proposed for analysis of plant stability with the aim of dissecting GEI and stable trait expression across environments. These models are used to assess the adaptability and stability of genotypes across the environments (Yan and Tinker, 2006).

AMMI is a potential tool to evaluate meterological data to interpret complex GEI (Yan and Tinker, 2006). It can effectively depict the interaction pattern graphically and delineate the environments to evaluate the various genotypes (Yan *et al.,* 2007). However, limited studies have been carried out by using this potential tool to analyze the MET in linseed. In the present investigation, 50 genotypes of linseed were evaluated by the AMMI analysis and the SSI statistics for selection of genotypes with high yield and stability in terms of number of bolls//plant, seeds//boll, seed yield//plant and oil content. The objectives of this study were to (i) dissect GEI for yield and component traits in 50 linseed genotypes using AMMI analysis and (ii) detect stable and high yielding genotypes across the environments (years) for future use in breeding programs.

MATERIALS AND METHODS

Experimental materials and location: Fifty linseed genotypes were sown during winter season for three consecutive years 2016-17, 2017-18 and 2018-19 at Department of Genetics and Plant Breeding, C.P. College of Agriculture, S.D. Agricultural University, S.K. Nagar, Gujarat, India. Genotypes with their pedigree/parentage, source/origin and characteristics features are given in table 1. Experimental site is located at 24°19'26" North latitude and 72°18'53" East longitude with an altitude of 172.00 meters above the mean sea level (Arabian Sea). The soil of experimental sight was loamy sand in texture with a pH of 7.5 and climatic condition falls under the category of semi-arid, characterized by less than 400 mm of annual average rainfall.

Field experiments and observations recorded: The genotypes were sown in randomized complete block design (RCBD) with 2 replications. Each genotype was represented by 2 rows of 2 m length with distance of 30 cm between rows and 10 cm between plants in a row. Thinning was performed after 21 days of germination to maintain plant geometry. From sowing till harvesting, all the recommended agronomic package of practices was followed to raise the good crops. Five plants were randomly selected and tagged for taking observations. The observations were recorded for quantitative traits such as number of bolls//plant, number of seeds//boll, seed yield//plant (g) and oil content (%). Harvested seeds from five randomly tagged plants from each entry were stored separately in a cloth bag for determination of oil content. Oil content of each sample was determined through soxhlet extraction method (Garcia-Hernandez *et al.*, 2017).

Statistical analysis

Analysis of AMMI model: The AMMI model (Zobel *et al.*, 1988) for the ith genotype in the jth environment is given by:

$$Y_{ijr} = \mu + g_i + e_j + b_r(e_j) + \sum_{k=1}^{n} \lambda_k \alpha_{ik} \gamma_{jk} + \rho_{ij} + \varepsilon_{ij}$$

where, Y_{ijr} is the yield of genotype *i* in environment *j* for replicate *r*, μ is the grand mean, g_i is the deviation of genotype *i* from the grand mean, e_j is the environment main effect as deviation from μ, λ_k is the singular value for the interaction principal component (IPC) axis *k*, α_{ik} and γ_{jk} are the genotype and environment IPC scores (i.e. the left and right singular vectors) for axis *k*, $b_r(e_j)$ is the effect of the block *r* within the environment *j*, *r* is the number of blocks, ρ_{ij} is the residual containing all multiplicative terms not included in the model, *n* is the number of axes or IPC that were retained in the model, and ε_{ij} is error under independent and identically distribution assumptions.

The AMMI stability index (ASI) as described by Jambhulkar (2014) was calculated as follows:

$$ASI = \sqrt{\left[PC_1^2 \times \theta_1^2\right] + \left[PC_2^2 \times \theta_2^2\right]}$$

where, PC_1 and PC_2 are the scores of 1st and 2nd IPCs respectively; and θ_1 and θ_2 are percentage sum of squares explained by 1st and 2nd principal component interaction effect respectively. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASI scores indicate a more stable genotype across environments.

Simultaneous stability index (SSI) incorporate mean and stability index in a single criteria and calculated as: SSI = rASI + rY where, rASI is the rank of ASI and rY is the rank of mean yield of genotypes across environments. This index considered the rank of AMMI stability index (ASI) and rank of genotypes based on yield across environments (Farshadfar *et al.,* 2011). The AMMI and stability indices were determined using R statistical software, version 3.4.1 (R Development Core Team, 2017).

RESULTS AND DISCUSSION

AMMI analysis of variance: The AMMI model retrieves the part of the sum of squares that determines the G × E interaction, which is called the standard portion (the genotype and environment effect), and a residual part, which corresponds to unpredictable and uninterpretable responses from the model (Cornelius *et al*., 1996). The present AMMI analysis indicated the genotypic effect scores comparatively more scattered than the environmental effect scores, demonstrating that variability due to the genotype is moderately greater than the variability caused by environmental effects (Figs. 1a, 1b, 1c and 1d). The AMMI analysis of number of bolls/plant over the environments showed that 96.50% significant sum of squares was explained by the genotype and 0.30% was attributable to the G×E interaction effects respectively (Table 2). The significant sum of square of genotype and G×E interaction effects of 74.01% and 4.24% respectively reported for seeds/boll. For seed yield/plant, significance of 94.06% total sum of squares was justified by genotype and 1.57% by GEI while significance sum of square of 92.06% mainly contributed by genotype effect for oil content in linseed. AMMI analysis of variance showed the large genotype and G×E interaction percentage for the sum of squares for all the traits studied. It indicated the significant differences that existed among the genotypes and the environments with respect to differential response of the genotypes. Similar results were previously observed by Alem and Tadesse (2014), Berti *et al.* (2010), Chobe and Ararsa (2018), Lirie *et al.* (2013), Soto-Cerda *et al.* (2013) and Tadesse *et al.* (2017) in linseed. The partitioning of GE interaction for number of bolls/plant, seeds/boll, seed yield/plant and oil content which was mainly explained by the first and second principal component axis (IPCA1 and IPCA2) with 89.60% and 10.40%; 75.20% and 24.80%; 79.60% and 20.40% and 99.90% and 0.10% of GEI sum of squares respectively (Table 2). The present G x E partitioning was fully in agreement with the previous study of Tadesse *et al.* (2017) in linseed.

Stability and genotypes performance: The genotypic mean, ASI, SSI and relative rankings of genotypes on the basis of yield and stability are presented in Table 3 and 4. Low value of ASI reflects the more stability of genotype and low GEI (Purchase, 2000). Low ASI value were observed of genotypes Parvati, S-36, IC96461, Ruchi, EC41528; Kartika, IC56363, Suyog, IC56365, IC96473; Rashmi, Kirtika, Hira, J-7, EC41528 and Pratap Alsi-1, S-36, EC41528, Sheela, Shikha for number of bolls/plant, seeds/boll, seed yield/plant and oil content respectively (Tables 3 and 4). Genotypes with smaller SSI value are closer to the genotype exhibiting more stability and high yield. SSI represents genotypic superiority in the sense of general adaptability or wide adaptation. Based on SSI and mean rank, genotypes IC56363, J-7, Ruchi, Rashmi, R-1(J-1) and IC56363, Kiran, IC96473, Janki, IC9646 were best for number of bolls/plant and seeds/boll respectively (Fig. 3b). Genotypes J-7, IC96491, IC96461, Baner, Hira desirable for seed yield/plant and EC41528, LC-185, R-1(J-1), Surabhi and Pusa-2 for oil content (Tables 3 and 4; Fig. 3d). Conclusively genotype IC56363 was most desirable genotype for both number of bolls/plant and seeds/boll while, J-7 and EC41528 for seed yield/plant and oil content respectively (Tadesse *et al.,* 2017).

When we evaluated environments independently, AMMI1 (Fig. 1a to d) also depicted the stability of genotype for mean number of bolls/plant, seeds/boll, seed yield/plant and oil content across the years. The genotypes located near the x-axis and on the right of the y-axis meant that they were stable and high-efficient, whereas the genotypes, which were located far from x-axis and left side of y-axis meant that they were unstable and low-yielding as classified by Crossa *et al.,* 1990. Accordingly, IC56363, J-7, Ruchi, Rashmi, R-1(J-1) for number of bolls/plant and IC56363, Kiran, IC96473, Janki, IC9646 for seeds/boll were best performing genotypes and more stable. Genotypes J-7, IC96491, IC96461, Baner were high yielders and more stable for seed yield/plant and EC41528, LC-185, R-1(J-1), Surabhi and Pusa-2 for oil content (Fig. 1a to d). Genotypes Mukta, Janki, Garima, Gaurav; Shival, Neelum, Meera, Pratap Alsi-1; R-1(J-1), S-36, Sharda, Garima and Baner, Gaurav, Kartika, Kiran were highly unstable across the years for number of bolls/plant, seeds/boll, seed yield/plant and oil content respectively which were placed far from x axis (Figs. 1a, 1b, 1c and 1d).

The AMMI2 biplot graph showed that genotypes S-36, Parvati, IC96461were the most stable genotypes for number of bolls/plant (Fig. 2a). Suyog and Sharda were the most desirable genotype as it posses high stability and better performance (Fig. 3a). Mukta, Janki and Gaurav possessed more bolls/plant and quite stable (Fig. 2a). Genotypes L-27 and Pratap Alsi-1 were unstable for number of bolls/plant (Fig. 2a). AMMI2 analysis model for seeds/boll showed that, Hira, Shubhra and IC54970 were the most efficient genotypes for bolls yield and stability while Deepika, NL-97

Table 1 List of linseed genotypes, pedigree, source / origin and their characteristic features

Genotype	Pedigree/Parentage	Source/Origin	Growth habit	Lodging/ Non-lodging	Flower colour	Seed coat colour
Baner	EC-21741 × LC-216	Himachal Pradesh	Semi erect	Lodging	White	Brown
Deepika	Kiran x Ayogi	IGKV, Raipur (CG)	Erect	Lodging	Blue	Brown
EC 41528	PONE-1005 / 65	Argentina	Erect	Non-lodging	Pale blue	Brown
Garima	T-126 x Neelum	CSAUAT, Kanpur (U.P.)	Erect	Non-lodging	Blue	Brown
Gaurav	Selection-3 x EC-1552	CSAUAT, Kanpur (U.P.)	Bushy	Lodging	Blue	Yellow
Hira	---	CSAUAT, Kanpur (U.P.)	Erect	Lodging	White	Brown
IC 53281	/P/619	Raigarh, M.P.	Erect	Non-lodging	Blue	Brown
IC 54970	---	India	Erect	Non-lodging	Blue	Brown
IC 56363	---	India	Erect	Non-lodging	Blue	Brown
IC 56365	---	Akola, MH	Erect	Non-lodging	Pale blue	Brown
IC 96460	---	India	Erect	Non-lodging	Blue	Brown
IC 96461	---	India	Semi-erect	Non-lodging	Blue	Brown
IC 96473	---	India	Erect	Non-lodging	Blue	Brown
IC 96491	---	India	Erect	Non-lodging	Pale blue	Brown
Janki	New River × LC-216	Himachal Pradesh	Erect	Non-lodging	Blue	Brown
JLS-9	RL-102 x R-7/J-23	Jabalpur, M.P.	Semi-erect	Non-lodging	Blue	Brown
Kartika	Kiran x LCK-88062	IGKV, Raipur (CG)	Erect	Non-lodging	Blue	Brown
Kirtika	---	India	Erect	Lodging	Blue	Brown
Kiran	Afg-8 x R-11 x Afg-8	IGKV, Raipur (CG)	Semi erect	Lodging	Blue	Brown
LC-27	---	Gurdaspur, Punjab	Bushy	Lodging	Blue	Brown
LC-185	---	Gurdaspur, Punjab	Bushy	Lodging	Blue	Yellow
LC-54	K2 x Kangra local	Gurdaspur, Punjab	Semi erect	Lodging	White	Light brown
Meera	RL-75-6-2 x RL-29-8 x LCK8528	Kota, Rajasthan	Erect	Non-lodging	Blue	Brown
Mukta	---	CSAUAT, Kanpur (U.P.)	Erect	Non-lodging	White	Brown
Nagarkot	New River × LC-216	Himachal Pradesh	Semi erect	Lodging	Blue	Brown
Neela	Local selection of WB	West Bengal	Erect	Non-lodging	Blue	Brown
Neelum	T-1 x NP (RR)-9	CSAUAT, Kanpur (U.P.)	Semi-erect	Non-lodging	Pale blue	Brown
NL-97	R-7 x RLC-4	Nagpur, Maharashtra	Erect	Non-lodging	Pale blue	Brown
Padmini	EC-41628 x EC-77959 x DPL-20 x Neelum	CSAUAT, Kanpur (U.P.)	Semi-erect	Non-lodging	Blue	Brown
Parvati	EC-41628 x EC-77959 x (DPL-20 x Neelum x EC-216 x Hira) x (BR-1 x NP-440)	CSAUAT, Kanpur (U.P.)	Semi erect	Lodging	Blue	Brown
Pratap Alsi-1	ACC.750 x RL 29-8	Kota, Rajasthan	Erect	Non-lodging	White	Brown
Pusa-2	Selection from BS-12	New Delhi	Erect	Non-lodging	White	Brown
Pusa-3	K2 x T-603	New Delhi	Erect	Lodging	White	Brown
R-1 (J-1)	---	Jabalpur, M.P.	Bushy	Lodging	Blue	Brown
Rashmi	Gaurav x Janki	CSAUAT, Kanpur (U.P.)	Erect	Non-lodging	Blue	Brown
RLC-92	Jeevan x LCK-9209	IGKV, Raipur (CG)	Erect	Non-lodging	Pale blue	Brown
Ruchi	---	CSAUAT, Kanpur (U.P.)	Semi-erect	Non-lodging	White	Brown
S-36	---	India	Semi erect	Lodging	Blue	Brown
Sharda	(Shubhra x J-1) x (J-1 x Kiran)	IGKV, Raipur (CG)	Erect	Non-lodging	White	Brown
Sheela	Gaurav x Janki	CSAUAT, Kanpur (U.P.)	Erect	Non-lodging	Pale blue	Brown
Shekhar	Laxmi-27 x EC-1387	CSAUAT, Kanpur (U.P.)	Erect	Non-lodging	Blue	Brown
Shikha	Hira x CRISTA	CSAUAT, Kanpur (U.P.)	Semi erect	Lodging	Blue	Brown
Shival	---	Nagpur, MH	Bushy	Lodging	White	Brown
Shubhra	Mukta x K-2	CSAUAT, Kanpur (U.P.)	Erect	Non-lodging	White	Brown
Subhra	---	India	Erect	Non-lodging	White	Brown
Surabhi	LC-216 × LC-185	Kangra Valley, HP	Erect	Non-lodging	Pale blue	Brown
Suyog	Kiran x KL168 x Kiran	Sagar, MP	Erect	Non-lodging	White	Brown
Sweta	Mukta x T-1206	CSAUAT, Kanpur (U.P.)	Erect	Non-lodging	Blue	Yellow
T-397	T-491 x T-1103-1	CSAUAT, Kanpur (U.P.)	Semi-erect	Non-lodging	Blue	Brown
J-7	---	Jabalpur, M.P.	Semi-erect	Non-lodging	Blue	Brown

Table 2 AMMI analysis of variance of yield and related traits for 50 linseed genotypes grown over 3 years

Sources of variation	Degree of freedom	Sum of squares	Mean sum of squares	F value	Pr (>F)	% explained	% accumulated	Sum of squares	Mean sum of squares	F value	Pr(>F)	% explained	% accumulated
		Number of bolls/plant						Number of seeds/boll					
Environment (E)	2	56	28.09	0.03	0.9747	0.05		1.11	0.56	0.07	0.936773	0.75	
Rep(E)	3	3256	1085.42	41122.74	<2e-16***	3.15		25.01	8.34	200.75	< 2.2e-16***	16.88	
Genotype (G)	49	99864	2038.03	77214.18	<2e-16***	96.50		109.70	2.24	53.90	< 2.2e-16***	74.01	
G×E interaction	98	309	3.16	119.60	<2e-16***	0.30		6.28	0.06	1.54	0.008498**	4.24	
IPCA1	50	277.04	5.54	209.92	0	89.6	89.60	4.73	0.09	2.28	0.00	75.20	75.20
IPCA2	48	32.32	0.67	25.51	0	10.4	100.00	1.56	0.03	0.78	0.84	24.80	100.00
Residuals	147	4	0.03			0.004		6.11	0.04			4.12	
		Seed yield/plant (g)						Oil content (%)					
Environment (E)	2	0.68	0.34	2.68E-02	0.9738	0.08		0.00	0.00	0.00E+00	1	0.00	
Rep(E)	3	38.00	12.67	2.65E+29	<2e-16***	4.29		131.25	43.75	3.02E+29	<2e-16***	7.94	
Genotype (G)	49	832.30	16.99	3.56E+29	<2e-16***	94.06		1522.10	31.06	2.15E+29	<2e-16***	92.06	
G×E interaction	98	13.85	0.14	2.96E+27	<2e-16***	1.57		0.00	0.00	1.01E+00	0.4842	0.00	
IPCA1	50	11.03	0.22	4.62E+27	0	79.60	79.60	0	0	6.72	0	99.90	99.90
IPCA2	48	2.82	0.06	1.23E+27	0	20.40	100.00	0	0	0.01	1	0.10	100.00
Residuals	147	0.00	0.00			0.00		0.00	0.00			0.00	

IPCA= Interaction Principal Component Analysis Axis; Significance codes: '***'=0.001, '**'=0.01, '*'=0.05

and S-36 had high bolls yield and quite stability (Fig. 2b). IC96461 was most stable genotype identified for the number of seeds/boll (Fig. 2b). Genotypes Sweta, Pusa-2, Janki, Subhra and JLS-9 were unstable for seeds/boll (Fig. 2b). Sharda and Neela were identified as high yield and quite stable genotypes for seed yield/plant whereas EC41528, Pratap Alsi-1, J-7, Shival and IC96491 were the most stable. RLC-92 and Subhra were the most desirable genotypes as it posses high seed yield and stability (Fig. 3c). The genotypes Meera, Padmini, Sweta, Suyog, S-36 and Parvati were unstable for seed yield/plant in linseed (Fig. 2c). The genotypes LC-54 and S-36 were most stable while Kartika and Parvati had high yield and quite stable for oil content. NL-97 and IC54970 were most desirable as they possessed higher oil content with more stability while Pratap Alsi-1, Subhra and Sheela were unstable for oil content (Fig. 2d). Results of AMMI1 and AMMI2 biplot analyses differed for most of the genotypes for number of bolls/plant, seeds/boll, seed yield/plant and oil content with some exceptions that indicated the different sets of genes and effect of environment on the cumulative expression of traits under study. Overall the desirable genotypes identified through the AMMI2 analysis were Suyog, Sharda for number of bolls/plant; Hira, Shubhra and IC54970 for seeds/boll; RLC-92 and Subhra for seed yield/plant and NL-97 and IC54970 for oil content. The contribution of AMMI2 to GEI sum of squares was in conformity with the previous studies of Alem and Tadesse (2014), Chobe and Ararsa (2018), Lirie *et al.* (2013) and Tadesse *et al.* (2017) in linseed.

