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Review

Sesame (*Sesamum indicum*) in the rice fallow environment - a critical appraisal

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ABSTRACT

Rice fallow sesame in the states of Tamil Nadu, Andhra Pradesh, Telangana, Odisha and to a limited extent in eastern Indian states, is an opportunity for horizontal expansion of sesame area and its production in the country. The productivity of sesame remains abysmally low as compared to the world average and research efforts needs to be focused to enhance the productivity of this crop which has a huge potential for export. Unlike rice fallow pulses cultivation, sesame cultivation needs concerted efforts to enhance its productivity in rice fallows. This review critically appraises the rice fallow environments in general, determinants of sesame production in this fragile environment and efforts needed for the successful area expansion of sesame crop in the country.

Keywords: Edible oilseed crops, Production, Rice fallow, Sesame

The setting

Oilseed crops continue to remain as the backbone of agricultural economy of the country since time immemorial and the largest producer of sesame in the world. Sesame is one of the most versatile crops that can be grown in semi-arid and arid regions with the unique attribute of being a short duration crop requiring minimal inputs (Oyeogbe *et al*., 2015) inhabiting "hungry and thirsty" environments. Vegetable oil consumption is expected to reach almost 200 billion kilograms by 2030 (Troncoso-Ponce *et al*., 2011). The level of productivity in India is far below the world productivity. The demand-supply gap in the edible oils has necessitated huge imports accounting for 60 per cent of the country's requirement (2016-17: import 14.01 million tonnes; cost ₹ 73,048 crore) (www.nfsm.gov.in). In the budget speech of 2019, finance minister was quoted saying that India imports about 15 million tons of edible oil spending around ₹ 77,000 crores to meet the annual requirement. To cope up with the increasing per capita demand of edible oils, horizontal expansion of oilseeds in rice fallow is one of the option. Sesame is an important oilseed crop with huge export potential. As majority of the area under oilseeds cultivation is still rainfed (around 75%), there is significant impact of vagaries of monsoon particularly water stress during most parts of the life cycle of the crop, on the productivity of sesame under rice fallow. Still there are several constraints and opportunities in utilising these rice fallow lands for sesame production.

The sesame crop

The sesame is one of the oldest oilseeds crops of the world (Langham, 1985) and the genus consists of about 36 species, of which the most commonly cultivated is *Sesamum indicum* L. (Falusi, 2006) and is one of the domesticated crop plants of India. Although, India ranks first in both acreage and production of sesame in the world, the productivity is too low compared to its original potential. India exports a large quantity of sesame to other countries. Sesame seed exports during April, 2018-February, 2019 stood at 2,86,760 tons in comparison to 3,08,172 tons during the previous year. In value terms, it increased to ₹ 3405.56 crores from ₹ 2701.24 crores. However, we have also imported 70,652 metric tons during April, 2018 - February, 2019. The export of sesame oil during April, 2018 to February, 2019 was 9229 tons mainly to Iran, China, Taiwan, Mexico, Netherlands, Singapore, UAE and USA (IOPEPC, 2019). It is cultivated in Africa, Middle East, and Asia since ancient times for its edible oil and seeds used in traditional foods (Park *et al.,* 2010). The top producer, exporter and importer of sesame in the world are Tanzania, Ethiopia and China respectively. India produces 13.1% (www.tridge.com) of the global output (Tanzania 15.4%, Myanmar 13.3%, China 10.6%, Nigeria 7.5% and Ethiopia 4.4%). A quantum of 350 mm of well distributed rainfall could sustain a successful sesame crop at an optimum temperature range of 25-35°C. As a dry season crop, it experiences severe water stress in one or the other part of its life cycle. Wherever raised as an irrigated crop, excess irrigation particularly under heavy soils is a serious concern which hampers the productivity. India produces a wide range of sesame seed varieties and grades, each peculiar to the region where they are grown. The following five states *viz.,* Gujarat, Madhya Pradesh, Rajasthan, Odisha and Uttar Pradesh house maximum acreage of sesame as a *kharif* (70%) season crop, although it is cultivated as a winter/summer crop to a limited extent (30%).

Rice fallow - an opportunity for the sesame crop

Rice occupies the *kharif* season in Southeast Asia, but a large chunk of this area (15 million ha) remains uncultivated or left as fallow in the subsequent season *rabi* or post-rainy

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season, due to water scarcity (Subbarao *et al.,* 2001). This land is regarded as paddy fallow. Of the total paddy fallow area in South and Southeast Asia, about 44 million hectares is in the country (Kumar *et al.,* 2018), with a share of 30% area (11.65 million ha) under *kharif* fallow (NAAS 2013). In addition to this area, there is one more paddy fallow under either paddy-paddy-fallow (summer) or Paddy-fallow (summer), wherein the farmer has two paddy crops in the system with short-medium duration rice crops, while the latter has only one medium duration rice coinciding the post monsoon or northeast monsoon paddy. As per an estimate in 2008, it is stated that more than 80 percent of the paddy fallow lies in the states of Assam, Bihar, Chhattisgarh, Madhya Pradesh, Odisha and West Bengal (Kumar Rao *et al.,* 2008). Rice covering an area of ~26.8 million ha and accounting for ~63.3% of the total rice acreage during the *kharif* in the Eastern India. Out of which, ~11.7 million ha area remains as rice fallow during the succeeding winter season due to several limitations (Kumar *et al.,* 2019).

Majority of rice grown soils in India are heavy soils and clay or clay loams. Such soils, with high water-holding capacity, produce higher rice yields and are suitable for second crop of pulses/oilseeds (Pande *et al.,* 2012). Alluvial, red, laterite and lateritic, black, saline and alkaline, and peaty and marshy soils are the dominant soil types in which rice is grown (Raychaudhuri *et al.,* 1963).

Rice fallow areas are characterized by a little residual moisture for sowing the *rabi*/summer crop (For eg. Ranchi and Hazaribagh in Jharkhand, Midnapore in West Bengal, Mayurbhanj in Odisha, Raichur in Karnataka, Jagdalpur/Kanker in Chhattisgarh; Mandla in Madhya Pradesh), waterlogging in selected areas resultant of excessive moisture in November/December (For eg. Nimpith and Gangasagar in West Bengal; Dhenkanal in Odisha; rice fallows of Assam), and to some extent socio-economic problems like stray cattle (for eg. Eastern Uttar Pradesh, Bihar and Jharkhand), blue bulls etc. (Ali and Kumar, 2009) destroying the crop. Improving the productivity of the land by growing the second crop in rice fallow needs suitable crop management techniques by utilizing the residual soil moisture. Regardless of ample opportunities for rice fallow systems, research in this area has not taken off due to a number of constraints. Being short duration in nature, sesame is an ideal crop for cultivation in rice fallow areas (Chauhan *et al.,* 2016). Choice of appropriate crop like sesame with short duration variety to tide over the water scarcity is the need of the hour. In addition, cultivation of early to medium duration varieties of rice (Behera *et al.,* 2014) during the *rabi* season to enable farmers to grow sesame on residual moisture in time is a felt need.

The rice-fallow environment

Rice grows in flooded conditions during part or all the crop period for about 6 months. In Tamil Nadu, the rice fallow is concentrated in the Cauvery deltaic zone as a result of single cropped medium duration rice (Season: Samba; Sowing/planting in August)) and double cropped short duration rice [Season: kuruvai (sowing/planting during Jun-Jul) - thaladi/late samba (sowing/planting during Sep-Oct)]. The harvest of samba season rice and thaladi season rice falls during January first fortnight to facilitate sowing of rice fallow crops around January 15.

In coastal Andhra Pradesh, covering the districts of Srikakulam, Vijayanagaram and Visakhapatnam, the rice fallow is the result of rice with 150 days duration which is harvested during December-January. Most part of this rice cultivated area is under submergence due to floods. Flood prone rice varieties are cultivated in this region.

Annual Sesame area is about 260.62 thousand ha and is cultivated in all the 30 districts of the Odisha State. Out of which summer irrigated (January-March) area is about 63.82 thousand ha in the coastal delta track. Major districts under Sesame are: Angul, Malkangiri, Sundargarh, Sambalpur, Dhenkanal and Bolangir (Singh and Samal, 2013). In Odisha, the rice fallow is the result of rice with 150 days duration which is harvested during November-December. Flood prone long duration rice varieties are cultivated in this region. At the time of harvest of rice, the atmospheric temperature remains below 15°C and environmental stress dictates the dates of sowing of sesame crop.

In a low land rice-based cropping system due to flooding of soil for over 2-3 months, the soil chemistry, microbiology, and the ultimate nutrient releasing capacity of the soil is altered to suit the low land rice crop. For example, soil redox potential, physical properties, light status, and nutrient sources for the micro flora are modified. In such a soil, Roger (1995) has opined that all kinds of N_2-fixing organisms are benefitted.

Way back in 1976, Patrick and Reddy (1976) have reported that, approximately one-fourth applied nitrogen to rice remains in the soil and roots at the time of harvest. i.e., precisely a considerable portion of applied nitrogen fertilizer to rice system (24.2 to 27.1 kg/ha) remains in the rice soil. A decade later, Buresh *et al.* (1989) confirmed that a significant portion of accumulated soil NO_3 may be lost from rice fallows upon the flooding of aerobic soil for rice production. When the flooded rice completes the life cycle, organic and NH_4-N could dominate in the soil over NO_3. Upon fallowing, transmission of aerobic N occurs and NO_3 starts accumulating.

Flooded soils are devoid of oxygen and two distinct soil layers *viz.,* aerobic top layer and an underlying reduced or anaerobic layer (Reddy, 1982) are formed. Traditionally rice fallows are occupied with leguminous crops like green gram and black gram as bonus crop to rice farmers. These crops can conserve the rice soil NO_3 besides capturing the atmospheric N through biological nitrogen fixation (BNF) (George *et al.,* 1992) although the amount of N fixed by legumes depends on the interaction of microbial, plant and environmental determinants. Legume-Rhizobium interactions are unique because they supply 80-90% of total nitrogen requirement of legumes. However, in case of oilseed crops like sesame, additional nutrients are ought to be supplied to reap the potential yields.

Ecological considerations for cropping in the rice fallow

Recent studies made by Haque *et al.* (2015) have projected an alarming situation that the dried fallow season after flooded mono paddy in the temperate zones of Korea and Japan contributed to approximately 30-60 per cent of the annual net global warming potential scale through greenhouse gas emissions. In such systems, paddy fields were flooded for less than 100 days during the rice cropping season and then are aerobically managed during the fallow season of over 200 days. Although this is applicable to temperate conditions, in Cauvery delta of Tamil Nadu, single rice (medium to long duration rice) crop is raised during the samba season and followed by pulses predominantly. Similar conditions prevail in the coastal Andhra Pradesh and Odisha. In both of these coastal regions, after the harvest of rice the land remains fallow for a period of not less than 45 days owing to low atmospheric temperature, which is unfavorable for sesame germination.

Determinants for sesame cultivation

Rice fallow or follow sesame? : Rice fallows are those lands either low land *kharif* or *rabi* sown rice areas which remained uncropped during *rabi* (winter)/summer season due to various reasons. Ghosh *et al.* (2012) reported an area of 11.7 m ha after *kharif* rice as fallow in the subsequent *rabi.* Unlike leguminous crops, there is no great deal of information on raising sesame under rice fallow conditions. Hence in parts of Andhra Pradesh and Odisha, the crop is raised only as rice follow crop in a rice-sesame cropping system. Although pulse crops are sown in the standing rice crop just 5-7 days before harvest in the wet/moist conditions of the soil, the seed ecology fits to the rice microclimate for first week and gets established well in the rice fallow ecosystem. But the sesame crop is poorly adapted to rice fallow regime (Harisudan and Sapre, 2019) due to the following possible reasons.

1. Ecological determinants

1.1. Effect of rice soil compaction on rice fallow sesame and tillage requirement : The extensive use of heavy machinery in rice farming brings about numerous benefits through the creation of a compact soil layer particularly to arrest the water loss through percolation and this could have a detrimental effect on the rice fallow sesame crop in general. Compaction normally increases the mechanical strength of the soil but excessive use may create soil management problem and can adversely affect plant growth (Raghavan *et al.,* 1977). Elfadil and Salih (2017) have found that soil compaction significantly affects sesame growth since excessive compaction impedes root penetration at levels higher than 1.6 g/cm^3. A decrease in the soil porosity after mechanical operations (Silva *et al.,* 2008) is a common phenomenon. In an experiment conducted at Vridhachalam, a part of Cauvery Delta area in Tamil Nadu, sowing of sesame after harvest of rice under till condition (rice-follow) had a positive impact on germination, crop growth rate and yield in comparison to sowing under no-till condition as rice fallow sesame (Annual Report, 2018-19; Harisudan and Sapre 2019). Moreover, the rice crop is under submerged conditions for over 2-3 months and changes the soil ecology as discussed above which is not favourable for the growth and development of sesame. In an organic fertilisation experiment, it was noticed that approximately 80% of the sesame roots were distributed in the top 10 cm (Rodrigues *et al.,* 2016), but this is not a universal fact. A change in soil ecology from flooded rice to aerated farming results in soil physical constraints and provides a hostile soil environment to sesame germination and establishment. Added to this, soil structure, soil water deficit, aeration, temperature, and mechanical impedance of the seed zone play the destroyer role. Possibilities of sesame shallow root distribution in rice fallow soils may be due to soil compaction from the puddled rice, porosity and lack of well drainage.

1.2. Atmospheric temperature : In many parts of the world including India, sesame is sown during the winter following rice harvest. As early in 1960s, Matsuoka (1958) has found that the germination temperature of sesame ranges from 10°C to 55°C, the proper temperature being between 30°C and 35°C and those varieties collected from tropical conditions show poor germination under low temperature. In Myanmar, farmers cultivate sesame in the winter in rice land after monsoon rice is harvested similar to the condition that prevails in coastal Andhra Pradesh and Odisha. To utilise the residual nutrients and utilising the moisture after rice harvest, the sesame needs to be seeded in cold, wet soil immediately after rice harvest. These conditions, however, are not suitable for germination of sesame. The seedlings which grow slowly are susceptible to damage by seed and root-rot organisms, which lead to an uneven plant stand low in vigor and yield potential. This winter planting subject the seeds to cold and wet soils, with erratic germination and seedling growth (Kyuak *et al.,* 1995) and is the major bottleneck in extending the sesame in rice fallows in India in Andhra Pradesh and Odisha. Crop seeds sown in cold soil are very slow to germinate and emerge and it would obviously be desirable to shorten the time from sowing to seedling emergence. Salicylic acid may provide a solution to the chilling injury, as this helps in chilling tolerance in plants (Farooq *et al.,* 2009) and its application alleviated the chilling (Miura and Tada, 2015) and freezing injury (Tasgin *et al.,* 2003). Khan *et al.* (1989) has found that at 15°C, root initiation did not occur up to 10 days after planting, and was delayed up to the fourth day at 20°C, and at 25°C, the main roots initiated on the second day. The lateral roots did not initiate until the sixth day after planting. One year later, Kyuak (1990) postulated that less than 20°C has adverse impact on sesame germination since only 46.86% germination was noticed at 15°C temperature. However, recently Bakhshandeh *et al.* (2017) have reported 14.7° C as the base temperature.

1.3. Poor moisture availability, anaerobic conditions and/or drought : It is important that sowing of sesame seed (either broadcast or line sowing) at optimum soil moisture content (either excess or deficit) in rice fallow fields. Excess soil moisture content can cause anaerobic environment for seed germination. Several studies (Mensah *et al.,* 2006; Tantawy *et al.,* 2007; Uçan *et al.,* 2007; Hassanzadeh *et al.,* 2009) have indicated that sesame is very susceptible to environmental stress particularly moisture be it for germination or subsequent growth and development. Recently, Bahrami *et al.* (2012) have concluded that regardless of the sesame cultivar, drought during early phases severely affects the germination and seedling growth. Low moisture content in the soil after rice harvest, fast receding of water table with the advancement of retreating monsoon season, and risk of intermittent soil moisture stress towards flowering and pod filling stages are some of the water related constraints for the establishment of fallow crop of sesame. During the *kharif* season water table is generally high but as the monsoon rains withdraw, the water table recedes very fast. Even if the crop gets well established utilizing available soil moisture, lack of *rabi* rainfall towards flowering stage creates drought conditions leading to crop failure (Kumar *et al.,* 2018). Chun *et al.* (2018) has concluded that sesame root growth from germination to early seedling is determined by soil moisture and not just genetic factors. This issue could be overcome by using appropriate seed pelleting chemicals to induce stress tolerance in sesame and /or appropriate seed drills.

2. Production constraints

2.1 Lack of improved varieties : Sesame crop varieties are highly photo sensitive. Varieties bred for *kharif* may not perform under rice fallow conditions. Except sesame variety VRI(SV) 1 released from TNAU, Coimbatore suitable for the rice fallow season of Tamil Nadu, in most of the states, all state recommended varieties for other seasons are only cultivated during rice fallow season also. Sesame crops are highly sensitive to water logging conditions. Crop will wither if water logging prevails for six hours in field during its vegetative stage. There is a lack of noticeable improved sesame varieties available for cultivation in rice fallows. Particularly sesame varieties which can tolerate excess water during the initial phase of establishment are not available. Besides low temperature tolerant sesame varieties are also not available.

2.2 Nutrient management: As an oilseed crop, sesame demands all essential nutrients for a profitable crop. Wherever, sesame is sown in rice fallows, the crop is seldom supplied with nutrients, and consequently the crop suffers due to nutrient stress. In an irrigated well managed lowland rice field with grain yields of 5 to 7 t/ha, fertilizer recovery efficiencies are 30 to 60 percent, 35 percent and 15 to 65 percent for N, P and K (BCI, 2002). In order to produce 1 tonne of paddy (rough rice), the rice crop absorbs an average of 20 kg N, 11 kg P_2O_5, 30 kg K_2O, 3 kg S, 7 kg Ca, 3 kg Mg, 675 g Mn, 150 g Fe, 40 g Zn, 18 g Cu, 15 g B, 2 g Mo and 52 kg Si (Roy *et al.,* 2006). Removal of straw from the field is widespread in India and so the depletion of soil K and Si reserves which has a significant impact on the succeeding fallow crop. In the process, some or all of the nutrients contained in straw may be lost from the rice field (Dobermann and Fairhurst, 2002). In order to produce 1 tonne of yield, the sesame crop absorbs an average of 51.7 kg N, 22.9 kg P_2O_5, 64 kg K_2O, 11.7 kg S, 37.5 kg Ca, 15.8 kg Mg (Roy *et al.,* 2006a). As the fallow sesame crop is cultivated with zero nutrient inputs, the nutrient management in rice would have an astounding impact on the succeeding sesame crop. Further, the physical condition of soil is poor due to puddled rice and consequently nutrient mobilization is reduced. The ongoing discussion indicated that sesame need to be supplied with balanced fertilisers in addition to the residual nutrients obtained from the previous rice crop in the rotation.

2.3 Weed management: A literature search for weed management in rice fallow sesame could not show any significant work in the direction. As a rice fallow crop, the sesame crop is vulnerable to weed competition. In Tamil Nadu, Cauvery delta areas of Tiruchirappalli district, rice fallow sesame area has become abysmally low due to severe weed competition from Carpet weed (*Trianthema portulocastrum*). Farmers are forced to postpone first irrigation to Sesame crop in the rice fallow season to avoid the proliferation of this weed species. The irrigation is scheduled in such a way that the weed competition period just crosses in four weeks after sesame sowing (Muralidharan, personal communication).

3. Opportunities for sesame cultivation in the rice fallow regions

Opportunities for the successful cultivation of crops in the rice fallow sesame with minimal investment need to be explored, particularly where a couple of supplemental irrigation is assured to realise optimum yields. The following research issues needs attention.

Mapping of rice fallow areas: The information on rice fallow areas are scattered and needs to be consolidated for accurate estimation. The available rice fallow area from various agencies provide only some preliminary information. National Mission on Oilseeds and Oil Palm has also made efforts for bringing additional area under rice fallow with pulses and oilseeds and sesame is one among the several crops. Recently the Government of India has made efforts to map the rice fallow areas of the country with satellite image from Mahalanobis National Crop forecast Centre, New Delhi under national Food security Mission.

Conservation agriculture practices: Considering the need to conserve the soil moisture and nutrients, zero tillage concept need to be studied soil wise to harness fullest potential of rice fallow sesame.

Research gaps: High yielding varieties are too few in sesame. Research on sesame specific to rice fallows, low temperature tolerant strains, water logging tolerant strains are needed in addition to drought tolerant cultivars to withstand moisture stress at later stages. Besides research information on soil health, pest management, mechanization etc. are also needed.

Research initiatives in NARS: ICAR has initiated developing package of practices for rice fallow experimentation through its Project Coordinating Unit (Sesame and Niger) located at Jabalpur through its coordinating centre at Tamil Nadu (Regional Research Station, Vriddhachalam) a couple of years back. ICAR-Indian Institute of Oilseeds Research, Hyderabad has initiated a network project on developing best management practices for enhancing sesame yield under rice fallow conditions at Hyderabad in collaboration with ICAR-Indian Institute of Rice Research, Agricultural Research Station (ANGRAU), Ragolu, Andhra Pradesh, Regional Research Station (TNAU), Vriddhachalam and AICRP sunflower centre at Dhenkanal, Odisha under OUAT in the year 2020 to identify optimum tillage and nutrient requirements for rice fallow sesame.

Thus, we feel that there is a great potential to increase sesame production in the country through exploitation of rice-fallow area that is available. However, there is a need to develop appropriate package of practice to make this a reality as there are grey areas in terms of availability of right technologies as well as adoption of the existing technologies. This opportunity is being explored through concerted efforts that have been initiated under NARS.

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Validation of QTLs for seed weight in a backcross population derived from an interspecific cross in soybean [*Glycine max* (L.) Merr.]

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ABSTRACT

Soybean [*Glycine max* (L.) Merr.] is a major oilseed crop of India. Seed weight is an important yield component trait which should be suitably optimized in soybean varieties to maximize productivity. To validate 100-seed weight quantitave trait loci (QTL), a backcross population of soybean was developed from a cross between wild species *Glycine soja* (Sieb. and Zucc.) and Indian soybean cultivar JS 335. The BC_2 backcross population was evaluated for three yield component traits, namely 100-seed weight, number of seeds/plant and seed yield/plant in BC_2F_2, BC_2F_3 and BC_2F_4 generation. Six QTLs reported to be associated with 100-seed weight in soybean were selected for QTL validation. SSR markers linked with two major QTLs for 100-seed weight could be validated successfully. One QTL, on linkage group D1a between Satt580-Satt179, identified for 100-seed weight explained 19.18% of phenotypic variance for combined data of three years. The second QTL for 100-seed weight was identified on linkage group C2 between marker Sat_251 and Sat_238 which contributed 10.97 and 9.28% of phenotypic variance in year 2015 and 2016, respectively.

Keywords: *Glycine soja,* QTLs (Quantitative trait loci), Seed weight, Seed yield, Soybean

Soybean [*Glycine max* (L.) Merr.] is a commercially and nutritionally important crop due to its high oil and protein content. It also contains minerals and health beneficial nutraceuticals like isoflavones and tocopherols. The productivity of soybean is low in India as compared to world average (Bhatia *et al.*, 2008). To improve productivity potential of soybean in India, location specific favourable alleles of genes for yield component traits derived from diverse genetic sources have to be combined in the adapted cultivars. The yield component traits like 100-seed weight (100-SW), seed number/ plant (SNPP), number of pods/plant (NPP), seeds/pod (SPP) and seed yield/plant (SY) are the major determinants of yield in soybean. In soybean, a large number of molecular markers have been developed through genomics research and a number of quantitative trait loci (QTLs) associated with various agronomic traits have been mapped using linkage mapping and association mapping (Ratnaparkhe *et al.*, 2014; Kumawat *et al.*, 2016). In cultivated soybean *G. max*, many QTLs have been identified for 100-SW and other yield component traits (https://soybase.org). Meta-analysis of previously reported 117 QTLs of 100-SW in the cultivated soybean had identified 15 consensus QTLs (Sun *et al.*, 2012). These consensus QTLs could be validated and utilized in new genetic backgrounds and environments through breeding.

It has been shown that wild species may have alleles of genes which positively influence agronomic traits (Tanksley and Mc Couch, 1997). Such favourable alleles might be beneficial if introduced into elite cultivars lacking such alleles. *Glycine soja* (Sieb. and Zucc.), a wild species of soybean, has characteristics of higher number of pods, smaller seeds, high protein content compared to cultivated soybean *Glycine max*, and have resistance to yellow mosaic disease (YMD) (Singh *et al.*, 1974; Wenbin and Jinling, 1988; Sebolt, 2000; Concibido *et al.*, 2003). *G. soja* is easily crossable with cultivated soybean (*G. max*), and therefore could be exploited for identification and incorporation of alleles for yield component traits and disease resistance. Studies on yield traits in wild soybean *G. soja* have identified some favourable alleles and suggested that *G. soja* can be used as the germplasm to improve yield traits (Concibido *et al.,* 2003; Wang *et al.*, 2004; Li *et al.*, 2008). In wild soybean PI407305, a QTL for seed yield was mapped on linkage group (LG) B2 in a backcross mapping population (Concibido *et al.*, 2003). A study by Wang *et al.* (2004) had identified four favourable yield QTLs in five BC_2 populations across two environments. Similarly, Li *et al.* (2008) had identified one yield QTL linked with Satt511 using *G. soja* derived BC_2F_4 population. Two QTLs for NPP and one QTL for SY were mapped by Kan *et al.* (2012) in a wild soybean derived mapping population phenotyped over two years. Association mapping in 113 wild soybean accessions also identified two SSR markers, sct_010 and satt316, associated with the SY (Hu *et al.*, 2014). Comparative genomic studies between gene models of *G. max* and *G. soja* had identified several unique genes among both the species (Joshi *et al.*, 2013).

Nonetheless, *G. soja* also possess several undesirable traits like smaller seed size, twinning growth habit, black seed coat colour and pod shattering, therefore extensive backcrossing is required. The backcrossing cycles and introgression breeding time could be reduced by application

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of molecular markers. When wild and cultivated lines are combined for dissection of complex traits and identification of molecular markers, the primary mapping populations are not preferred because these mapping populations can hardly be able to estimate individual QTL precisely due to their genetic background noise and poor general agronomic performance of lines. Therefore, there is a need to study QTLs for complex traits like yield and component traits in a backcross population that has improved agronomic performance (Tanksley and Nelson, 1996).The objectives of this study were to evaluate a BC_2 derived backcross population developed from wild species *G. soja* and a high yielding Indian soybean cultivar JS 335 for yield component traits and to validate selected SSR markers linked to consensus QTLs for 100-seed weight.

MATERIALS AND METHODS

Plant material and mapping population development: A BC_2 progeny row backcross population was developed by crossing between an Indian soybean cultivar JS 335 and an accession of *G. soja*, a wild species of soybean (Figure 1). The cultivar JS 335was used as recurrent parent for backcrossing. JS 335 is a popular soybean cultivar of India having characteristics of semi-determinate growth habit, medium maturity duration (100 days), 100-SW of 10-13 gm, 100-120seeds/ plant , seed yield/plant of 12-14 gm. The *G. soja* accession used for crossing is a long duration genotype having 100-SW of 2-3 gm and traits of seed shattering, indeterminate growth habit and YMD resistance.

Phenotypic evaluation for yield component traits: The BC_2 backcross population in BC_2F_2, BC_2F_3 and BC_2F_4 generation was grown for phenotypic evaluation of yield component traits during crop season of the year 2014, 2015 and 2016, respectively, at the research farm of ICAR-Indian Institute of Soybean Research, Indore (India). Augmented block design was used and three entries, namely JS335, JS 97-52 and JS 71- 05were randomly planted as checks in each block. Each progeny row was planted in two meters row length with row to row spacing of 50 cm and plant to plant spacing of 4-5 cm. Standard agronomic practices of soybean cultivation recommended for central India were followed to raise the crop. Ten plants from the middle of each row were harvested for phenotypic evaluations of three yield component traits i.e., 100-SW (gm), SNPP, and SY (gm).