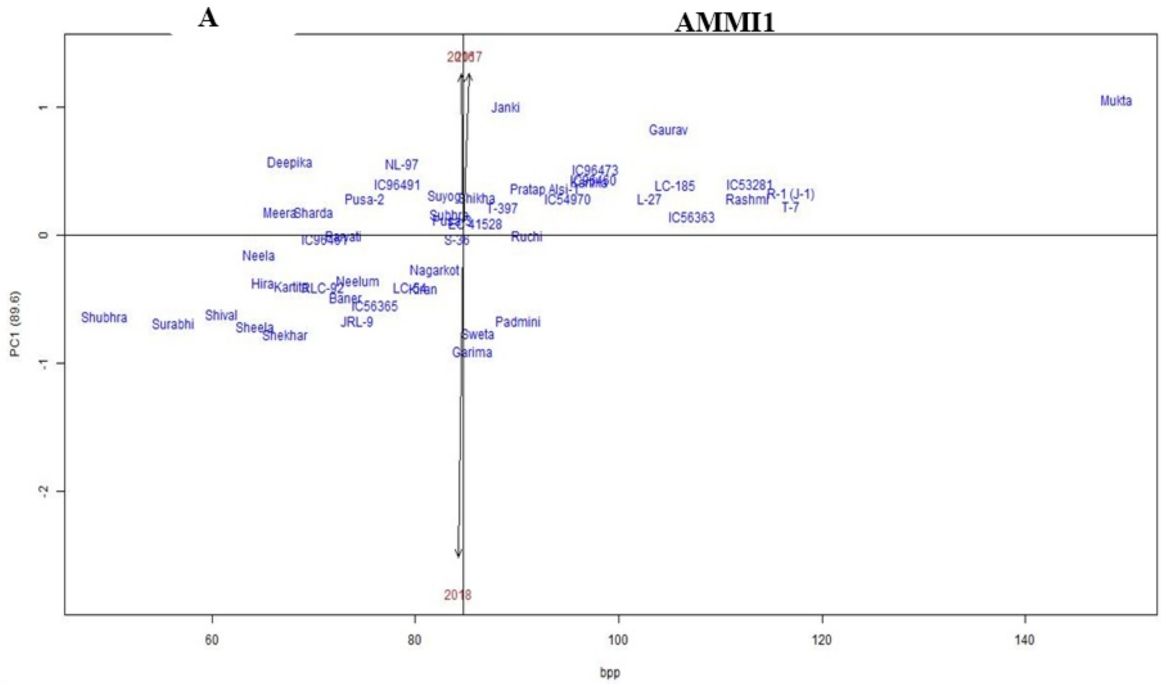
Environments with IPCA1 scores nearly or equal to zero have small contribution to the interactions and accordingly have large contribution to the stability of genotypes (Oliveira *et al.,* 2009; Akter *et al.,* 2014). The AMMI1 biplot graph of number of bolls/plant, seeds/boll, seed yield/plant and oil content showed that environments 2016, 2017 (moderate) and 2018 (low); 2017 (high), 2016 (moderate) and 2018 (low); 2017 (high), 2016 (moderate) and 2018 (low) and 2017, 2018 (moderate) and 2016 (low) contributed for stability of genotypes in linseed (Fig. 1a to d respectively). The AMMI2 biplot graphs showed similar response of the environment effects for all the characters studied as in case of AMMI1 analysis (Figs. 2a, 2b, 2c and 2d respectively). In AMMI2, environments placed near to the origin with low values of IPCA1 and IPCA2 had small contribution to the GE interaction, but large contribution to the stability of genotypes. AMMI2 biplot may be more accurate to extract GEI variation as it contains information of two IPCAs and greater pattern proportion compared to the AMMI1. AMMI2 model is simple and elucidates the stability, genotypic performance, genetic variance between genotypes, and the environments that optimize varietal performance (Miranda *et al.,* 2009). In the AMMI2 biplot graph, similar genotypes and environments have positive associations and placed near the origin of biplot of stable genotypes (Silveira *et al.,* 2013). In the present study environments imposed similar effects towards the genotypes in both AMMI1 and AMMI2 analysis models for all the traits studied (Alem and Tadesse, 2014; Chobe and Ararsa, 2018; Tadesse *et al.,* (2017).

Table 3 Average number of bolls/plant and number of seeds/boll of linseed (Y) and other stability parameters: Additive Main effects and Multiplicative Interaction (AMMI) stability Index (ASI), rankings of mean yield (rY), rankings of ASI (rASI) and Simultaneous Selection Index (SSI)

Genotype	Number of bolls/plant					Number of seeds/boll				
	Y	ASI	rY	rASI	SSI	Y	ASI	rY	rASI	SSI
Baner	73.15	0.44	36	34	70	6.23	0.18	49	42	91
Deepika	67.72	0.51	42	38	80	7.63	0.21	20.5	45	65.5
EC 41528	85.98	0.09	21	5	26	7.13	0.10	38	24	62
Garima	85.68	0.81	22	48	70	7.20	0.13	36.5	33	69.5
Gaurav	104.95	0.75	8	47	55	8.07	0.16	8	39	47
Hira	65.08	0.33	45	24	69	7.93	0.13	10.5	31	41.5
IC53281	112.95	0.36	4	28	32	7.60	0.05	22	9	31
IC54970	95.02	0.25	13	16	29	8.40	0.09	4	19	23
IC56363	107.22	0.14	6	7	13	8.70	0.01	1	2	3
IC56365	76.08	0.49	32	36	68	7.70	0.01	19	4	23
IC96460	97.55	0.40	11	33	44	7.75	0.12	15	30	45
IC96461	71.15	0.02	38	3	41	7.83	0.04	13	8	21
IC96473	97.75	0.46	10	35	45	7.90	0.01	12	5	17
IC96491	78.35	0.36	31	27	58	7.93	0.10	10.5	23	33.5
Janki	88.95	0.91	17	49	66	8.63	0.07	3	16	19
JLS-9	74.35	0.60	34	42	76	7.57	0.06	24	15	39
Kartika	97.08	0.37	12	31	43	7.10	0.01	39.5	1	40.5
Kirtika	67.92	0.35	41	26	67	7.23	0.11	34	26	60
Kiran	80.85	0.38	28	32	60	8.17	0.04	7	7	14
LC-27	103.12	0.27	9	19	28	7.77	0.09	14	18	32
LC-185	105.62	0.35	7	25	32	6.80	0.06	44.5	12	56.5
LC-54	79.48	0.36	29	30	59	8.00	0.09	9	21	30
Meera	66.72	0.16	44	11	55	7.23	0.25	34	48	82
Mukta	148.98	0.95	1	50	51	7.57	0.14	24	35	59
Nagarkot	81.95	0.25	27	14	41	7.20	0.13	36.5	32	68.5
Neela	64.68	0.14	46	8	54	8.63	0.11	2	27	29
Neelum	74.32	0.32	35	22	57	6.60	0.30	47	49	96
NL-97	78.68	0.50	30	37	67	7.63	0.21	20.5	46	66.5
Padmini	90.15	0.60	16	41	57	7.40	0.15	28.5	37	65.5
Parvati	73.02	0.01	37	1	38	6.80	0.06	44.5	14	58.5
Pratap Alsi-1	92.72	0.32	14	23	37	7.10	0.22	39.5	47	86.5
Pusa-2	75.02	0.25	33	15	48	7.37	0.15	30	36	66
Pusa-3	83.65	0.11	24	6	30	5.80	0.06	50	13	63
R-1 (J-1)	116.92	0.29	3	21	24	7.50	0.08	26	17	43
Rashmi	112.72	0.26	5	17	22	7.43	0.16	27	38	65
RLC-92	70.98	0.36	39	29	68	6.87	0.17	43	40	83
Ruchi	91.02	0.05	15	4	19	6.90	0.05	42	11	53
S-36	84.15	0.02	23	2	25	7.00	0.20	41	44	85
Sharda	70.02	0.16	40	10	50	7.27	0.17	32	41	73
Sheela	64.32	0.64	47	44	91	7.73	0.04	16.5	6	22.5
Shekhar	67.15	0.69	43	46	89	8.20	0.09	6	22	28
Shikha	86.05	0.27	20	18	38	7.70	0.05	18	10	28
Shival	60.98	0.56	48	39	87	6.37	0.31	48	50	98
Shubhra	49.45	0.57	50	40	90	8.37	0.14	5	34	39
Subhra	83.38	0.15	25	9	34	7.30	0.11	31	29	60
Surabhi	56.28	0.62	49	43	92	7.57	0.20	24	43	67
Suyog	82.88	0.28	26	20	46	6.70	0.01	46	3	49
Sweta	86.18	0.68	19	45	64	7.73	0.11	16.5	28	44.5
T-397	88.62	0.19	18	12	30	7.23	0.11	34	25	59
J-7	116.95	0.20	2	13	15	7.40	0.09	28.5	20	48.5

Table 4 Average seed yield/plant and oil content (Y) and other stability parameters: Additive Main effects and Multiplicative Interaction (AMMI) stability Index (ASI), rankings of mean yield (rY), rankings of ASI (rASI) and Simultaneous Selection Index (SSI)

Genotype	Seed yield/plant (g)					Oil content (%)				
	Y	ASI	rY	rASI	SSI	Y	ASI	rY	rASI	SSI
Baner	7.52	0.08	10	17	27	35.64	3.61E-07	42	50	92
Deepika	5.56	0.22	32	38	70	34.4	2.46E-08	46	39	85
EC 41528	6.11	0.03	28.5	5	33.5	41.39	3.36E-09	1.5	3	4.5
Garima	7.48	0.31	12	47	59	34.13	1.76E-08	50	35	85
Gaurav	6.15	0.04	26	6	32	36.57	9.30E-08	36	49	85
Hira	6.19	0.03	24	3	27	34.37	1.31E-08	48	27	75
IC53281	5.53	0.11	33	27	60	41.39	4.00E-08	1.5	46	47.5
IC54970	8.43	0.23	4	40	44	39.86	1.92E-08	15	36	51
IC56363	7.73	0.11	7	26	33	37.88	2.99E-08	26	43	69
IC56365	7.28	0.11	15	24	39	40.05	1.01E-08	13	22	35
IC96460	6.30	0.08	23	19	42	37.7	6.92E-09	27	11	38
IC96461	8.63	0.08	3	20	23	40.72	1.95E-08	7	38	45
IC96473	6.06	0.11	30	25	55	38.64	2.92E-08	19	42	61
IC96491	7.38	0.04	14	8	22	39.39	1.50E-08	16	31	47
Janki	5.75	0.13	31	32	63	36.29	1.38E-08	38	29	67
JLS-9	6.11	0.06	28.5	13	41.5	40.45	2.59E-08	9	40	49
Kartika	6.19	0.04	25	7	32	41.21	5.18E-08	4	48	52
Kirtika	4.27	0.02	43	2	45	37.68	1.16E-08	28	25	53
Kiran	2.92	0.06	49	12	61	38.43	4.02E-08	21	47	68
L-27	6.43	0.05	22	11	33	37.19	1.62E-08	30	33	63
LC-185	5.23	0.05	36	10	46	40.53	7.27E-09	8	12	20
LC-54	3.00	0.11	47	23	70	37.23	6.07E-09	29	8	37
Meera	7.74	0.25	6	44	50	36.51	2.72E-08	37	41	78
Mukta	7.05	0.08	18	18	36	36.71	7.85E-09	33	16	49
Nagarkot	5.50	0.12	34	31	65	40.06	3.33E-08	12	45	57
Neela	4.55	0.30	40	46	86	38.03	1.06E-08	23	23	46
Neelum	8.64	0.12	2	29	31	36.72	1.63E-08	32	34	66
NL-97	3.60	0.22	44	39	83	40.1	1.13E-08	10	24	34
Padmini	5.09	0.28	37	45	82	41.33	1.32E-08	3	28	31
Parvati	7.50	0.17	11	35	46	36	3.27E-08	39	44	83
Pratap Alsi-1	6.73	0.05	20.5	9	29.5	34.49	8.89E-10	43	1	44
Pusa-2	6.73	0.12	20.5	30	50.5	39.99	6.57E-09	14	10	24
Pusa-3	7.12	0.07	17	16	33	36.6	1.94E-08	35	37	72
R-1 (J-1)	7.68	0.44	8	50	58	40.91	7.66E-09	6	15	21
Rashmi	5.37	0.02	35	1	36	37.95	3.80E-09	25	6	31
RLC-92	4.47	0.14	41	33	74	37.17	1.53E-08	31	32	63
Ruchi	2.97	0.06	48	14	62	34.41	1.48E-08	44	30	74
S-36	2.72	0.43	50	49	99	38.01	2.60E-09	24	2	26
Sharda	3.39	0.39	45	48	93	38.1	8.04E-09	22	19	41
Sheela	8.12	0.20	5	36	41	34.33	3.46E-09	49	4	53
Shekhar	4.74	0.16	38	34	72	35.85	6.41E-09	40	9	49
Shikha	6.15	0.10	27	21	48	36.7	3.52E-09	34	5	39
Shival	4.67	0.06	39	15	54	39.28	7.98E-09	17	17	34
Shubhra	3.05	0.10	46	22	68	34.4	7.56E-09	46	14	60
Subhra	6.75	0.23	19	41	60	34.4	1.30E-08	46	26	72
Surabhi	7.57	0.21	9	37	46	41.11	8.03E-09	5	18	23
Suyog	4.28	0.24	42	42	84	38.48	5.75E-09	20	7	27
Sweta	7.39	0.24	13	43	56	40.08	9.79E-09	11	20	31
T-397	9.01	0.12	1	28	29	35.67	7.47E-09	41	13	54
J-7	7.26	0.03	16	4	20	39.23	9.94E-09	18	21	39