DNA isolation and genotyping of mapping population: Leaf samples were collected from 3 week old BC_2F_2 lines (10 plants from each line) and stored at -80°C. Genomic DNA was isolated from stored leaf samples by CTAB method (Doyle and Doyle 1990). For validation of yield component trait QTLs in soybean, six genomic regions identified for the presence of consensus QTLs for 100-SW, were selected for SSR marker genotyping (Table 1).

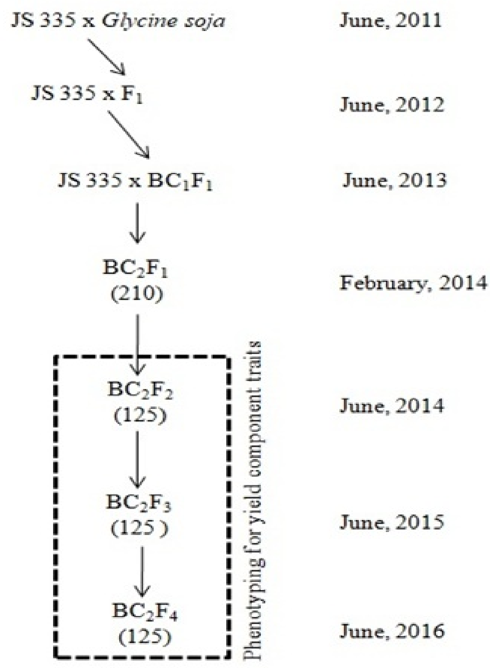

Fig. 1. Flow chart showing development and evaluation of backcross mapping population used in this study (Values in parentheses indicate number of seeds/progeny rows sown in a particular year)

Five to eight SSR markers from each selected genomic region were amplified using PCR and separated on Metaphor™ agarose gels for polymorphic markers identification. PCR reaction was performed in 20 µl volume of PCR mixture, containing 50 ng genomic DNA, 1X Taq DNA polymerase buffer, 2.5 mM $MgCl_2$, 0.5 mM dNTPs, 0.5U DreamTaq DNA polymerase (Thermo Scientific, USA) and 10 pmol of each primer. Thermal profiling was set up with initial denaturation temperature of 95°C for 05 min followed by the 35 cycle of denaturation (95°C for 60s), annealing (55°C for 60 s) and extension (72°C for 90s). The PCR amplified product was separated by electrophoresis on 3.5% Metaphor™ gels containing GoodView™ dye (SBS Genentech, China), run in 1X TBE buffer. The identified polymorphic SSR markers were genotyped in the individual BC_2F_2 lines of the mapping population.

Statistical analysis and QTL validation: Least square means of phenotypic data were obtained using PROC GLM procedure of SAS software (Copyright SAS 2017). Descriptive statistics of phenotypic data was calculated using SAS software. Single marker analysis (SMA) of variance and Inclusive composite interval mapping (ICIM) methods were used for QTL detection using QTL Ici Mapping Software (Meng *et al.,* 2015). LOD threshold for declaring a QTL were identified using 1000 permutations at P=0.05 for type I error.

Table 1 List of consensus QTLs of 100-seed weight trait selected for QTL validation

Linkage group	Map positions of consensus QTLs {Gm Consensus 4.0 (cM)}	SSRs selected for polymorphism analysis (http://www.soybase.org/search/qtllist.php)	References
B2	60-75	Satt230, Satt474, Satt066, Sct_064, Satt063	Concibido *et al*., 2003; Smalley *et al*., 2004; Guzman *et al*., 2007; Liu *et al*., 2011; Sun *et al*., 2012
C2	115-125	Sat_251, Satt142, Sat_238, Satt658, Satt079, Satt708, Satt312, Satt307	Zhang *et al*., 2004; Wang *et al*., 2004; Guzman *et al*., 2007; Palomeque *et al*., 2009; Du *et al*., 2009; Liu *et al*., 2011; Sun *et al*., 2012
D1a	40-55	Satt548, Satt254, Satt179, Sat_201, Satt580, Satt370, Satt106, Satt077	Orf *et al*., 1999; Hyten *et al*., 2004; Liu *et al*., 2011; Sun *et al*., 2012
I	35-50	Satt496, AB002807, Satt174, Satt239, Satt270	Concibido *et al*., 2003; Du *et al*., 2009; Liu *et al*., 2011; Sun *et al*., 2012
K	30-40	Satt055, Satt167, Satt247, Satt178, Satt555	Yuan *et al*., 2002; Wang *et al*., 2004; Kabelka *et al*., 2004; Guzman *et al*., 2007
M	10-25	Satt201, Satt150, Satt316, CSSR305, Satt567	Orf *et al*., 1999; Concibido *et al*., 2003; Zhang *et al*., 2004; Sun *et al*., 2012

RESULTS AND DISCUSSION

For validating the yield component QTLs in BC_2 backcross population, phenotypic data were recorded for three yield component traits i.e. 100-SW, SNPP and SY in the year 2014, 2015 and 2016, however, SNPP and SY data of the year 2015 was not used for analysis due to poor seed harvest. Least square means of the observed data were calculated and frequency distribution of phenotypic data for 100-SW, SNPP and SY had been fitted in a normal distribution curve which showed quantitative nature of traits (Fig. 2). Transgressive segregation on higher side of the observed values of all three traits indicated the presence of favourable alleles and new recombinant genotypes between both the parents (Table 2). In the year 2016, transgressive segregants were observed for 100-SW, SNPP and SY with observed value higher than JS 335. In the year 2016, BC_2F_4 line S47 showed highest 100-SW of 13.9 gm followed by SS171 with 13.29 gm. BC_2F_4 line SS147 showed highest SNPP of 210 followed by SS190b with 196.39 SNPP. BC_2F_4 line SS187 showed highest SY of 20.06 gm followed by SS177 and S122 with 18.55 and 18.25 gm, respectively. Normal distribution pattern observed among recorded phenotypic data of all three yield component traits indicated that the backcross population was suitable for QTL mapping.

Out of a total of 36 SSR markers used for parental polymorphism analysis from six genomic regions selected for QTL validation, 14 SSRs were polymorphic (Table 3). These 14 polymorphic SSRs were genotyped in 125 BC_2F_2 lines of backcross mapping population. Phenotyping data of 100-SW, SNPP and SY in BC_2F_2 and BC_2F_4 populations were used for QTL analysis, whereas for BC_2F_3, only phenotyping data of 100-SW were used for QTL analysis.

Using SMA method, three markers of a genomic region on LG D1a were identified to be linked with 100-SW trait in the year 2014 (Table 4). For this QTL region, highest phenotypic variance (PV) of 14.37% was explained by Satt580 at LOD score of 4.11. In the year 2015, two markers of LG C2 and one marker of D1a showed linkage with 100-SW trait. Satt580 on LG D1a was again identified to be linked with 100-SW in the year 2015, albeit with less phenotypic variance explained (PVE) and LOD of 7.89% and 2.06, respectively. Similarly, two closely linked markers Sat_251 and Sat_238 on LG C2 explained 10.15% and 10.24% PV at LOD score of 2.69 and 2.72, respectively. In the year 2016, SMA identified six SSR markers from three LGs associated with 100-seed weight, of these; five markers were identified to be linked in previous two years also (Table 4). Out of three markers identified for 100-SW on LG D1a, the highest PV of 20.55% at LOD score 6.09 was explained by Satt580. Sat_251 identified on LG C2 had explained 12.31% PV at LOD score of 3.48. A new marker Satt474 on LG B2 was identified to be linked with 100-SW explaining 8.59% of PV in this particular year.

Out of total six markers identified for three 100-SW QTLs, Satt580 showed linkage with 100-SW trait in all of the three years, whereas, Sat_251 showed linkage with 100-SW trait in two of the three years evaluated, both explaining more than 10% of PV. The favourable alleles of all the linked SSR markers identified were contributed by the recurrent parent JS 335. SMA analysis of SY trait had identified one SSR marker on LG B2 associated with SY for combined data of two years. Satt474 on B2 contributed 6.73% to PV for SY at LOD value of 1.89. Satt474 identified with additive value of 1.61 contributed by JS 335 alleles. None of SSR markers genotyped were associated with SNPP trait.

Using ICIM method, two QTLs were detected for 100-SW trait (Table 5). One QTL for 100-SW was identified on LG D1a between SSR Satt580 and Satt179,which was present between 36.58 to 38.58cM position. This particular 100-SW QTL was identified in all of the three years phenotypic evaluation data and explained up to 19.59 % of PVE. Another QTL for 100-SW was identified on LG C2 between marker Sat_251 and Sat_238 contributing 10.97% PV in the year 2015 and 9.28% in the year 2016.The SSR markers of both the QTLs were also identified using SMA method with similar level of PVE for 100-SW. The favourable alleles of 100-SW were contributed by recurrent parent 'JS 335' at both the QTLs. Since, the QTLs for 100-SW on LG C2 and D1a were identified at the same genomic location over the years in both the mapping methods, markers linked with these two major and consensus QTLs for 100-SW in soybean can be utilized in molecular breeding program confidently.

Previously, several QTLs for 100-SW and SY were mapped on to the six genomic regions which were selected for validation in this study (Sun *et al.,* 2012; Concibido *et al.,* 2003; Wang *et al.,* 2004; Smalley *et al.,* 2004; Guzman *et al.,* 2007; Liu *et al.,* 2011; Zhang *et al.,* 2004; Orf *et al.,* 1999; Hyten *et al.,* 2004). Although, these genomic regions comprise several SSR markers, two of the SSR markers identified in this study were specifically identified to be linked with 100-SW and SY traits in some of the previous studies (Concibido *et al.,* 2003; Guzman *et al.,* 2007; Du *et al.,* 2009; Fox *et al.,* 2015). In our study, Satt474 on LG B2 was identified to be linked with 100-SW in the year 2016 and SY for combined data of two years. Study by Concibido *et al.,* 2003, had also identified a yield QTL associated with Satt474 at LOD score of 2.14 in a *G. soja* derived population. In *G. max,* Guzman *et al.,* (2007) had identified a QTL for seed yield associated with SSR marker Satt474 and Fox *et al.,* (2015) confirmed this seed yield QTL. On LG D1a, Hyten *et al.,* (2004) identified a 100-SW QTL linked with Satt179 contributing 13.9% PVE in cultivated soybean population. In soybean, 100-SW is positively correlated with seed yield. Several factors had been identified that could affect soybean 100-SW, i.e. cotyledon cell number, cell growth rate, cell volume and weight, seed size, relationship between endogenous hormones and seed growth, and exogenous hormones (Sun *et al.,* 2012; Hirshfield *et al.,* 1992). Fine mapping and cloning of genes for 100-SW QTLs in near isogenic lines (NILs) could decipher the molecular mechanism of 100-SW variation in soybean. In India, molecular markers linked with YMD resistance and seed coat im-permeability traits were identified from *G. soja* (Rani *et al.,* 2018; Ramakrishna *et al.,* 2018). Recently, Mohekar *et al.* (2019) also validated SSR markers for pod shattering tolerance in Indian landrace Kalitur. The SSR markers validated for 100-SW QTLs in present study will be useful for rapid recovery of 100-SW during introgression of YMD resistance and seed coat im-permeability traits through marker assisted backcross breeding in soybean.

The present study reports development of a backcross population by utilizing a wild species *Glycine soja* in the background of Indian soybean cultivar JS 335. The BC_2 backcross population has been characterized for yield component traits and SSR markers linked with two major QTLs for 100-seed weight trait have been validated. A minor QTL has also been validated for seed yield/plant. The identified SSR markers for 100-seed weight can be used as preferred markers for the background selection to facilitate speedy recovery of seed weight in early generations while using wild relative *G. soja* as a donor for biotic and abiotic stress resistance. Further, the backcross population developed in this study is very useful for genetic mapping, development of near isogenic lines for fine mapping and identification of trait specific pre-breeding lines i.e. high protein content, disease resistance.

Table 2 Statistical details for phenotypic data of three yield component traits in backcross population derived from JS 335 and *G. soja*

Year	Population	Trait*	Recurrent parent	Backcross population				
			JS 335	Minimum	Maximum	Mean	Standard Error	Coefficient of Variance
2014	BC_2F_2	100-SW (gm)	10.4	5.9	12.0	8.14	0.125	16.93
		SNPP	141	79	245	148.39	3.344	24.89
		SY (gm)	13.2	2.7	17.8	9.75	0.313	35.21
2015	BC_2F_3	100-SW (gm)	7.6	3.1	10.4	6.37	0.103	20.52
2016	BC_2F_4	100-SW (gm)	11.5	5.8	13.9	9.25	0.124	17.51
		SNPP	104	23	210	113.49	2.833	32.16
		SY (gm)	12.5	1.3	20.0	9.93	0.295	38.77

*100-SW = 100-seed weight, SNPP = seed number/plant, SY = seed yield/plant

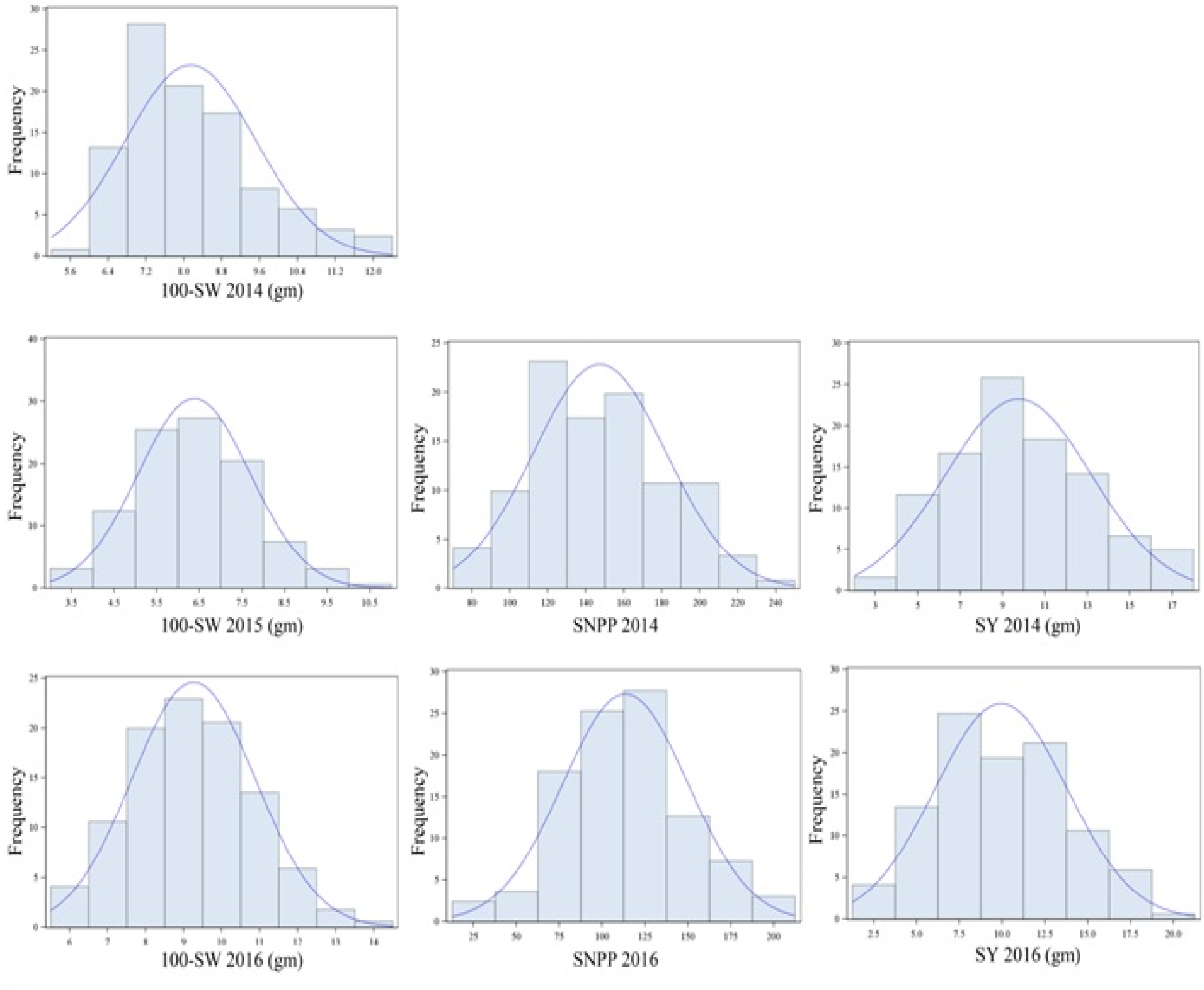

Fig. 2. Frequency distributions of 100-SW, SNPP, SY traits phenotyped over the years. 100-SW=100-seed weight, SNPP=Seed number per plant, SY=Seed yield

Table 3 Details of polymorphic SSRs identified between two parental genotypes JS 335 and *G. soja* for each consensus 100-SW QTL

Linkage Group	Position of selected genomic region (cM)	Number of SSRs surveyed	Number of SSRs polymorphic	Polymorphic SSR Name
B_2	63-73	5	3	Satt474, Sct_064, Satt063
C_2	115-125	8	2	Sat_238, Sat_251
D1a	35-45	8	3	Satt179, Sat_201, Satt580
I	35-45	5	2	Satt239, Satt270
K	30-40	5	2	Satt055, Satt555
M	10-20	5	2	Satt150, Sat_316
Total		36	14	

Table 4 QTLs for 100-seed weight identified by SMA method in backcross population derived from JS 335 and *G. soja*

Year	Linkage group	SSR name	Map Position (cM)*	LOD[a] (Threshold =1.83 at P = 0.05)	PVE[b] (%)	Additive effect
2014	D1a	Satt580	36.58	4.11	14.37	1.21
		Satt179	41.18	3.61	12.74	1.04
		Sat_201	42.50	2.95	10.54	1.00
2015	C2	Sat_251	104.50	2.69	10.15	1.11
		Sat_238	107.00	2.72	10.24	1.07
	D1a	Satt580	36.58	2.06	7.89	0.83
2016	B2	Satt474	63.36	2.37	8.59	1.13
	C2	Sat_251	104.50	3.48	12.31	1.52
		Sat_238	107.00	2.87	10.27	1.34
	D1a	Satt580	36.58	6.09	20.55	1.68
		Satt179	41.18	2.60	9.35	1.03
		Sat_201	42.50	4.38	15.23	1.41
Three years combined	C2	Sat_251	104.50	2.83	9.92	1.09
		Sat_238	107.00	2.52	8.87	0.99
	D1a	Satt580	36.58	5.47	18.25	1.26
		Satt179	41.18	2.95	10.31	0.87
		Sat_201	42.50	2.77	9.72	0.90

*Based on GmConsensus 4.0 map on Soybase; LOD[a]= Log of odds ratio; PVE[b]= Phenotypic variance explained by associated marker

Table 5 QTLs for 100-seed weight identified by ICIM method in backcross population derived from JS 335 and *G. soja*

Year	Linkage group	Left marker	Right marker	Map Position (cM)*	LOD[a] (Threshold =1.83 at P = 0.05)	PVE[b](%)	Additive effect
2014	D1a	Satt580	Satt179	38.58	4.41	17.42	1.25
2015	C2	Sat_251	Sat_238	105.50	2.80	10.97	1.11
	D1a	Satt580	Satt179	36.58	2.06	7.89	0.83
2016	C2	Sat_251	Sat_238	104.50	2.69	9.28	1.20
	D1a	Satt580	Satt179	36.58	5.38	19.59	1.49
Three years combined	D1a	Satt580	Satt179	36.58	5.47	19.18	1.26

*Based on Gm Consensus 4.0 map in Soybase; LOD[a]; Log of odds ratio; PVE[b]; Phenotypic variance explained by associated marker

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Yield stability and association of its component characters in soybean (*Glycine max* L.) genotypes

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ABSTRACT

The present investigation was carried out to study stability performance for seed yield and its components in 24 soybean varieties using a randomized complete block design. The partitioning of (environment + genotype x environment) mean squares showed that environments (linear) differed significantly for yield and its component characters except for 100-seed weight. Stable genotypes were identified for wider environments and specific environments with high *per se* performance (over population mean) for seed yield/ha. The investigation revealed that the genotype AMS 243 and DSB 20 possessed desirable stability across the environments. Genotypes AMS MB 5-19, NRC 2007 2-19 were suitable for favourable situations for seed yield.

Keywords: G x E interaction, Performance, Seed yield, Soybean, Stability analysis

Soybean (*Glycine max* L. 2n=2x=40) is an important oilseed produced in several parts of the world with rich source of protein and phytochemicals. This crop has amino acid composition in their protein which is on par with that of meat, milk products and eggs. The top producer of soybean is the USA occupying 34% of world's soybean production and contributing to 42% of market share. The soybean area in India has been increasing and has reached 10.84 m ha with a production of 11.48 m t and productivity of 1059 kg/ha during 2018-19.

Under changing climatic conditions the target put forth for breeders for increasing the productivity is development of high yielding and stable varieties of soybean. Soybean breeding in India mainly focuses on developing high yielding early maturing varieties with pest and disease resistance, suitability for food and vegetable purpose, improved seed germination & longevity and quality traits. In addition, this developed variety should have wider adaptability and stable performance across locations. Genotype x Environment (GxE) interaction determines the phenotypic expression among genotypes. The study of GxE interaction is crucial for indicating genotypes to each locality (Hamawaki *et al.,* 2015). Strong GxE interaction for quantitative traits like seed yield severely limits the gain in selecting superior genotypes for cultivar development (Kang, 1990). Hence evaluating stability of performance and adaptation range is very important for cultivar development. According to Polizel *et al.* (2013) a new soybean cultivar should have desirable characteristics like plant height, high grain yield, production stability and wide adaptation to diverse environments. JS 335, is a popular variety grown for more than a decade in the country and it is also the only variety being grown in Telangana zone since the introduction of the crop. Present study was carried out to identify the stable high yielding soybean genotypes for Telangana state.

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MATERIALS AND METHODS

The experiment was carried out in three consecutive rainy seasons of 2014-16. The material was sown on June 17, 2014, on July 7, 2015 and on June 22, 2016 at Farm of Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad located at 77°88 East and 18°58 North at an elevation 404 m above mean sea level. The soil pH at the test location ranged between 7.5-8.0 and the experimental material involved twenty four diverse genotypes of soybean collected from Agricultural Research Station, Adilabad, Telangana. The experiment was laid out in RCBD design with two replications. Each genotype was grown in 4 rows of 4 m length and at a spacing of 30×10 cm. The recommended dose of fertilizer of 30:60:40 of N, P_2O_5 and K_2O was applied to raise healthy crop. Entire P_2O_5 and K_2O was applied as basal dose while, N was applied in two splits, 1st at the time of sowing as basal and 2nd dose at 25 DAS. The weather conditions during the sowing season is presented in Table 1. Observations were recorded on five randomly selected plants from each plot for the traits plant height (cm), number of branches/plant, number of nodes/plant, number of clusters/plant, number of pods/plant and 100 seed weight, while days to 50% flowering and seed yield was recorded on whole plot basis. Varieties were analysed for stability parameters by following Eberhart and Russell model (1966).

RESULTS AND DISCUSSION

The analysis of variance revealed that genotypes differed significantly for all the characters indicating the presence of diversity among the genotypes under study. Similarly the environments in which the genotypes were grown varied significantly for all the characters. Variance due to GxE interaction was also significant for all the characters except for plant height indicating that most of the genotypes had differential response under varied environments. Similar significant observations were recorded by Rajkumar and Hussain (2008) and Pan *et al.* (2007). A significant variation due to environment (linear) was observed for all the characters studied and its higher magnitude when compared to G x E (linear) indicated that linear response of environments accounted for the major part of total variation for all the characters studied. A significant pooled deviation for all the characters suggested that the deviation from linear regression also contributed substantially towards the differences in stability of genotypes. Thus it could be assumed that both predictable and unpredictable components contributed significantly to genotype x environment interactions. Similar results were reported by Ramana and Satyanarayana (2005) and Dhillion *et al.* (2009).

The stability parameters analysed for the traits are presented in Table 3. Days to 50% flowering ranged from 47.13 to 50 days, genotypes AMS MB 5-19, KS 103, DS 2614 showed stable performance for days to 50% flowering. For the character branches/plant DSB-20, NRC 2007 A-3-1, AMS MB 5-19 and DS 2614 showed high mean performance with regression coefficient near to unity hence were considered to be most widely adaptable, while Basar with high mean performance with significant regression coefficient of less than unity could be considered as suitable for poor environments. The number of clusters/plant was highest in DSB 20 followed by GP 13 and Basar. GP 13 and Basar with high mean performance and significant bi >1 are suitable for favourable environments.

The mean number of pods/plant ranged from 34.78 (RKS 18) to 100.9 (GP 13) over the seasons with an average of 67.92. NRC 2007 2-19, Bragg and DSB 20 recorded higher mean no. of pods/plant and regression coefficient near to unity, and thus considered stable and widely adaptable to varied environments, while GP 13, Basar and KS 103 were suitable for favourable environments since their regression value was significant and more that unity. For the character 100 seed weight NRC 2011 F-1-15, AMS MB 5-18, RKS 18 and JS 335 showed high mean performance with regression coefficient near to unity and thus categorised as most widely adaptable, while NRC II R1 and NRC 2006 G-1-1 were found suitable for poor environments.

The seed yield/ha ranged from 13.75 q/ha (NRC 2007 2-19) to 33.13 q/ha (AMS 243) with a mean yield of 23.01 over seasons. AMS MB 5-19 with high per se performance and a significant regression value of more than unity was suitable for favourable environments, while genotypes AMS 243, NRC 2008 B-26 and DSB 20, with high mean performance were widely adaptable.

This study clearly showed the presence of GxE interactions among the genotypes under study for seed yield and its component characters. The genotype AMS 243 and DSB 20 with desirable traits and stability across the environments for seed yield and its component characters and could be used as parents in future breeding programmes to develop genotypes suitable for diverse environments.