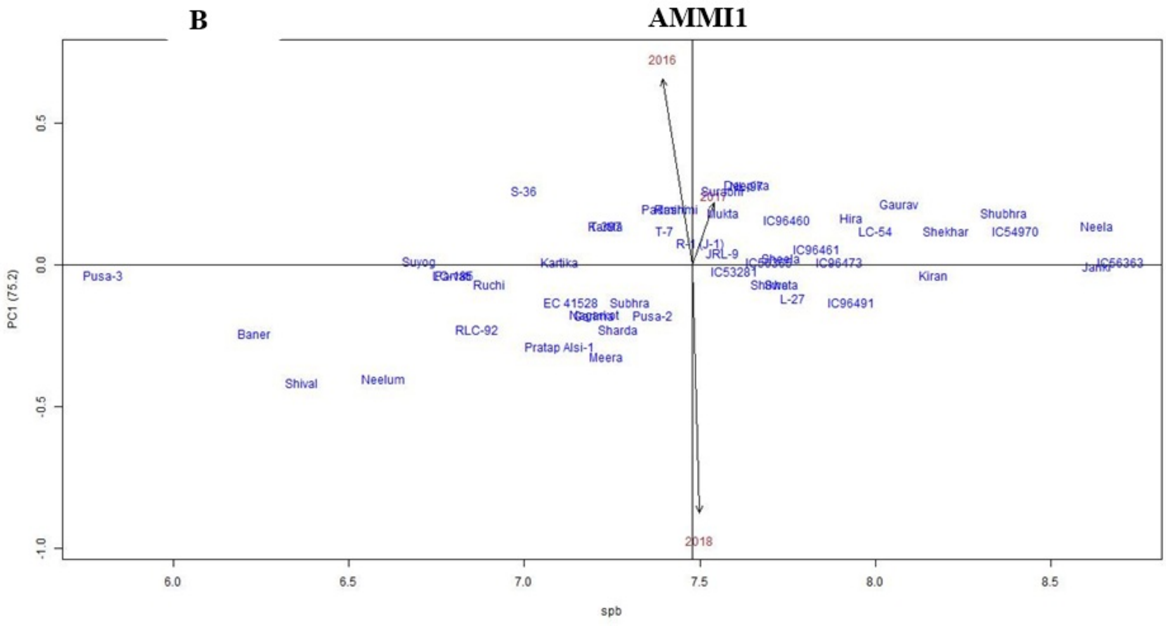


Fig. 1. AMMI biplot showing AMMI1 for a. number of bolls/plant and b. seeds/boll of 50 linseed genotypes

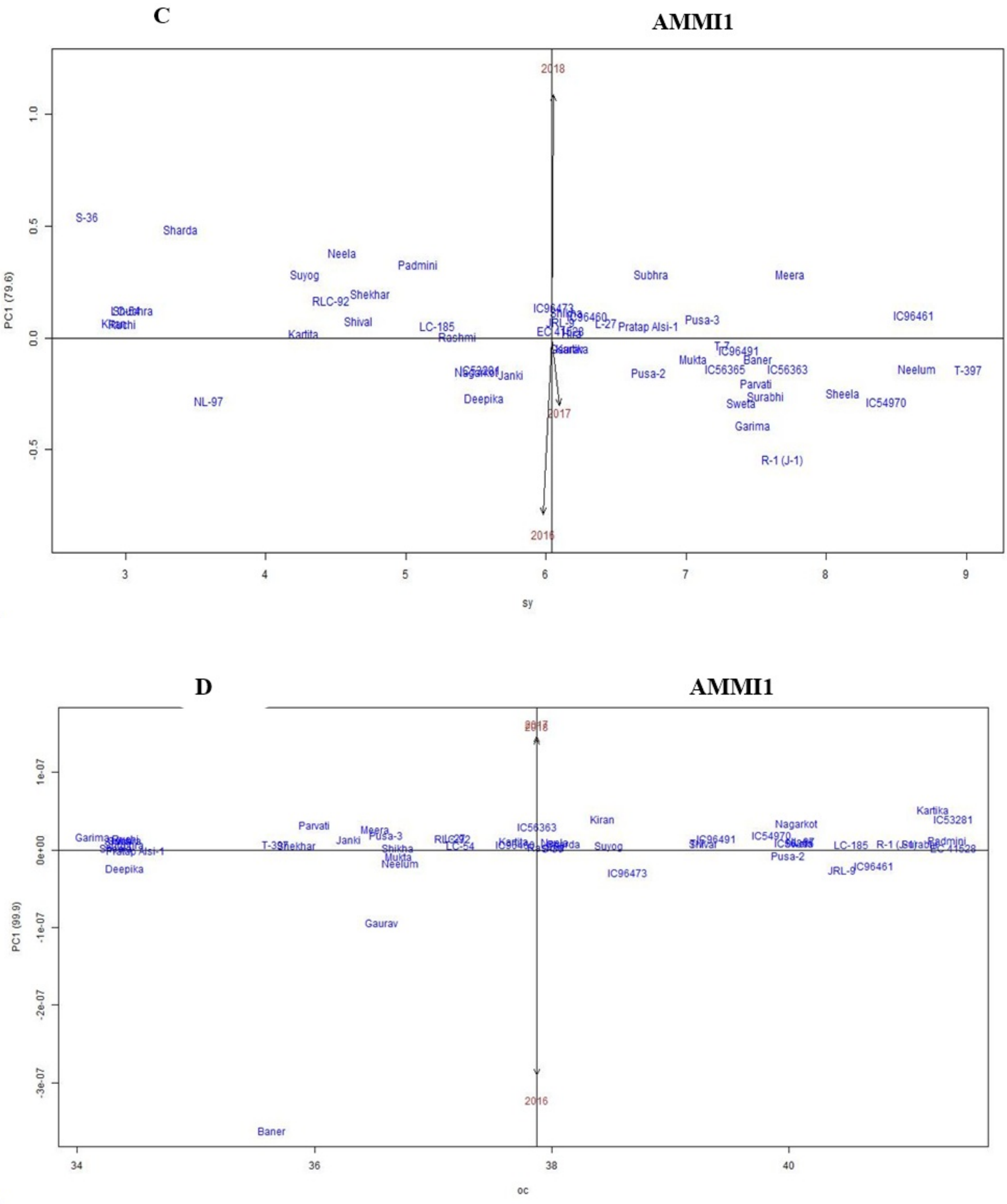


Fig. 1. AMMI biplot showing AMMI1 for c. seed yield/plant and d. oil content of 50 linseed genotypes

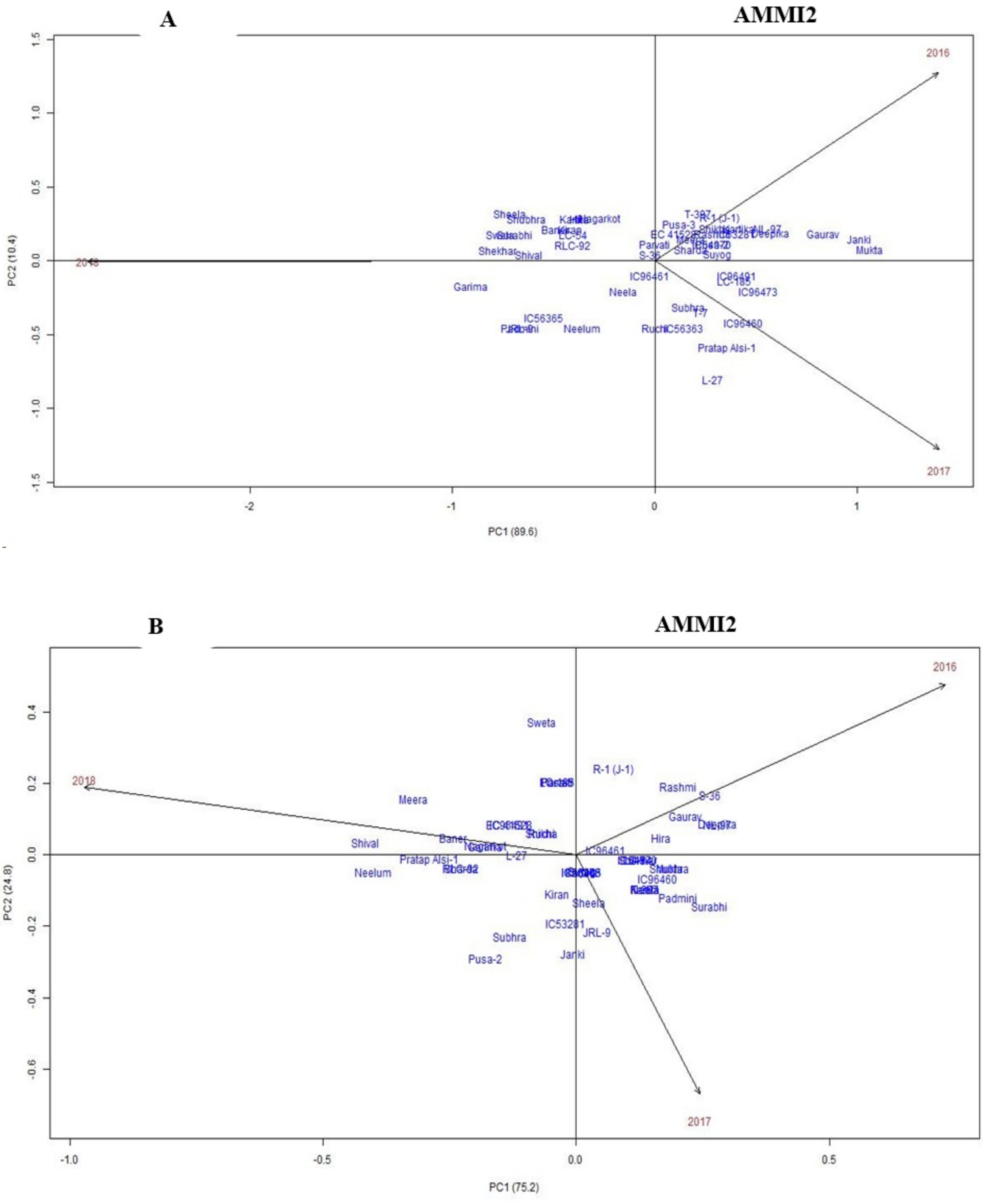
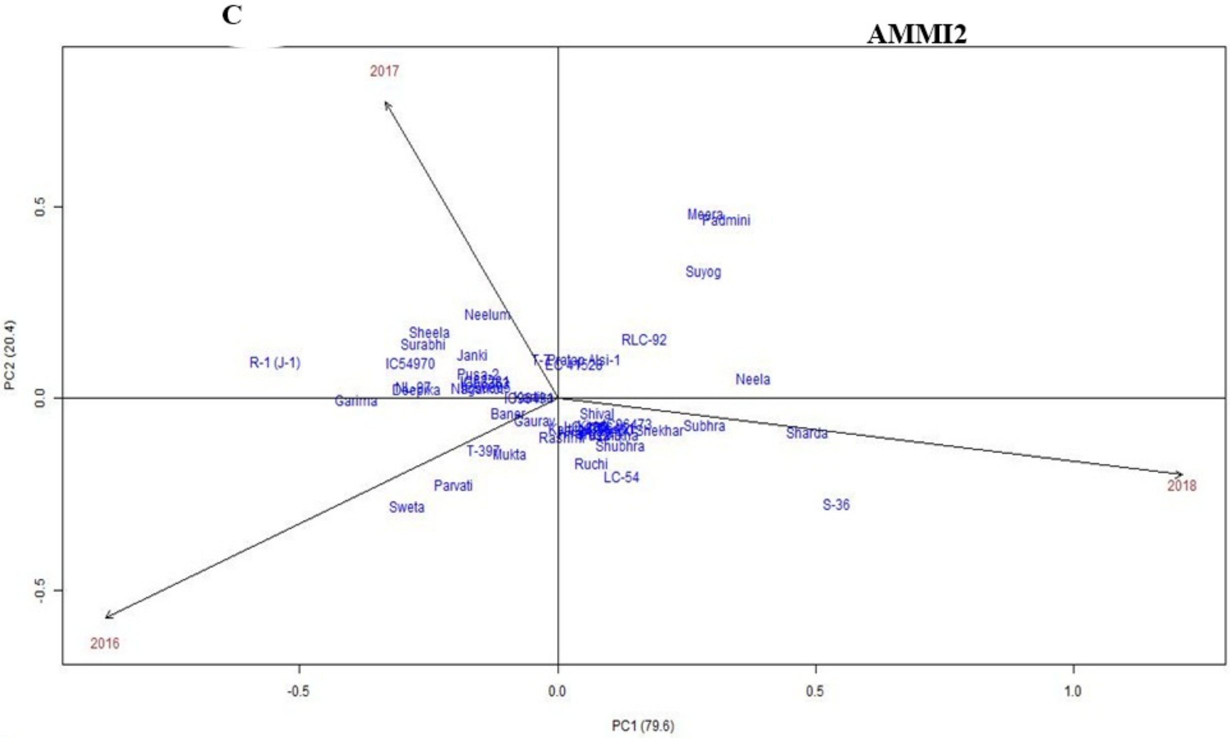


Fig. 2. AMMI biplot showing AMMI2 for a. number of bolls/plant and b. seeds/boll of 50 linseed genotypes



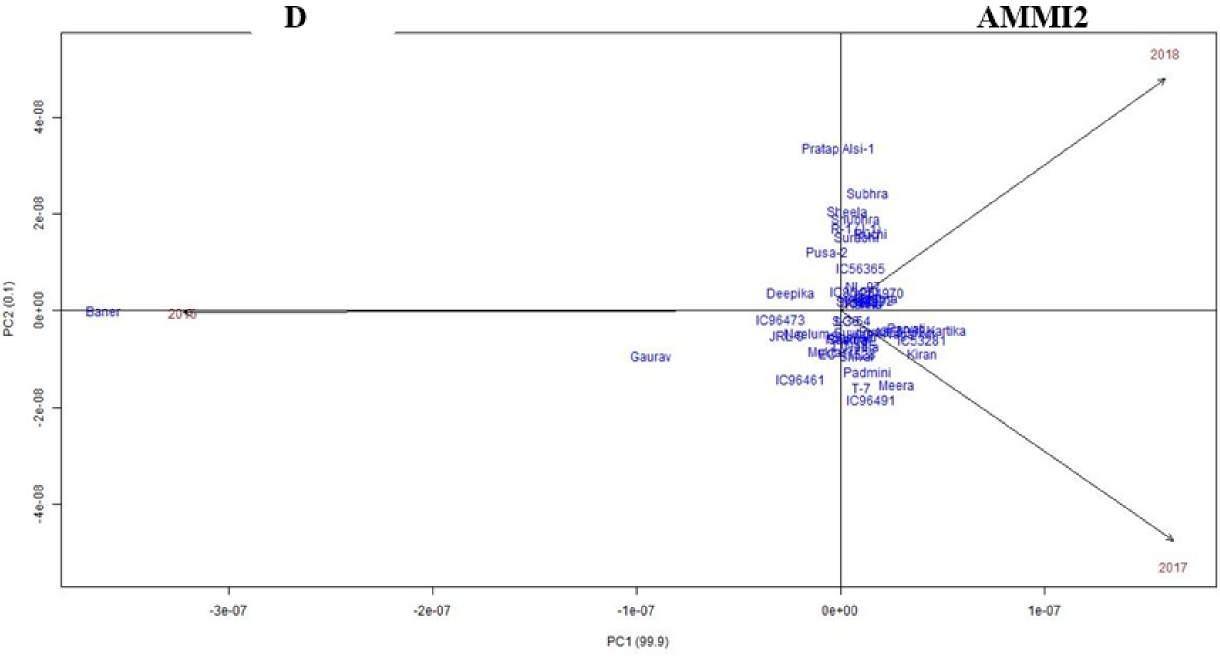


Fig. 2. AMMI biplot showing AMMI2 for c. seed yield/plant and d. oil content of 50 linseed genotypes

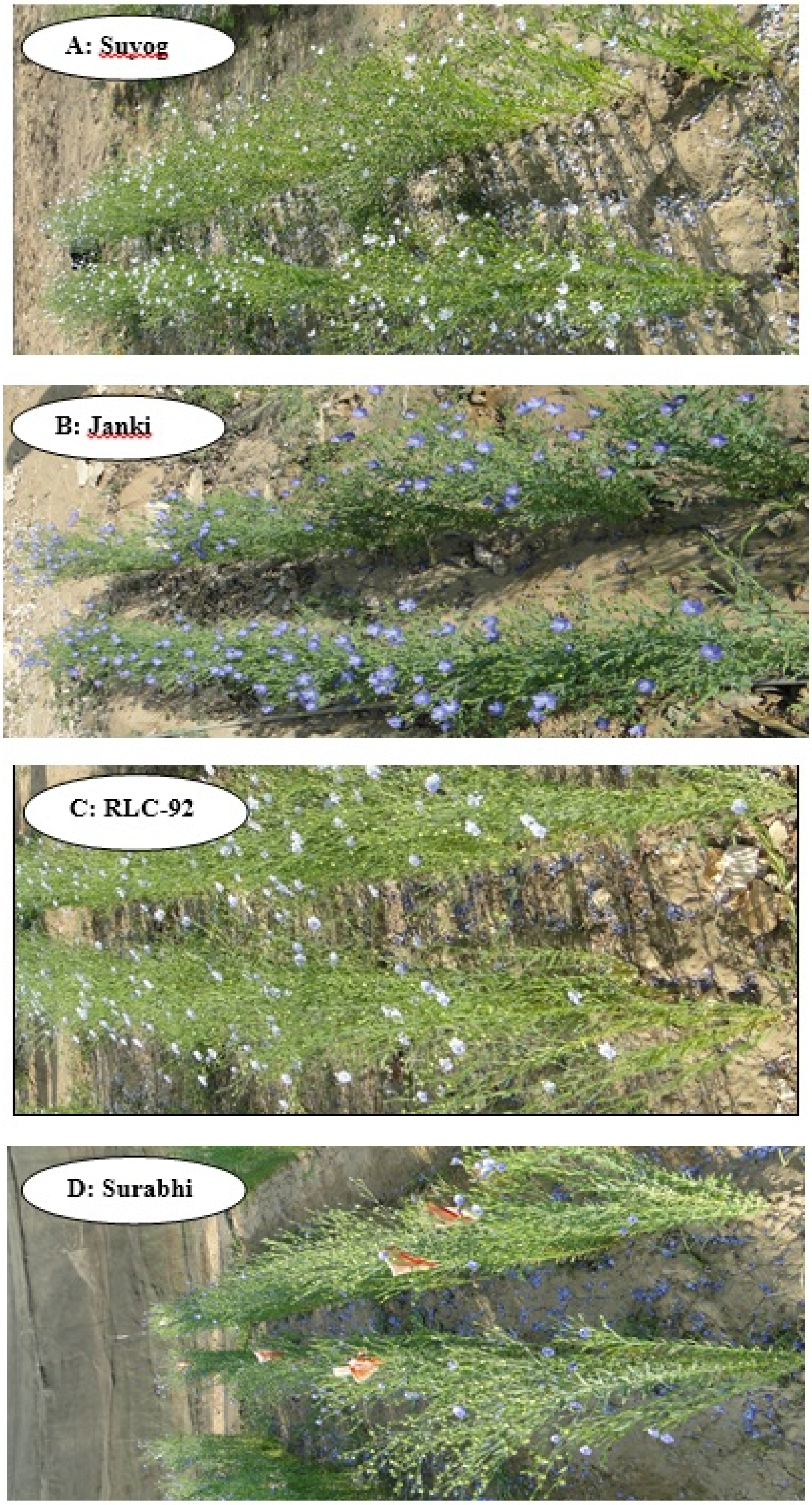


Fig. 3. Diagram showing desirable linseed genotypes a. Suyog (bolls/plant), b. Janki (seeds/boll) c. RLC-92 (seed yield) and d. Surabhi (oil content)