Table 1 Analysis of variance for stability for seed yield and component characters in soybean

Source	Df	Days to 50% flowering	Plant height	Branches/ plant	Clusters/ plant	Pods/ plant	100 seed weight	Seed yield (q/ha)
Genotyes	23	3.67	119.71**	3.25**	67.98**	1041.01**	2.32	90.95**
Environment.	2	758.95**	353.82**	156.75**	202.99**	2407.78**	10.77**	529.51**
Gen.X Env.	46	4.18**	19.37	1.03*	14.53**	169.11**	1.41*	38.92**
Env + (Gen. X Env)	48	35.63**	33.30	7.52	22.38	262.37	1.80	59.36
Env (lin)	1	1217.96**	707.63**	313.50**	405.98**	4814.95**	21.55	1059.02**
Gen. X Env.(Lin)	23	4.78	38.74	-5.63	10.08	-18.47	2.28	-14.34
Pooled Deviation	24	3.43**	27.37	7.38**	18.18**	341.83**	5.51**	88.34**
Pooled Error	69	1.10	40.45	0.53	5.79	61.80	0.78	9.14

Table 2 Weather parameters during the study

	Average temperature (°C)			Total rainfall (mm)			Average RH (%)		
Months	2014	2015	2016	2014	2015	2016	2014	2015	2016
June	32.03	32.01	31.11	194.3	46.5	147	85.24	85.08	83.25
July	29.01	27.7	32.26	380	101	42	90.62	90.6	83.53
August	28.54	29.83	29.89	145	145.7	138	88.03	92.72	86.12
September	28.66	28.93	30.41	84	40.6	46.3	87	86.8	84.35

Table 3 Stability parameters of soybean for seed yield and component characters in soybean

Variety	Days to 50% flowering			Branches/plant			Clusters/plant			Pods/plant			100 seed weight (g)			Seed yield (q/ha)		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
AMS MB 5-19	50.00	0.94	-0.44	12.30	1.31*	0.04	22.58	-0.09	3.38	73.48	-0.28	3.64	10.72	1.21*	0.27	29.06	1.81*	0.39
KDS 344	49.00	1.12	1.83	11.83	1.11	0.16	18.23	0.51	0.26	58.52	0.24	3.34	11.45	-2.64	-0.31	17.50	-0.44	0.00
GP 13	48.33	0.87	3.84	10.98	1.47*	0.05	29.88	2.94*	0.85	100.90	3.63**	0.24	10.67	2.49	-0.39	25.68	2.05	70.63**
KS 103	48.00	0.84	-0.14	11.78	0.97	0.39	22.07	0.49	0.07	87.37	1.98*	0.21	8.92	0.91*	0.12	20.21	-0.74	0.54
JS 335	49.17	1.23	3.96	11.13	1.43	0.25	18.03	1.26	0.21	47.33	0.81	1.76	12.16	-0.78	0.52	20.42	0.98*	0.02
BHEEM	48.33	0.95	2.82	9.75	1.05*	0.01	18.10	1.10	0.47	49.47	0.99	27.92	11.13	3.27	0.41	16.46	2.74	2.40
RKS 18	49.33	1.39*	0.20	11.08	1.60*	0.03	12.45	-0.74	1.28	34.78	-0.87	19.31	12.61	-0.34	-0.32	16.56	1.42	15.13
NRC 2007 2-19	49.00	0.54	-0.47	11.88	0.67	0.13	22.68	0.42	0.48	88.70	2.49	35.66	11.46	-0.26	-0.21	13.75	1.79*	0.16
NRC 2009 A-4-3	47.83	0.77	8.78	11.68	0.75	0.02	23.97	1.22	1.04	80.18	0.62	0.77	12.06	1.26	-0.26	22.60	0.02	2.35
AMS 243	47.33	1.17	5.47	12.58	0.36	0.11	22.45	-0.19	0.74	84.82	0.75	3.58	11.69	1.89	0.76	33.13	4.20	13.11
BASAR	48.00	1.42	0.86	12.32	0.50*	0.02	28.00	2.99*	0.20	94.37	3.58*	3.68	11.55	2.03	-0.37	26.09	1.22	27.00
NRC II RI	49.50	1.21	5.72	11.65	0.35	0.06	23.77	1.09	0.23	77.48	-0.05	1.42	12.30	-0.08**	0.01	21.98	1.61	1.41
NRC 2008 B-26	47.17	0.56	-0.12	11.08	1.32*	0.01	23.35	1.25	0.86	64.53	0.36	2.51	11.82	4.14	-0.31	28.65	1.85	12.70
BRAGG	47.17	1.02	0.88	10.62	1.70**	0.00	23.20	1.49	1.37	88.83	1.57	21.96	11.44	3.26	-0.35	28.96	0.60	10.69
NRC 2006 G-1-1	50.00	1.31	11.44	10.13	0.80*	0.05	19.08	1.73	0.35	65.17	2.45	11.80	12.49	-1.26*	0.62	30.73	-0.97	6.50
LSB 23	48.00	0.60	1.46	10.60	1.13*	0.06	21.33	0.18	0.57	69.90	0.76	8.87	10.62	1.72	-0.28	20.63	-0.85	0.83
AMS MB 5-18	49.83	1.36	11.03	11.37	0.93*	0.01	20.42	0.23	2.29	70.83	1.06	15.57	12.33	-0.58	-0.23	27.19	1.18	1.89
NRC 2011 F-1-15	46.17	1.07	4.90	11.57	1.09	0.17	19.70	1.26	0.91	49.44	0.70*	0.55	13.05	1.32	-0.37	20.10	1.71	0.54
DSB 20	49.83	1.24	0.54	13.92	1.22	0.35	34.38	5.10	8.38	86.75	3.18	70.90	10.33	1.17	-0.39	28.49	-0.31	4.00
DS 2614	47.67	1.03	-0.30	12.17	0.70	0.08	17.53	-0.12	0.19	59.45	-0.14	12.26	11.83	1.22*	0.08	14.58	-0.65	0.05
NRC 2007 A-3-1	46.50	0.97	4.35	12.32	0.68	0.90	19.47	0.30	0.04	56.57	0.08	3.93	11.07	1.69	-0.37	25.94	0.69	3.80
NRC 2007 A-2-3	47.50	0.46	-0.26	8.87	0.75	0.30	18.70	0.26	0.51	58.65	-0.56	6.62	11.96	0.84*	0.10	25.94	1.66	5.12
GP 18	47.67	0.90	0.63	10.93	0.69	0.10	15.42	-0.37	0.16	41.12	-0.16	0.54	11.88	2.23	0.46	21.25	1.02*	0.14
JS 93-05	47.83	1.02	2.22	10.55	1.41**	-0.53	15.90	1.70	-5.38	41.37	0.80	-60.01	11.29	-0.71	3.76	16.25	1.41	4.11
Population Mean	48.30			11.38			21.28			67.92			11.53			23.006		

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Trombay Bidhan Mustard-204 (TBM-204): A high yielding yellow seed coat mustard [*Brassica juncea* (L.) Czern. & Coss.] variety notified for West Bengal

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ABSTRACT

Trombay Bidhan Mustard-204 (TBM-204) has been notified through Central variety release committee (CVRC) for cultivation in the state of West Bengal [S.O.No. 3220 (E) 5th September, 2019]. The variety recorded a significant increase of 23% over the national check, Kranti (1213 kg/ha) in initial varietal trial (IVT) under timely sown rainfed conditions of Zone-V during *rabi* 2016-17. Further, the variety demonstrated a potential average seed yield of 1336 kg/ha compared to national check Kranti (1211 kg/ha), zonal check Pusa Bold (1159 kg/ha) and local check B-9 (948 kg/ha) in multi-location yield trial conducted at different agroclimatic zones of West Bengal over 4 years. TBM-204 is tolerant to insect pest aphids and diseases like Alternaria blight and white rust under field conditions. The variety, TBM-204 with yellow seed coat and high oil content (41%) is also preferred by the farmers because it does not lodge or shatter at maturity. The variety with higher seed yield and B:C ratio over B-9 in field demonstration is proposed as an alternative to B-9. Molecular marker analysis depicted distinct SSR alleles for TBM-204 compared to Kranti and Pusa Bold.

Keywords: Mustard, TBM-204, Variety, Yellow seed coat

Among the nine oilseed crops grown in India, mustard [*Brassica juncea* (L.) Czern. & Coss.] is an important edible oilseed crop next to soybean and groundnut (Hegde, 2009). It is cultivated in 6.3 million hectares with a productivity of 1100 kg/ha. The average seed yield of mustard in the world is 2144 kg/ha while maximum possible seed yield of 3640 kg/ha indicating a large gap of 85% over world average and 213% over maximum possible yield. Low productivity in mustard is mainly due to cultivation of old varieties under rainfed conditions without following the improved agronomic practices (Paroda, 2013; Prajapati *et al.,* 2019).

The diverse agro ecological condition of West Bengal is favourable for growing mustard crop. Rapeseed mustard solely contributes 53% of the total oilseed production with a productivity of 909 kg/ha in the state (Dutta, 2014) which is far below the potential yield. The major constraints in production are late sowing due to late harvesting of *kharif* (aman) paddy, inadequate moisture at sowing time, particularly in rice-fallow lands, flood affected areas leading to delayed land preparation and formation of heavier soils and major biotic stresses *viz.,* mustard aphid, Alternaria blight, white rust and club root. Although there are several factors for poor yield, one of the main factors is the use of very old varieties in large areas of the state. The variety B-9 is popular in West Bengal but since it is cultivated for the last 35 years, the productivity is often low due to high incidence of pest and diseases. Since development of high yielding varieties of Indian mustard is foremost to enhance productivity (Meena *et al.,* 2014), evaluation of Trombay mustard high yielding genotypes was carried out under collaboration of Bhabha Atomic Research Centre, Mumbai and Bidhan Chandra Krishi Viswavidyalaya, West Bengal. Based on the superior performance in multi-location yield trials during the year 2013-14, to 2016-17 in sixteen locations, TBM-204 has been released and notified for cultivation in the state of West Bengal.

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MATERIALS AND METHODS

Development and evaluation of TBM-204: TBM-204 was developed through pedigree method of breeding by crossing TM102 and TM28. The female parent TM102 is a recombinant developed through interspecific cross between *B. juncea* and *B. napus* characterized with waxy leaves and bold glossy seeds. The male parent TM28 is yellow and bold seeded mutant of *B. juncea* with long main fruiting axis and 95 days to maturity. Hybridization between these two parents was attempted at Bhabha Atomic Research Centre, Trombay, Mumbai with the objective of development of high yielding, early maturing and high oil content progenies. Selection in F_2 and subsequent generations resulted in the development of early maturing, high yielding genotype TM 204 of yellow seed coat. Based on performance of station trial at Bhabha Atomic Research Centre, Trombay, Mumbai, it was evaluated under coordinated trial (Zone V) and also simultaneously in six locations of West Bengal namely Kalyani, Shekhampur, Kakdwip, Burdwan, Raghunathpur and Jhargram during the period 2013-14 to 2016-17 in different agro climatic zones.

Genotyping of TBM-204 along with Pusa Bold and Kranti: DNA from TBM-204 along with Pusa Bold and

Kranti was isolated from leaf tissue using CTAB method (Doyle and Doyle, 1990). One hundred and twenty (120) microsatellite markers (SSR) (http://www.brassica.info/resource/markers/ssr-exchange.php) were used to study DNA polymorphism. The PCR reaction was set for 25µl reaction volume which comprised of 2.5 µl 10 × PCR reaction buffer (invitrogen), 0.5 µl dNTPs, 1 µl (2 pico moles) each forward and reverse primers, 0.25µl (5 U/µl) Taq DNA polymerase (invitrogen), 2 µl template DNA (25 ng/µl) and 17.75µl sterile Milli-Q water. The PCR reaction conditions were initial denaturation at 95°C for 5 minutes, followed by 35 cycles of denaturation at 94°C for 30 seconds, annealing at 50-55°C for 30 seconds and extension at 72°C for 30 seconds and final extension at 72°C for 10 minutes and reaction was held at 4°C. All the PCR products were stored at 4°C until resolved on 2.5% agarose prepared in 1× TBE buffer containing 0.5 µg/ml ethidium bromide (EtBr).

RESULTS AND DISCUSSION

Seed yield of TBM-204 in Initial Varietal Trial (IVT) under timely sown rainfed conditions of All India Co-ordinated Research Project (AICRP) on Rapeseed and Mustard during 2016-17 was 1498 kg/ha which is 23.4% higher over national check Kranti (1213 kg/ha) (Table 1). TBM-204 recorded oil content of 38.4-42.1% and oil yield of 544 kg/ha which is 9.7% higher than Kranti (NC). In multi-location yield trials conducted during 2013-14 to 2016-17 (Table 2) under the jurisdiction of BCKV Kalyani, seed yield of TBM-204 was 1336 kg/ha which is 10.3% higher over Kranti (1211 kg/ha), 15.3% higher over Pusa Bold (1159 kg/ha) and 41% higher over B-9 (948 kg/ha).

Date of sowing trial revealed that sowing of the crop in the month of October (4^{th} Week) produced maximum seed yield as compared to other dates of sowing with fertilizer dose of N, P_2O and K_2O fertilizers @ 140:70:70 kg/ha. The entry showed negligible to moderate infestation against mustard aphid and moderately resistant reaction at 75 days after sowing and 15 days before harvest against the major disease Alternaria blight. Number of siliquae/plant contributed to the enhanced seed yield. Varietal characteristics of TBM-204 in comparison to check varieties have been presented in Table 3.

Large scale field demonstrations (Table 4) at farmers fields for two consecutive years under three agro-climatic zones of West Bengal, revealed 18.8 to 45% yield increase of TBM-204 over farmers practices under similar agronomic practices. During 2016-17, the increase of seed yield of TBM-204 was 18.8% and 24.3% respectively over local check variety in two districts. The benefit: cost ratio was also higher in case of TBM-204 than the local varieties in all locations. During 2017-18 altogether 40 farmers field were selected in Murshidabad, Nadia and Hooghly districts of West Bengal. At Nakashipara block of Nadia district, seed yield of TBM-204 was 25.9% higher over farmers' variety (B-9). At Dangarail village of Murshidabad district, TBM-204 showed 45% increase of seed yield over farmers' variety (B-9). TBM-204 performed better in Hooghly district also. It showed 27.9% yield advantage over local variety B-9. On an average TBM-204 showed 32.9% yield advantage over local check variety in three districts. The benefit:cost ratio was also higher in case of TBM-204 in all districts than the local varieties. The standard recommended package of practices is mentioned in the Table 5.

Molecular marker analysis was carried out at Bhabha Atomic Research Centre, Mumbai to discriminate the TBM-204 from Pusa Bold and Kranti. One hundred and twenty microsatellite or simple sequence repeat (SSR) markers were screened, out of which only three primers (Ra2A11, OI12F02, OI10F 09) showed allelic variation among the varieties. The sequence of the same is given below:

Primer name	Forward primer sequence (5'-3')	Reverse primer sequence (5'-3')	Ta
Ra2A11	GACCTATTTTAATATGCTGTTTTACG	ACCTCACCGGAGAGAAATCC	55 °C
Oi12F02	GGCCCATTGATATGGAGATG	CATTTCTCAATGATGAATAGT	56 °C
Oi10F09	AGAGAGCCAGATGATTGGC	AAACGACCACGAGTGATTC	56 °C

Polymorphic bands of approximately 200 bp and 150 bp were found for primers Ra2A11 and Oi12F02 respectively whereas an allele of around 100 bp was not found in TBM-204 for primer Oi10F09. Gel images showing polymorphism is given in Fig. 1.

Based on performance of TBM-204, the Project Review Committee, The Regional Nuclear Agriculture Research Centre (RNARC), recommended for submission of release proposal of TBM-204. Accordingly, variety was identified for release by State Variety Release Committee on 07.09.2018 and State Seed Sub Committee on 28.12.2018 by Government of West Bengal. It was notified through Gazette notification by Government of India vide S.O.3220 (E) New Delhi the 5^{th} September, 2019.

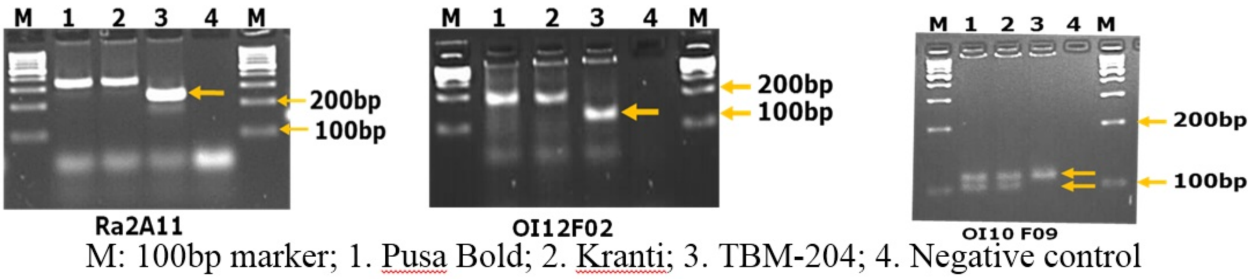

Fig. 1. Gel image of PCR products

Although a large number of short duration varieties of mustard are now available, which could be cultivated as sole crop as well as under rice fallows but there is no variety that is suitable under West Bengal condition under late sown condition. A short winter spell and cultivation of mustard as a catch crop in between kharif and boro rice necessitated the need for identification of short duration mustard varieties with high seed and oil yield potential. In this context, TBM-204, the newly released, high yielding mustard variety has a great scope for cultivation as a catch crop after the harvest of kharif paddy as a sole crop.

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Table 1 Zonal performance of TBM-204 for seed yield and oil yield in IVT-Timely sown Rainfed, Zone-V, rabi 2016-17

Variety	Seed yield (kg/ha)	Seed yield (% increase over checks)	Oil Yield kg/ha	Oil yield % increase over checks
TBM-204	1498		544	
Kranti (NC)	1213	23.5	496	9.67
DRMR-150-35 (ZC)	1407	6.47	537	1.30

Table 2 Average performance of TBM-204 for seed yield in multi-location trials (*rabi* 2013-14 to 2016-17)

Year	Genotypes	Seed yield (kg/ha)	% increase of seed yield over		
			Kranti(NC)	Pusa Bold(ZC)	Local Check
2013-14	TBM 204	1097	19.60	35.90	91.4
(Mean of 3 locations)	Kranti	917			
	Pusa Bold	807			
	B-9	573			
2014-15	TBM 204	1390	13.1	16.7	38.2
(Mean of 4 locations)	Kranti	1229			
	Pusa Bold	1191			
	B-9	859			
2015-16	TBM 204	1520	2.5	3.7	9.4
(Mean of 6 locations)	Kranti	1483			
	Pusa Bold	1465			
	LC	1389			
2016-17	TBM 204	1337	10.2	14.0	37.7
(Mean of 3 locations)	Kranti	1213			
	Pusa Bold	1172			
	B-9	971			
Mean over 4 years	TBM 204	1336	10.3	15.3	41.0
	Kranti	1211			
	Pusa Bold	1159			
	Local Check	948			

NC: National Check; ZC: Zonal Check; LC: Local Check

Table 3 Varietal characteristics of TBM 204 in comparison to check varieties

Characters	TBM 204	Kranti (NC)	Pusa Bold (ZC)	B-9 (LC)
Plant height (cm)	155.7	160.1	161.8	103.3
50% flowering (days)	51.0	52.2	53.1	38.8
Maturity (days)	110.7	111.5	111.8	93.2
No. of primary branches/pant	5.2	4.9	5.1	5.1
No. of siliqua/plant	233.3	233.7	245.3	193.1
Length of siliqua (cm)	6.2	5.7	5.8	5.9
No. of seeds siliqua	14.8	12.9	13.5	14.7
1000 seed weight (g)	4.7	5.2	4.9	3.4

Table 4 Performance of TBM-204 in at farmers' field demonstrations

District	No. of demonstrations	B:C ratio	Mean yield (kg/ha)		% seed yield increase over farmers variety
		IT:FP	IT	FP	
2017-18					
Nadia	20	2.12:1.70	1700	1350	+25.9
Murshidabad	10	2.51:1.66	1850	1275	+45.0
Hooghly	10	2.19:1.76	1650	1290	+27.9
2016-17					
Birbhum	15	1.66:1.40	1276	1016	+18.8
South 24 parganas	15	2.42:1.93	815	687	+24.3

IT-TBM-204; FP:B-9 variety

Table 5 Recommended package of practices

Suitability of the variety for the areas	Timely sown condition of the state West Bengal
Season	*Rabi* (Winter)
Selection of land	Well drained and levelled
Seed treatment	Carbendazim @ 2 g/kg of seed or Apron 35 SD @ 6g/kg seed
Sowing time	End of October to 1st week of November
Seed rate	6-7 kg/ha
Spacing	30 cm x 10 cm (Row to row and plant to plant)
Fertilizer dose	N: P_2O_5:K_2O @ 140:70:70, N in three splits (50% as basal, 25% at 30 days after sowing and 25% at 45 days after sowing)
Weed control	Two hand weeding. 15 days after sowing and 30 days after sowing
Disease and pest control	For Alternaria blight seed treatment and first spray of Ridomil MZ @ 0.25% at 50 days after sowing followed by two sprays of Mancozeb @ 0.2% at 15 days interval. For aphids spray of metasystox 25 EC @ 0.025% at ETL.
Irrigation	Three (30, 45-50 and 75 days after sowing)
Harvesting	115 days after sowing
Quality characteristics of the variety	Yellow seed coat mustard having high oil content (41%)
Attainable yield level	1500-1800 kg/ha (under optimum time of sowing and management)

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Effect of different phosphorus management practices on growth, yield and economics of summer groundnut (*Arachis hypogaea* L.)

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ABSTRACT

A field experiment was conducted during summer, 2018 at Junagadh Agricultural University, Junagadh, Gujarat, to study effect of improved microbial cultures on P nutrients, growth and yield of summer groundnut using improved microbial cultures. The experiment was laid out in randomized block design with ten treatments, replicated thrice. The results revealed that application of 100 % RDP + FYM @ 5 t/ha was found significantly superior over rest of the treatments with respect to growth, yield and nutrient uptake. Treatments comprising microbial cultures *viz.,* 100% RDP + DGRC 1 and 100% RDP + DGRC 2 produced significantly higher number of pegs/plant, number and weight of mature pods/plant, pod and haulm yield over 100% RDP. Maximum gross returns (1,12,251/ha) were obtained with the application of 100% RDP + FYM @5 t/ha compared to rest of the treatments while highest net returns (₹56,058/ha) and benefit-cost ratio (2.3) was gained with 100% RDP + DGRC 1.

Keywords: DGRC, FYM, Groundnut, Phosphorus, PSB

Groundnut is third most important oilseed crop in India, however, the productivity of groundnut in India is quite low (1465 kg/ha) as compared to other countries like USA and China. Gujarat has wide variability in groundnut productivity depending upon cropping season, soil types and crop management practices. The importance of phosphorus in maintenance of soil fertility and improving groundnut productivity is well recognized (Taliman *et al.,* 2019). Phosphorus exists in soil as both organic and inorganic form. Despite abundant phosphorus amount in soils, more than 80% of soluble P in soil remains unavailable for plant uptake due to fixation and low solubility in soil (Gulati *et al.,* 2008). Also, soluble forms of P fertilizers applied to the soil are easily precipitated (Haque and Dave, 2005). Sundara *et al.* (2002) reported that the recovery rate of P fertilizers by plants is only about 25%. The remaining 75% gets fixed in soil in immobile form bound to Al/Fe in acid soils and Ca/Mg in alkaline soils (Prochnow *et al.,* 2006; Yang *et al.,* 2010).

FYM has profound effect on improving soil physical, chemical and biological properties and enhancing productivity of crops (Rao and Shakawat, 2002). Thus, FYM plays key role in transformation, recycling and availability of P to the crop plants. Nowadays, chemical fertilizers are frequently being applied to the agriculture fields to meet the P requirement of crops and thus huge quantity of P gets fixed in soil just after application. Microorganisms play an important role in improving phosphorus use efficiency by enhancing P solubility and reducing fixation in the soil. Phosphate solubilizing bacteria (PSB) can solubilize and mineralize P from insoluble inorganic and organic sources through different mechanisms (Dey and Pal, 2014; Kamala *et al.,* 2019). In the soil, different bacterial species are able to exercise beneficial effects, by different mechanisms, on plant growth and have been termed as plant growth promoting Rhizobia (PGPR). DGRCs are the consortia microbial cultures containing PGPR, PSB, and Rhizobium. This study was carried out with the objectives of evaluating the effect of FYM and DGRCs on improving yield, profits, and phosphorus uptake in summer groundnut in light black calcareous soil.

MATERIALS AND METHODS

A field experiment was conducted in summer 2018 at Research Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (21.5° N and 70.5° E) on clayey (54% clay) slightly alkaline soil (pH 7.8 and electrical conductivity 0.33 dS/m), low in available nitrogen (237.0 kg/ha) and sulphur (17.5 kg/ha), medium in available phosphorus (21.5 kg/ha) and high in available potassium (284.0 kg/ha). The DTPA extractable micronutrients viz., Fe, Mn and Zn and available B were 5.35, 4.80, 0.78 and 0.66 ppm, respectively.

The experiment comprised of ten treatments i.e. T1 (Absolute Control), T2 (100% of recommended dose of phosphorus i.e., 50 kg/ha P_2O_5), T3 (DGRC 1), T4 (DGRC 2), T5 (100% RDP + DGRC 1), T6 (100% RDP + DGRC 2), T7 (50 % RDP + DGRC 1), T8 (50 % RDP + DGRC 2), T9 (PSB), and T10 (100 % RDP + FYM @ 5 t/ha), and laid out in randomized block design (RBD) with three replications. DGRC 1 and DGRC 2 are the consortia cultures consisting of two species of Rhizobium and a PGPR [(DGRC 1= (NRCG 4 + TAL 1000) + (*Pseudomonas gessardii* BHU 1); DGRC 2 = (NRCG 4 + TAL 1000) + (*Pseudomonas putida* S1)] and PSB (*Bacillus polymyxa* N5). Recommended dose of nitrogen and potassium (25 kg/ha N and 50 kg/ha K_2O)

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was applied in all plots including control, whereas doses of phosphorus were applied as per the treatments to the respective plots just before sowing. FYM was applied before sowing of the crop in treatment T10. Nitrogen was applied through DAP and urea, phosphorus through DAP and potash through MOP. DGRC 1 and DGRC 2 were applied as seed treatment @ 750 gm/ha in the respective plots. While PSB was applied through soil application @ 1200 ml/ha and then mixed in the soil through cultivator. The graded and healthy seed of groundnut GJG 31 were treated with vitavax powder @ 2 g/kg seed followed by treatment with DGRC 1, DGRC 2 @ 750 gm/ha or PSB @ 1200 ml/ha and the treated seeds, after drying in shade, were sown at 30x10 cm spacing. Irrigation was given just after the sowing and subsequent irrigation was given 4 days after sowing for getting successful germination. Post germination, total eight irrigations were given to the crop. The maximum and minimum temperature ranged between 28.1°C and 41.1°C and 12.1°C and 26.0°C, respectively and total rainfall received during the crop season was 35.9 mm. The crop was sown on 22nd February, 2018 and harvested on 18th June, 2018. Analysis of variance was worked out using standard statistical procedure as described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Growth and yield attributes and yield: Significantly highest in plant height, dry matter accumulation, no. of branches, number of pegs and mature pods, weight of pods, pod yield and haulm yield was recorded at harvest due to application of 100 % RDP + FYM @ 5 t/ha (Table 1 and 2). This might be attributed to supply of adequate quantity of phosphorus through integration of chemical fertilizer and FYM. These results are in conformity with the findings of Ananda *et al.* (2004), Patra *et al.* (2011) and Dalei *et al.* (2014). Application of 100% RDP + DGRC 1 and 100% RDP + DGRC 2, recorded relatively greater number of pegs/plant, number and weight of mature pods/plant, pod yield and haulm yield over 100% RDP. This might be attributed to the role of DGRC 1 and DGRC 2 in solubilization of plant nutrients and making them readily available for uptake by plants. The improvement in above attributes finally resulted in higher pod and haulm yield over application of 100% RDP. These results support the findings of Panwar and Singh (2003), Mir *et al.* (2013) and Dey and Pal (2014). Similar effect of PGPR and PSB on plant growth and yield due to their increased P uptake have been reported by many authors (Ismail and Bodkhe, 2013; Patra *et al.*, 2011; Bastani and Hajiboland, 2017; Suneetha and Ramachandrudu, 2017).

P uptake and available P in soil: Enhanced P uptake by plants and available phosphorus in soil at harvest was noticed with 100 % RDP + FYM @ 5 t/ha. Further, application of 100% RDP + DGRC 1 and 100% RDP + DGRC 2 had also improved the uptake and available P in soil after harvest in comparison to 100% RDP while lowest values were recorded for control (Table 2). Increased P uptake with combined application of inorganic fertilizer and FYM might be due to improved supply of P. DGRs cultures solubilized the unavailable form of phosphorus resulting in increased available P in soil (Kamala *et al.*, 2019). This can be attributed to higher dry matter production and higher NPK concentration (Table 2), as uptake is the positive function of dry matter yield (Ramakala *et al.*, 1985).

Table 1 Effect of different phosphorus management practices on number of branches, plant height, dry matter accumulation, number of pegs/plant, number and weight of immature and mature pods/plant of groundnut

Treatments		Number of branches/plant			Plant height (cm)	Dry matter accumulation (g/plant)	Number of pegs/plant	Number of mature pods/plant	Weight of mature pods/plant (g)
		60 DAS	90 DAS	At harvest	At harvest	At harvest			
T1	Absolute Control	4.1	4.7	5.7	18.8	20.8	15.3	9.6	7.8
T2	100 % RDP	5.4	6.2	7.3	21.1	25.4	18.8	11.1	10.1
T3	DGRC 1	5.2	5.9	6.7	20.3	24.5	17.5	10.6	9.3
T4	DGRC 2	5.2	5.8	6.7	20.1	24.5	17.4	10.6	9.2
T5	100% RDP + DGRC 1	6.5	7.4	8.6	22.9	27.7	20.7	12.7	11.7
T6	100% RDP + DGRC 2	6.4	7.3	8.5	22.9	27.7	20.7	12.7	11.6
T7	50 % RDP + DGRC 1	5.3	6.1	7.3	20.9	25.0	18.2	11.0	9.7
T8	50 % RDP + DGRC 2	5.3	6.0	7.2	20.8	25.0	18.1	11.0	9.6
T9	PSB	5.1	5.5	6.5	19.6	24.2	17.2	10.6	9.1
T10	100 % RDP + FYM @ 5 t/ha	6.7	8.6	9.8	24.7	30.1	22.6	14.3	13.0
	S.Em.±	0.3	0.4	0.4	0.6	0.7	0.6	0.5	0.4
	CD at 5%	1.0	1.1	1.2	1.7	2.2	1.8	1.5	1.3
	CV%	10.2	10.3	9.0	4.7	5.1	5.7	7.7	7.5

Table 2 Effect of different phosphorus management practices on pod and haulm yield, p uptake and P_2O_5 status at harvest

Treatments		Pod yield (kg/ha)	Haulm yield (kg/ha)	P uptake (kg/ha)	P_2O_5 status in soil at harvest (kg/ha)
T_1	Absolute Control	1307	2084	11.6	12.2
T_2	100 % RDP	1558	2449	17.0	21.4
T_3	DGRC 1	1450	2225	14.4	19.8
T_4	DGRC 2	1430	2205	13.9	19.7
T_5	100% RDP + DGRC 1	1776	2685	24.2	24.5
T_6	100% RDP + DGRC 2	1765	2680	23.2	24.4
T_7	50 % RDP + DGRC 1	1531	2354	16.0	20.7
T_8	50 % RDP + DGRC 2	1522	2348	15.7	20.4
T_9	PSB	1404	2160	13.0	19.5
T_{10}	100 % RDP + FYM @ 5 t/ha	1994	2909	31.4	27.5
	S.Em.±	66.04	73.61	1.3	1.0
	CD at 5%	196.21	218.71	3.8	2.9
	CV (%)	7.31	7.00	11.5	8.1

Table 3 Effect of different phosphorus management practices on economics of groundnut

Treatments		Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	BCR
T_1	Absolute Control	41344	74463	33119	1.8
T_2	100 % RDP	44051	88587	44536	2.0
T_3	DGRC 1	41686	82175	40489	2.0
T_4	DGRC 2	41686	81095	39409	1.9
T_5	100% RDP + DGRC 1	44391	100449	56058	2.3
T_6	100% RDP + DGRC 2	44391	99885	55494	2.2
T_7	50 % RDP + DGRC 1	43038	86789	43751	2.0
T_8	50 % RDP + DGRC 2	43038	86318	43280	2.0
T_9	PSB	41493	79596	38103	1.9
T_{10}	100 % RDP + FYM @ 5 t/ha	66794	112251	45457	1.7

Economics: Maximum gross returns (₹1,12,251/ha) was obtained with the application of 100 % RDP+ FYM @ 5 t/ha (Table 3). This could be attributed to higher pod and haulm yield as compared to other treatments. However, maximum net returns (₹56,058) and BCR (2.3) was obtained with the application of 100% RDP + DGRC 1. This is mainly due to lower cost of cultivation (₹44,391) as compared to 100% RDP + FYM @ 5 t/ha (₹66,794). The lowest gross returns (₹74,463) and net returns (₹33,327) were found with control. These results are supported by the findings of Jat and Ahlawat (2010), Mahajan *et al.* (2013) and Dalei *et al.* (2014).

Thus, from the experiment it could be concluded that among different phosphorus management practices in groundnut, application of 100 % RDP+ FYM @ 5 t/ha gave significantly highest pod and haulm yield but highest net returns were obtained with the application of 100% RDP + DGRC 1.

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Response of castor (*Ricinus communis* L.) to crop geometry and potassium on growth, yield attributes and yields under irrigated condition

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ABSTRACT

A field experiment was conducted at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh (Gujarat) during *kharif* season of 2013-14 to 2015-16. The soil was medium black and clayey in texture. The experiment was laid out in Split Plot Design comprising four levels of plant geometry (G1:150 cm x 90 cm, G2: 150 cm x 60 cm, G3: 120 cm x 90 cm and G4: 120 cm x 60 cm) allotted to main plots and four potassium levels (K1: Control, K2: 20 kg K_2O/ha, K3: 40 kg K_2O/ha and K4: 50 kg K_2O/ha) assigned to sub plots and replicated thrice. The results indicated that castor sown at 150 cm x 60 cm and 120 cm x 60 cm spacing recorded significantly higher plant population, plant height, number of branches, number of spikes, length of main spike, number of capsules per spike and seed yield in pooled results. While, almost all the growth characters, yield attributes, quality parameters and seed yield were found significantly higher when crop was fertilized with 40 and 50 kg K_2O/ha. Interaction effect between crop geometry and potassium levels was significant and crop geometry of 120 cm x 60 cm with potassium application @ 40 kg K_2O/ha (G4K3) recorded significantly higher castor seed yield (3714 kg/ha) and net return (`1,01,290/ha) with B:C ratio of 3.81. It was concluded that *kharif* castor should be sown at 120 cm x 60 cm with an application of potassium @ 40 kg K_2O/ha along with recommended dose of nitrogen and phosphorus (120-50 kg NP/ha) for obtaining higher seed yield and net return.

Keywords: Castor, Crop geometry, Potassium, Yields

Productivity of crop depends upon several agronomic factors. Among them plant geometry and nutrient management play an important role in castor production. Plant population is the basic component of package of production technology, but more important than this, is the proper adjustment of plants in field. Yield is a function of inter and intra plant competition and there is a considerable scope for increasing the yield by adjusting plant population to an optimum level. Balance fertilizer is also necessary for raising the castor yield, maintaining the quality of crop and productivity of soil. Potassium element is important in growth of crop, seed formation and development. Considering all these facts, the present study has been proposed to find out the influence of plant geometry and potassium levels on the growth and yield of castor crop.

MATERIALS AND METHODS

A field experiment was conducted at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat during *kharif* season of 2013-14 to 2015-16. The soil was medium black and clayey in texture. The initial soil organic carbon content, pH and bulk density were 0.64%, 7.820 and 1.31 Mg/m^3, respectively and having 217, 31.50 and 291 kg/ha available N, P_2O_5 and K_2O respectively. The experiment was laid out in Split Plot Design comprising four levels of plant geometry (G1:150 cm x 90 cm, G2: 150 cm x 60 cm, G3: 120 cm x 90 cm and G4: 120 cm x 60 cm) allotted to main plot and four potassium levels (K1: Control, K2: 20 kg K_2O/ha, K3: 40 kg K_2O/ha and K4: 50 kg K_2O/ha) assigned to sub plot and replicated thrice. Sowing of castor (var. GCH-7) was done as per treatments. Two inter cultivation followed by a hand weeding was done at 20 and 40 DAS to control the weeds. Recommended normal spacing and fertilizer dose for castor are 120 cm x 60 cm and 120-50-00 kg NPK/ha respectively. Full dose of phosphorus through diammonium phosphate and half dose of nitrogen was applied as basal dose at the time of sowing while the remaining quantity of nitrogen applied as top dressing in two equal splits at 30 and 70 DAS in the form of urea. Crop received 6 irrigations during each crop season. The crop was harvested by picking of matured spikes at different growth stages. The oil content in seed was determined using nuclear magnetic resonance. Five plants were tagged randomly in the net plot area for sampling in each plot at 50 days and were used for recording growth and yield attributes of the crop under different treatments. Economics such as net returns and benefit: cost ratios were worked out at the existing market rate. Bulk density, pH and soil organic carbon and available K content of soil were determined at the beginning of experiment and after harvesting of crop by flame photometric method as described by Jackson (1974) for this purpose, soil samples were drawn from each treatment and analysed for these physico-chemical properties.

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RESULTS AND DISCUSSION

Effect of plant geometry on crop growth and yield attributes: The pooled data for three years (2013-14 to 2015-16) showed that plant population, plant height, number of branches, number of spikes, length of main spike and number of capsules per spike were significantly influenced due to crop geometry (Table 1 and 2). Significantly the maximum plant population (13477) and plant height (111.99 cm) was observed at harvest under crop geometry of 120cm x 60cm. Plant geometry of 150cm x 90cm recorded significantly more number of branches (6.18), number of spikes (8.45), length of main spike (54.40) and number of capsules per spike (78.46). Wider plant geometry provided more space around each plant resulting in more metabolic activities through better utilization of light, space, water and nutrients which might have resulted in better vegetative growth. Dense population under closer plant geometry reduced number of branches and number of spikes per plant may be due to less availability of space for each plant which increased competition among the plants for resources. The results corroboratef with the findings of Venugopal *et al.* (2007), Sardana *et al.* (2008) and Man *et al.* (2017).

Effect of plant geometry on yield: The seed yield and stalk yield (Table 3) increased significantly due to different geometry treatments. The spacing of 120cm x 60 cm recorded higher seed yield (3387, 3563 and 3493 kg/ha, respectively) and stalk yield (5853, 5407 and 5769 kg/ha, respectively) during 2013-14, 2014-15 and pooled results, while crop geometry 150cm x 60 cm recorded higher seed yield (3612 kg/ha) and stalk yield (6050 kg/ha) during 2015-16, which was remained at par with geometry 120cm x 60cm. Higher seed yield with 120 cm x 60 cm plant geometry might be due to the fact that narrow spacing having higher plant population than wider spacing and numerically higher uptake of nutrients by seed and stalk (Table 2). The findings are in close conformity with that of Tank *et al.* (2007), Kathmale *et al.* (2008) and Man *et al.* (2017). Number of internodes per plant, 100 seed weight, oil per cent and K available status in soil after harvest of crop no found significant differences due to different treatments.

Effect of potassium levels on crop growth and yield attributes: The data furnished in Table 1 and 2) indicate that significantly maximum plant height (110.17 cm), number of branches (6.05), yield attributes *viz.,* number of spike (8.55), length of main spike (54.12 cm), number of capsule per spike (81.41), 100 seed weight (35.02 g) and oil content (49.66 %) were recorded when crop was fertilized with 50 kg K_2O/ha. This may be due to the favourable effect of potash known to augment cell division and cell expansion resulting in positive effect on growth and yield parameters. These results are in accordance with the findings of Mavarkr *et al.* (2009), Patel *et al.* (2010), Polara *et al.* (2010) and Shirisha *et al.* (2010).

Table 1 Effect of crop geometry and potassium on growth and yield attributes (Pooled of three year)

Treatment		Plant stand/ha	Plant height (cm)	No. of branches/plant	No. of spike/plant	Capsules/ spike
Crop geometry						
G1	150 cm x 90 cm	6700	100.43	6.18	8.45	78.46
G2	150 cm x 60 cm	10198	110.09	5.31	8.01	76.56
G3	120 cm x 90 cm	9272	105.25	5.61	8.16	79.09
G4	120 cm x 60 cm	13477	111.99	5.34	7.14	71.39
	S.Em±	88	2.07	0.23	0.18	1.59
	CD at 5%	260	6.14	0.67	0.53	4.71
	CV(%)	5.30	11.59	11.72	13.50	12.46
Potassium levels						
K1	Control	9928	100.83	4.94	6.64	69.54
K2	20 kg K_2O/ha	9928	107.80	5.46	8.09	74.24
K3	40 kg K_2O/ha	9877	110.17	5.97	8.47	80.33
K4	50 kg K_2O/ha	9915	108.96	6.05	8.55	81.41
	S.Em±	53	1.58	0.08	0.08	1.16
	CD at 5%	NS	4.46	0.23	0.22	3.28
	CV(%)	3.18	8.87	10.86	11.83	9.13
Interaction G x K: CD at 5%		NS	NS	NS	0.39	5.50

Table 2 Effect of crop geometry and potassium on quality, uptake of K and soil available K_2O (Pooled of three year)

Treatment		Length of spike (cm)	100 seed wt (g)	Oil %	K uptake by seed (kg/ha)	K uptake by stalk (kg/ha)	Available status of K_2O (kg/ha)
Crop geometry							
G1	150 cm x 90 cm	54.40	35.03	49.33	13.36	43.34	332
G2	150 cm x 60 cm	53.94	34.18	49.53	16.70	54.38	319
G3	120 cm x 90 cm	50.73	34.24	49.48	15.32	50.12	322
G4	120 cm x 60 cm	50.61	34.84	49.01	16.76	55.09	322
	S.Em±	1.10	0.32	0.17	0.34	0.76	18
	CD at 5%	3.27	NS	NS	1.18	2.64	NS
	CV(%)	7.34	5.61	2.01	7.58	5.20	19.65
Potash levels							
K1	Control	50.32	33.82	48.56	14.17	46.08	279
K2	20 kg K_2O/ha	51.80	34.51	49.55	14.40	47.18	332
K3	40 kg K_2O/ha	53.44	34.95	49.57	16.80	55.00	340
K4	50 kg K_2O/ha	54.12	35.02	49.66	16.78	54.68	344
	S.Em±	0.81	0.27	0.19	0.32	0.98	14
	CD at 5%	2.30	0.76	0.53	0.93	2.85	41
	CV(%)	6.08	4.68	2.27	7.12	6.67	15
Interaction G x K: CD at 5%		NS	NS	NS	NS	NS	NS

Ave. initial status of soil K_2O: 291 kg/ha

Table 3 Effect of crop geometry and potassium on castor seed and stalk yield

Treatment		Castor seed yield (kg/ha)				Castor stalk yield (kg/ha)			
		2013-14	2014-15	2015-16	Pooled	2013-14	2014-15	2015-16	Pooled
Crop geometry									
G1	150 cm x 90 cm	2635	2618	2739	2664	4458	4333	4607	4466
G2	150 cm x 60 cm	3153	3187	3612	3317	5336	4887	6050	5424
G3	120 cm x 90 cm	2815	2750	3178	2914	4808	4799	5458	5021
G4	120 cm x 60 cm	3387	3563	3527	3493	5853	5407	6049	5769
	S.Em±	66	92	118	55	150	134	224	100
	CD at 5%	229	319	409	162	520	464	777	299
	CV(%)	7.66	10.53	12.55	10.58	10.17	9.56	14.03	11.66
Potassium levels									
K1	Control	2408	2641	3046	2698	4094	4977	5189	4753
K2	20 kg K_2O/ha	3062	3000	3140	3068	5215	4356	5339	4970
K3	40 kg K_2O/ha	3207	3135	3425	3256	5482	4944	5788	5405
K4	50 kg K_2O/ha	3312	3342	3444	3366	5662	5148	5849	5553
	S.Em±	64	89	115	76	105	143	188	226
	CD at 5%	187	259	334	215	305	417	548	638
	CV(%)	7.40	10.16	12.15	10.23	7.09	10.18	11.74	9.98
Interaction G x K CD at 5%		NS	NS	NS	218	NS	NS	NS	660

Significant interaction effect was observed due to crop geometry and potassium levels. Crop geometry 150cm x 60cm with potassium application @ 50 kg K_2O/ha (G2K4) recorded significantly higher castor seed yield (3758 kg/ha), which remained at par with G4K3 (spacing 120 cm x 60 cm with potash @ 40 kg K_2O/ha), G4K4 (spacing 120 cm x 60 cm with potash @ 50 kg K_2O/ha) and G2K3 (spacing 150 cm x 60 cm with potash @ 40 kg K_2O/ha). While, castor stalk yield (6245 kg/ha) was significantly higher by geometry of 120 cm x 60 cm with potassium application @ 40 kg K_2O/ha (G4K3).

Effect of potassium levels on yields: The data (Table 3) indicated that the seed yield and stalk yield of castor was significantly influenced by various levels of potassium in individual year as well as when pooled across years. Application of 50 kg K_2O/ha recorded higher seed yield (3312, 3342, 3444 and 3366 kg/ha, respectively) and stalk yield (5662, 5148, 5849 and 5553 kg/ha, respectively) during individual years and in pooled results as compared to control (0 kg K_2O/ha), which was remained at par with application of 40 kg K_2O/ha. This might be due to cumulative effects of increasing trend observed on major growth and yield attributes. Moreover, overall improvement in vegetative growth at higher fertility level, which favorably influenced flowering and fruiting which ultimately, resulted in increased number of capsules per spike and yield of crop. The results are in line with the findings of Polara *et al.* (2010).

From the above results it could be concluded that castor sown at 120 cm x 60 cm spacing with an application of potassium @ 40 kg K_2O/ha along with recommended dose of nitrogen and phosphorus (120-50 kg NP/ha) gives higher seed yield.

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Studies on the effect of various priming treatments for quality seed production in sesame cv. VRI 1

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ABSTRACT

Sesame (*Sesamum indicum* L.; Pedaliaceae) is one of the oldest oil seed crops grown widely in tropical and subtropical areas for its edible oil, proteins, vitamins, and amino acids. Quality seeds along with other improved package of practices play a vital role in improving productivity of crops under rainfed condition. Different techniques are used to enhance vigour of the plants and crop yield of which, seed priming is the simple and suitable technique to increase germination, emergence and establishment. Hence, the present investigation was carried out to study the effect of various seed priming treatments on quality seed production in sesame cv. VRI 1. The seeds of sesame were given with various priming treatments i.e., priming with GA_3 @ 100 ppm, IAA @ 100 ppm, $MnSO_4$ @ 0.5, $FeSO_4$ @ 0.5%, KCl @ 0.5%, prosopis leaf extract @ 2%, pungam leaf extract @ 2%, arappu leaf extract @ 2%, tamarind leaf extract @ 2% and nochi leaf extract @ 2%. Seeds treated with just water acted as control. All the treated seeds were evaluated for the initial quality characteristics and field performance. Among the treatments, it was found that prosopis leaf extract treatment @ 2% registered higher values for initial seed qualities. In field evaluation also, prosopis leaf extract treatment @ 2% recorded higher growth, physiological and yield parameters in sesame cv. VRI 1.

Keywords: Sesame, Seed Priming, Seed quality

Sesame (*Sesamum indicum* L.) is one of the ancient oilseed crops grown in India. Seed is one of the most vital and critical inputs for increasing agricultural production and productivity. Even though we have achieved self-sufficiency in food grain production, the productivity in pulses and oilseeds is very low leading to import of them to meet out the shortages (Govindaraj *et al.,* 2016). The seeds of improved varieties have played a key role in agricultural transformation of India. Out of many constraints leading to low production of this oilseed crop, seed quality is of prime importance. Sesame seeds deteriorate more rapidly after harvest, which reduce the quality of seeds (Prakash *et al.,* 2019). Seeds can retain their high vigor for some time and thereafter begin to deteriorate losing their germination capacity, vigor and viability. During ageing of seeds, several biochemical and physiological changes occur that result in a progressive decline in seeds quality and performance (Mc Donald, 1999). These low vigor seeds germinate and emerge poorly and result in smaller plants as compared to high vigor seeds. Various techniques are available which enhance the vigor of seeds and these technologies are termed as seed invigoration/seed enhancement techniques (Kyrychenko, 2014). Seed enhancements are the beneficial techniques performed on seeds to improve germination, emergence and seedling growth by altering seed vigor and or the physiological state of the seed (Black and Peter, 2006).

Seed priming treatment is done before sowing seeds, which involves hydration of seeds to initiate metabolic events before germination to take place, although preventing radicle emergence to occur. Priming is an approach that involves treating seeds with different organic or inorganic chemicals and or with high or low temperatures. It entails imbibition of seeds in different solutions for a specified duration under controlled conditions, then drying back them to their original moisture content, so that radicle do not emerge before sowing. This stimulates various metabolic processes that improve germination and emergence of several seed species, particularly seeds of vegetables, small seeded crops and ornamental species. Seed priming is considered to be an easy, highly effective, low cost and low risk technique. Primed seeds are more useful because of numerous advantages such as uniformity, early and faster appearance, crop establishment, and efficient use of water, enhancing roots to grow deeper, allowing germination in dormant seeds by increasing metabolic events, to initiate growth of organs for reproduction, early flowering and maturity (Singh *et al.*, 2015). Seed germination is a complicated process involving different metabolic events which results in change from stored food reserve to activation phase where radicle and plumule emerge. Due to this, different benefits such as synchronisation of radicle emergence, increase in growth rate and enhancing large number of seeds to germinate are imparted. During priming, seeds complete the initial phases of germination and complete the imbibition process faster, and this reduces the time required for cellular activities to take place (Varier *et al.,* 2010). In the present investigation, studies were conducted to understand the effect of various invigorative priming treatments on quality seed production in sesame cv. VRI 1.

MATERIALS AND METHODS

The sesame (*Sesamum indicum*) cv. VRI 1 released from Oilseed Research Station, Vridhachalam formed the base material for the study. The VRI 1 variety is the ruling variety in the cauvery delta zone of Tamil Nadu. The present investigations were carried out at the Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University to study the influence of various seed invigorative hardening treatments on quality and productivity. Freshly harvested genetically pure bulk seeds of sesame cv. VRI 1 were imposed with the following seed invigorative treatments. The treatments included T0 - Control, T1- GA_3 @ 100ppm, T2 - IAA @ 100ppm, T3 - $MnSO_4$ @ 0.5%, T4- $FeSO_4$ @ 0.5%, T5- KCl @ 0.5%, T6- Prosopis leaf extract @ 2%, T7- Pungam leaf extract @ 2%, T8- Arappu leaf extract @ 2%, T9- Tamarind leaf extract @ 2% and T10- Nochi leaf extract @ 2%.

The seeds were soaked in equal volume of (1:1) growth regulators *viz.,* GA_3 and IAA @ 100 ppm, for 4h along with water. The seeds were soaked for four hours in $MnSO_4$ @ 0.5%, $FeSO_4$ @ 0.5% and KCl @ 0.5% at equal volume (1:1) of seeds. The seeds were soaked for four hours in Pungam leaf extract (2%), Prosopis leaf extract (2%), Arappu leaf extract (2%), Tamarind leaf extract (2%) and Nochi extract (2%) at equal volume of (1:1) seeds. The above soaked seeds were dried back to original moisture content. The treatments were evaluated for seed quality parameters *viz.,* germination percentage, shoot length, root length, dry matter production following the procedure of ISTA (1999), vigour index by Abdul-Baki and Anderson (1973) and EC by Presley (1958). The above treated seeds were also evaluated for their field performance by adopting Randomized Block Design (RBD) with three replications under dry land condition. The plot size was $4 \times 2.5\ m^2$. The crop was raised with the spacing of 30×15 cm and recommended package of practices for sesame were followed. The following observations were recorded i.e., field emergence (%), plant height (cm), number of branches/plant, days to 1st flowering, days to 50% flowering, number of flowers/plant, chlorophyll content, gas exchange parameters, number of capsules/plant, dry weight of capsule (g), capsule yield/plant(g), capsule yield/plot (g), number of seeds/capsule, seed weight/capsule (g), seed yield/ plant (g), seed yield/plot (g), capsules to seed recovery (%) and 100 seed weight (mg). All the data were analyzed statistically with appropriate tools and expressed as mean values as per the method of Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Pre-sowing hardening or imbibition and drying back of seed is one of the methods which results in modifying physiological and biochemical nature of seeds so as to develop or manifest the characters that are favorable for drought resistance. During the hardening treatment, the drought resistance in seed is created by the alternate wetting and drying process, using either water or chemicals or botanicals based on its suitability for invigoration and productivity which varies with crop and the seed lot used for sowing. It has been reported that these treatments improve the germination behavior of different crops under extremely varying conditions by fortification or hardening the seeds prior to planting. Such effects were due to activation caused by the treatments on metabolism, which is related to germination and also on the pathways that impart stress tolerance.

In the present study, in laboratory analysis the 2% Prosopis leaf extract hardened seeds recorded better seed qualities viz., germination percentage, root length, shoot length, dry matter production, vigour index with 17.9, 47.8, 45.3, 42.4, 73.6 percentages higher than control respectively with respect to these characters (Table 1). Similar results were reported by Srimathi *et al.* (2007), Kamaraj and Padmavathi (2012) and Sathiya Narayanan *et al.* (2015) in green gram. This could be due to the modification of physiological and biochemical nature of the seeds so as to get the characters that were favorable for drought resistance (Henckel, 1964). The percentage of germination is an excellent indicator for survival and growth potential of seed. The Prosopis leaf extract (2%) hardened seeds would become physiologically advanced by carrying out some of the initial steps of germination and the subsequent improvement in germinability of these 2% Prosopis leaf extract hardened seeds could be because the hardened seeds could just take off from the germination step they would have ceased at the end of the hardening process and continue from that stage for further growth and development once the germination conditions are restored. The first step of germination is formation of GA_3 and hydrolytic enzyme that aid in translocation of food material in simpler form to the germinating radical (Copeland, 1995). The reason for the higher germination of seeds treated with Prosopis leaf extract was due to the presence of greater hydration of colloids, higher viscosity and elasticity of protoplasm, increase in bound water content, lower water deficit, more efficient root system (May *et al.,* 1962) and increased metabolic activities of seeds that were hastened by the hardening. The increase in dry weight was claimed to be due to enhanced lipid utilization through glyoxalate cycle, a primitive pathway leading to faster growth and development of seedling to reach autotrophic stage well in advance of others and enabling them to produce relatively more quantity of dry matter.

The hardened seeds were also evaluated under field condition, the biometrical, gas exchange and yield parameters were observed. The results revealed that the 2% Prosopis leaf extract hardened seeds recorded higher values for the biometrical traits *viz.,* field emergence, plant height, number of branches/plant, number of flowers/plant which were 20, 23.3, 50, and 28.1 percentages higher than the control respectively for the above mentioned characters (Table 2). Paddy seeds hardened with KCl @ 1% followed by pelleting with pungam leaf powder @ 200 g/kg recorded increased growth and biometric characters (Prakash *et al.,* 2013). The chlorophyll content and gas exchange parameters such as, photosynthesis, transpiration, intercellular CO2 concentration and stomatal conductance were also found higher in 2% prosopis leaf extract hardening treatment which were 30, 25.4, 11.30, 17.32, 26.50 percentages higher than control respectively with respect to the mentioned characters (Table 3). Increased chlorophyll 'a', 'b' and total chlorophyll contents were observed in pungam leaf powder pelleted seeds @ 200 g/kg. This increase could be due to the presence of mineral nutrients like nitrogen, potassium and calcium which play a major role in chlorophyll synthesis (Prakash *et al.,* 2013: Ophelia, 2017). Prakash *et al.* (2018) found that plants treated with pungam leaf powder @ 150 g/kg recorded more photosynthesis, transpiration rates and stomatal conductance. This treatment also recorded higher yield attributes such as number of capsules/plant, dry weight of capsule, number of seeds/capsule, seed weight/capsule and seed yield/plant that were 29.6, 33.9, 17.4, 20.9, 52.8 percentages higher than control respectively (Table 4). Similar results were reported by Sathiya Narayanan *et al.* (2015), Sathiya Narayanan *et al.* (2013) and Srimathi *et al.* (2007) in green gram.

Rapid and uniform field emergence are the two essential pre-requisites to increase the yield. The Prosopis hardening supplies the bio active materials such as, GA like substances to seed, which play an important role in enhancing the seed vigour and seed germination which leads to rapid growth under drought condition (Saitoh *et al.,* 1991). Early germination may be due to the greater hydration of colloids and higher viscosity of protoplasm and cell membrane that allows the early entrance of moisture which activates the early hydrolysis of reserve food materials in the seed when compared to untreated seeds. Prosopis leaf extract contains plant mineral nutrients like nitrogen (5.6%), phosphorus (P_2O_5-0.9%), potassium (K_2O^{-3}.11%) and calcium (CaO^{-1}.0%) (Nadeem Binzia, 1992). The higher germination might be due to the role of calcium as an enzyme co-factor in the germination process by increasing protein synthesis as reported by Christansen and Foy (1979).

The stimulatory effect on germination and the growth of seedlings of hardened seeds could be due to the fertilizing effect resulting from the nutrient release from damaged or decayed tissue of storage organ by hydrolysis (Orr *et al.,* 2005). The increase in dry weight was claimed to be due to enhanced lipid utilization and enzyme activity due to the presence of bioactive substances like auxin in Prosopis leaf extract (Rathinavel and Dharmalingam, 1999) and development of seedling to reach autotrophic stage and enabling them to produce relatively more quantity of dry matter which discerning the cause for the hike in vigour index by hardening treatment. This may be due to the beneficial effect of Prosopis leaf extract seed hardening which activates the growth promoting substances and translocation of secondary metabolites to the growing seedling. Physiologically active substances might in turn activate the embryo and other associated structures which result in the absorption of more water due to cell wall elasticity and development of stronger and efficient root system ultimately resulting in higher vigour index (Rangaswamy *et al.,* 1993).