The AMMI model is effective as it contributes to a large portion of the GEI sum of squares and separate the main and interaction effects. This model is valuable for identifying the stable genotypes across environments. The results showed that the AMMI1 and AMMI2 biplot models had differential response for number of bolls/plant, seeds/boll, seed yield/plant and oil content in sight of genotype performance across the environments. This indicated that trait is governed by different sets of genes and effect of environment on the cumulative expression of different set of genes will vary considerably. Similar results were obtained for environmental contribution towards the genotype performance in both AMMI1 and AMMI2 analysis for all the traits studied. The results of SSI statistic agreed with the results of the AMMI1 biplot models for number of bolls/plant, seeds/boll, seed yield/plant and oil content of top ranked genotypes in all environments

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REFERENCES

Akter A, Jamil Hassan M, Umma Kulsum M, Islam M R and Hossain K 2014. AMMI biplot analysis for stability of grain yield in hybrid rice (*Oryza sativa*). *Journal of Rice Research*, **2**(2): 126-129.

Alem C and Tadesse D 2014. Study on genotype x environment interaction of seed yield, oil content, fatty acid profile and stability analysis of related trait in linseed (*Linum usitatissimum* L.) in north western Ethiopia. *International Journal of Plant Breeding and Genetics*, **8**(2): 66-73.

Anonymous 2005. *Linseed: Technology for increasing production,* Project Co-ordinator, Project Co-ordinating Unit (Linseed), C. S. Azad University of Agriculture and Technology Campus, Kanpur.

Berti M, Fischer S, Wilckens R, Hevia F and Johnson B 2010. Adaptation and genotype × environment interaction of flaxseed (*Linum usitatissimum* L.) genotypes in South Central Chile. *Chilean Journal of Agricultural Research*, **70**: 345-356.

Chobe A C and Ararsa A D 2018. AMMI and GGE biplot analysis of linseed (*Linum usitatissimum* L.) genotypes in central and south-eastern highlands of Ethiopia. *Journal of Plant Breeding and Genetics*, **6**(3): 117-127.

Cornelius P L, Crossa J and Seyedsadr M S 1996. Statistical tests and estimators of multiplicative models for genotype-by-environment interaction. In: *Genotype-by-environment interaction,* Kang M S, Gauch H G (Eds.), CRC Press, Boca Raton, FL, USA, pp. 199-234.

Crossa J, Gauch H G and Zobel R W 1990. Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. *Crop Science*, **30**: 493-500.

Diederichsen A and Ulrich A 2009. Variability in stem fibre content and its association with other characteristics in 1177 flax (*Linum usitatissimum* L.) genebank accessions. *Industrial Crops and Products*, **30**: 33-39.

FAOSTAT 2018. FAO statistical data. http://faostat.fao.org.

Farshadfar E, Mahmodi N and Yaghotipoor A 2011. AMMI stability value and simultaneous estimation of yield and yield stability in bread wheat (*Triticum aestivum* L.). *Australian Journal of Crop Science*, **5**: 1837-1844.

Garcia-Hernandez V M, Hojjati M, Carbonell-Barrachina A A, Sánchez-Soriano J, Roche E and García-García E 2017. Comparison of soxhlet and ultrasound methods for oil extraction from Spanish flaxseeds. *Journal of Microbiology, Biotechnology and Food Sciences*, **7**(3): 332-336.

Jambhulkar N N, Bose L K and Singh O N 2014. AMMI stability index for stability analysis, January-March 2014, CRRI Newsletter, Central Rice Research Institute, Cuttack, Orissa, T Mohapatra (Ed.), Available at: http://www.crri.nic.in/CRRI_newsletter/crnl_jan_mar_14_web.pdf.

Lirie E, Habtamu Z and Adugna W 2013. AMMI analysis of yields and oil content in some linseed (*Linum usitatissimum* L.) genotypes in south and central Ethiopia. *Ethiopian Journal of Agriculture Sciences*, **24**: 79-98.

Miranda G V, Souza L V, Guimarães M, Lauro J M, Namorato H, Oliveira L R and Marcelo O S 2009. Multivariate analyses of genotype × environment interaction of popcorn. *Pesquisa Agropecuaria Brasileira,* **44**(1): 45-50.

Neisse AC, Kirch JL and Hongyu K 2018. AMMI and GGE Biplot for genotype × environment interaction: a medoid-based hierarchical cluster analysis approach for high-dimensional data. *Biometrical Letters*, **55**(2): 97-121.

Oliveira E J, de Freitas J P X and de Jesus O N 2009. AMMI analysis of the adaptability and yield stability of yellow passion fruit varieties. *Scientia Agricola*, **71**(2): 139-145.

Purchase J L, Hatting H, Van Deventer C S 2000. Genotype × environment interaction of winter wheat in South Africa: II. Stability analysis of yield performance. *South African Journal of Plant and Soil*, **17**: 101-107.

Rad M N, Kadir M A, Rafii M Y, Jaafar H Z, Naghavi M R and Ahmadi F 2013. Genotype environment interaction by AMMI and GGE biplot analysis in three consecutive generations of wheat (*Triticum aestivum*) under normal and drought stress conditions. *Australian Journal of Crop Science*, **7**(7): 956-961.

R Development Core Team 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org.

Reddy M P, Reddy B N, Arsul B T and Maheshwari J J 2013. Genetic variability, heritability and genetic advance of growth and yield components of linseed (*Linum usitatissimum* L.). *International Journal of Current Microbiology and Applied Sciences*, **2**: 231-237.

Silveira L C I, Kist V, Paula T O M, Barbosa M H P, Peternelli L A and Daros E 2013. AMMI analysis to evaluate the adaptability and phenotypic stability of sugarcane genotypes. *Scientia Agricola*, **70**(1): 27-32.

Soto-Cerda B J, Westermeyer F, In˜iguez-Luy F, Gasto´n Mun˜oz, Montenegro A and Cloutier S 2013. Assessing the agronomic potential of linseed genotypes by multivariate analyses and association mapping of agronomic traits. *Euphytica*, doi: 10.1007/s10681-013-1012-1.

Tadesse T, Parven A, Singh H and Weyessa B 2010. Estimates of variability and heritability in linseed germplasm. *International Journal of Sustainable Crop Production*, **5**: 8-16.

Tadesse T, Tekalign A, Sefera G and Muligeta B 2017. AMMI model for yield stability analysis of linseed genotypes for the highlands of Bale, Ethiopia. *Plant*, **5**(6): 93-98.

Vavilov N I 1951. The origin, variation, immunity and breeding of cultivated plants. *Chronica Botanica*, **13**: 20-43.

Worku N, Heslop-Harrison J S and Adugna W 2015. Diversity in 198 Ethiopian linseed (*Linum usitatissimum*) accessions based on morphological characterization and seed oil characteristics. *Genetic Resources and Crop Evolution*, **62**: 1037-1053.

Yan W, Kang M S, Ma B, Woods S and Cornelius P L 2007. GGE Biplot vs. AMMI analysis of genotype-by-environment data. *Crop Science*, **47**: 643-655.

Yan W and Tinker N A 2006. Biplot analysis of multi-environment trial data: Principles and applications. *Canadian Journal of Plant Science*, **86**(3): 623-645.

Zobel R W, Wright M J and Gauch H G 1988. Statistical analysis of a yield trials. *Agronomy Journal*, **80**: 388-393.

Development of web-based system for soybean insect pests management

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ABSTRACT

The paper describes the development of a web-based system for identification of soybean insects and their management. It presents the system design, development methodology, functionality and utility of the system. The user interface of the system is developed using ASP.NET and backend using SQL. It is designed using responsive web design so that the users can easily use the system on different devices with variable screen sizes-Desktops, Laptops, iPads, Tablets and Mobile phones. The system is accessible from the institute website https://iisrindore.icar.gov.in. It is very useful for farmers in taking right decision at right time in their fields. The users could identify the insects correctly with the image-based identification interface. The information in Hindi language will help farmers to easily understand the contents. The system was evaluated on eight user interface design features on 1-10 point scale. The overall average rating was more than 8 points indicating that most of the evaluators were satisfied with the user interface. It served as an effective IT tool for farmers to take appropriate and timely measures to minimize field losses due to insect attack.

Keywords: Agriculture, Insect identification, Insect Management, Soybean, Web-based System

Soybean [*Glycine max* (L.) Merril)] has a prominent place among modern agricultural commodities, as the world's most important seed legume, which contributes about 25% to the global edible oil production, about two thirds of the world's protein concentrate for livestock feeding and is a valuable ingredient in formulated feeds for poultry and fish. It is also an important commodity for food manufacturers, pharma industry and many more industrial uses (AICRPS Report, 2019). At present, the crop is grown in ~11.0 million hectares in India with a production of 13.7 million tons (Annual Report, 2019). The abiotic and biotic stresses have serious influence on soybean production. Unfortunately, this crop is attacked by 350 species of insects in different parts of the world (Luckmann, 1971). The insect attack is one of the major factors affecting the crop production. It causes losses upto 25-30% and in some cases upto 100% (Sharma, 2013). Pest management is a highly challenging problem that needs immediate attention otherwise it may lead to severe yield losses during insect-pest outbreak. The experts for identification of soybean insects and their management may not be available everywhere at the time of incidences of insect attacks.

Web-based systems have been widely used for effective decision-making in different agriculture scenarios (Rok *et al.,* 2019; Lagos-Ortiz *et al.,* 2019; Cambra *et al.,* 2019; Ángel *et al.,* 2019; Bhaskar *et al.,* 2019). Information system is a computer application that presents information in textual form, figures, tables and graphs or a combination of these so that users can make decisions more easily. Soybean cultivators and soya advisors need pest information in different forms to reach right decision. They can then use this information to make their own decisions on when and how to control pests. Therefore, a web-based information system was developed to get immediate information for insect identification and to take proactive decisions for their effective management.

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MATERIALS AND METHODS

The web-based system was developed using C# language of ASP.NET framework. Three-tier software architecture was used for this process. The detailed structure of three tiers of the system included:

Presentation Layer (User Interface Layer): It has interface with menu options for giving inputs of insect symptoms based on morphology and damage, integrated pest management, predisposing climatic conditions for insect attack, losses by insect attack, image gallery, video gallery, other important information and data management of soybean insects. It also contains forms for producing output results based on user inputs to display complete information about the identified insects, specific information selected by the user viz. monthly outbreak of insects, recommended doses of insecticides, fungicides, pesticides, insect resistant soybean varieties available etc.

Business Logic Layer (used for writing the logic code): It is the middle layer that communicates with the presentation layer and data access layer. It contains all the experts' technical knowledge for insect identification based on insect morphology and type of damage observed in the field. It also provides appropriate management practices for timely control of insect attack. It also has validation code for accurate data entry and information retrieval.

Data Access Layer (DAL used for connectivity with Database): It has all the data about twenty soybean insects, stages of insect life cycle, their morphology, damage symptoms, management, losses etc stored in the database tables. It also has stored procedures and database queries for correct information retrieval. It also has connection string to connect to the SQL Server database to provide information to the logical layer.

The system has different modules for image-based identification of insects and their effective management. These are - i) Insect Morphology based insect identification, ii) Damage symptom based insect identification, iii) Insect-pest management, iv) Insect information retrieval, v) Image gallery and vi) Video gallery. The system design can be understood better with the Entity-Relationship diagram as shown in Fig. 1.

The system also has Insect Data Management subsystem for adding new insect information, modifying the existing insect data and other important information. Soybean Insects database is developed to store data on different aspects *viz.* scientific name, morphology, distribution, damage detail, economic impact, management, photos and videos. Presently it has data on 20 soybean insects. The Data-flow of the insect data can be seen in Fig. 2.

Different methods used for correct identification of soybean insects based on multiple criteria included (as adopted by Saini *et al.,* 2002).

Morphology based identification- It is an identification method based on appearance of insect or morphological characters. The insect morphology is divided into three categories based on insect stages- Caterpillar, Moth and Adult.

Part Affected- It is identification based on the part of the plant affected by the insect attack. The parts of plant affected are - Stem, Leaf, Pod, Sap sucking and Root.

Type of Damage- It is based on the type of damage caused by the insects in the field.

Symptom based identification- It is based on feeding habits (Table 1) of the insects and the damage caused to the crop.

Image or Picture based identification- It is insect identification based on images of different morphology of insects and damage caused by them.

Diagnosis and Management- It provides detailed information regarding the insects and their effective management practices for its control.

Table 1 Classification of Insects based on their feeding habits

Feeding habits	Insects
Stem borers	Stem fly [*Melanagromyza sojae* (Zehntner)] Girdle beetle [*Obereopsis brevis* (Swedenbord)]
Defoliators	Blue beetle (*Cneorane* sp.) Green semiloopers [*Chrysodeixis acuta* (Walker) *Diachrysia orichalcea* (Fabricius)] Brown stripped semilooper (*Mocis undata* Fabricious) Tobacco caterpillar [*Spodoptera litura* (Fabricius)] Bihar hairy caterpillar [*Spilosoma obliqua* (Walker)]
Pod borer	Gram pod borer [*Heliothis armigera* (Hubner)] Leaf miner (*Aproaerema modicella* Deventer) Leaf folder [*Hedylepta indicata* (Fabricius)]
Sap feeders	White fly (*Bemisia tabaci* Gennadius) Green stink bug (*Nezara viridula* Linnaeus)
Root feeders	White grub [*Holotrichia consanguinea* (Blanchard)]

RESULTS AND DISCUSSION

A web-based system was developed for identification and management of soybean insects. It was developed using responsive web design and therefore, it automatically accommodates for different screen sizes, resolution and image size based on settings on multiple types of devices like laptops, iPad, Tablets, Mobile phones etc. It has complete information in Hindi for better understandability by soybean growers across the country. It provides information on different aspects of soybean insects *viz.,* economic losses, pre-disposing climatic condition for insect attack, seasonal incidence of soybean pests during *kharif* season and friendly-insects of soybean. It also provides information on insect management *viz.,* recommended pesticides for soybean crops, use of insect resistant or tolerant varieties, recommended pesticide amount for spraying and use of chemical pesticides and scientific recommendations of integrated pest management in soybean.

The system is hosted on the institute server and is linked to the institute website http://iisrindore.icar.gov.in. The users can use the system by clicking the hyperlink "Insect Management System" on the website. The main home page of the system has different menu options for different purposes - i) Insect Information, ii) Integrated Insect Management, iii) Economic losses from insects, iv) Pre-disposing climatic conditions, v) Gallery, vi) Other important information and about system (Fig. 3).

- Insect information menu option facilitates the user to select the insect to get detailed information about it (Fig. 4). The user can select insect one by one to view their details and can thus gain knowledge about 20 soybean insects stored in the system.

- Integrated insect management provides the information on the recommended integrated pest management practices to different users.
- Economic losses by insect menu option provides information about the percentage of economic losses caused by different insects at different plant growth stages.
- Pre-disposing climatic conditions gives user the climatic conditions - Min and Max temperature, Relative Humidity and Rainfall pattern that are favorable for particular insect attack so that proactive action can be taken by the cultivators to avoid insect attacks.
- The other menu options are - Gallery and Other Important Information. Former gives Image and video gallery of different types of insects and their damage (Fig 5); and later gives other useful information as shown in Fig. 6.
- The menu option About System provides a shortcut to access all the information as it has links for different modes of information retrieval at one place (Fig 7). This makes the system easy to view particular information for novice users. Insect Data Management Subsystem allows authorized user to manage insect data into the system. After logging into the system (Fig 8), the user can add new insect information, edit and delete old insect information on different aspects as mentioned in aforesaid sections (Fig 9). Insect pictures and videos and their descriptions can also be added, edited and deleted with the options provided here. The user can also view the complete insect information that is already stored in the system by clicking the button provided in the interface (Fig. 9).