The Prosopis leaf extract hardening treatments might have improved the growth of plant during early stage of the crop with increased vigour and associated stronger root system which in turn might have favoured the derivation of available soil moisture and nutrients enabling better growth that resulted in higher yield (Jegathambal and Shanmugam, 2007). Generally the seedlings with initial vigour perform better and utilize all the available resources for better growth. The initial vigour of the Prosopis leaf extract invigorated seeds might have induced the quick seedling growth and increased plant height with increased number of branches. Chlorophyll is the most important compound as it is involved in photosynthate production (Mishra and Srivastava, 1983). When nitrogen is supplied either through inorganic or organic source of the crop, the increase in chlorophyll occurs (Austin *et al.,* 1973).. Effect of organic seed treatment and foliar spray on growth and yield has been reported in sesame by Prakash *et al.* (2019).

In the laboratory and field evaluation, the seeds primed with GA_3 improved significantly the seed yield and quality followed by Prosopis leaf extract hardening. The gibberellins are known to regulate developmental and physiological processes such as germination, stem, leaf growth, synthesis of food, transporting and partitioning it, stimulating transcription of genes involved in hydrolytic enzymes in various plants. Pretreatment with GA_3 increased total germination percentage, decreased mean germination time and increased seedling growth performances. The endogenous gibberellic acid synthesized by the seed embryo might not be sufficient and as such the external application probably boosted the growth by increasing cell multiplication and cell elongation, resulting in rapid plant growth. The higher vigour of seedling due to GA_3 pre-soaking can be correlated with higher seed germination, higher shoot length and root length and number of leaves leading to the overall assimilation and distribution of food material within the plant (Brain and Hemming, 1955) and hence resulted in higher seedling vigour (Pampanna and Sulikeri, 1995). The beneficial effect of GA_3 application may be attributed to the cell multiplication and elongation in the cambium tissue (Shirol *et al.,* 2005). The GA_3 seed hardening improved the rate of photosynthesis and caused greater accumulation of photosynthates leading to increased dry matter of plant and significant improvement in growth rate. This also helps in invigoration of physiological process of plant and stimulatory effect of chemicals to form new leaves at faster rate as suggested by Sharma *et al.* (1999).

Table 1 Influence of invigorative hardening treatments on initial seedling qualities in sesame cv. VRI 1

Treatment	Germination (%)	Root length (cm)	Shoot length (cm)	Dry matter production 10/seedling (mg)	Vigour index	Electrical conductivity (dS/m)
T0	78 (62.02)	9.6	6.1	35.8	1224	0.19
T1	89 (70.63)	13.1	8.1	47.5	1886	0.09
T2	86 (68.02)	12.1	7.6	43.9	1694	0.11
T3	84 (66.42)	12.6	7.8	46.4	1713	0.14
T4	79 (62.72)	11.5	7.5	43.5	1501	0.12
T5	81 (64.15)	9.8	6.8	36.4	1334	0.11
T6	92 (73.57)	14.2	8.9	49.8	2125	0.07
T7	87 (68.86)	12.9	7.9	46.9	1809	0.14
T8	88 (69.73)	9.9	7.7	36.1	1548	0.09
T9	82 (64.89)	9.7	6.4	42.1	1320	0.08
T10	81 (64.15)	9.8	6.2	38.4	1296	0.10
Mean	84 (66.87)	11.38	7.3	42.36	1586	0.11
SED	1.633	0.163	0.244	1.633	0.816	0.016
CD	3.386	0.338	0.508	3.386	1.693	0.033

Figures in parentheses are arc sine transformed values

Table 2 Effect of invigorative hardening treatments on growth parameters in sesame cv. VRI 1

Treatment	Field emergence (%)	Plant height (cm)	Number of branches	Days to first flowering	Days to 50 percent flowering	Number of Flowers/plant
T0	75(60.00)	91.1	4.0	42	51	110
T1	88(69.73)	111.4	5.0	31	43	138
T2	83(65.65)	100.2	5.0	37	49	128
T3	85(67.21)	108.4	5.0	39	50	132
T4	79(62.72)	91.4	5.0	33	44	124
T5	78(62.02)	93.3	5.0	32	45	121
T6	90(71.56)	112.4	6.0	30	42	141
T7	87(68.86)	110.3	5.0	34	46	134
T8	76(60.66)	97.2	5.0	39	48	119
T9	79(62.72)	96.1	5.0	38	49	116
T10	78(62.02)	100.5	5.0	37	47	118
Mean	82(64.09)	101.11	5.0	35	46	125
SED	0.142	0.042	0.816	1.633	2.382	2.444
CD	0.296	0.088	1.693	3.386	4.941	5.088

Figures in parentheses are arc sine transformed values

Table 3 Effect of invigorative hardening treatments on physiological parameters in sesame cv. VRI 1

Treatment	Chlorophyll content (mg)	Pn (mg CO_2 $m^{-2}S^{-1}$)	Tr (mmol H2O $m^{-2}s^{-1}$)	Ci (μ mol mol^{-1})	CS (mol H_2O $m^{-2}s^{-1}$)
T0	0.070	16.9	7.891	262.1	0.449
T1	0.089	20.9	8.617	305.2	0.558
T2	0.078	19.3	8.101	297.9	0.531
T3	0.081	19.7	8.113	299.3	0.538
T4	0.076	18.7	7.997	271.4	0.499
T5	0.075	18.4	7.976	279.3	0.491
T6	0.091	21.2	8.718	307.5	0.568
T7	0.087	20.1	8.413	301.4	0.547
T8	0.072	17.1	7.981	281.2	0.483
T9	0.074	17.9	7.989	283.4	0.511
T10	0.071	17.7	7.986	285.3	0.510
Mean	0.078	18.9	8.162	289	0.516
SED	0.008	0.816	0.009	3.375	0.016
CD	0.017	1.693	0.018	7.000	0.033

Note: Pn - Photosynthetic rate, Tr - Transpiration rate, Ci - Intercellular CO_2 concentration and CS -Stomatal conductance

Table 4 Effect of invigorative hardening treatments on yield parameters in sesame cv. VRI 1

Treatment	Number of capsules/plant	Dry weight of capsule (g)	Capsule yield/plant (g)	Capsule yield/plot (g)	Seed number/ capsule	Seed weight/ capsule (g)	Seed yield/ plant (g)	Seed yield/plot (g)	Capsule seed recovery (%)
T0	108	0.516	57.12	1972	63	0.210	22.32	993	38.10 (38.11)
T1	138	0.596	79.25	2891	72	0.252	32.10	1199	42.35 (40.60)
T2	121	0.548	71.11	2555	68	0.242	25.09	1164	39.15 (38.73)
T3	126	0.553	73.25	2785	70	0.245	27.04	1168	39.85 (39.14)
T4	112	0.551	68.45	2318	68	0.242	24.03	1153	38.23 (38.19)
T5	116	0.542	66.43	2416	66	0.224	24.02	1130	39.23 (38.78)
T6	140	0.691	82.12	2913	74	0.254	34.11	1211	43.12 (41.04)
T7	130	0.586	76.35	2799	71	0.249	29.12	1187	40.15 (39.32)
T8	119	0.529	69.44	1998	71	0.221	24.08	1029	39.10 (38.70)
T9	121	0.528	68.33	2312	67	0.229	23.01	1035	39.15 (38.73)
T10	118	0.539	65.53	2410	69	0.226	24.09	1045	40.10 (39.29)
Mean	123	0.561	70.67	2488	69	0.235	26.27	1119	39.86 (39.15)
SED	2.449	0.008	0.168	1.633	2.449	0.816	0.1913	1.633	0.816
CD	5.080	0.017	0.348	3.386	5.080	1.693	0.3968	3.386	1.693

Figures in parentheses are arc sine transformed values

The third best treatment was recorded by Pungam leaf extract priming which recorded higher seed yield and seed quality. The better performance of Pungam leaf extract might be because it acts as a wick in absorbing, regulating and correcting the soil moisture availability and thus enhanced seed soil relationship (Lu *et al.,* 1983). The leaf powders also contain gibberellin like substances, the saponins and micronutrients like zinc, which synergistically activate production of Indole acetic acid (IAA). The chlorophyll molecules present in the Pungam leaf powder and amino acids, humic acid present in the soil rhizosphere might have acted as a chelating agent and activated the growth and development of plant growth and reflect on the crop yield. Seed treatment with Pungam leaf powder might have stimulated the production of auxin and ethylene, which have positive influence on seed germination as reported earlier

(Clouse and Sasse, 1988). It also improves the seedling growth. The probable reason for elite seedling growth might be due to cell elongation, cell division and enhancement in enzyme activities induced by Pungam leaf powder.

To conclude, the influence of various invigorative priming treatments on quality seed production in sesame cv. VRI 1 revealed that 2%, Prosopis leaf extract primed seeds recorded higher seed yield and initial seedling quality when compared to other treatments and control.

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Physico-chemical and organoleptic properties of palm oil and it's comparison with other oils regarding their utility in preparation of food products

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ABSTRACT

Palm oil is the most widely used vegetable oil in the world. It is widely used by food and non-food manufacturers because of its functional benefits, versatility and availability. The consumption of palm oil is increasing as it is one of the cheapest forms of vegetable oil. It is rich in natural chemical compounds important for health and nutrition. The present study was carried out to prepare and assess the physico-chemical qualities of food products formulated by palm oil and other commonly used vegetable oils. Properties of palm oil with other vegetable oils (soybean oil and sunflower oil) were compared by preparing two food products namely Namak Para and Sev and they were evaluated for sensory evaluation. The chemical properties of the oils were analysed by calculating the acid value, peroxide value, specific gravity, percentage of oil absorption and beta-carotene. The cost of developed products was also calculated. The results indicated that organoleptic scores of Namak Para and Sev prepared using palm oil were significantly higher than the products prepared in other oils. Therefore, palm oil is recommended for cooking purposes because of its comparatively better sensory, physico-chemical and nutritional qualities.

Keywords: Acid value, Beta-carotene, Organoleptic, Palm oil, Physico-chemical properties

Palm oil is also known as palm fruit oil (Elaeis guineensis). Among the major oilseed crops, the palm tree fruit accounts for the smallest percentage (5.5%) of all the cultivated land for oils and fats globally, but produces the largest percentage (32 %) of total output (Anonymous, 2016). These advantages have led palm oil to be the most widely consumed vegetable oil in the world (Anonymous, 2016a). According to Tan and Nehdi (2012), palm oil has a balanced fatty acid composition in which the level of saturated and unsaturated fatty acids are almost equal with 50% saturated, 40% monounsaturated and 10% polyunsaturated fatty acids. Crude palm oil also known as red palm oil (RPO) has been cold-pressed from the fruit of the oil palm while white palm oil is the product of processing and refining. When refined, the palm oil loses its red colour. Palm oil also contains minor constituents which include carotenoids, tocopherols, sterols, phosphatides, triterpenic and aliphatic alcohols. Among them, the most important compounds are carotenoids and tocochromanols (tocopherols and tocotrienols). The most active and important form of carotenoids found in palm oil is beta-carotene. Phoon *et al.* (2018), reported that crude palm oil contains 500-700 ppm of carotenoids and 1000-1200 ppm tocochromanols. Tocochromanols are powerful antioxidant, capable of reducing the harmful types of oxygen molecules (free radicals) in the body and help to protect from chronic diseases, while delaying the body's ageing process. The fatty acid composition of palm oil offers food manufacturers greater latitude to formulate hydrogenated fat free and trans fat free products. Palm oil provides desirable oxidative stability, texture, and flavor characteristics. Because it is very stable with respect to free radical-induced oxidation, the formation of harmful oxidized products during processing and cooking is negligible as compared with that of polyunsaturated oils. Products incorporating naturally trans-free palm oil directly or as blends will have a long shelf life and other desirable properties (Ong and Goh, 2002).

Soybean oil is obtained from the raw bean by solvent extraction andit is the world's leading vegetable oil in terms of both production and consumption. Soybean oil has considerable nutritional properties. It has both n-6 and n-3 fatty acids. It is a good source of vitamin E. Sunflower oil is the non-volatile oil expressed from sunflower seeds. Sunflower oil is commonly used in food as frying oil. Sunflower oil is high in the essential vitamin E and low in saturated fat. A study by a group of researchers in China comparing palm, soybean, peanut oils and lard showed that palm oil actually increased the levels of good cholesterol and reduced the levels of bad cholesterol in the blood (Koh, 2006).

MATERIALS AND METHODS

Three different vegetable oils (T1: palm oil, T2: soybean oil and T3: sunflower oil) and two food products namely Namak Para and Sev were selected for the study. All the raw ingredients were collected from the local market of Allahabad. The recipes were prepared as follows:

1) Namak Para: All the raw ingredients *viz.,* refined flour, baking soda, salt, ajwain an oil were mixed together and a hard dough was prepared with water. From the dough, chappatis were prepared and cut into square shapes and fried in oil till golden brown.

2) Sev: Raw ingredients such as bengal gram flour, chilli powder, ajwain, salt and oil were mixed together and a soft dough was prepared. Part of dough was filled in sev maker and deep fried till golden. Sev were crushed and stored in container.

The organoleptic characteristics of the developed products were analyzed in five replications, using 9 point Hedonic Scale by five panel members randomly selected from the Department of Food Nutrition and Public Health, SHUATS, Prayagraj, Uttar Pradesh, India. The cost of the developed products was calculated at the prevailing prices of raw materials purchased from the local market.

The physico-chemical parameters of selected oils were analyzed, in three replications, using standard procedures which were as follows:

3) Acid value: 50 mL of neutral alcohol was added to 10 mL of oil and boiled in water bath. Then, 1mL of phenolphthalein was added into the solution and stirred for a while and titrated while hot against the standard 0.1N NaOH solution. The end point was noted when the pink color persisted for about 30 seconds. The acid value was determined on the basis of the following formula:

$$\text{Acid value} = \frac{56.1 \times V \times N}{W}$$

where, 56.1 is gm equivalent of KOH; V is the volume of standard alkali used; N is the normality of the standard alkali used and W is weight of oil taken (Anonymous, 1979).

4) Peroxide value: Five g (±50 mg) of the sample was weighed into a 250 ml stoppered conical flask with stopper cock. Thirty ml of acetic acid chloroform solvent was added to the mixture and swirled to dissolve. 0.5 ml of saturated potassium iodide solution was added with a Mohr pipette. After letting it stand for 1min in dark with occasional shaking, 30 ml of water was added. The liberated iodine was titrated with 0.1 N sodium thiosulphate solution, with vigorous shaking until yellow colour was almost gone. 0.5 ml of starch solution was added as an indicator and titrated until blue colour disappeared.

$$\text{Peroxide value} = \frac{(V - V_0) \times N \times 100}{W}$$

where V is the titre value (mL) of sodium thiosulphate solution for sample, V0 the titre value (mL) of sodium thiosulphate solution for blank, N the normality of sodium thiosulphate solution and W the weight of sample in gram (Anonymous, 2000).

5) Specific Gravity: A density bottle was used which was a slightly round bottomed type of glass vessel fitted with a glass cork containing a fine capillary. The bottle was first washed with chromic acid solution then with distilled water and finally with alcohol. Then it was dried and weighed. The bottle was then filled with distilled water and a stopper was fitted without any air bubble. The bottle was again weighed. Water was then poured out and washed with alcohol and dried. The bottle was then filled with sample as before and weighed again.

$$\text{Specific Gravity} = \frac{\text{Density of oil sample}}{\text{Density of water}} = \frac{W_3 - W_1}{W_2 - W_1}$$

Where W3 is weight of bottle with oil sample; W2 is weight of bottle with water; W1 is weight of empty bottle (Anonymous, 2000a).

6) β-carotene extraction and analysis: The β-carotene was determined by soaking 1 g of the sample (that is the paste or pulp of the fresh fruits) in 5 ml of methanol for 2 h at room temperature under dark condition in order to get a complete extraction. The β-carotene layer was separated using hexane through separating funnel. The volume was made up to 10 ml with hexane and then this layer was again passed through sodium sulphonate through a funnel in order to remove any moisture from the layer. The absorbance of the layer was measured at 436 nm using hexane as a blank. The β-carotene was calculated using the formula:

$$\beta\text{-carotene (?g/100g)} = \frac{\text{Absorbance(436 nm)} \times V \times D \times 100 \times 100}{W \times Y}$$

where: V = Total volume of extract; D = Dilution factor; W= Sample weight; Y=Percentage dry matter content of the sample (Ranganna, 1999).

7) Percentage of oil absorption: Oil absorption was determined by using the Soxhlet method based on oil extraction by using petroleum ether as the solvent, and weighing the collected fat. The determination was conducted in duplicates. Oil absorption percentage was expressed as oil content (o) and average oil content (O) and quantified as

$$O = \frac{(Wf - We) \times 100}{(W0 - We)}$$

where W f and W 0 are the mass (g) of the final and initial samples, respectively; We is the mass of the empty glass cartridge (Pardun, 1969).

8) The data obtained from the experiment was statistically analyzed using analysis of variance technique Two-Way Classification and Critical Difference.

RESULTS AND DISCUSSION

In organoleptic analysis, scores given to sensory attributes of Namak Para made with different oils showed that the overall acceptability was highest in T1 (palm oil) followed by T3 (sunflower oil) and T2 (soybean oil) but there was no significant difference between the three treatments. All the treatments were highly acceptable. In Sev, the sensory score of T1 (palm oil) was best regarding the overall acceptability followed by T3 (sunflower oil) and T2 (soybean oil) (Table 1). In chemical estimation, the percentage of oil absorption was highest in T2 (soybean oil) followed by T1 (palm oil) and T3 (sunflower oil) and there was a significant difference between the treatments of Namak Para and Sev. Therefore, it was evident that the products fried in soybean oil absorb more oil than palm oil and sunflower oil. The comparison of specific gravity for the three oils showed that the soybean oil had the highest value followed by sunflower oil and palm oil. The acid value of three oils was compared and the result revealed that the values increased with storage as reported earlier (Archana and Premkumari, 2005). But, the highest value was noticed in the sample of soybean oil followed by palm oil and sunflower oil. When the oil comes in contact with air, light, heat and temperature etc the acid value increases and the oil also becomes rancid. Kamsiah (2001) found that most oils become rancid from exposure to heat, light, and oxygen. Red palm oil is naturally protected by its high levels of vitamin E antioxidants, and has a natural resistance to oxidation and rancidity. It can be safely used for cooking, and in fact, a study examining the cooking with red palm oil at high temperatures showed that it does not have an adverse effect on blood lipids. The peroxide value of selected oils before and after frying was evaluated and found that the fresh sample of oils were free from peroxide content but oils left after frying had peroxide value highest in soybean oil (0.03 meq/g) followed by sunflower oil and palm oil. Peroxide value is a measure to detect rancidity of fats and oils. After comparing the beta-carotene content of selected oils it was evident that the palm oil (2520µg/100g) scores maximum value than soybean oil and sunflower oil. According to many studies it was found that red palm oil is the richest source of beta-carotene but due to refining process beta-carotene content becomes lower in palm oil but then also it has higher values of beta-carotene than other oils. The cost of developed products were calculated and found that the cost of products (Namak Para, Sev) made with palm oil (` 4.35 and ` 6.7) were lowest and products made with sunflower oil (` 6 and ` 7.69) were highest respectively. Therefore it could be concluded that the palm oil was economical and safe for frying purpose.

Table 1 Attributes of selected oils

Organoleptic Scores	Decreasing order of treatments based on mean values of Namak para		
Colour	T2 (7.7)	T3 (7.7)	T1 (7.65)
Flavour	T1 (7.72)	T3 (7.66)	T2 (7.6)
Texture	T2 (7.8)	T1 (7.73)	T3 (7.67)
Taste	T1 (7.92)	T2 (7.66)	T3 (7.67)
Overall acceptability	T1 (7.75)	T3 (7.7)	T2 (7.6)
Cost (`/kg)	T3 (6)	T2 (5.2)	T1 (4.35)
Organoleptic Scores	Decreasing order of treatments based on mean values of Sev		
Colour	T3 (7.5)	T1 (7.46)	T2 (7.3)
Flavour	T3 (7.7)	T1 (7.6)	T2 (7.5)
Texture	T3 (7.7)	T1 (7.7)	T2 (35)
Taste	T1 (8.05)	T3 (7.6)	T2 (7.4)
Overall acceptability	T1 (7.7)	T3 (7.66)	T2 (7.4)
Cost (`/kg)	T3 (7.69)	T2 (7.21)	T1 (6.7)
Chemical Scores	Decreasing order of treatments based on mean values		
Acid value (mg KOH/g)	T2 (0.35) F T2 (0.74) U	T1 (0.336) F T1 (0.62) U	T3 (0.28) F T3 (0.448) U
Peroxide value (meq/g)	T2 (0.03) U	T3 (0.02) U	T1 (0.01) U
Specific gravity	T2 (0.92) F T2 (0.922) U	T3 (0.917) F T3 (0.92) U	T1 (0.911) F T1 (0.912)U
Percentage of oil absorption	T2 (24.86)	T1 (19.32)	T3 (18.8)
β-carotene (µg/100g)	T1 (2520)	T3 (720)	T2 (240)

T1- Palm oil; T2- Soybean oil; T3- Sunflower oil; U- Used oil; F- Fresh oil

Based on this study, it could be concluded that palm oil was found to be the most acceptable in terms of overall acceptability in comparison with other selected oils. The cost of products made with palm oil was cheaper than other oils. In addition, as the palm oil is loaded with other phytonutrients protective to health, such as, tocotrienols, carotenoids, phytosterols etc. incorporation of palm oil in recipes of daily diet can be recommended to risk (vulnerable) groups (preschool, adolescent, pregnant and lactating mothers) in order to improve their health.

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An application of ARIMAX model for forecasting of castor production in India

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ABSTRACT

When an ARIMA model includes other time series as input variables, the model is referred to as an ARIMAX model. The autoregressive integrated moving average with exogenous variable (ARIMAX) model can take the impact of covariates on the forecasting into account, improving the comprehensiveness and accuracy of the prediction. In this paper, ARIMAX model has been applied to forecast castor production in India which includes time series data on rainfall as input exogenous variable. ARIMAX (111) is found to be the best model for future projections of castor production in India. The analysis of 53 years data from 1966-67 to 2018-19 predicted that castor production may increase to 1547.05 thousand tonnes by the year 2020-21 and 1674.90 thousand tonnes by the year 2021-22.

Keywords: ARIMAX model, Forecasting, Mean absolute percentage error, Partial autocorrelation functions

The ARIMAX model was originally proposed by Box and Tiao (1975) for their study on the effect of gas input velocities on CO_2 output concentrations. The model is mainly applied to stock forecasting, macroscopic prediction of traffic accidents and disease prediction in domestic and foreign studies. At present, only a handful of studies have applied the ARIMAX model to short-term production forecasting. When an ARIMA model includes other time series as input variables, the model is referred to as an ARIMAX model (Pankratz, 1991).

Forecasting a response series using an ARIMA model with exogenous variables whose values correspond to the forecast periods may generate price forecasts driven by these shocks, captured through the selected critical variable. ARIMA-X (ARIMAX) model includes exogenous covariates (input variables in the forms of external shocks resulting from climate, production/supply, marketing/trade policy changes etc.) along with the dependent variable (prices, in this case) of the time series observation. In this paper, ARIMAX model has been applied to forecast castor production in India which uses time series data on rainfall as input variable. Autoregressive integrated moving average (ARIMA) forecasting model is the most popular and widely used forecasting model for uni-variate time series data. Although it is applied across various functional areas, its application is very limited in agriculture, mainly due to non - availability of required data and also due to the fact that agricultural product depends typically on monsoonal rain and other factors, which the ARIMA models failed to incorporate.

Castor is mostly grown in arid and semi-arid regions. It is cultivated in 30 different countries on commercial scale of which India, China, Brazil, Russia, Thailand, Ethiopia and Philippines are major castor seed growing countries accounting for nearly 88 % of the world's production. All India *kharif* oilseeds sown area was reported as 173.34 lakh ha in 2019 as against 173.55 lakh ha in the corresponding period of last year. Castor area was reported as 7.63 lakh ha during *kharif* in 2019 as against 6.46 lakh ha during the same period of last year. In India, major castor producing states are Gujarat (5.77 lakh ha), Rajasthan (1.14 lakh ha), Andhra Pradesh (0.30 lakh ha), Telangana (0.22 lakh ha) and Odisha (0.04 lakh ha). In India castor oil exports were 2.36 lakh MT from April to August 2019 which is 12.27 per cent lower than last year exports of 2.69 lakh MT during the same period. Keeping in view the growing importance of castor crop and export potential, it is felt to estimate the future production of castor in India in the present paper.

Kumar *et al.* (2001) studied the effect of different weather variables on wheat yield and found that maximum temperature was negatively correlated with yield of late sown wheat in Tarai region. Wangdi *et al.* (2010) used ARIMA model to forecast the number of cases of malaria in endemic areas of Bhutan and further employed the ARIMAX model to determine the predictors (meteorological factors). Their findings revealed that the mean maximum temperature lagged at one month was a strong positive predictor of an increased malaria cases for four out of seven districts under study. Durka and Pastorekova (2012) conducted a study to test which approach is better between ARIMA and ARIMAX in the analysis and forecast of macroeconomic time series in Slovakia. Tsingotis *et al.* (2012) examined how information on weather affects the performance of short-term traffic forecasting models. Using several vector ARMAX models to evaluate effects of weather and traffic mix on the predictability of traffic speed, they concluded that inclusion of exogenous variables in the forecasting models marginally improved their prediction performance, while modeling innovations such as vector and Bayesian estimation improves the model significantly. Paul *et al.* (2013) demonstrated that the ARIMAX methodology is able to provide pre-harvest forecasts based on weather variables at various stages of wheat crop growth, starting from CRI stage (21 days after sowing) to dough stage (126 days after sowing). It is observed that, as wheat crop grows towards maturity; pre-harvest forecasts get closer to actual values. Hamjah (2014) measured the climatic and hydrological effects on cash crop production in Bangladesh. Using these factors as input variables he found that climatic effects have significant impact on crops production. Sanjeev and Urmil (2016) studied ARIMA versus ARIMAX modeling for sugarcane yield prediction in Haryana and found that the ARIMAX model performed well with lower error metrics as compared to the ARIMA model in all time regimes.

MATERIALS AND METHODS

Data description: The time series data pertaining to the production and mean annual rainfall of castor crop were collected from the IMD and website: http://www.indiastat.com for the period of 53 years i.e., from 1966-67 to 2018-2019.

Pearson's correlation analysis: Pearson's correlation coefficient is a type of linear correlation coefficient, reflecting the linear correlation level between two variables. The value of Pearson's correlation coefficient r is between -1 and 1. If $r>0$, then the two variables are positively correlated. If $r<0$, then the two variables are negatively correlated. The larger absolute value of r represents the higher correlation level. However, if $r=0$, the result means that the two variables are not linearly correlated.

Autoregressive integrated moving average (ARIMA) model: A generalization of ARIMA models which incorporate a wide class of non-stationary time-series is obtained by introducing the differencing into the model. ARIMA econometric modeling takes into account historical data and decomposes it into an autoregressive (AR) process where there is a memory of past events and integrated (I) process which accounts for stabilizing or making the data stationary, making it easier to forecast, and a moving average (MA) of forecast errors, such that the longer the historical data, the more accurate forecast will be as it learns from over time. The simplest example of a non-stationary process which reduces to a stationary one after differencing is Random Walk. A process { yt } is said to follow an Integrated ARIMA model, denoted by ARIMA (p, d, q).

The ARIMA methodology is carried out in three stages viz., identification, estimation and diagnostic checking. Parameters of the tentatively selected ARIMA model at the identification stage are estimated at the estimation stage and adequacy of tentatively selected model is tested at the diagnostic checking stage. If the model is found to be inadequate, the three stages are repeated until satisfactory ARIMA model is selected for the time-series under consideration.

ARIMAX model: When an ARIMA model includes other time series as input variables, the model is sometimes referred to as an ARIMAX model i.e., in addition to past values of the response series and past errors, the response series is modeled using the current and past values of input series.

An ARIMAX form of the model is presented as follows: Based on the ARIMA model, ARIMAX model can take the impact of covariates into account by adding the covariate to the right hand of the ARIMA model equation.

The equation of ARIMAX model is presented as follows:

$$\Phi(B)\Delta^{d} y_t = \mu + \Theta(B)x_t + \Theta(B)\varepsilon_t$$

Initially, it is required to test the stability of the response series. If the stationary condition is not satisfied, the non-stationary can be removed by an initial differencing step. Calculate the statistics describing the characteristics of the response series, for example, ACF and PACF, to determine the parameters p and q. Estimate the unknown parameters of the model and test the significance as well as the residual series. Conduct the same procedure to the input series as the response series. Estimate the cross correlation coefficient between the response series and the input series to determine the configuration of the ARIMAX model. Establish diagnostic analysis to verify that the model corresponds to the characteristics of the data.

The ARIMAX model concept requires testing of stationarity of exogenous variable before modeling. The transformed variable is added to the ARIMA model in the second step, in which the lag length r is also estimated. Nonlinear least squares estimation procedure is employed to estimate the parameters of ARIMAX model (Bierens, 1987). Fortunately, the ARIMAX model can be fitted to data by using a software package, like SAS, MATLAB, EViews and R. In the present investigation, SAS, Version 9.3 is used for data analysis.

Validation of the Forecasts: It is important to evaluate/validate the forecasts obtained in terms of accuracy of the predicted values. The commonly used measures for validation are Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and Standard Error. In this study, validation of the forecasts was done by computing MAPE (Mean Absolute Percentage Error) for the hold out data as it is a scale independent measure.

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|$$

Where, A_t is the actual value and F_t is the forecast values of prices.

The estimates of parameters along with corresponding standard error and p-value of selected model were worked out. The best forecast models were selected based on Akaike

Information Criteria (AIC) / Schwartz Bayesian Criteria (SBC). The residuals of fitted models were examined for adequacy of fitted model. The final forecasts were validated by using lower MAPE value.

The Akaike information criterion (AIC) and Bayesian information criterion (BIC) values for ARIMA model are computed by:

Akaike's information criterion (AIC):

$$AIC = \log \hat{\sigma}^2 + 2\frac{p+q}{n}$$

where $\hat{\sigma}^2$ is the estimated variance of e_t.

Schwarz's Bayesian Information criterion (SC, BIC, or SBC):

$$BIC = \log \hat{\sigma}^2 + 2\frac{p+q}{n}\log(n)$$

Usually, the model with the smallest AIC or BIC values are preferred. However, the two criteria differ in their trade-off between fit and parsimony; the BIC criterion can be preferred because it has the property that it will almost surely select the true model.

ACF and PACF plots of the residuals: In the model-building process, if an ARIMA (p, d, q) model is chosen (based on the ACFs and PACFs), some checks on the model adequacy are required. A residual analysis is usually based on the fact that the residuals of an adequate model should be approximately white noise. Therefore, checking the significance of the residual autocorrelations and comparing with approximate two standard error bounds, i.e., $\pm 2/\sqrt{n}$ are need.

RESULTS AND DISCUSSION

Pearson correlation coefficient between price and rainfall is presented in Table 1. It clearly shows the significantly positive correlation that exists` between price and rainfall. Castor is mostly grown as rainfed crop and its production is mainly dependent on rainfall, hence time series data on rainfall was taken as input exogenous variable.

The input series for ARIMAX needs to be stationary. A stationary series should have a constant mean, variance, and autocorrelation through time. The purpose of identification phase is to determine the differencing required for producing stationary and also the order of non seasonal AR and MA operators for a given series. When the observed time series presents trend, differencing and transformation are often applied to the data to remove the trend and stabilize variance before an ARIMAX model can be fitted. The input time series show upward trend with spike (Fig. 1). Then we differentiated one-time non-seasonal and one-time seasonal, the result being stabilized over mean (Fig. 2).

Cross correlation estimation: The most critical part of fitting the ARIMAX model is to test the cross correlation between the response series and the input series. Figure 3 shows the result of the cross correlation of data between castor production and annual average rainfall in India. The result shows that the value of two lags is significant. Thus, a selection up to lag=2 is adequate for the ARIMAX model.

Estimation and testing: Estimation stage consists of using the data to estimate and make inferences about parameters of tentatively identified model. The parameters are estimated such that an overall measure of residuals is minimized. The last stage of model building is the testing or diagnostic checking of model adequacy. This stage determines whether residuals are independent, homoscedastic and normally distributed. Several diagnostic statistics and plots of the residuals are used to examine the goodness of fit. After identifying tentative model, the process is again followed by the stage of parameter estimation and model verification. Diagnostic information may help to suggest alternative model(s). Now, when the series was stationary and several models were selected based on their ability of reliable prediction. On examining its autocorrelation functions (ACF) and partial autocorrelation functions (PACF) and significance of AR and MA parameters, the ARIMAX (111) model was found suitable. Parameter estimates along with corresponding standard errors of fitted ARIMAX (111) model are presented in Table 2. Similarly, diagnostic checking was done through minimum of Akaike Information Criteria (AIC), Schwarz Bayesian Criteria (SBC or BIC) and MAPE values also calculated for holdout data (5 number or 10 percent of observations are holdout for MAPE calculation) (Table 3).

Forecasting: From the above models, we further streamlined the model by looking at the residual, in order to know whether the model had white noise. If the model had white noise then it could be used for forecasting. The residual of ARIMAX (111) showed white noise (see Fig 5). Our next objective was to predict the 2 future values of time series. Table 2 shows yearly forecasted results with confidence limits for time series. Production of castor, in India using ARIMAX (111) is found to be the best model for future projections. It is predicted that the castor production would be increasing to 1674.90 thousand tonnes by the year 2021-22 (Table 4 and Fig. 5).

The foregoing analysis of time series data on castor production in India from 1966-97 to 2018-19 to forecast future production using econometric models clearly revealed that ARIMAX (111) model is the best fit with inclusion of rainfall data as input exogenous variable as castor is being grown mostly as rainfed crop in India. The model has predicted that castor production in India may increase to 1547.05 thousand tonnes by the year 2020-21 and 1674.90 thousand tonnes by the year 2021-22.

Table 1 Pearson Correlation Coefficient between price and rainfall

	Pearson Correlation Coefficient (Price)
Rainfall	0.66628
Prob > |r| under H0: Rho=0	<.0001
Number of Observations	53

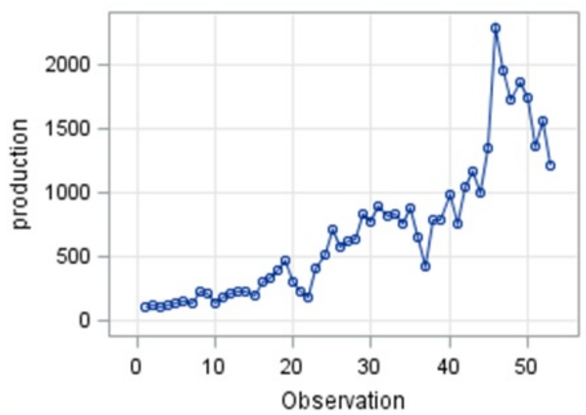

Fig. 1. Line plot of the original series castor production data

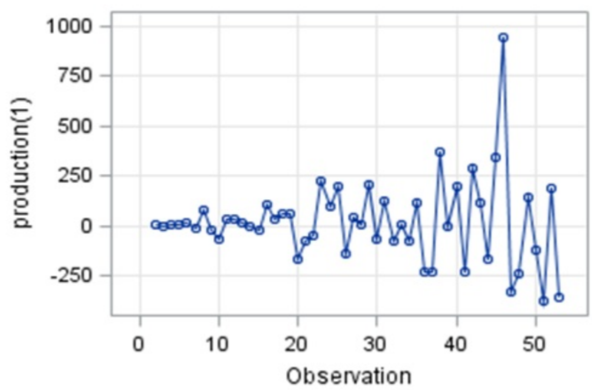

Fig. 2. Line plot of the first order differenced castor production data

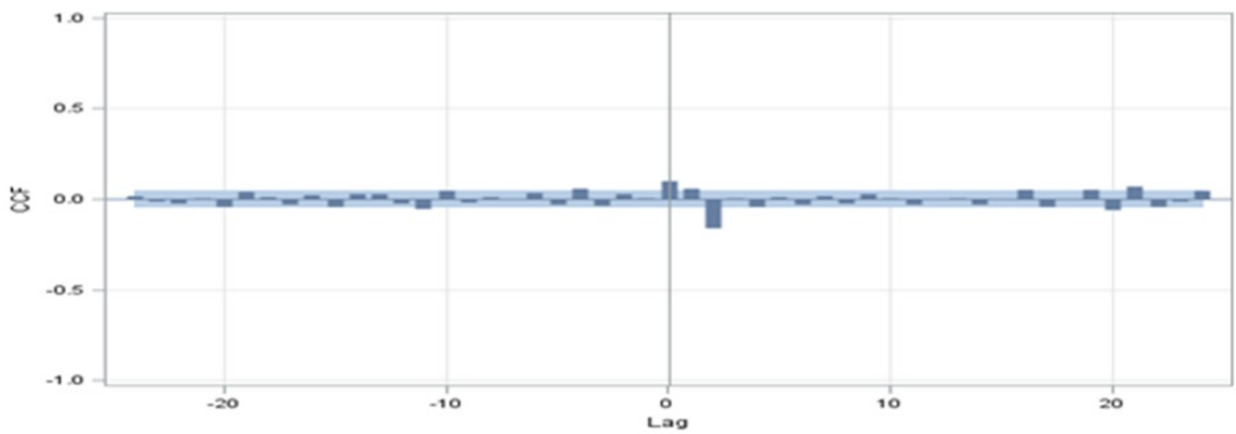

Fig. 3. Cross correlation between castor production and annual average rainfall in India

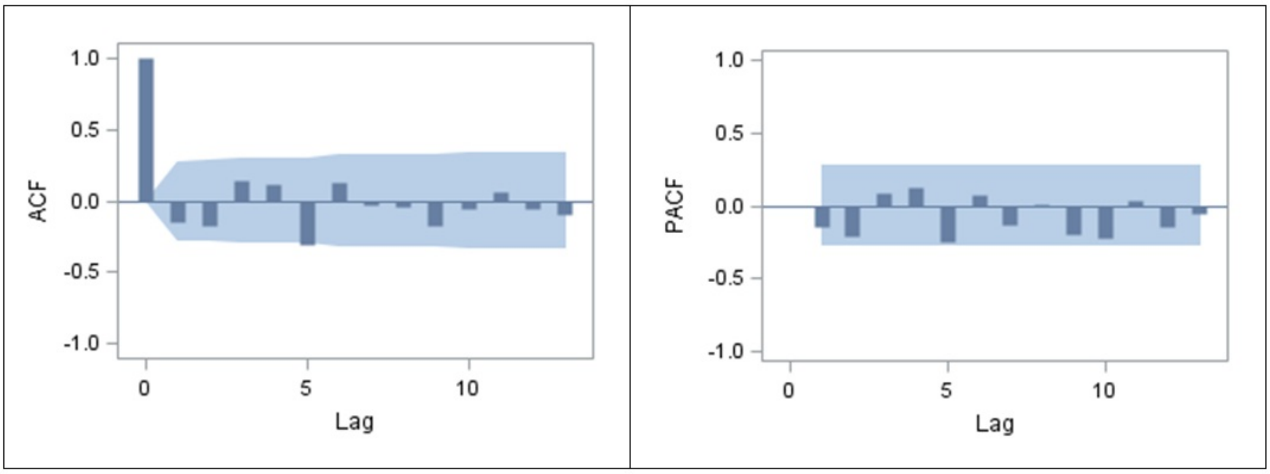

Fig. 4. Autocorrelation functions (ACF) and partial autocorrelation functions (PACF) plots of fitted ARIMAX model

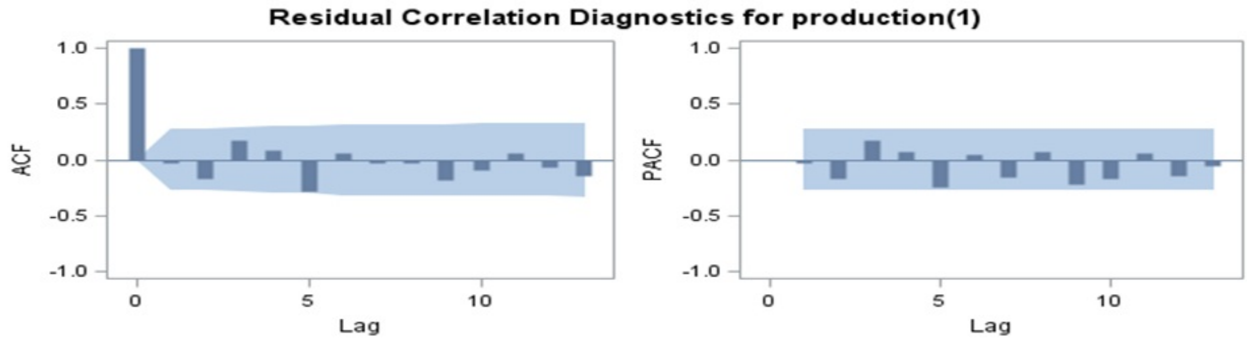

Fig. 5. ACF and PACF of the residuals of fitted ARIMAX model

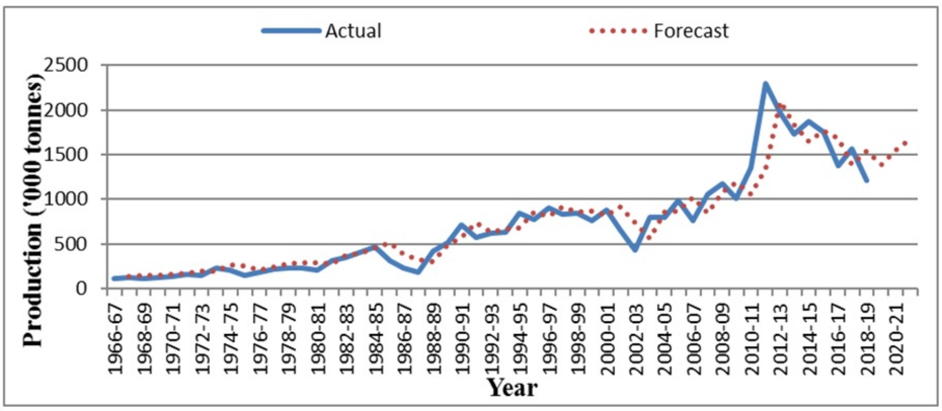

Fig. 6. Castor production ('000 tonnes) in India actual and forecasted data from the year 1966-67 to 2021-22

Table 2 Parameter estimates along with corresponding standard errors

Conditional Least Squares Estimation							
Parameter	Estimate	Standard Error	t Value	Approx Pr > |t|	Lag	Variable	Shift
MU	-111.09	109.521	-1.01	0.3155	0	price	0
MA1,1	1	0.21261	4.7	<.0001	1	price	0
AR1,1	0.73774	0.22878	3.22	0.0023	1	price	0
NUM1	0.29965	0.11454	2.61	0.0054	0	rainfall	0

Table 3 AIC, BIC and MAPE values for different ARIMAX models

Model	AIC	BIC	MAPE
ARIMAX(011)	706.29	712.14	19.59
ARIMAX(110)	707.09	712.94	20.10
ARIMAX(111)	701.97	709.77	16.54
ARIMAX(210)	706.60	714.42	20.21
ARIMAX(012)	707.13	714.94	19.18
ARIMAX(211)	703.50	713.26	22.15
ARIMAX(112)	709.69	719.44	19.61
ARIMAX(212)	708.39	720.09	17.40

Table 4 Forecasts of castor production ('000 tonnes) in India up to year 2021-22

Year	Forecast	Std Error	95% Confidence Limits	
2019-20	1391.37	199.12	1001.10	1781.64
2020-21	1547.05	247.44	1062.06	2032.03
2021-22	1674.90	270.13	1145.44	2204.37

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Optimum plot size for oil palm (*Elaeis guineensis* Jacq.) field experiments

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ABSTRACT

For standardization of water and nutrient requirements of oil palm field experimentation is essential. In order to get accurate results from the field experimentation, optimal plot size is very important. Not much work has been done on these lines to find out the optimum size of the plot for field experimentation in oil palm. In the present study, two statistical methods were employed and compared to find out the optimal plot size for conducting field experiments in oil palm under Indian conditions using 6 years yield data from ICAR-Indian Institute of Oil palm Research. Oil palm yield is measured in FFBs (fresh fruit bunches) and the FFB number and yield data of individual palms was collected from 10 different cross combinations having three replications and 270 palms. Two statistical procedures were employed on these data *viz.,* Mean Square Error (MSE) and Maximum curvature method. From both these methods, 7 palms per plot were found to be the optimum size in oil palm for field experiments. As both MSE and maximum curvature of coefficient of variation methods have given same result, if secondary data is available for any other tree crops, one of these two methods can be employed for finding out the optimum plot size.

Keywords: CV, Maximum curvature, Mean square error, Oil palm, Optimum plot size

Oil palm is a tall tree which grows up to 10-12 m height with a radial spread of up to 6 -7 m from the centre. Its economic life span is 30-35 years, which stresses the need for more accurate recommendations in order to harvest better yields. It has been proved that it is far more efficient than all other oil crops in terms of oil yield and land usage (Murphy 2014). Cultivation of oil palm, by giving irrigation is a unique practice in the world and is being followed only in India (Kalidas *et al*., 2014). Besides laboratory studies, most of the technologies need field level testing for obtaining most appropriate and accurate recommendations with reasonable confidence. Oil palm is cultivated in about 18 million ha worldwide and a huge number of research institutes are working on it for improving the productivity and net profit. Conducting field experiments in perennial crops like oil palm is a difficult task because of its perennial nature and requirement of large area and other inputs. Experiments with insufficient plot size or insufficient palm numbers may not give accurate results and thereby the conclusions drawn may not be correct. This can lead to incorrect recommendations which may cause reduction in yield and/or enhanced environmental degradation. Hence, identification of optimal plot size for field experimentation in oil palm holds the key for accuracy in results.

The plot is that part of the trial to which a single treatment is applied and on which observations are made (Saste and Sanense, 2015). Different authors used different methods to find out the optimal plot size in crops. Very little work is done to find out the efficient plot size for conducting field experiments in tree crops especially plantation crops. To determine the most efficient plot size for tree crops Peiris and Thattil (1997) proposed two methodologies using data from experiments based on randomized complete block design and reported that efficient plot size in field experiments for coconut in Sri Lanka was four or six palms in different agro-climatic regions. Bowman (2001) determined the best plot size in uniformity trials to measure stability of phenotypes or measure variation in other individual or population attributes and Polson (1964) compared three methods viz., comparable variance, Smith's regression method and Hathaway's convenient plot size method to determine optimum plot size in safflower and concluded that all three methods were in fairly good agreement. This shows that different researchers recommended different methods for estimating optimal size in different crops.

Generally, the plot size depends on soil heterogeneity as the source of variation. But in case of oil palm in addition to soil characteristics, the non-uniformity of experimental material due to segregating properties of D x P teneras is another source of variation while deciding the optimal plot size. Hence, estimating an optimum size of plot for oil palm field experiments assumes greater significance. Generally, in most of the crops, Uniformity trials are used to determine the optimum size and shape of the plots to minimize the variation that occurs due to different factors. But, in oil palm (and other tree crops) conducting a separate uniformity trial for calculating optimum plot size is very difficult as it is very time consuming and requires lot of land and other inputs. At present, field trials are being conducted in oil palm with different plot sizes (with 5, 6, 7, 8 and 9 palms) depending upon the availability of land and its orientation. If we could find a solution for optimal size of the plot for field experimentation, it will definitely serve the purpose by giving accuracy in recommendations and also it may be possible to save input cost if the size of the plot is smaller than what usually is being used. Hence, the data available on number and yield of fresh fruit bunches for six years in a crop improvement trial for 10 different crosses was analyzed by grouping the data into different plot sizes.

MATERIALS AND METHODS

The experimental field is located in ICAR-IIOPR farm area (16°48'43"N latitude and 81°7'53"E longitude), Pedavegi, West Godavari District of Andhra Pradesh, India. The soil of the field has been characterized as deep red loamy type. The climate of the area is humid tropical type with annual average rainfall of 1250 mm spread over a period of eight to nine months, i.e. from April to November. The hottest month is June. The mean daily maximum temperature is 34.5°C and daily minimum temperature is 21.10°C with relative humidity of > 70% throughout the year. During summer season, the day temperature may exceed 39°C on normal days.

The cultivated oil palm is a hybrid (called tenera) between Dura (thick shelled) and Pisifera (shell-less) having good mesocarp content for giving better oil yield. Ten cross combinations (Deli x Avros, Deli x Ekona, Deli x Ghana, Deli x Lame, 65d x 111, 12 x 313, 12 x 266, 18c x 2501, 9c x 1001, 1M-0069D x P) of oil palm hybrid teneras were planted in the year 2000 and the inflorescences were removed by ablation for the first three years. These plants were planted at 9 x 9 x 9 m spacing of equilateral triangle and in each treatment only one row of plants were there. Generally oil palm trees are allowed to develop bunches from fourth year onwards in order to divert maximum nutrition for vegetative growth during the initial three years. The data on number and yield of fresh fruit bunches (FFBs) was recorded from the year 2004 to 2009 for about six years and it was considered as uniformity trial.

The palm wise number and yield data of FFBs was collected from each harvest in all the six years and it was pooled year wise. In general, 8-12 bunches are formed in each palm and there were 30-40 number of harvests per year in different years. Further, there is a peak season (June to November) and lean season (December to May) of six months each and the yields recorded are more in peak season. Yield levels also followed a regular trend of up and down year after year. Harvesting of bunches was carried out using chisels during the initial years and at later period (9th and 10th year of age) it was with the help of a curved knife fitted to a light weight aluminum pole.

The FFB yield and bunch number data collected from these 10 crosses was subjected to grouping to arrive the yield under different plot sizes. In this trial there were 9 trees in each treatment. The data was grouped into different plot sizes of 3, 4, 5, 6, 7, 8 and 9 as per the palm numbers. The grouping for the first 8 plot sizes was arrived in the following manner (Tables 1).

In each plot, data was grouped in different combinations for each treatment (n number of palms) and the mean of these combinations was used for analysis purpose. There were three replications for each treatment and the data was analysed for mean square error and also for coefficient of variation. Year wise values of yield and number of FFBs were analysed separately and finally pooled analysis was also carried out for six years for the sake of comparison.

Mean squared error (MSE) method: MSE indicates the deviation from line of best fit under regression and the minimal value indicates the efficient point. Mean squared error values were estimated using SAS ver 9.3 statistical package and the treatment with lower MSE was considered as more efficient.

Maximum curvature of coefficient of variation method: In maximum curvature method, the CV (coefficient of variation) values were plotted against plot size and the point where the curve gets stabilized is considered as the efficient plot size. Descriptive statistics were calculated in MS-excel and the CV was calculated using the following formula.

Coefficient of variation (CV) =
(Standard deviation/Mean)*100

Among the two methods used, maximum curvature method is very simple and it could be estimated with MS-excel itself. To our knowledge, this is the first report on optimal plot size for field experiments of oil palm under irrigated conditions. Descriptive statistics of yields obtained from various plot sizes were calculated to get mean, coefficient of variation, coefficient of skewness, coefficient of kurtosis, variance, and variance per unit area in MS-excel.

Yield deviation: The percent deviations in yield per unit area (one square meter) from that of average values were calculated with the following formula and the values were compared.

% Deviation = (Yi-m)/m*100

RESULTS AND DISCUSSION

Yield trends: The 10 hybrids planted in the year 2000 started yielding from 2004 onwards and the FFB yield data collected palm wise (individual oil palm tree wise) in three replications was pooled into four quarters (Jan-Mar, Apr-Jun, Jul-Sep and Oct-Dec) to see the impact of weather. In general, yields were high in third quarter of the year mainly because of good rainfall (South-West monsoon) received in this season (Fig. 1). Though it is grown as irrigated crop with regular supply of water, high rainfall during July to September favored its performance in terms of FFB yield. The FFB yields of all the hybrids were high during third quarter (July-September) of the year and the lowest during first quarter (January-March).Yield levels of FFB also followed a regular trend of high and low, year after year in all the cross combinations indicating the pattern of flower production (Fig. 2). In oil palm male and female flowers are produced on the same plant (monoecious) and number of female flowers produced depends on many factors. A regular cycle of flower production also observed with more number of female flowers in alternate years.

Descriptive analysis: Mean values of plots differed with plot size and higher values were recorded in smaller plot sizes. Coefficient of skewness ranged between -0.798 to 0.659 and the minimum value was recorded in the plot size with 7 plants (0.039). Kurtosis ranged between -0.1 to 7.47. In the plot of 7 palm sizes, the value of kurtosis was minimum and the mean and median values are almost similar showing a normal distribution (Table 2).

Mean square error: Mean square error is used to measure the relative variability among the treatments in an experiment. Minimum value represents less variability and so more suitability of the treatment. In the present investigation, MSE was estimated for bunch weight and bunch number for five years along with pooled data analysis. In case of FFB yield, the MSE showed a declining trend from 3 palms per treatment up to 7 palms per plot treatment during all the five years and also in pooled data analysis. The same has again showed an increased value at 8 palms/plot treatment in 2 years out of five and also in pooled data. Similarly, in case of bunch number also the trend was similar and the pooled data showed decreasing trend up to 7 palms/plot treatment and then started increasing afterwards (Fig. 3a and 3b and Table 3).

Here, it can be observed that with increasing palm number per treatment, the MSE decreased. At 7 palms/plot treatment the MSE recorded lowest values both in FFB yield and number showing lesser error than other levels of plot sizes both on lower as well as higher side. Barreto and Raun (1990) evaluated corn field experiments conducted in Mexico and demonstrated that increasing plot size decreased mean square errors.

Maximum curvature (Coefficient of Variation): The same secondary data under RBD with three replications was subjected to CV estimation with same treatments of 3 to 9 palms/plot. Year wise values were estimated and they were plotted against the treatments i.e., number of palms/treatment. The CV values of treatments showed a sharp decline up to seven palms/plot and afterwards the rate of decline slowed down in all the years. It could be observed that the CVs of different years became stabilized at seven palms/plot (Fig. 4) and afterwards there was no much change. This showed that seven palms/plot could be efficient size for field experimentation.

Yield variability per square meter: The variability in yields in terms of variance/meter^2 was estimated in different plot sizes and it was found that it decreased with increase in plot size in general. This showed that larger plots are capable of showing less variation in yield. However, the variability/meter^2 plateaued at 7 palms/plot and there was no appreciable decrease observed after that (Fig. 5).

Relationship between MSE and CV: In the above two methods, it was tried to find out the most efficient plot size for conducting field experiments in oil palm research. Both the methods reported the same result and so it was also tried to find out the relationship between these two values of MSE and CV by plotting them in a graph (Fig. 6).