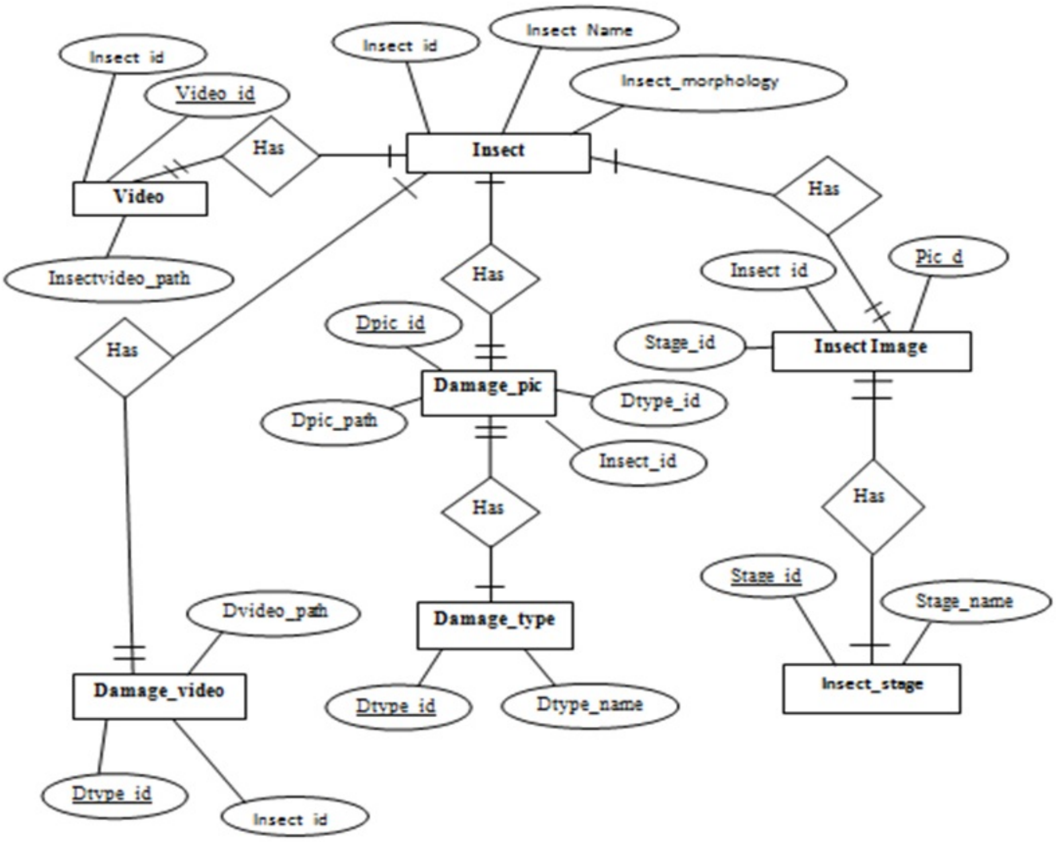

Fig. 1. Entity relationship diagram of the web-based system developed

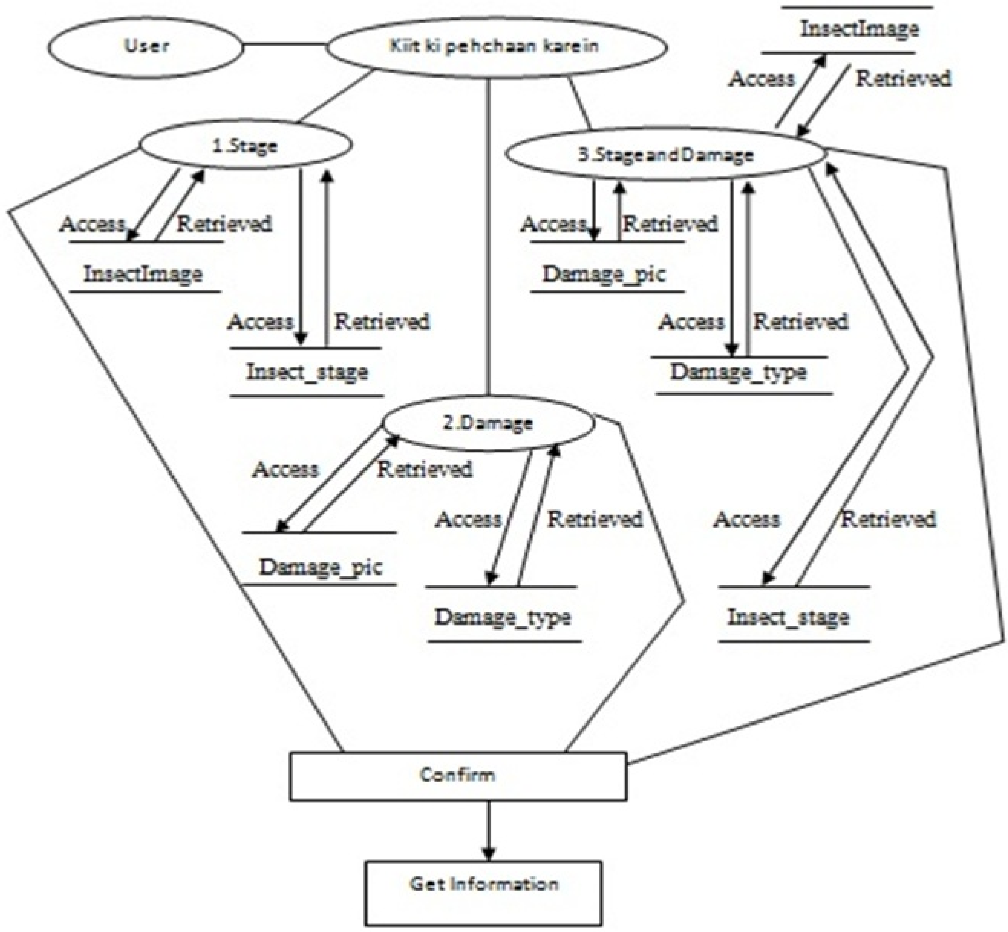

Fig. 2. Data flow diagram of soybean insects

Fig. 3. Snapshot of 'Main Menu Web Page' containing different menu options

Fig. 4. Web page showing Insect Information in detail based on the insect selected by user

Fig. 5 Screen shot showing Picture Gallery and Video Gallery links

Fig. 6. Screen showing different links provided in 'Other Important Information' of the system

Fig. 7. Different links at one menu option-About System

Fig. 8. Login window to allow only authorized users

Fig. 9. Web form for data management of Insect data

The system was evaluated based on the feedback given by a team of 20 agriculture researchers. The group was a combination of people with different levels of computer skills and exposure to agriculture websites and web applications. The system evaluators were asked to mark a feedback questionnaire form on 8 user interface design features - Ease of use, Navigation, Screen design, Content covered, Information presentation, Image-Video integration, Usefulness and Overall functionality. Each of the evaluation parameter was rated on 1-10 point scale with 1 being highly negative and 10 being highly positive. The overall average rating was more than 8 points indicating that most of the evaluators were satisfied with the user interface. It also showed that the interface developed was comfortably used by the evaluators.

The users were satisfied with easy-to-use interface design. The users could easily use the system on different devices with variable screen sizes-Desktops, Laptops, iPads, Tablets and Mobile phones, because of responsive web design of the system. The users could identify the insects correctly with the image-based identification interface. The information in Hindi language helped farmers to easily understand the contents. They found the system to be very useful in taking right decision at right time in their fields as it could be easily used on mobile phones also. The users of the system found that the system can serve as an educational/training tool or ready reckoner for soybean insect management. It can thus augment the conventional educational methodologies in specific courses in entomology. The system will enable farmers to take appropriate and timely measures to minimize field losses due to insect attack. This will ultimately help in increasing the national productivity of soybean.

REFERENCES

AICRPS Report 2019. *Annual Report 2018-19,* All India Coordinated Research Project on Soybean, ICAR-Indian Institute of Soybean Research, Indore, pp. 367.

Annual Report 2019. *Annual Report 2018-19,* ICAR-Indian Institute of Soybean Research, Indore, pp. 160.

Ángel Cobo, Ignacio Llorente, Ladislao Luna, Manuel Luna 2019. A decision support system for fish farming using particle swarm optimization. *Computers and Electronics in Agriculture*, **161**: 121-130.

Batchelor W D, McClendon R W, Adams D B and Jones J W 1989. Evaluation of SMARTSOY: An expert system for insect pest management. *Agricultural Systems*, **31**(1): 67-81.

Bhaskar B, Gardas, Rakesh D, Raut, Naoufel Cheikhrouhou, Balkrishna E and Narkhede 2019. A hybrid decision support system for analyzing challenges of the agricultural supply chain. *Sustainable Production and Consumption*, **18**: 19-32.

Carlos Cambra Baseca, Sandra Sendra, Jaime Lloret and Jesus Tomas 2019. A smart decision system for digital farming. *Agronomy*, **9**: 216.

Cirio U, Remotti P C, Santoro C and di Girolamo A 1998. Expert system for diagnosis of olive tree pests and diseases. *Phytoma-Espana (Espana),* **102**: 133-135.

Gonzalez-Andujar J L 2009. Expert system for pests, diseases and weeds identification in olive crops. *Expert Systems with Applications*, **36**(2): 3278-3283.

Kramers M A, Conijn C G M and Bastiaansen C 1998. EXSYS, an expert system for diagnosing flower bulb diseases, pests and non-parasitic disorders. *Agricultural Systems*, **58**(1): 57-85.

Lagos-Ortiz K, Medina-Moreira J, Alarcón-Salvatierra A, Morán M F, del Cioppo-Morstadt J and Valencia-García R 2019. Decision support system for the control and monitoring of crops. In: ICT for Agriculture and Environment, Valencia-García R *et al.* (Eds.), CITAMA2019, *Advances in Intelligent Systems and Computing*, **901**: 20-28.

Luckmann W H 1971. *The insect-pests of soybean.* World Farm, 13(5): 18-22.

Rok Rupnik, Matjaž Kukar, Petar Vra?ar, Domen Košir, Darko Pevec and Zoran Bosni? 2019. Agro DSS: A decision support system for agriculture and farming. *Computers and Electronics in Agriculture*, **161**: 260-271.

Saini, Harvinder S, Raj Kamal and Sharma A N 2002. Web-based fuzzy expert system for integrated pest management in soybean. *International Journal of Information Technology*, **8**(2): 54-74.

Sharma, Amar Nath 2013. Soybean ke hanikarak keet evam unka samekit prabandhan. *Technical Bulletin No. 11,* ICAR-Indian Institute of Soybean Research, Indore, pp. 36.

Wang, Airu 1999. An expert system for apple and pear diseases and pest insects diagnose. *Journal of Agricultural University of Hebei (China), Hebei Nongye Daxue XueBao (China)*, **22**(1): 60-62.

Assessment of molecular diversity among linseed (*Linum usitatissimum* L.) genotypes using SSR markers

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ABSTRACT

The high nutritive value of linseed increases its market demand for human nutrition, cosmetic, pharmaceutical and textile industry. However, the decreasing trends in area under linseed cultivation and yield stagnation necessitate its genetic improvement. SSR markers have been widely used in diversity analysis in linseed. In this study, molecular diversity analysis of 31 linseed genotypes were carried out using 18 SSR markers. Out of 18 SSR primers, 15 were polymorphic. The similarity coefficient ranged from 0.5 to 0.9. Among the 31 linseed genotypes studied, the lowest similarity coefficient was observed between GS-202 and Neelum (0.50). Clustering of linseed genotypes using UPGMA based on the similarity coefficient data derived from SSR markers, grouped 31 genotypes into two major clusters and ?sub clusters. It was evident from dendrogram that the genotypes GS-202, Neelum, H-40 and EC-1424 were the most diverse. Therefore, it is suggested that these genotypes may be used in breeding programme for improvement of linseed.

Keywords: Linseed, Molecular diversity, SSR

Linseed (*Linum ussitatissimum* L.) is a self-pollinated crop commonly known as, tisi, linum, and linen etc. It is mainly grown for its multipurpose oil and fibre in the world (Kajla *et al*., 2015). The seed provides the oil rich in omega-3 fatty acid, digestible protein and lignans with antibacterial, antifungal, anticancer, and anti-inflammatory properties (Zuk *et al*., 2015). Flaxseed serves as the best omega 3 fatty acid source to the non-fish eaters. Apart from human consumption there is a huge demand of linseed oil in commercial industries for making of paint, varnish and printing ink. The high strength and durable fibre extracted from the stem of plant used in textile industries to make high priced 'linen cloth'. India ranks first among the leading flaxseed producing countries in terms of acreage accounting to 23.8% of the total and third in production contributing to 10.2% of the world's production (Singh *et al.,* 2011, 2012; Agashe *et al.,* 2018). In spite of being a leader in linseed production, in India the productivity level has remained virtually static in the last couple of year with no major breakthrough in achieving productivity enhancement (Agashe *et al.,* 2018). Further, the research directed toward the improvement of linseed has been limited due to its narrow genetic base of existing germplasm to induce new variation.

Molecular marker based diversity analysis for identification of genetically diverse parents and using them in breeding programme could augment linseed improvement. There are only a few reports of identification and use of molecular markers in linseed breeding programmes (Soto Cerda *et al.,* 2011, 2012; Wu *et al.,* 2017; Choudhary *et al.,* 2017). A range of molecular markers have been used previously for assessment of diversity in linseed (Ijaz *et al.,* 2013, Bibi *et al.,* 2015; Rajwade *et al.,* 2010; Chandrawati *et al.,* 2017; Nag and Mitra 2017; Choudhary *et al.,* 2017). SSR markers have been widely used for genetic analysis because of their abundance, co-dominance inheritance, high polymorphism, reproducibility and ease of assay by PCR (Pali *et al.,* 2015). Therefore, in the present study an assessment of genetic diversity was performed with 31 linseed genotypes using 18 SSR markers.

Genomic DNA was extracted from leaf tissues of 31 linseed genotypes using modified CTAB method (Kang *et al.,* 1998). Eighteen SSR markers were used for diversity analysis. Details of the SSR primers used are provided in Table 1. SSR marker amplification was executed in 10 µl volume containing 5 µl of Premix Taq® Version 2.0 (Xcelris Lab Ltd. Ahmedabad, Gujarat), 0.2 µ and genomic DNA (50 ng) in a thermal cycler (Agilent Technologies). The amplification reaction involved an initial denaturation at 94°C (5 min) followed by 30 cycles of 1 min at 94°C, 30 sec at 51°C, 1 min at 72°C and final extension at 72°C for 3 min. The PCR products were separated on 2% Agarose gel containing ethidium bromide and photographed under UV light.

A similarity matrix was calculated based on Jaccard's coefficient (Jaccard, 1908) using NTSYS software. Cluster analysis based on the dissimilarity matrix, was performed using un-weighted pair group method arithmetic averages (UPGMA) of the NTSYS-PC version 2.2 (Rohlf, 2005).

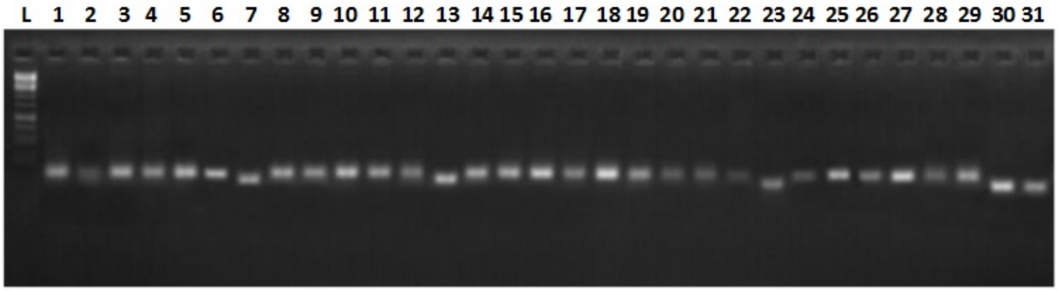
Thirty one linseed genotypes (Ruchi, SLS-72, K. Selection, BRLS-101, BRLS-102, BRLS-103, BRLS-104, BRLS-105, H-49, EC-1424, Parvati, H-40, Sharda, Polf-23, JRF-5, NL 260, LBR-6, Meera, EC-537911, CI-1552, CI-1559, CI-1663, CI-2057, GS-202, GS-440, EC-1529, EC-537911A, LCK-7035, Neelum, T-397 and Shekhar) were subjected to allelic diversity analysis using 18 SSR markers (Table 1). Out of the 18 SSR markers used, only 15 showed polymorphism (Fig. 1). The number of alleles in SSR markers varied from 2 to 4. A total of 43 alleles were amplified with SSRs having an average of 2.66 alleles per marker locus. Similar findings have been reported previously (Dash and Samal 2016; Nag *et al.,* 2017).