Table 1 Methodology Adopted For Arriving Palm Oil Yield Under Different Plot Sizes (3, 4, 5, 6, 7 and 8 Palms/Plot)

Palm No.	3 palms/plot	4 palms/plot	5 palms/plot	6 palms/plot		
P1	P1+P2+P3)/3	(P1+P2+P3+P4)/4	(P1+P2+P3+P4+P5)/5	(P1+P2+P3+P4+P5+P6)/6	(P1+P2+P3+P4+P5+P6+P7)/7	(P1+P2+P3+P4+P5+P6+P7+P8)/8
P2	(P4+P5+P6)/3	(P5+P6+P7+P8)/4	(P6+P7+P8+P9+P1)/5	(P2+P3+P4+P5+P6+P7)/6	(P2+P3+P4+P5+P6+P7+P8)/7	(P2+P3+P4+P5+P6+P7+P8+P9)/8
P3	(P7+P8+P9)/3	(P9+P1+P2+P3)/4	(P2+P3+P4+P5+P6)/5	(P3+P4+P5+P6+P7+P8)/6	(P3+P4+P5+P6+P7+P8+P9)/7	(P3+P4+P5+P6+P7+P8+P9+P1)/8
P4	(P2+P3+P4)/3	(P2+P3+P4+P5)/4	(P3+P4+P5+P6+P7)/5	(P4+P5+P6+P7+P8+P9)/6	(P4+P5+P6+P7+P8+P9+P1)/7	(P4+P5+P6+P7+P8+P9+P1+P2)/8
P5	(P5+P6+P7)/3	(P6+P7+P8+P9)/4	(P4+P5+P6+P7+P8)/5	(P5+P6+P7+P8+P9+P1)/6	(P5+P6+P7+P8+P9+P1+P2)/7	(P5+P6+P7+P8+P9+P1+P2+P3)/8
P6	(P8+P9+P1)/3	(P3+P4+P5+P6)/4	(P5+P6+P7+P8+P9)/5	(P6+P7+P8+P9+P1+P2)/6	(P6+P7+P8+P9+P1+P2+P3)/7	(P6+P7+P8+P9+P1+P2+P3+P4)/8
P7	(P3+P4+P5)/3	(P7+P8+P9+P1)/4	(P7+P8+P9+P1+P2)/5	(P7+P8+P9+P1+P2+P3)/6	(P7+P8+P9+P1+P2+P3+P4)/7	(P7+P8+P9+P1+P2+P3+P4+P5)/8
P8	(P6+P7+P8)/3	(P4+P5+P6+P7)/4	(P8+P9+P1+P2+P3)/5	(P8+P9+P1+P2+P3+P4)/6	(P8+P9+P1+P2+P3+P4+P5)/7	(P8+P9+P1+P2+P3+P4+P5+P6)/8
P9	(P9+P1+P2)/3	(P8+P9+P1+P2)/4	(P9+P1+P2+P3+P4)/5	(P9+P1+P2+P3+P4+P5)/6	(P9+P1+P2+P3+P4+P5+P6)/7	(P9+P1+P2+P3+P4+P5+P6+P7)/8

Table 2 Descriptive statistics of FFB yield data in different plot sizes

Descriptive statistics	Plot size (No of palms)						
	3	4	5	6	7	8	9
Mean	160.34	61.15	58.51	56.21	54.99	55.14	57.34
Standard Error	7.42	4.93	3.55	4.42	3.73	3.45	3.01
Median	163.11	61.83	55.93	54.21	53.88	56.55	57.35
Standard Deviation	24.62	16.37	11.76	14.66	12.39	11.46	9.99
Sample Variance	606.51	267.85	138.34	214.98	153.40	131.34	99.82
Kurtosis	-0.108	-0.557	7.471	-0.948	-1.301	0.36	0.53
Skewness	-0.798	-0.362	2.549	0.224	0.039	0.65	0.48
Range	78.11	49.09	42.46	44.79	35.33048	38.08	35.09
Minimum	112.78	34.29	49.11	35.55	37.10762	40.84	40.72
Maximum	190.89	83.38	91.58	80.34	72.4381	78.93	75.81

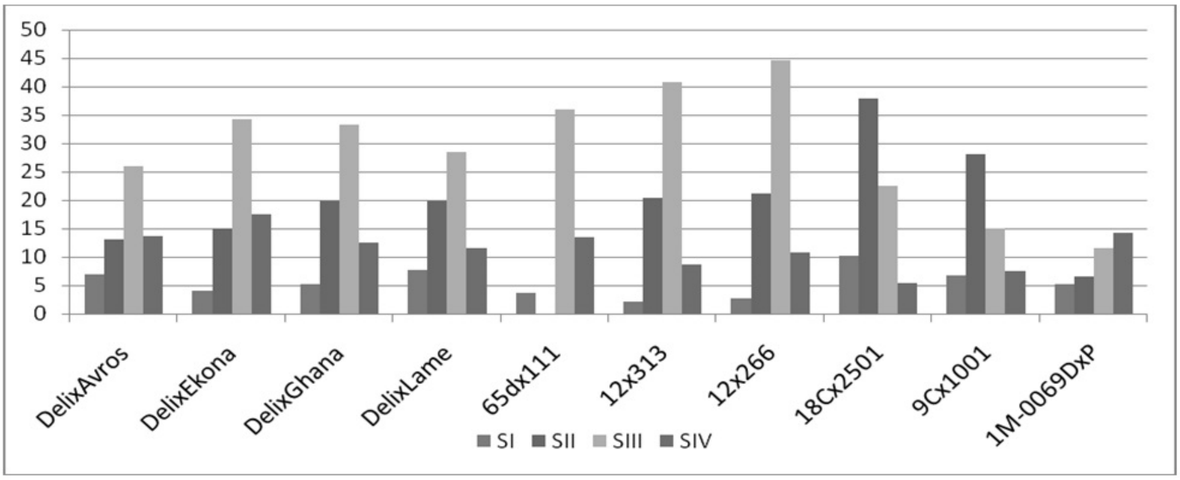


Fig. 1. Seasonal variations in FFB yields (kg) of oil palm under irrigated conditions

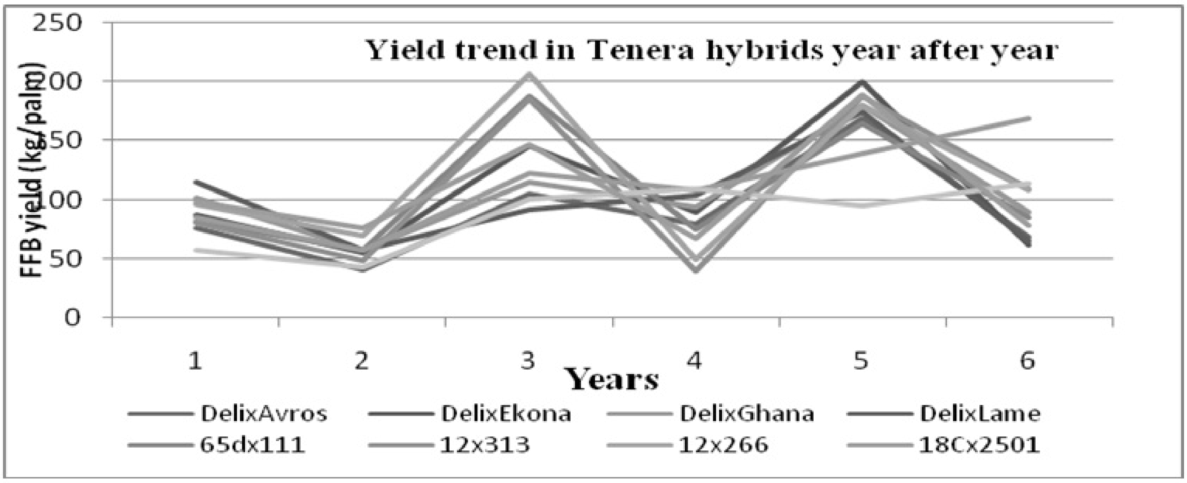
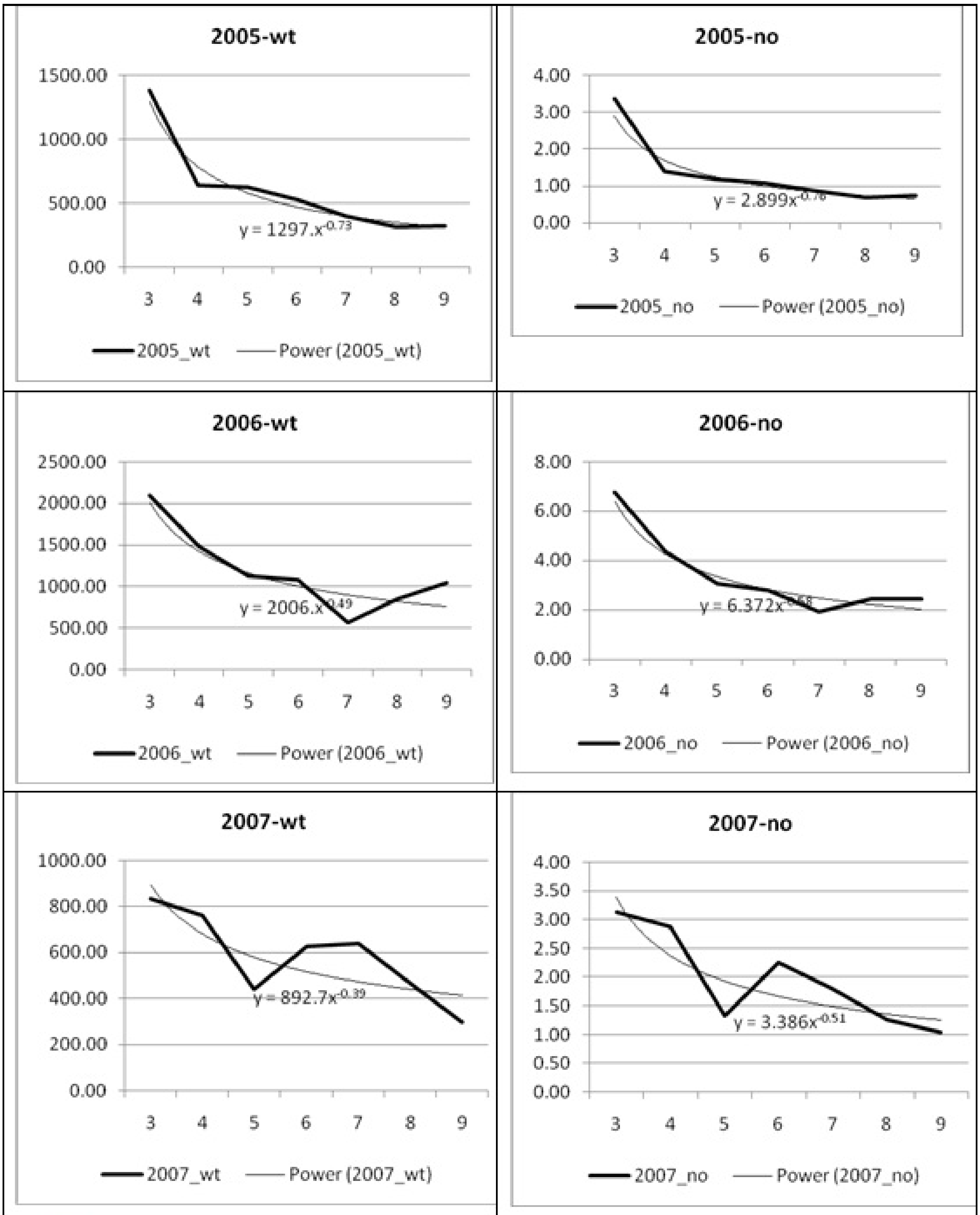
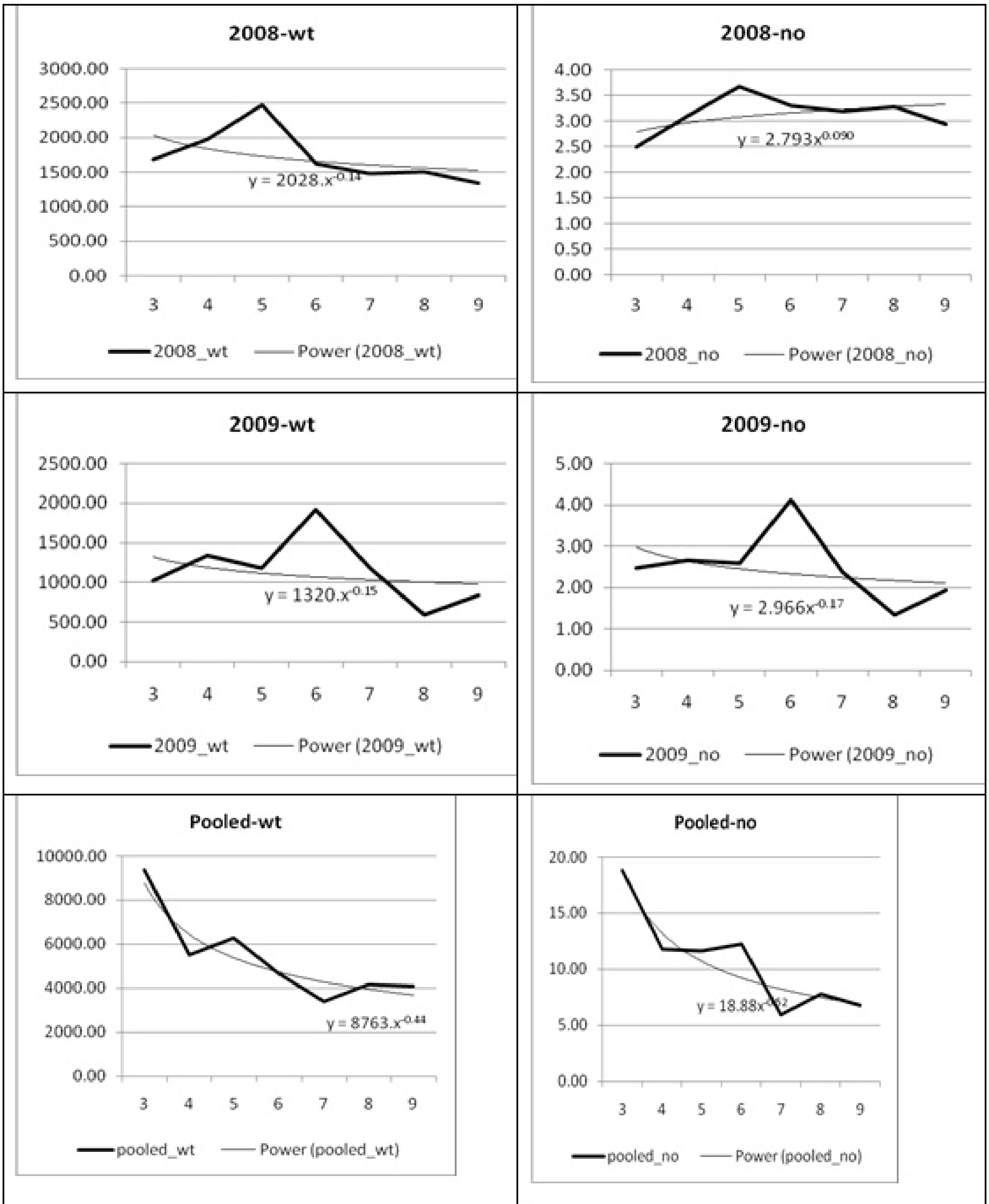


Fig. 2. Yield trend in tenera hybrids year after year



Note :Wt : FFB weight no: FFB number

Fig. 3a. Graph representing MSE of FFB weight and number in three years



Note : Wt : FFB weight no: FFB number

Fig. 3b. Graph representing MSE of FFB weight and number in two years and pooled analysis

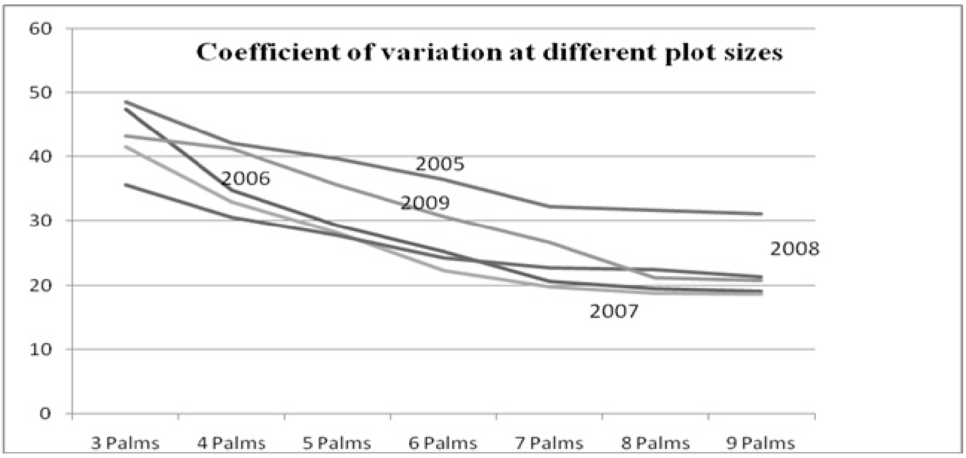


Fig. 4. Relationship between coefficient of variation and plot size in oil palm

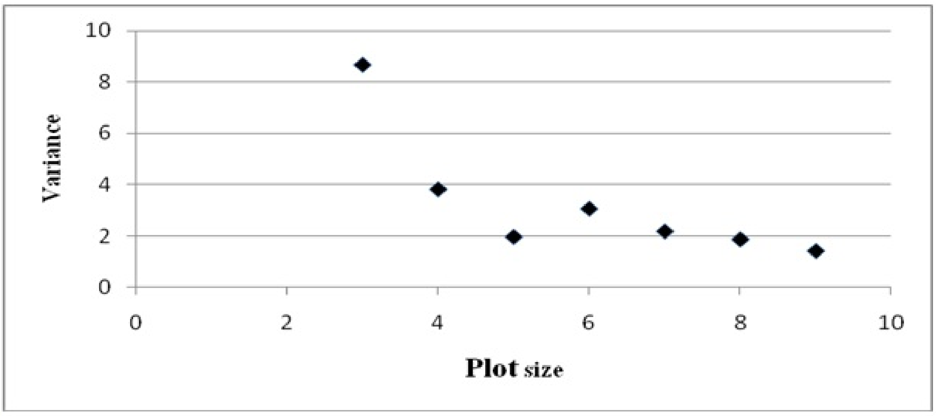


Fig. 5. Variance in yield per unit area at different plot sizes

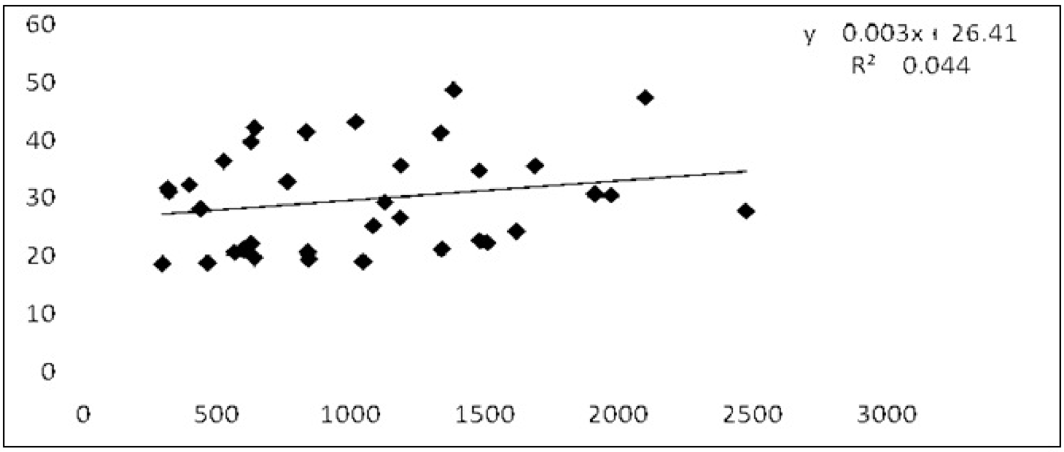


Fig. 6. Relationship between MSE and CV

Table 3 Mean square error (MSE) values of FFB yield and number in different years

Plot size	MSE of Bunch wt						MSE of Bunch No					
(Palms/plot)	2005	2006	2007	2008	2009	Pooled	2005	2006	2007	2008	2009	Pooled
3	1383.9	2099.2	833.6	1687.0	1018.9	9369.8	3.34	6.8	3.1	2.5	2.5	18.83
4	641.5	1479.3	761.7	197160	1333.3	5526.0	1.39	4.3	2.9	3.1	2.7	11.85
5	626.7	1126.5	438.6	2474.6	1186.4	6287.3	1.18	3.1	1.3	3.6	2.6	11.65
6	524.4	1082.8	627.4	1617.6	1911.5	4652.8	1.07	2.8	2.3	3.3	4.1	12.26
7	396.5	564.7	639.8	1480.9	1183.4	3394.1	0.86	1.9	1.8	3.2	2.4	5.98
8	314.5	841.4	465.0	1510.4	596.8	4173.0	0.68	2.4	1.3	3.3	1.3	7.81
9	320.5	1045.6	296.5	1338.7	838.2	4093.8	0.74	2.4	1.0	2.9	1.9	6.85
a	1297.1	2006.1	892.7	2028.2	1320.4	8763.4	2.90	6.37	3.39	2.8	3.0	18.89
b	0.74	0.48	0.39	0.15	0.16	0.45	0.77	0.59	0.512	-0.0901	0.177	0.520

Relationship between MSE and CV: In the above two methods, it was tried to find out the most efficient plot size for conducting field experiments in oil palm research. Both the methods reported the same result and so it was also tried to find out the relationship between these two values of MSE and CV by plotting them in a graph (Fig. 6).

The graph shows that they both the parameters were weakly but positively related. It indicated that these two methods are effective in identifying the efficient plot size but both were independent. Although the variance showed a decreasing trend with increase in plot size the per cent deviations from average values per unit area were more in large sized plots (Table 4).

In the present investigation we tried to compare two methods for estimating optimum plot size which could be considered as effective with the available secondary data. Both methods provided similar result and seven palms/plot was identified as the optimum size in oil palm field experiments. In this trial, we could not estimate shape of the plot as the available data did not give scope for it.

Table 4 Per cent deviation in FFB yield per unit area in different plot sizes

Plot size (No of palms)	% Dev
3	3.163636
4	3.981818
5	4.8
6	5.618182
7	6.436364
8	7.254545
9	8.072727

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Association analysis in linseed (*Linum usitatissimum* L.)

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ABSTRACT

The present study was taken up to work out correlation coefficient among the various yield and yield related traits and to estimate direct and indirect effect of different traits on grain yield through path analysis in linseed. Forty diverse linseed genotypes were assessed for different traits in a field experiment. Correlation as well as path coefficient analysis were calculated among the traits. Association analysis revealed that seed yield/plant showed the highest and significant positive association with biological yield/plant, number of capsules/plant, harvest index, 1000-seed weight and number of secondary branches/plant. Path coefficient analyses, at genotypic and phenotypic level, indicated the significant direct and indirect effects of the traits on yield.

Keywords: Association analysis, Indirect selection, Linseed, Path analysis

Flax or linseed (*Linum usitatissimum* L.) is one of the ancient cultivated crops in the world including India. It is the only agriculturally important species in the family Linaceae, which consists of 22 genera and 300 species (Hickey, 1988), and is widely spread in temperate and subtropical areas of the world. The species is believed to have originated in either the Central Asia Centre of Origin or the Abyssinian Centre of Origin and spread throughout Asia and Europe, prior to its introduction into the New World (Soto-Cerda *et al.,* 2013). Morphologically two distinct types of linseed are grown. Fibre type flax is tall with thin stem and top branched plant which is specially grown for fibre from the stem. Fibre flax cultivars are grown in the cool temperate regions of China, the Russian Federation and Western Europe (Soto-Cerda *et al*., 2013). Oilseed type flax plants (linseed) are more branched and shorter than the fibre type and are grown over a wider area in continental climatic regions of Canada, India, China, the United States and Argentina (Soto-Cerda *et al*., 2013).

Linseed is the second most important winter (*rabi*) oilseed crop and stands next to rapeseed- mustard in area and production in India. Almost every part of the linseed plant is utilized commercially either directly or after processing. It is commercially cultivated for its seed, which is processed into oil and after extraction of oil, a high protein livestock feed is left (Sankari, 2000; Kurt and Bozkurt, 2006). Its oil is largely of drying type and non-edible because of high amount of linolenic acids. Its oil content ranges from 33-45% with protein content of 24% (Gill, 1987). Recent advances in neuro biology have established that it is the best herbal source of Omega-3 and Omega-6 fatty acids which helps in regulating the nervous system. Singh and Marker (2006) reported that its oil is high in omega-3 fatty acid which is believed to be helpful in lowering cholesterol level when included in the diet chain. Linseed cake is a superior supplement for the dairy cattle due to its excellent palatability. Its meal contains 3% oil and 36% protein and serves as nutritious feed for milch cattle. It is a good source of calcium (170 mg/100g), phosphorus (370 mg/100g), potassium, manganese, waxes (0.012-0.450%), sterols and phospholipids (0.11-0.21%). It is also used as organic manure. It contains about 5% N, 1.4% P_2O_5 and 1.8% K_2O (Ahlawat, 2008). In plant breeding, it is essential to establish the associations between yield and yield attributing traits so that effective selection indices could be developed. The present study was taken up to work out correlation coefficient among the various characters and to estimate direct and indirect effect of different traits on grain yield through path analysis in linseed.

The material for this study comprised of forty diverse linseed accessions grown at Crop Research Center (Chirori), Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) during *rabi* season 2016-17. The experiment was laid out in Randomized Complete Block Design (RBD) with three replications. Each treatment was grown in 3 m long double row plot spaced 30 cm apart. The plant to plant distance was maintained at 10 cm by thinning. All advocated agronomic practices and plant protection measures were followed during the crop growth period. The experimental data was recorded on five plants randomly selected and tagged from each plot, replication wise, for all the genotypes except for observations, days to 50% flowering and days to maturity, which were recorded on the plot basis, all other observations were taken at maturity. The recorded data was subjected to analysis of genotypic and phenotypic correlation coefficients and path coefficient analysis as per the standard formula (Singh and Narayanan, 2013).

The grain yield or economic yield, in almost all the crops is referred to as main character of interest which results from

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interaction of several other component characters that are termed as yield components. Thus, genetic architecture of grain yield, in linseed as well as other crops is based on the balance or overall net effect produced by various yield components directly or indirectly by interacting with one another. Therefore, identification of important yield component and information about their association with yield and also with each other is very useful for understanding efficient breeding strategy for evolving high yielding variety. In the present study, estimates of genotypic and phenotypic correlations were estimated among 40 genetically diverse genotypes of linseed (Table 1). Association analysis revealed that seed yield/plant showed the highest and significant positive association with biological yield/plant, number of capsules/plant, harvest index, 1000-seed weight and number of secondary branches/plant. However, days to 50% flowering and days to maturity exhibited significant negative association with seed yield/plant at both genotypic and phenotypic levels. Hence, it is surmised that improvement of seed yield/plant can be achieved by improving these characters. The above mentioned findings are in agreement with the findings of Gauraha *et al.* (2011) for number of secondary branches/plant, number of capsules/plant and 1000-seed weight; Tewari *et al.* (2012) for secondary branches/plant and capsules/plant; Paul *et al.* (2017) for biological yield/plant.

Genotypic and phenotypic path coefficient analysis was carried out for all the traits (Table 2). At genotypic level, path coefficient analysis of seed yield/plant and its component characters indicated that harvest index had the highest positive direct effect on seed yield/plant followed by biological yield/plant and days to 50% flowering. Seeds/capsule, plant height and number of primary branches/plant exhibited low positive direct effect on seed yield per plant. At phenotypic level, path coefficient analysis of seed yield and its component characters exhibited that biological yield/plant had the highest positive direct effect on seed yield/plant followed by harvest index. Plant height, number of secondary branches/plant, 1000-seed weight, number of capsules/plant and days to maturity exhibited low positive direct effect on seed yield/plant. This indicated that biological yield/plant and harvest index are most important traits in influencing seed yield/plant. Thus, selection for higher biological yield/plant and harvest index is a pre-requisite for attaining higher seed yield in linseed. The direct and positive effects of the remaining characters on seed yield/plant were of low magnitude. Similar findings were obtained by Basavaraj *et al.* (2011), Kanwar *et al.* (2013), Chaudhary *et al.* (2014), Paul *et al.* (2015) and Kumar and Paul (2016) where it was observed that harvest index and biological yield/plant had the high positive direct effect on seed yield/plant.