The polymorphism information content (PIC) value is a measure of variability at specific locus. Higher the PIC value for a locus, greater is the probability that polymorphism will exist between two randomly selected genotypes at that locus. The PIC values ranged from 0.1 (LUSSR-12) to 0.447 (LUSSR-13) with an average of 0.245. LUSSR-13 showed highest PIC value of 0.447 was followed by the primers namely, LUSSR-11, LUSSR-2 and LUSSR-6 with PIC value of 0.411, 0.379 and0.329, respectively. Previous reports also showed similar PIC value for linseed genotypes (Bickel *et al.,* 2011; Singh *et al.,* 2015; Dash and Samal, 2016), whereas Pali *et al.* (2015) reported higher PIC values in linseed.

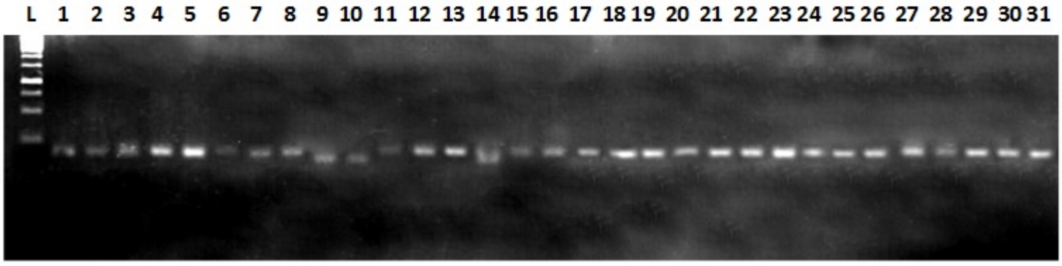
The binary data from the SSR markers were used for computing similarity coefficients. The similarity coefficient ranged from 0.50 to 0.90. The lowest similarity coefficient (0.50) was observed between GS-202 and Neelum followed by the pair EC-1424 and H-40 (0.51) and Neelum and NL-260 (0.51). This observation indicated that these genotypes were distant. The highest value was observed between Meera and EC-537911 (0.90) followed by the pair T-397 and SLS-72(0.89) which inferred that the genotypes might have shared a common ancestry. Lower similarity coefficient was observed in previous reports in linseed purity studies using SSR markers (Singh *et al.,* 2015).

Table 1 List of SSR primers used in molecular study and their respective annealing temperature

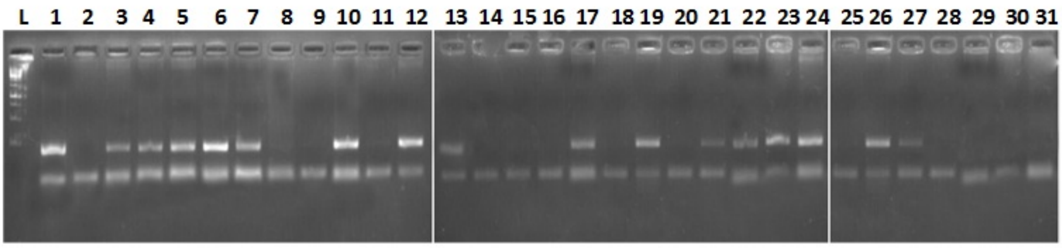
Primers		Sequence 5' to 3'	Tm (°C)	No. of alleles	Size of alleles (bp)	PIC
LUSSR-1	F	TCCCYTTATTCCCCTTTGCT	50.8	1	185	0
	R	CCAAACGCCATTGGAKAAAG	50.8			
LUSSR-2	F	CATCCAACAAAGGGTGGTG	51.1	3	70-340	0.379
	R	GGAACAAAGGGTAGCCATGA	51.8			
LUSSR-4	F	CTCTCCCTCGCTCTTTTCTT	51.8	2	96-144	0.113
	R	GGGGGAGCTATTAGGACTTCT	54.4			
LUSSR-6	F	AAGGGTGGTGGTGGGAAC	52.6	3	90-354	0.329
	R	GTTGGGGTGAAGAGGAACAA	51.8			
LUSSR-7	F	GTGTGGGAATTGGACACTTG	51.8	2	90-150	0.271
	R	CAAACCGAAGAGGCAAGAAG	51.8			
LUSSR-8	F	TCATTCATCTCCTTCCACTAAAA	49.9	2	125-144	0.147
	R	TTGAAAGCCCTAGTAGACACCA	53			
LUSSR-9	F	TCCGGACCCTTTCAATATCA	49.7	2	60-130	0.238
	R	AACTACCGCCGGTGATGA	50.3			
LUSSR-10	F	GCTCGTGATCTCCTTCATCC	53.8	3	70-230	0.102
	R	AAAACCACGTCCAGATGCTC	51.8			
LUSSR-11	F	TTATTTCCGGACCCTTTCAA	47.7	3	83-450	0.411
	R	AAACTACCGCCGGTGATGAT	51.8			
LUSSR-12	F	GTCACTGGGTGTGTGTTTGC	53.8	4	200-526	0.10
	R	AGCAGAAGAAGATGGCGAAA	49.7			
LUSSR-13	F	AAATATGGGGTTGATAACGGTTT	49.9	4	51-436	0.447
	R	CTAACGGTGCATTCCAATAACTC	53.5			
LUSSR-14	F	ACTAGGATTGTTGGGGTTAGGAG	55.3	2	190-240	0.244
	R	ACATGATTTTCTCTAAGCGGACA	51.7			
LUSSR-15	F	TGAACAGAAACAACATTCTGGTG	51.7	2	60-200	0.275
	R	CGTCTTCATCTTCGTCTTTCACT	53.5			
LUSSR-16	F	AAATTCAAAGCCAAATGCATAGA	48.1	1	250	0
	R	ACTCGTGATCAAGTTGAACGATT	51.7			
LUSSR-17	F	GACAGCAGGTCAACGATAAATTC	53.5	2	71-242	0.174
	R	GGACAAATTAAATTAGGTCGGGA	51.7			
LUSSR-18	F	ATTCTGTCGTATTTGGCTGTGTT	51.7	1	250	0
	R	TCACTAACAATATTCGATTGGGC	51.7			
LUSSR-19	F	GAGTCTTGGAAGGTTCTGGAAAT	53.5	3	98-240	0.204
	R	TGTTACTACATCATTCGAAAAGACAA	51.7			
LUSSR-20	F	CGCATCCTTGTTTCTCTCTTTTA	51.7	3	58-96	0.233
	R	GTTAGTTACGGATTTACCCGGAC	55.3			



Amplification profile of LUSSR-07



Amplification profile of LUSSR-08



Amplification profile of LUSSR-14

Fig. 1. Amplification pattern of linseed SSR profile

L-Ladder,1-T-397,2-Shekhar,3-Ruchi,4-SLS-72,5-K.Selection,6-BRLS-101,7-BRLS-102,8-BRLS-103,9-BRLS-104,10-BRLS-105,11-H-49,12-EC-1424,13-Parvati,14-H-40,15 Sharda,16-Polf-23,17-JRF-5,18-NL-260,19-LBR-6,20-Meera,21-EC-537911,22-CI-1552,23-CI-1559,24-CI-1663,25-CI-2057,26-GS-202,27-GS-440,28-EC-1529,29-EC-537911A,30-LCK-7035,31-Neelum

Cluster analysis was carried out based on the similarity coefficient data derived from SSR marker which grouped the 31 genotypes into two major clusters which provided a clear resolution of relationships among all the genotypes (Fig. 2). The two major clusters were generated at 0.77 coefficient value. The first major cluster included 28 genotypes. Further, it was grouped into two minor clusters, IA and IB having 25 and 3 genotypes respectively. Cluster IA further grouped into two i.e. IA1 and IA2. IA1 included genotypes, H-40, BRLS-101, BRLS-102, BRLS-103, BRLS-104, BRLS-105, CI-1559, Ruchi, K.Selection, H-49, JRF-5, T-397, SLS-72, GS-202, CI-1663, CI-1552, Meera, EC-537911, EC-1424 and Sharda. The sub-cluster IA2 included Polf-23, EC-1529, CI-2057, GS-440 and EC-537911A. The sub cluster IB included 3 genotypes namely, NL-260, Shekhar and Parvati. The cluster II was further grouped into two sub-clusters i.e. IIA and IIB. The sub-cluster IIA included LBR-6 and LCK-7035 and IIB included only single genotype, Neelum.

The results showed that the range of genetic diversity was considerable among the genotypes of two clusters. It was evident from dendrogram that the genotypes GS-202, Neelum, H-40 and EC-1424 were the most distantly related and therefore, could be used in crossing programmes to generate additional variability useful in breeding pogrammes.

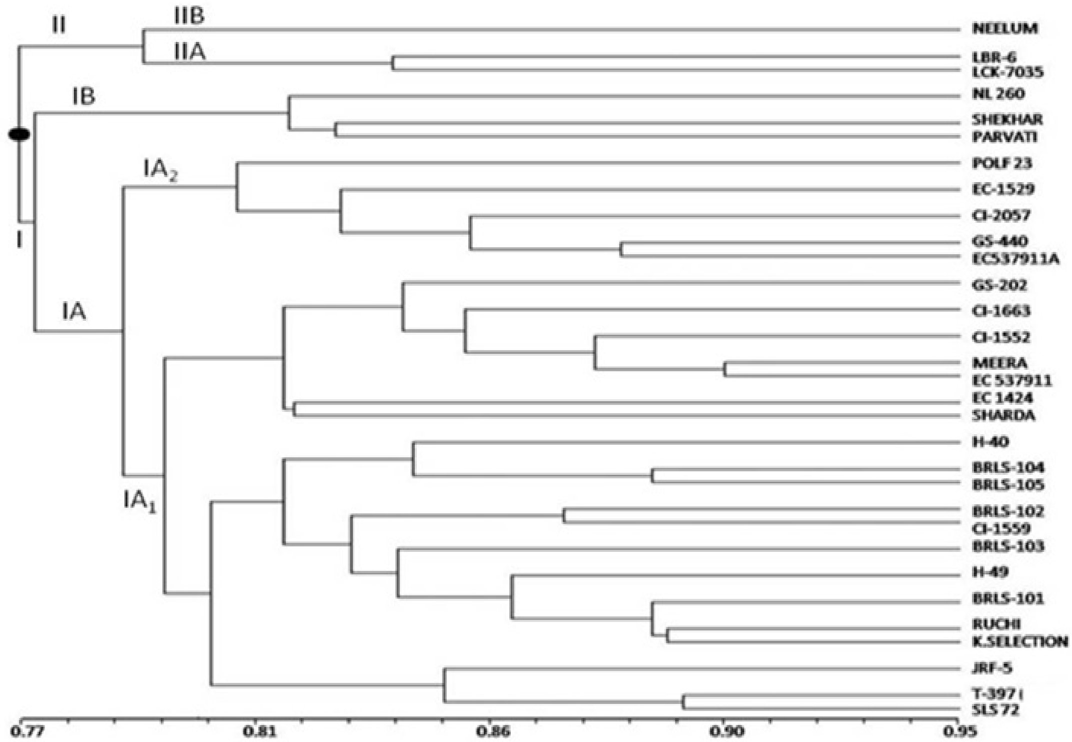


Fig. 2. Dendrogram of cluster analysis of linseed genotypes using UPGMA

REFERENCES

Agashe D R, Sastri A S R A S, Bobade P and Agashe R 2018. Trends of area, production and productivity of linseed in different districts of Chhattisgarh, India. *International Journal of Current Microbiology and Applied Sciences*, **7**(7): 711-718.

Bibi T, Saad H, Mustafa H S B, Rauf S, Mahmood T and Ali Q 2015. Analysis of genetic diversity in linseed using molecular markers. *Life Science Journal*, **12**(4s).

Bickel C L, Gadani S, Lukacs M and Cullis C A 2011. SSR markers developed for genetic mapping in flax (*Linum usitatissimum* L.) *Research and Reports in Biology*, **2**: 23-29.

Chandrawati S N, Kumar R, Kumar S, Singh P K, Yadav V K 2017. Genetic diversity, population structure and association analysis in linseed (*Linum usitatissimum* L.). *Physiology and Molecular Biology of Plants*, **23**: 1-14.

Choudhary S B, Sharma H K, Kumar A A 2017. SSR and morphological trait based population structure analysis of 130 diverse flax (*Linum usitatissimum* L.) accessions. *Comptes Rendus Biologies*, **340**: 65-75.

Dash M and Samal K C 2016. Agro-molecular diversity analysis of linseed (*Linum usitatissimum*) genotypes using microsatellite based Simple Sequence Repeat (SSR) marker. *Journal of Plant Science Research*, **32**(1): 87.

Rohlf F J and Slice D 1990. Extensions of the Procrustes method for the optimal superimposition of landmarks. *Systematic Biology*, **39**(1): 40-59.

Ijaz A, Shahbaz A, Ullah I, Ali S, Shaheen T, Rehman M, Ijaz U and Samiullah 2013. Molecular characterization of linseed germplasm using RAPD DNA fingerprinting markers. *American-Eurasian Journal of Agricultural and Environmental Sciences*, **13**(9): 1266-1274.

Jaccard P 1908. Nouvelles recherches sur la distribu- tion florale. *Bulletin de la Société vaudoise des sciences naturelles*, **44**: 223-270.

Kajla P, Sharma A and Sood D R 2015. Flaxseed-a potential functional food source. *Journal of Food Science and Technology*, **52**(4): 1857-1871.

Kang H W, Yong G C, Ung H Y and Moo Y E 1998, A rapid DNA extraction method for RFLP and PCR analysis from a single dry seed. *Plant Molecular Biology*, **16**: 1-9.

Nag S and Mitra J 2017. Genetic divergence of flax genotypes (*Linum usitatissimum* L.) utilizing microsatellite markers. Current Agriculture Research, 5(1) DOI: http://dx.doi.org/10.12944/CARJ.5.1.14.

Nag S, Trivedi D V, Sarkar S S, Adhikari A S, Sunitha M S, Sutton S, Ruppel K M and Spudich J A 2017. The myosin mesa and the basis of hypercontractility caused by hypertrophic cardiomyopathy mutations. *Nature Structural and Molecular Biology*, **24**(6): 525-533.

Pali V and Mehta N 2015, Evaluation of genetic divergence Indian flax (*Linum usitatissimum* L.). *Supplement on Genetics and Plant Breeding*, **10**(4): 2043-2047.

Rajwade A V, Arora R S, Kadoo N Y, Harsulkar A M, Ghorpade P B and Gupta V S 2010. Relatedness of Indian flax genotypes (*Linum usitatissimum* L.): an inter-simple sequence repeat (ISSR) primer assay. *Molecular Biotechnology*, **45**(2): 161-170.

Singh K K, Jhamb S A and Kumar R 2012. Effect of pretreatments on performance of screw pressing for flaxseed. *Journal of Food Process Engineering*, **35**(4): 543-556.

Singh K K, Mridula D, Rehal J and Barnwal P 2011. Flaxseed: a potential source of food, feed and fiber. *Critical Reviews in Food Science and Nutrition*, **51**: 210-222.

Singh P, Mehta N, Nair K S and Sao A 2015. Genetic divergence analysis for seed classes of four popular linseed (*Linum usitatissimum* L) varieties of Chhattisgarh India. *International Journal of Farm Sciences*, **5**(2): 42-46.

Soto-Cerda B J, Urbina S H, Navarro C and Mora O P 2011. Characterization of novel genic SSR markers in *Linum usitatissimum* (L.) and their transferability across eleven Linum species. *Electronic Journal of Biotechnology*, **14**: 4.

Wu J, Zhao Q, Wu G, Zhang S and Jiang T 2017. Development of novel SSR markers for flax (*Linum usitatissimum* L.) using reduced-representation genome sequencing. *Frontiers in Plant Science*. DOI: 0.3389/fpls.2016.02018.

Zuk M, Richter D, Matu?a J and Szopa J 2015. Linseed, the multipurpose plant. *Industrial Crops and Products*, **75**(B): 165-177.

Management of safflower aphid (*Uroleucon compositae*) through newer insecticides

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ABSTRACT

A field experiment was conducted for three years during *rabi* 2013-14 to 2015-16 to evaluate the efficacy and compatibility of insecticides, fungicides and bio-agents for the management of the insect pest, aphid (*Uroleucon compositae*) and the diseases like Alternaria leaf spot and Fusarium wilt in safflower. The pooled data of three years showed significant reduction in aphid infestation in terms of number of aphids per 5 cm apical twig in all the treatments in comparison with the absolute control. The extent of aphid control in different treatments ranged from 70.2 to 88.0% after first spray and from 81.6 to 91.4% after second spray. Thus, all the treatments were capable of keeping the aphid population below the ETL level (35-40/5cm apical twig). There was no notable buildup of Alternaria leaf spot as the crop was sown during the normal recommended time. The Fusarium wilt incidence was also less which ranged from 1.2 to 7.6%. All the treatments recorded significant improvement in yield over the absolute control but they were at par with each other. However, the highest average seed yield of 907 kg/ha was recorded by T5 (Spray of thiamethoxam @ 0.25 g/l). The seed yield in other treatments ranged from 801 to 875 kg/ha as against only 292 kg/ha in the absolute control. The benefit-cost analysis of the treatments showed that the treatment T5 recorded the highest B:C ratio of 2.06 followed by T6 (1.94), T7 (1.89), T4 (1.62), T2 (1.44), T1 (1.40) and T3 (1.39). There was no phytotoxic effect on safflower crop in any of the treatments involving combination of different insecticides, fungicides and bio-agents. Therefore, seed treatment with *T. asperellum* TaDOR 7316 @ 10 g/kg and tank mixing of insecticides and fungicides together for need-based pest and disease management in safflower is recommended.

Keywords: Alternaria leaf spot, Aphid, Fusarium wilt, Pesticides, Management, Safflower

Safflower (*Carthamus tinctorius* L.) is one of the important *rabi* edible oilseed crops of the country. India is a major safflower growing country in the world with an area of 1.27 lakh ha, production of 0.53 lakh tones and productivity of 416 kg/ha (Anonymous, 2017a). Maharashtra state contributes nearly 45 per cent (0.57 lakh ha) and 25 per cent (0.13 lakh tonnes) to the total area and production of the country, respectively. The productivity of safflower in Maharashtra state and also in the country are very low i.e. 228 and 416 kg/ha, respectively. One of the important reasons for lower productivity is that the crop is affected by a number of insect-pests and diseases causing substantial losses in yield. The safflower aphid (*Uroleucon compositae* Theobald) is the most destructive pest infesting the crop from elongation stage up to flowering period (Akashe *et al*., 2013; Akashe *et al*., 2018) and causes yield losses to the tune of 11.19 to 54.95 per cent in different cultivars (Anonymous, 2017b). Among the various diseases, wilt (*Fusarium oxysporum* f. sp. *carthami*) and the leaf spot caused by *Alternaria carthami* are the major problems (Bhale *et al.,* 1998). In the integrated pest and disease management, combined use of compatible fungicides and insecticides minimizes the cost involved on labour and saves the time and offers timely pest and disease management together. The tank mixing of incompatible pesticides has been reported to affect the IPM/IDM (Anderson and Roberts, 1983). Hence, the present study was undertaken to find out the compatibility of some insecticides and fungicides commonly used for insect pest and disease control in safflower.

A field experiment was conducted for three consecutive *rabi* seasons from 2013-14 to 2015-16 at the All India Coordinated Research Project on Safflower, Zonal Agricultural Research Station (75" 56' E, 17" 41' N), Solapur, Maharashtra, India using less spiny and aphid susceptible safflower variety, SSF-658. Field experiments were taken up in randomized block design with three replications with individual plot size of 4.0 x 4.5 m^2 with inter and intra-row spacing of 45 and 20 cm, respectively. The crop was sown during the normal recommended time i.e. in the last week of September to first week of October. A basal recommended fertilizer dose of 50 kg N and 25 kg P_2O_5 was applied by drilling at the time of sowing. Eight treatments inclusive of an absolute control were imposed. The seed treatment with *Trichoderma asperellum* @ 10 g/kg was done before sowing as a preventive measure for Fusarium wilt and two need-based foliar sprays of insecticide + fungicide @ 500 l/ha were applied at an interval of 15 days for controlling the aphid and Alternaria leaf spot.

The observations on aphid count (5 cm apical twig/plant) were recorded on five randomly selected plants in each

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treatment before and after sprays. Pre-count was taken a day prior to the imposition of treatments. The data on surviving aphids/plant before and after treatment was subjected to pooled statistical analysis and the per cent decline over control was worked out. The intensity of Alternaria leaf spot was in traces and the incidence of wilt was noticed to a lesser extent. The observations on physical changes in the spray solution due to tank mixing of chemicals, alteration in their efficacy and phytotoxicity on plants in the field in each treatment etc. were also recorded simultaneously.

The pooled data on the aphid population before and after the first and second sprays are presented in Table 1. The aphid population recorded before the first spray showed non-significant differences among the treatments indicating uniformity in the aphid population (35.8 to 36.5 aphids/5 cm twig) before imposition of the treatments. All the treatments recorded significantly low aphid population than the absolute control after the first and second spray. The average aphid population/5 cm apical twig in different treatments after first and second spray ranged from 7.1 to 17.8 and 8.8 to 18.9 as against 60 and 103 in the absolute control, respectively. Thus, the aphid population was controlled well below the ETL (35-40 aphids/5cm apical twig) in all the treatments. The decline in aphid population in different treatments after first and second spray ranged from 70.2 to 88.0 % and 81.6 to 91.4 %, respectively. The intensity of Alternaria leaf spot was in traces and restricted to lower 3-4 leaves during all the years and as such exhibited no differences due to different treatments. This could be due to the sowing of crop during the recommended time and existence of fairly dry weather during the crop growth in all the years. The wilt incidence was noticed to a lower extent ranging from 1.2 to 7.6 % without much influence on seed yield.

Treatment details:

T1	Seed treatment with T. asperellum TaDOR7316@ 10 g/kg followed by spray of clothianidin @ 0.1 g/l + carbendazim 12% + mancozeb 63% @ 2.5 g/l
T2	Seed treatment with T. asperellum, TaDOR7316@ 10 g/kg followed by spray of thiamethoxam @ 0.25 g/l + carbendazim 12% + mancozeb 63% @ 2.5 g/l
T3	Seed treatment with T. asperellum, TaDOR7316 @ 10 g/kg followed by spray of acetamiprid @ 0.20 g/l + carbendazim 12% + mancozeb 63% @ 2.5 g/l
T4	Spray of clothianidin @ 0.1 g/l
T5	Spray of thiamethoxam @ 0.25 g/l
T6	Spray of acetamiprid @ 0.20 g/l
T7	Spray of carbendazim 12% + mancozeb 63% @ 2.5 g/l + dimethoate @ 1.0 ml/l
T8	Absolute control

The pooled data on the grain yield and the overall economics of safflower production are presented in Table 2. All the treatments recorded significantly higher seed yield than the absolute control with a low seed yield of 292 kg/ha. The highest average seed yield of 907 kg/ha was recorded by T5 (907 kg/ha) which was followed byT4 (875 kg/ha), T7 (857 kg/ha), T2 (835 kg/ha),T1 (826 kg/ha),T6 (811 kg/ha) and T3 (801 kg/ha). However, all these treatments were at par with each other. The studies on economics of the treatments revealed the highest average benefit-cost ratio of 2.06 from T5 which was closely followed by T6 (1.94). The other treatments in the descending order of their B:C ratio were T7 (1.89), T4 (1.62), T2 (1.44), T1 (1.40) and T3 (1.39). There was no apparent phytotoxic effect on safflower crop in any of the treatments involving combination of different insecticides, fungicides and bio-agents which indicated that they are quite compatible with each other and can be safely used for preparing the tank mix for the large-scale spray purpose (Anonymous, 2016).

The overall results indicated that all the pesticide spray treatments with or without seed treatment with *T. asperellum,* TaDOR7316 @ 10 g/kg recorded significant control of the safflower aphid below the economic threshold level. There was no phytotoxic effect on safflower crop in any of the pesticide treatment. It indicated that they were compatible with each other and therefore could be used together in the integrated pest and disease management in safflower. On the basis of aphid control below the ETL level, higher seed yield and benefit-cost ratio, the spray of thiamethoxam @ 0.25 g/l or acetamiprid @ 0.20 g/l may be recommended for the pest management in safflower. Similarly, the technology of tank mixing of these insecticides and fungicides together for need-based pests and disease management is recommended for safflower.

Table 1 Aphid population before and after sprays, per cent decline in aphid population and phytotoxicity in safflower as influenced by different treatments (Pooled Data: 2013-14, 2014-15 and 2015-16)

Treatment	No. of aphids/5 cm twig/plant								% decline over control	No. of aphids/5 cm twig/plant				% decline over control	Phyto-toxicity
	Before spray				After first spray					After second spray					
	2013-14	2014-15	2015-16	Mean	2013-14	2014-15	2015-16	Mean		2013-14	2014-15	2015-16	Mean		
T1	37.8	31.6	39.0	36.1	5.8	5.3	10.3	7.1	88.0	9.8	10.0	6.6	8.8	91.41	0.0
T2	37.8	31.3	39.0	36.0	8.6	6.0	11.3	8.6	85.5	13.4	11.0	8.0	10.8	89.5	0.0
T3	37.6	31.6	39.0	36.0	8.8	8.0	13.0	9.9	83.4	13.7	13.0	9.0	11.9	88.4	0.0
T4	37.6	31.3	39.0	36.0	11.0	11.0	13.6	11.8	80.2	18.2	15.6	10.6	14.8	85.5	0.0
T5	37.5	31.6	39.0	36.0	11.0	10.6	15.6	12.4	79.2	19.5	17.6	11.0	16.0	84.4	0.0
T6	37.8	31.6	39.3	36.2	12.3	11.6	18.6	14.2	76.3	20.4	19.0	12.6	17.3	83.1	0.0
T7	37.7	31.0	38.6	35.7	19.5	13.6	20.3	17.8	70.2	21.1	21.3	14.3	18.9	81.6	0.0
T8	37.8	32.0	39.6	36.4	57.4	55.0	67.6	60.0	0.0	99.2	100.0	110.0	103.0	0.0	-
SE ±	-	-	-	0.2	-	-	-	0.5	-	-	-	-	1.0	-	-
CD 5 %	-	-	-	NS	-	-	-	1.4	-	-	-	-	3.0	-	-
CV %	-	-	-	1.7	-	-	-	8.5	-	-	-	-	12.7	-	-

Where, T1 to T8 indicate treatments and their details are provided in the text

Table 2 Grain yield and economics of safflower production as influenced by different treatments (Pooled Data: 2013-14, 2014-15 and 2015-16)

Treatment	Grain yield (kg/ha)				Benefit:Cost ratio			
	2013-14	2014-15	2015-16	Mean	2013-14	2014-15	2015-16	Mean
T1	518	1078	883	826	1.23	1.54	1.42	1.40
T2	504	1102	900	835	1.22	1.61	1.48	1.44
T3	451	1073	845	801	1.13	1.61	1.43	1.39
T4	485	1169	872	875	1.52	1.82	1.53	1.62
T5	488	1314	920	907	1.55	2.60	2.04	2.06
T6	479	1006	948	811	1.57	2.06	2.18	1.94
T7	467	1199	905	857	1.45	2.29	1.94	1.89
T8	198	535	142	292	0.57	1.13	0.34	0.68
SE ±	-	-	-	42	-	-	-	-
CD 5 %	-	-	-	120	-	-	-	-
CV %	-	-	-	16.27	-	-	-	-

Where, T1 to T8 indicate treatments and their details are provided in the text

REFERENCES

Akashe V B, Gud M A, Shinde S K and Kadam J R 2013. Biodiversity of insect pests of safflower and their natural enemies in Maharastra. *Bioinfolet*, **10**(4B): 1389-1392.

Akashe V B, Indi D V, Shinde S K, Khadtare S V and Amrutsagar V M 2018. Pests scenario of safflower (*Carthamus tinctorius* L.) in scarcity zone of Western Maharashtra (India). *Contemporary Research in India*, **2**(Spl. Issue): 265-269.

Anderson T E and Roberts D W 1983. Compatibility of *Beauveria bassiana* strain with formulations used in Colorado potato beetle (Coleoptera: Chrysomelidae) control. *Journal of Economic Entomology*, **76**: 1437-1441.

Anonymous 2016. *Annual Report 2015-16,* ICAR-Indian Institute of Oilseeds Research, Hyderabad.

Anonymous 2017a. State-wise area, production and productivity of safflower in India (2015-16). *Director's Report 2017,* ICAR-Indian Institute of Oilseeds Research, Hyderabad, pp. 17-18.

Anonymous 2017b. Yield loss evaluation in aphid resistant accessions. *Annual Report 2016-17,* ICAR-Indian Institute of Oilseeds Research, Hyderabad, pp. 153.

Bhale M S, Bhale U and Khare M N 1998. Diseases of important oilseed crops and their management. In: *Pathological Problems of Economic Crop Plants and their Management.* Paul Khurana S M (Ed.), Scientific Publishers, Jodhpur, pp. 251-279.

Oilseeds scenario in Himachal Pradesh: analysis and some reflections

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ABSTRACT

Oilseeds are very important due to being an integral part of Indian kitchen and imports basket. The diverse agro-ecological conditions in India favour growing of many oilseeds, whose demand goes unmet domestically. Area, production and yield of oilseeds in India have witnessed positive growth over time. But these appear to be missing crops in Himachal Pradesh. Sesamum in *kharif* and rapeseed & mustard in *rabi* are the most important crops. The present study analysed the trends in area, production and yields of these two oilseed crops in Himachal Pradesh using time-series data for the period 1974-75 to 2016-17. The economics of cultivating these two crops was also studied to examine their profitability. The results revealed negative and significant growth rate for area under all oilseeds in the state, while the same for the yield was positive and significant. The growth in production of rapeseed & mustard was contributed both by acreage as well as yield during the study period. The area under sesamum observed a steep fall in the state, more so during the past two and a half decades. Human labour alone accounted for the highest cost in these crops on sample farms. The cost and returns analysis clearly brought out that the two oilseed crops were profitable only when paid out cost were considered. Also, sesamum turned out to be more profitable as compared to rapeseed & mustard due to higher output price. These results call for incentivized approach to re-popularize these crucial crops in the state through an appropriate mix of technology and extension services.

Keywords: Cost and returns, Oilseeds, Trends

Oilseeds constitute an important group of commercial crops. These provide easily available and highly nutritious food to human beings and animals. Majority of the oils extracted from oilseeds are consumed as edible oil and the rest are used as raw materials for manufacturing large number of items like paints, varnishes, hydrogenated oil, soaps, perfumery, lubricants, etc. Oilcakes and meals are used in animal feed and as manures. Thus, oilseeds are promising crops with high potential to improve human diets, prevent malnutrition and food insecurity. The diverse agro-ecological conditions in the country are favourable for growing oilseeds which include seven edible oilseeds *viz.,* groundnut, rapeseed, mustard, soybean, sunflower, sesamum and niger and two non-edible sources i.e., castor and linseed. The total oilseeds area in the country stood at 24.65 million hectares with a production of 31.31 million tonnes during 2017-18 yielding 1270 kg/ha. India meets more than half of its domestic demand through imports due to lower production as compared to its domestic demand. In 2017-18, India imported about 1.54 crore tonnes of vegetable oils costing of Rs. 74,996 crore. Despite rising prices of edible oils, its consumption is growing rapidly (Anonymous, 2018).

Contrary to the scene at national level where the area, production and yield of oilseed crops have been registering positive trends over time, oilseeds appear to be the missing crops in the cropping pattern in Himachal Pradesh. During 1972-73, area under oilseed crops was 23,346 hectares in this state which was halved to 11.0 thousand hectares presently. As a proportion of gross cropped area it reduced from 2.58 per cent in 1972-73 to 1.88 per cent in 2004-05 (Kumar and Najibullah, 2013) and further to about 1.15 per cent in 2016-17. At present, of total acreage under oilseeds, 3/4th is devoted to *rabi* oilseeds whereas 1/4th is under *kharif* oilseeds. While sesamum, soybean and groundnut are grown in *kharif* season, rapeseed and mustard and linseed are the main oilseed crops of *rabi* season. The spatial distribution of oilseed crops is highly skewed in the state as most of the crops are confined to only two or three districts except rapeseed and mustard which is grown in all the districts except two tribal districts of Lahaul Spiti and Kinnaur. The sesamum in *kharif* and the rapeseed & mustard in *rabi* are the most important crops as these account for about 90.00 per cent of total area under oilseeds in the state. With this background in view, the present study was conducted to study the trends in area, production and yields of these two oilseed crops in Himachal Pradesh and economics of these two crops were worked out.

The trends in area, production and yields were studied using secondary data collected from various publications of departments like the Directorate of Economics & Statistics and Land Records of the State Government for the period 1974-75 to 2016-17. To estimate the costs and returns of these oilseeds, primary data were collected using a combination of purposive and random sampling procedure from 80 farmers from Kangra district through a specially designed survey schedule. Kangra district was purposively chosen for primary survey as both these crops are grown on large tracts in this district.

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The objectives of the study were accomplished using tabular analysis, computing compound annual growth rates (CAGRs) and by estimating costs and returns.

The CAGRs were computed for the area, production and yields by using the formula: Y= abt

In logarithmic term: Log Y = log a + t log (b)

The per cent CAGR were calculated as: CAGR (%) = [Antilog (log b) -1] × 100

The standard error (SE) of CAGR was calculated as: SE (CAGR) = 100 × b × SE(b)

where,

Y= Area, production and productivity of selected crop

a = Constant term,

b = Regression coefficient,

t = Time variable in years (1,2,3…..n)

The costs and returns were computed using the standard farm management cost concepts such as Cost A1, Cost A2, Cost B1, Cost B2, Cost C1, Cost C2 and Cost C3.

The production of a crop, *inter alia,* is influenced by technological factors and policy prescriptions which are highly complex in nature. Thus, it becomes meaningful to measure the growth behaviour in area, production and yield of these crops as both technology and policy change over time. The state has varied topography and climate providing good opportunity for growing different oilseeds. The area under oilseeds and consequent production has decreased considerably in the past. In order to capture these changes in the oilseeds cultivation, data were analysed for the period Triennium Ending (TE) 1974-75 to TE 2016-17. The entire study period was further divided into two sub periods: period I (1974-75 to 1994-95) and period II (1995-96 to 2016-17) as there was a decrease in area under oilseeds during 1970s to 1990s but after early nineties, a very steep decline in area has been observed in the state.

It can be seen from Table 1 that in absolute terms the total area of all oilseeds in HP was 22536 hectares with a production of 9682 tonnes and yield of 0.430 tonnes/ha in Triennium Ending (TE)1974-75, which declined to 11225 hectares area with a production of 5289 tonnes in TE 2016-17. The yield of all oilseeds, however, increased marginally to 0.471 tonnes/ha in TE 2016-17. Similar findings were reported by Kumar and Najibullah (2013). Despite a fall in area, the production of total oilseeds increased substantially during TE 2001-02 due to a rise in yields of oilseeds. A wide variability in yield was observed due to the fluctuations in area and production during this period. This could be attributed to the fact that most of these oilseeds are grown under rainfed conditions in the state.

Table 2 portrays compound annual growth rates of all oilseeds in Himachal Pradesh from TE 1974-75 to TE 2016-17. During period I, the production and yield both had negative but significant growth rates of 2.37 per cent and 2.20 per cent per annum, respectively, though the growth rate of area under all oilseeds was negative but non-significant. During period II, the area and production both declined significantly (2.70% p.a. and 2.32% p.a.). An analysis for the overall study period revealed that while the growth rate for the area was negative and significant (1.28% p.a.) in Himachal Pradesh, the same for the yield was positive and significant (1.30% p.a.). This could be attributed to the technological up-scaling along with the appropriate extension efforts in the state.

Table 1 Area, production and yield of all oilseeds in Himachal Pradesh, TE 1974-75 to TE 2016-17

Year (TE)	Area (ha)	Production (tonnes)	Yield (tonnes/ha)
1974-75	22536	9682	0.430
1983-84	20847	5264	0.253
1992-93	21158	6762	0.320
2001-02	18188	8459	0.465
2010-11	15551	6464	0.416
2016-17	11225	5289	0.471

Table 2 Compound Annual Growth Rates (CAGRs) of area, production and yield of oilseeds in Himachal Pradesh, TE 1974-75 to TE 2016-17(per cent per annum)

Period/Year (TE)	Area	Production	Yield
Period I (1974-75 to 1994-95)	-0.18 (0.1236)	-2.37* (0.8154)	-2.20* (0.8021)
Period II (1995-96 to 2016-17)	-2.70* (0.1601)	-2.32* (0.3424)	0.39 (0.3565)
Overall Period (1974-75 to 2016-17)	-1.28* (0.1128)	0.01 (0.3027)	1.30* (0.3062)

Note :i) * Indicates significance at 5 per cent level; ii) Figures in parentheses indicate standard errors.

As indicated earlier, two major oilseeds namely, rapeseed &mustard and sesamum account for about 90 per cent entire oilseeds acreage in Himachal Pradesh. Hence, it was deemed imperative to study the trends in area, production and yield of these two oilseed crops individually as well.

Rapeseed and mustard is the most important oilseed grown in Himachal Pradesh during *rabi* season. Table 3 depicts trends in area, production and yield of rapeseed & mustard during the study period (TE 1974-75 to TE 2016-17). The production of rapeseed & mustard was 2097 tonnes from an area of 6086 hectares and yielding 0.345 tonnes/ha in TE 1974-75. This was the only oilseed crop that experienced an increase in area and yield continuously in the state, peaking in 2001-02 when the production increased to 4297 tonnes from an area of 9104 hectares with an yield of 0.472 tonnes/ha. The CAGRs in area, production and yield of rapeseed and mustard (Table 4) showed that the area under rapeseed and mustard registered a growth rate of 2.68 per cent per annum during period I. The trend analysis concluded that growth in production (3.20% per annum) of rapeseed and mustard was contributed both by increase in acreage as well as yield in the overall study period wherein the contribution of yield (1.92%) was noticeably higher than that of area (1.25%). This is a result of overall research and extension emphasis on this crop in the state backed by farmers' interest in this oilseed. Similar results have been reported by Prasad and Kumari (2015) in Himachal Pradesh and by Mandiwal (1989) in Rajasthan state. The yield contributed more to production as compared to total area under rapeseed and mustard crop in the state.

Table 3 Area, production and yield of rapeseed & mustard in Himachal Pradesh, TE 1974-75 to TE 2016-17

Year (TE)	Area (ha)	Production (tonnes)	Yield (tonnes/ha)
1974-75	6086	2097	0.345
1983-84	6844	1437	0.210
1992-93	8831	3041	0.344
2001-02	9104	4297	0.472
2010-11	8950	3214	0.359
2016-17	8369	3643	0.435

Table 4 Compound Annual Growth Rates (CAGRs) of area, production and yield of rapeseed and mustard in Himachal Pradesh, TE 1974-75 to TE 2016-17 (per cent per annum)

Period/Year (TE)	Area	Production	Yield
Period I (1974-75 to 1994-95)	2.68* (0.2315)	2.03 (1.1446)	-0.63 (1.0692)
Period II (1995-96 to 2016-17)	-0.15 (0.1026)	-0.16 (0.4867)	-0.01 (0.4569)
Overall Period (1974-75 to 2016-17)	1.25* (0.1255)	3.20* (0.3766)	1.92* (0.3468)

Note: i) * Indicates significance at 5 per cent level;
ii) Figures in parentheses indicate standard errors

Table 5 Area, production and yield of sesamum in Himachal Pradesh, TE 1974-75 to TE 2016-17

Year (TE)	Area (ha)	Production (tonnes)	Yield (tonnes/ha)
1974-75	8130	2428	0.299
1983-84	7581	1985	0.262
1992-93	7759	2002	0.258
2001-02	4496	2074	0.461
2010-11	3129	848	0.271
2016-17	1613	518	0.321

Sesamum has been an important *kharif* oilseed crop of the state since old times. The analysis of the trends in area, production and yield of sesamum in Himachal Pradesh during the period TE 1974-75 to TE 2016-17 (Table 5 and Table 6) revealed very high negative and significant growth rates in area (5.57% p.a.), production (7.13% p.a.) and yield (1.65% p.a.) during the second period from TE 1995-96 to TE 2016-17. This clearly shows that there has been a steep fall in the area under sesamum in the state during the past two and half decades or so. However, in the overall period, negative and significant growth rates were observed for area and production (3.30% p.a. and 2.21% p.a.), while the yield recorded positive growth rate of 1.13 per cent per annum during this period. This could be ascribed to the fluctuations in rainfall and shifting of area to other remunerative commodities in the state. Similar results have been reported by Prasad and Kumari (2016) in Himachal Pradesh and by Debnath *et al.* (2015) in Tripura state.

Both these crops are grown as marginal crops in the state. Broad cost structure of rapeseed and mustard and sesamum in Kangra (Table 7) showed that human labour (including imputed value of family labour) alone constituted 71.92 and 66.53 per cent in rapeseed and mustard and sesamum, respectively of the total inputs cost on sample farms whereas the cost of tractor hiring accounted for 15.26 and 15.94 per cent in these crops, respectively. The cost of fertilizers was about 6-7 per cent of total cost in these crops.

Table 6 Compound Annual Growth Rates (CAGRs) of area, production and yield of sesamum in Himachal Pradesh, TE 1974-75 to TE 2016-17 (per cent per annum)

Period/Year (TE)	Area	Production	Yield
Period I (1974-75 to 1994-95)	-0.29 (0.2671)	-1.89 (0.9917)	-1.60 (0.9887)
Period II (1995-96 to 2016-17)	-5.57* (0.4823)	-7.13* (0.8411)	-1.65* (0.7274)
Overall Period (1974-75 to 2016-17)	-3.30* (0.2483)	-2.21* (0.4474)	1.13* (0.3944)

Note: i) * Indicates significance at 5 per cent level;
ii) Figures in parentheses indicate standard errors.

Table 7 Broad cost structure of rapeseed and mustard and sesamum in Kangra (₹/ha)

Particulars	Rapeseed and Mustard		Sesamum	
	Cost (₹)	% of variable cost	Cost (₹)	% of variable cost
Seed	656	2.03	805	2.65
FYM	766	2.37	865	2.68
Fertilizers	2367	7.33	2077	6.43
Irrigation	350	1.08	0.00	0.00
Tractor charges	4928	15.26	5146	15.94
Human labour*	23223	71.92	21481	66.53
Total	32290	100.00	30374	100.00

Note:* includes imputed value of family labour.

Table 8 Cost and returns in rapeseed and mustard and sesamum on sample farms (₹/ha)

Particulars	Rapeseed &mustard	Sesamum
Cost A1	18577	18793
Cost C3	74102	72274
Gross Returns	47601	62759
Net returns over:		
Cost A1	29023	43966
Cost C3	-26502	-9515

The cost and returns structure of the two crops have been presented in Table 8. It shows that on an average farm, the variable cost (cost A1orpaid out cost) in rapeseed and mustard was ₹ 18,577/ha whereas the total cost (Cost C3) amounted to ₹ 74,102/ha. Similarly, in case of sesamum the cost A1 was found to be ₹ 18,793/ha while the cost C3 was estimated to be ₹ 72,274/ha. The net returns over cost A1 were observed to be ₹ 29023 and ₹ 43,966per hectare in rapeseed & mustard and sesamum, respectively. However, for both these crops the net returns over cost C3 were observed to be negative to the extent of ₹ 26502 and ₹ 9,515 per hectare in the study area. These results clearly brought out that the two oilseed crops were profitable only when paid out cost were considered and the imputed value of family labour, rental value of owned land and interest of fixed capital, etc., were not taken into account. Also, sesamum was more profitable as compared to rapeseed and mustard on sample farms due to higher output price as a consequence of more demand and less production.

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REFERENCES

Anonymous 2018. *Agricultural Statistics at a Glance.* Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare, GOI, New Delhi.

Kumar V and Najibullah 2013. Land use and cropping pattern changes in Himachal Pradesh - an analysis of four decades. *Himachal Journal of Agricultural Research*, **39**: 1-12.

Mandiwal A 1989. Economics of mustard cultivation in Jaipur district of Rajasthan. *Indian Journal of Agricultural Economics*, **44**: 408-412.

Prasad R and Kumari V 2015. Impact of rainfall on area and production of *rabi* oilseed crops in Himachal Pradesh. *Himachal Journal of Agricultural Research*, **41**: 6-12.

Prasad R and Kumari V 2016. Impact assessment of rainfall on area and production of sesame in Himachal Pradesh. *Himachal Journal of Agricultural Research*, **42**: 9-14.

Debnath P, Singh R, Feroze S M and Sarkar A 2015. Study on growth and instability in north-eastern hill region of India. *Economic Affairs,* **60**: 193-196.

OBITUARY

Prof. Virender Lal Chopra

(9.8.1936-18.4.2020)

In the sad demise of Prof. V. L. Chopra, India has lost a great visionary, revered teacher, an eminent agricultural scientist, and, besides all, a good human being. ISOR pays profuse tributes and salutations to Prof. (Dr.) Chopra for his immense contributions to Indian agriculture, in general, and research and development of oilseeds sector, in particular.

Prof. Chopra was born in a village "Adwa" near Karachi (now in Pakistan). His family relocated to Delhi in 1947, after the post-independence partition. Prof. Chopra obtained B.A. (Honors) in 1955 from the Central College of Agriculture (University of Delhi) and the Master's degree in Genetics in 1957 from then Imperial Agricultural Research Institute (now IARI), New Delhi; and, joined as a staff member of IARI. He earned his Ph.D. in 1967 from the University of Edinburgh (U.K.). On his return, Prof. Chopra worked with notable leaders of Indian agriculture, like Prof. B. P. Pal, Dr. M. S. Swaminathan, at IARI and served in various capacities- as Head, Division of Genetics, IARI; Director, IARI; and, Prof of Eminence and Head, NRCPB (now NIPB), New Delhi. Later, he ascended to the position of Director General, ICAR and Secretary, DARE; and, also served as a member of the scientific advisory committee to the Prime Minister of India. After his tenure as DG, ICAR, he served as National Professor (B.P. Pal-Chair) of Plant Biotechnology; Member of the Planning Commission of India; Chancellor of the Central Agricultural University of Imphal; and, Chancellor of Central University of Kerala.

Prof. Chopra's research interests encompassed microbial genetics, Drosophila genetics, cytogenetics, wheat genetics, tissue culture and genetic engineering of oilseeds and vegetable Brassicas; and, he excelled equally in fundamental and applied research. Indian mustard variety Pusa Jaikisan, developed as a somaclonal variant by his research group, is still popular among the farmers. His research team pioneered on somatic hybridizations in Brassicas that led to development of male sterility systems, which paved the way for exploitation of heterosis in Indian Mustard. His team also developed several transgenic lines in Brassica which led to functional characterization of the genes. Besides the research and review articles, he has published many books that continue to be handy material of knowledge, information and erudition to the students and teachers alike.

Prof. Chopra was a visionary and an institution-builder. He laid the foundation for agricultural biotechnology education in India as early as 1983 by carving out a Division of Biotechnology at IARI, which is now ICAR- NIPB. Alumni of biotechnology discipline from IARI have contributed to building the agricultural biotechnology disciplines in various universities/institutes in India as well as abroad. His services were also sought by national and international organizations. He was invited by the Government of Vietnam for helping in establishing the Institute of Genetics at Hanoi. He served as a member of the Science Council of CGIAR; and, Board member of CGIAR Institutes such as IBPGR , the Netherlands; IRRI, Philippines; CIMMYT, Mexico; and ICRISAT, Hyderabad. He was instrumental in establishing the National Academy of Agricultural Sciences (NAAS) and served as its founder-President.

Dr. Chopra was recognized at the national and international levels for his distinguished services. He was honored with Padma Bhushan in 1985 by Government of India. Further, he was bestowed with numerous awards including Borlaug Award; Aryabhatta Medal of INSA; B.P. Pal Award of NAAS; FAO Food Day Award; FICCI

Award; Krishi Shiromani Samman (for Lifetime Achievement) by Mahindra & Mahindra Ltd.; and, D.Sc. (Honoris Causa) from eight Universities, which speak for his exemplary contributions.

Furthermore, he was recognized as a member of various scientific academies including Indian National Science Academy (New Delhi), Indian Academy of Sciences (Bangalore), National Academy of Agricultural Sciences (New Delhi), National Academy of Sciences India (Allahabad), The World Academy of Sciences (Italy), and European Academy of Science, Arts and Humanities (Paris). Besides, he also served as President of many scientific societies.

It is a moment of pride for ISOR to say that Prof. Chopra served as President of the Indian Society of Oilseeds Research, during which time he not only guided the society to expand its activities and responsibilities but also brought in reforms in its functioning. Prof. Chopra also guided and shaped the research programmes of several premier institutions of ICAR and of CSIR, including ICAR-IIOR, Hyderabad, in his capacity as the Chairman of the Research Advisory Council.

Prof. Chopra is well known for his simplicity, sense of humor, unassuming and very amicable demeanor which made him approachable for all. Prof. Chopra was a great teacher who used to genuinely nurture and inspire everyone around him. On a personal note, during the long standing association with Prof. Chopra, first as his student and then as a young scientist of his team, I have seen him as a perfect amalgam of scientific spirit and inquiry, un-satiated curiosity, absolute humbleness, simplicity and humanity personified and exemplified. He had a great penchant for science and scientific writing skills. It has been bewildering that behind such an overwhelming and towering personality with great accomplishments and recognitions, Prof. Chopra remained a very caring, simple and fatherly figure to all his students and staff alike. Even though he nurtured everyone with gentleness, he never compromised in instilling the scientific ethics and work discipline. The lessons learnt from this great persona are, in a way, too many to be expressed in words. It is just the pure gratitude that could be expressed for all that he showered on those known to him.

Prof. Chopra will be ever remembered for his scientific contributions, the institutions he has built, the legacy of knowledge, discipline and workmanship that he has left behind, and for his worth-emulating personal qualities. Once again ISOR salutes and salutes Prof. Chopra.

V. Dinesh Kumar
Editor

For more information readers may visit this site: https://en.wikipedia.org/wiki/Virender_Lal_Chopra

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.

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All these headings or matter thereof should start from left hand side of the margin, without any indent.

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A shortened title (approximately of 30 characters) set in capital letters should convey the main theme of the paper.

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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.

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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.

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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.

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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.

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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±, NS (not C.D., S.E.m±, 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.

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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^3m^2s (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

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