Table 1 Estimates of genotypic (G) and phenotypic (P) correlation coefficients among eleven characters in linseed

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Capsules/ plant	Seeds/ capsule	Biological yield/ plant (g)	Harvest index (%)	1000 seed weight (g)	Seed yield/plant (g)
Days to 50% flowering	G	1.0000	0.7586	0.4670	0.3439	0.3893	-0.1859	0.0031	0.1396	-0.5514	-0.3298	-0.2142*
	P	1.0000	0.7462**	0.4188**	0.3068**	0.3601**	-0.2007*	-0.0097	0.0920	-0.4582**	-0.3049**	-0.2046*
Days to maturity	G		1.0000	0.4415	0.1456	0.2474	-0.1901	-0.2195	0.1084	-0.2979	-0.1081	-0.0643
	P		1.0000	0.3710**	0.1254	0.2106*	-0.2002*	-0.2100*	0.0591	-0.2561**	-0.0923	-0.0858
Plant height (cm)	G			1.0000	-0.1917	-0.2810	-0.0706	-0.0586	-0.0267	-0.4219	-0.3821	-0.2688**
	P			1.0000	-0.1466	-0.2614**	-0.0275	-0.0404	0.0105	-0.3779**	-0.3508**	-0.2019*
Primary branches/plant	G				1.0000	0.6043	-0.0165	-0.0920	0.0870	-0.0148	-0.0122	0.0771
	P				1.0000	0.5788**	0.0393	-0.0932	0.0941	-0.0390	-0.0055	0.0657
Secondary branches/plant	G					1.0000	0.1002	0.1471	0.3278	0.1350	0.1680	0.3858**
	P					1.0000	0.1268	0.1278	0.3127**	0.1164	0.1647	0.3569**
Capsules/plant	G						1.0000	0.1017	0.5588	0.3005	0.1831	0.6438**
	P						1.0000	0.0838	0.5366**	0.2058*	0.1629	0.5750**
Seeds/capsule	G							1.0000	-0.0237	-0.0968	-0.0357	-0.0732
	P							1.0000	-0.0130	-0.0832	-0.0369	-0.0658
Biological yield/plant (g)	G								1.0000	-0.1483	0.4391	0.6837**
	P								1.0000	-0.1681	0.3857**	0.6650**
Harvest index (%)	G									1.0000	0.3678	0.6263**
	P									1.0000	0.3293**	0.5706**
1000 seed weight (g)	G										1.0000	0.5963*
	P										1.0000	0.5313**
Seed yield/plant (g)	G											1.0000
	P											1.0000

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

Table 2 Estimates of path coefficient showing direct and indirect effects of component characters on seed yield at genotypic and phenotypic level in linseed

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches/ plant	Secondary branches/ plant	Capsules/ plant	Seeds/ capsule	Biological yield/ plant (g)	Harvest index (%)	1000 seed weight (g)	Correlation with seed yield (g)
Days to 50% flowering	G	0.1485	0.1127	0.0694	0.0511	0.0578	-0.0276	0.0005	0.0207	-0.0819	-0.0490	-0.2142*
	P	0.0007	0.0006	0.0003	0.0002	0.0003	-0.0002	0.0000	0.0001	-0.0003	-0.0002	-0.2046*
Days to maturity	G	-0.0093	-0.0122	-0.0054	-0.0018	-0.0030	0.0023	0.0027	-0.0013	0.0036	0.0013	-0.0643
	P	0.0175	0.0234	0.0087	0.0029	0.0049	-0.0047	-0.0049	0.0014	-0.0060	-0.0022	-0.0858
Plant height (cm)	G	0.0191	0.0181	0.0410	-0.0078	-0.0115	-0.0029	-0.0024	-0.0011	-0.0173	-0.0156	-0.2688**
	P	0.0303	0.0269	0.0724	-0.0106	-0.0189	-0.0020	-0.0029	0.0008	-0.0273	-0.0254	-0.2019*
Primary branches/plant	G	0.0083	0.0035	-0.0046	0.0240	0.0145	-0.0004	-0.0022	0.0021	-0.0004	-0.0003	0.0771
	P	0.0014	0.0006	-0.0007	0.0046	0.0027	0.0002	-0.0004	0.0004	-0.0002	0.0000	0.0657
Secondary branches/plant	G	-0.0317	-0.0201	0.0229	-0.0492	-0.0814	-0.0082	-0.0120	-0.0267	-0.0110	-0.0137	0.3858**
	P	0.0160	0.0094	-0.0116	0.0258	0.0445	0.0056	0.0057	0.0139	0.0052	0.0073	0.3569**
Capsules/plant	G	0.0172	0.0175	0.0065	0.0015	-0.0092	-0.0923	-0.0094	-0.0516	-0.0277	-0.0169	0.6438**
	P	-0.0053	-0.0052	-0.0007	0.0010	0.0033	0.0262	0.0022	0.0140	0.0054	0.0043	0.5750**
Seeds/capsule	G	0.0002	-0.0127	-0.0034	-0.0053	0.0085	0.0059	0.0579	-0.0014	-0.0056	-0.0021	-0.0732
	P	0.0000	-0.0009	-0.0002	-0.004	0.0005	0.0004	0.0043	-0.0001	-0.0004	-0.0002	-0.0658
Biological yield/plant (g)	G	0.1247	0.0968	-0.0238	0.0778	0.2929	0.4993	-0.0212	0.8936	-0.1325	0.3924	0.6837**
	P	0.0684	0.0440	0.0078	0.0699	0.2324	0.3989	-0.0097	0.7434	-0.1249	0.2867	0.6650**
Harvest index (%)	G	-0.5029	-0.2717	-0.3848	-0.0135	0.1231	0.2741	-0.0883	-0.1352	0.9120	0.3354	0.6263**
	P	-0.3255	-0.1819	-0.2684	-0.0277	0.0826	0.1462	-0.0591	-0.1194	0.7103	0.2339	0.5706**
1000 seed weight (g)	G	0.0116	0.0038	0.0135	0.0004	-0.0059	-0.0064	0.0013	-0.0155	-0.0130	-0.0352	0.5963*
	P	-0.0083	-0.0025	-0.0095	-0.0002	0.0045	0.0044	-0.0010	0.0104	0.0089	0.0271	0.5313**

Residual Effect = 0; Bold values indicate direct effects; *, ** significant at 5% and 1% level, respectively

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Influence of sowing environments on yield of sesame genotypes under shifting weather conditions of Deccan Plateau (Telangana)

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ABSTRACT

Climate change poses a challenge to sustainability of agricultural ecosystems and in turn the social and economic development, livelihoods of communities in the world and India is no exception. Sesame is an important oilseed crop that has nutritional components such as lignans (antioxidant), sesamol along with tocopherols. This crop is grown under varied climatic conditions in the country even though it is highly sensitive to thermal regimes. Therefore, identifying or breeding sesame varieties with adaptation to wider ecological regions with high yield potential is the need of the hour. To identify high yielding sesame genotypes under shifting weather conditions of Deccan Plateau, an experiment was conducted with different dates of sowing. The sowing dates were designed in such a way that it considered the present cropping situation where it is grown after the harvest of the *kharif* crop. A set of popular farmer preferred sesame varieties that are generally grown in different sesame growing regions of the country *viz.,* GT 10, GT 3, GT 4, RT 346, RT 351, Swetha til, YLM 66 and CUMS 17 were selected for the study. Among them, GT 10 performed better under October sowing under agro-ecological regions of Telangana while GT3, GT 4, RT 346, RT 351, Swetha til, YLM 66 and CUMS 17 recorded maximum seed yield with November sowing. Among the genotypes, CUMS 17 recorded the maximum seed yield during both October and November sowings. If a farmer has a choice of sowing *rabi* crop immediately after the harvest of *kharif* crop, he may opt for late *rabi* sowing area of Telangana with GT 10. In case there is a delay, choose other varieties to harvest maximum seed yield.

Keywords: Genotypes, Sesame yield, Shifting Weather Scenario, Sowing environments,

Sustainability of agricultural systems is dictated by the climate of any region. Successful cultivation of crops depends on the use of new varieties/strains with resilience traits. Sesame is an important oilseed crop for the Deccan Plateau (Telangana), Eastern Ghats, hot semiarid eco-region and is a hardy drought resistant crop. Sesame, the 'queen' of oilseeds (oil 38-54%; protein 18-25%), has high unsaturated fatty acid (Linoleic acid) and Tocopherol to make it an nearly ideal oil (Lokesha and Prasad, 2006). India produces sesame seed varying in colour from white to red, brown and black. Brown seeds are used mainly for crushing for oil. White variety with desirable taste, is used for making sweets and confectionary products. Black seeds are used in Japan for seasoning. Hulled white sesame is used in Europe and other Western countries in making bakery products. The oil has long shelf life due to the presence of lignans (antioxidant), sesamol together with tocopherols, while its protein is used for industrial purposes (Ashri, 1998) and it holds tremendous potential for export. In India, sesame is cultivated over an average area of >17 lakh ha with a production of >7 lakh tonnes. More than 85% production comes from West Bengal, Madhya Pradesh, Rajasthan, Uttar Pradesh, Gujarat and Andhra Pradesh (status paper on oilseeds, 2016). India ranks second in production of sesame in the world. Notwithstanding to this fact, the productivity is just 413 kg/ha (http://www.commoditiescontrol.com). This productivity often oscillates due to severe abiotic stresses.

Sesame is grown in India during *kharif, rabi* and summer seasons. It is grown both in *kharif* and *rabi* in parts of Maharashtra, Madhya Pradesh, Chhattisgarh, Gujarat, Odisha and also as summer crop after late paddy or potato in Odisha and in all the seasons in parts of Southern India. The hitherto popular sesame crop of Telangana region is slowly diminishing due to various reasons like competitive crops, price dis-advantages and a change in climate. Identification of an efficient genotype which can be cultivated in the current climatic condition of Telangana is necessary for recommendation to the farmers and also for increasing the production of sesame in the state.

Telangana state falls in semi-arid zone category of climatic classification wherein hot and dry climate is a common phenomenon. The areas covered by the Deccan Plateau are characterized by hot summers with relatively mild winters. The mean maximum temperature oscillates between 40°C and 43°C during the month of May and the mean minimum temperature is 13°C to 17°C in winter season (December and January). Telangana state action plan on climate change document has mentioned that the minimum temperature falls rapidly after October, and less than 10oC has also been recorded on certain days which is a major concern for the *rabi*/winter season crops particularly sesame. Relative temperature disparity (RTD) a factor of temperature significantly affects the sowing environments for several

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crops such as wheat etc. (Pal *et al*., 2013). The mean annual surface-air-temperature projections are evaluated by considering mean monthly temperature from January to December.

A field experiment was conducted during the *rabi* season of 2017-18 at Narkhoda Research Farm, geographically located at 17°15'6" N Longitude, 78°18' 30"E latitude at an altitude of 542 m above MSL, of ICAR-Indian Institute of Oilseeds Research, Hyderabad The soil of the farm is classified as typical "chalka" soil. The popular and released varieties of sesame (Table 1) *viz*., GT 10, GT3, GT 4 (Gujarat til varieties), RT 346, RT 351 (Rajasthan til varieties), Sweta Til (Telangana variety), YLM 66 (Andhra Pradesh variety) and CUMS 17 (West Bengal variety) were sown from 42nd meteorological standard week (MSW) of 2017 to 07th MSW of 2018 at monthly intervals *viz.,* 42 (15 Oct - 21 Oct), 46 (12 Nov - 18 Nov, 2017), 50 (10 Dec - 16 Dec, 2017), 03 (15 Jan - 21 Jan, 2018) and 07th (12 Feb - 18 Feb, 2018) MSW. The experimental period recorded minimum and maximum temperatureof 8.5°C and 42°C respectively with a total of 236 mm rainfall (Fig. 1). Accumulated growing degree days were calculated by the formula given by Iwata (1984). Relative temperature disparity (RTD) was calculated from the difference of maximum to minimum temperature upon the maximum temperature. Data on yield and yield components was recorded from 4 m^2 experimental plots of three replications.

$$\text{Heat unit (Growing degree days)} = \sum_{I=1}^{n} \frac{(\text{Max. temp.} + \text{Min. temp.})}{2} - \text{Base temp.}$$

$$\text{RTD} = \frac{(\text{Max} - \text{Min})\ \text{Temp}\ (^{o}\text{C})}{\text{Average Max Temp}\ (^{o}\text{C})} \times 100$$

A perusal of the data presented in the Table 2 indicated that the duration of the crop was extended up to 111 days when the crop was sown in mid *rabi* season (Dec 2017) over the crops sown immediately after the harvest of *kharif* season crop (Oct 2017), whereas sowing after 15th Jan or 15th Feb maintained a duration of ±10% of the original duration of the sesame crop. It is evident that raising the crop during mid *rabi* from November to December is not a profitable venture as the duration gets extended and the farmer has to make additional investment for the protection of the crop from biotic stresses *viz.,* pest and diseases as well as the abiotic stress *viz.,* low temperature stress.

From a meteorological point of view, the base temperature for the optimum growth of sesame (10°C) was a deterrent for few meteorological standard weeks for the crop raised during October to December.

Table 1 List of sesame genotypes (with their seed colour, pedigree, year and state of release used in the present study

Cultivar/Variety	Seed colour	Pedigree	Year of release	Released state
GT 10	Black	TNAU17 selection	2005	Gujarat
GT 4	White	GT 1 x RT 125	2012	Gujarat
GT 3	White	GT 1 x AHT 85	2009	Gujarat
RT 346	White	RT 127x HT 24	2009	Rajasthan
RT 351	White	NIC 8409 x RT 127	2011	Rajasthan
YLM 66	Brown	PS 201x YLM-17	-	Andhra Pradesh
Swetha til	White	E 8 x IS 1 14	1999	Telangana
CUMS 17	Brown	IC 21706 mutant	2017	West Bengal

Table 2 Temperature range and change in duration as influenced by sowing dates of sesame during 2017-18

Sowing week	Harvesting week	Total duration (days)	Max temperature range (°C)	Min temperature range (°C)
43rd MSW (23.10.17)	05th MSW (02.02.2018)	102	29.2 - 31.1	9.7 - 20.0
46th MSW (16.11.2017)	11th MSW (13.03.2018)	117	28.2 - 36.2	9.7 - 18.6
50th MSW (15.12.2017)	14th MSW (04.04.2018)	111	28.2 - 37.6	9.7 - 20.3
03rd MSW (16.01.2018)	17th MSW (23.04.2018)	98	29.9 - 39.7	10.3 - 22.9
07th MSW (15.02.2018)	20th MSW (17.05.2018)	92	30.8 - 39.1	14.6 - 24.9

MSW: Meteorological standard week

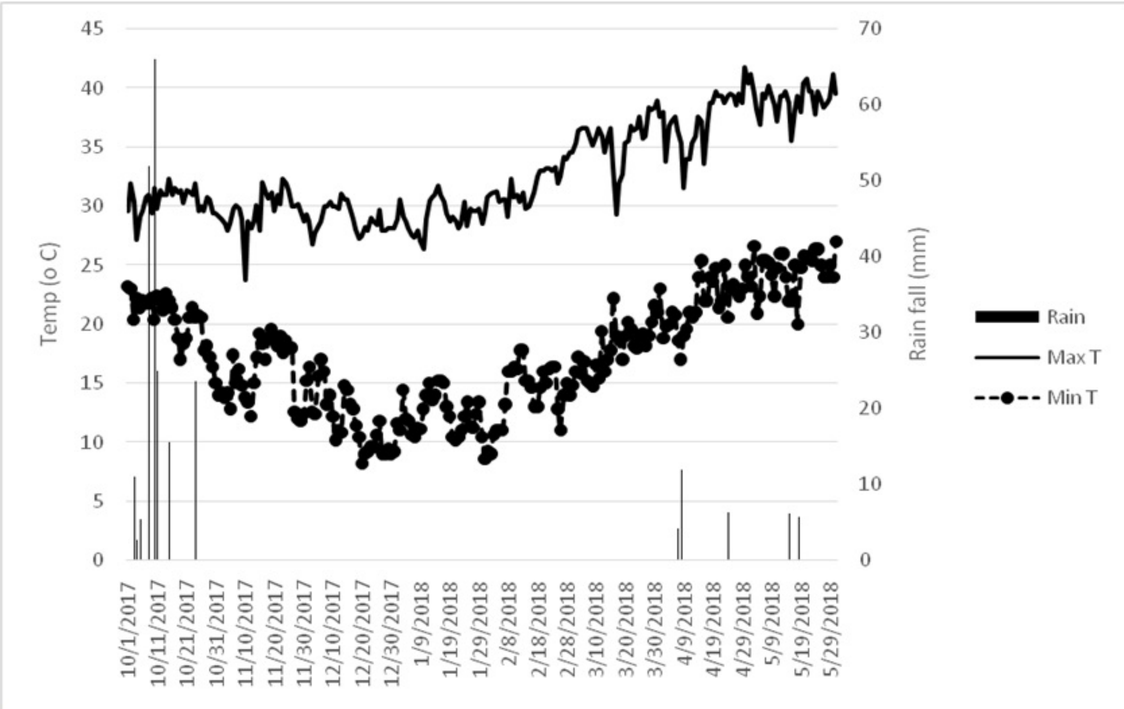

Fig. 1. Minimum and maximum temperatures (°C) and rainfall (mm) during different sowings of sesame crop (2017-18) at IIOR research farm, Narkhoda where series of experiments conducted

Table 3 Temperature indices of different sesame varieties and their yields

Sowing (MSW)	Accumulated GDD	Mean HTU	Seed yield/plant (g)							
			GT10	GT 3	RT 346	GT 4	RT 351	Swetha til	YLM 66	CUMS 17
43	173.62	770.3	10.75	12.29	8.66	9.63	8.67	13.7	13.77	16.95
46	221.00	837.1	10.23	12.9	11.6	11.97	9.71	17.57	15.9	21.94
50	223.61	888.7	12.88	8.84	5.98	8.42	8.19	15.38	11.49	11.68
03	232.71	1005.6	8.78	9.12	5.09	6.87	4.65	6.57	7.91	6.46
07	252.72	1188.9	6.94	8.43	4.18	6.56	4.79	8.98	8.08	9.24

Table 4 Relative temperature disparity and harvest index of sesame genotypes

Sowing (MSW)	Mean RTD	Harvest Index (%)							
		GT10	GT 3	RT 346	GT 4	RT 351	Swetha til	YLM 66	CUMS 17
43	28.98	0.29	0.32	0.27	0.28	0.28	0.30	0.32	0.35
46	30.25	0.27	0.32	0.32	0.32	0.30	0.34	0.32	0.37
50	31.50	0.35	0.47	0.41	0.32	0.51	0.53	0.32	0.48
03	33.22	0.40	0.40	0.31	0.36	0.25	0.29	0.40	0.25
07	35.76	0.43	0.44	0.30	0.42	0.29	0.53	0.40	0.44

In the context of climate change, temperature is one of the most important environmental factors influencing the sesame crop growth, development, and yield. The duration of each phenological phase is influenced by temperature which has direct impact on yield. Growing degree days or accumulated day degree is the effective heat units calculated from the base temperature of the crop. The accumulated heat unit system is based on the definite temperature requirements the crops have to attain certain phenological stage (Rani and Margatham, 2013). For the sowings between October to December, accumulated GDD was increasing, thereafter a decline was noticed. These changes can be attributed to decrease in the minimum temperatures for the early sown crops. On the other hand, declining trends in GDD could be attributed to decreases in maximum temperature. A maximum accumulated GDD of 305.33 was found to be optimum for GT 10 for the December sowing. A maximum accumulated GDD of 221 was found to be optimum for GT 3, RT 346, GT 4, RT 351, Swetha til, YLM 66 and CUMS 17 for the November sowing.

The data (Table 3) indicate that as the sowing date progresses from October to February, the relative temperature disparity for sesame increased. Air temperature, particularly the minimum temperature during winter season is an important weather parameter that affects sesame growth, development and yield. It is universally known that winter crops are vulnerable to high temperature during reproductive stages and differential response of temperature change (rise) to various crops has been noticed under different production environments. The temperature differences between the minimum and maximum is considered important because the activity of all the enzymes is controlled by temperature variation (Pal *et al*.,2013) and the water uptake is controlled by VPD (Vadez and Ratnakumar 2016)

Among the genotypes, RT 351 (Table.4) registered maximum harvest index of 0.51 with equal allocation of source to seed, and stem and leaves. The national check variety GT 10 could allocate maximum source to seed when the sowing was advanced to February. GT3, RT 346, RT 351, Swetha til and CUMS 17 could allocate more biomass to seed when sown during December.

Identification of appropriate variety for the changed climate scenario is crucial for obtaining higher yield in sesame crop during winter season. All the tested varieties performed better under November sowing except GT 10 which was better under October sowing.

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Meeting Report
Brainstorming meeting on "Value Addition in Castor Oil"

Preamble

Reiterating that "while science is universal, technology must be local", the Hon. Prime Minister has called for innovations in the agriculture sector that would lower wastage and eliminate entirely India's dependence on imports of agriculture products. Particularly the Prime Minister indicated the status of castor production in India with the highest production and export but with little value addition and prompted for exploring the opportunities for value addition in castor oil. Castor oil finds myriad industrial and pharmaceutical applications and more than 200 products are produced with the use of different grades of derivatives.

Status

India stands *numero uno* in terms of area, production and productivity of castor in the world contributing more than 85% to global production. Castor is grown in an area of 0.89 million ha, with a production of 2.06 million tonnes at productivity of 2315 kg/ha (2019-20, Advance Estimates, DES, GoI). Worldwide, castor is cultivated in more than 29 countries over an area of 1.29 million ha, with a production of 1.40 million tonnes and productivity of 1079 kg/ha (2017-18, FAOSTAT). Mozambique, China and Brazil are the other major castor producing countries with a total share of 8.3% of world production. 75% of the castor oil produced in the country is exported as raw oil. In India, castor oil and its derivatives are mainly consumed in the paint industry (45-50%), soap industry (25-30%), and in lubricants (15-20%).

India holds a monopoly of castor oil exports (80-85%) in the world followed by Brazil (3%) and the USA (2%). China is the highest importer of castor oil from India. On an average, India exports about 5 lakh tonnes of castor oil and its fractions earning about Rs.5657 crores to the exchequer annually while the total castor products exported amounts to 1.1 million tonnes earning Rs.6390 crores (Table 1).

Table 1. Production and export of castor oil, meal and derivatives

(Qty in lakh tonnes; Value in Rs. crores)

	Castor oil and its fractions		Hydrogenated castor oil		Oil cake and meal		Others		Total Castor Exports	
Year	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
2010-11	3.95	2729.11	0.28	239.03	1.62	65.37	0.03	23.15	5.88	3056.65
2011-12	4.55	4156.15	0.36	397.81	0.76	37.00	0.03	25.91	5.70	4616.87
2012-13	5.27	3966.54	0.37	328.52	0.29	15.39	0.02	19.85	5.95	4330.30
2013-14	5.05	3995.47	0.38	356.40	6.02	352.21	0.02	20.04	11.48	4724.12
2014-15	5.06	4304.08	0.60	393.65	5.26	370.40	0.02	17.38	10.93	5085.50
2015-16	5.43	4213.94	0.42	388.89	5.49	378.52	0.02	20.84	11.37	5002.19
2016-17	5.56	4145.34	0.43	373.69	5.11	253.08	0.02	20.13	11.13	4792.23
2017-18	6.51	6235.28	0.44	477.85	4.35	211.87	0.02	22.65	11.33	6947.65
2018-19	5.74	5657.83	0.44	497.62	3.47	212.19	0.02	22.68	9.67	6390.31

(Source: Ministry DGCIS, Ministry of Commerce and Industry, GOI)

Castor-oil based derivatives are highly priced in the international market and can fetch more than 40% higher value at Generation - I level derivatives, about 350% at Generation - II level and more than 800-900% at Generation - III level derivatives. The most prominent second-generation derivatives are ricinoleic acid, Turkey red oil, hydrogenated castor oil, 12-hydroxy stearic acid (12-H.S.A.), dehydrated castor oil (commercial), sebacic acid, and undecylenic acid. It was noted that except for sebacic acid, indigenous technologies are available for all the products in India for their manufacture. Recently sebacic acid is being manufactured in the country by a company. China is the major importer of castor oil from India and is the largest producer of sebacic acid in the world. Third generation derivatives of castor oil are high specialty chemicals such as zinc ricinoleate, that are being produced outside India in smaller volumes.

There is a great and urgent need for production of second and third-generation castor oil derivatives in India to achieve higher value addition and foreign exchange realization. The immense potential of utilizing the available technology for value addition needs to be exploited by appropriate linking of the stakeholders in the value chain including technology developers, extractors, processors, and industries by framing appropriate policies that enable and foster domestic production of value-added products. It was felt necessary that the stake holders involved in the production and utilization of castor oil and its derivatives are engaged in deliberation to prepare a roadmap to exploit the potential of value-added products of castor in India.

The meeting

With this background, a brainstorming session was organized to take stock of the status and the scope for embarking on value addition in castor oil with the strong base of the highest raw material supply in India. The brainstorming session involved all the stakeholders including research, technology and industry partners directly involved in castor supply and value chain under the chairmanship of Dr. Trilochan Mohapatra, Secretary, DARE and Director General, ICAR on Nov 29, 2019 at ICAR- Indian Institute of Oilseeds Research, Hyderabad. The chairman emphasised on the necessity to - map the market demand for different value added products of castor, document all the available technologies for production of value-added products, understand the industry perspectives in scaling up of these technologies, and provide an enabling platform to exploit the huge potential of the value-added products. Presentations were made by Dr. Vishnuvardhan Reddy, Director, IIOR, Dr. RBN Prasad, Former Chief Scientist & Head, Centre for Lipid Research, CSIR-IICT, Mr. Abhay Udeshi, Chairman, Solvent Extractors' Association (SEA) of India, Dr. Prabhavathi Devi, Senior Principal Scientist and Head, Centre for Lipid Research, CSIR-IICT, Dr. Prachi Agarwal, Senior Manager (Projects), BIRAC, New Delhi and Dr. J.B. Misra Technical Adviser, Indian Oilseed Producer and Exports Promotion Council (IOPEPC) on different aspects of value addition in castor oil.

Recommendations/ action points

The following recommendations/action points emanated. The action points along with the agencies to be involved in implementation were also identified.

Supply-side:

- Tripling the productivity of castor for ensuring higher profitability to farmers.
- (Current national average: 1900kg/ha (Range: 500 to >3000kg/ha)

Demand driven requirements:

Quality seed

Best Management Practices

Seed to Seed Contract farming (FPOs, private players)

Assured market price

Creating awareness and demonstration

Partners: ICAR (IIOR/SAU/Seed corporations), FPOs

Demand-side:

- Ensuring adequate local processing/extraction of oil
- Bridging demand-supply gap and continuity with assured demand

Partners: Industries and aggregators

Policy issues

- Incentives for export of value-added products over primary oil so that the drive will be for value-added products of castor oil.
- Policy for regulating diversion of edible oils for industrial use

Agencies: Government of India in consultation with the concerned ministries and IOPEPC

Comprehensive database to be developed (with inputs from Directorate General of Foreign Trade, Ministry of Commerce and Industry and IOPEPC)

- Disappearance of domestic castor oil to different sectors.
- Imports of castor oil products and their uses/industries.
- Creating awareness about healthy consumption of vegetable oils
- Dynamic import duty regulation on vegetable oils – current policy
- Issues of regulation of import of poor quality sebacic acid over high quality domestic product and their use.

Bringing out value addition

- Inter institute Research – industry interface for discovery/innovation/novelty, competitiveness/low cost/efficiency and scale-up.
- BIRAC to support projects.
- Identify newer products/cost-effective products and scope for commercialization and identify partnership.
- Assess market demand for new molecules or products and applications.

Partners: IICT - industry – BIRAC (Secondary agriculture)

Discovery of new compounds in castor that could be commercially exploited

- Identification of crop varieties specifically identified/ bred for unique quality traits of industrial value.
- Quantification of the important biomolecules in germplasm lines
- To explore biotechnological approaches to develop toxin (Ricin/Ricinine / Allergen /RCA) free castor

Agency: ICAR – IIOR

A.Vishnuvardhan Reddy, Vice President, ISOR; M. Sujatha, General Secretary, ISOR and V. Dinesh Kumar, Meeting Co-ordinator and Editor, JOR

INDIAN SOCIETY OF OILSEEDS RESEARCH

Instructions to Authors for Preparation of Manuscript for Journal of Oilseeds Research

Prospective author(s) are advised to consult **Issue No. 27(1) June, 2010 of the Journal of Oilseeds Research** and get acquainted with the minor details of the format and style of the Journal. Meticulous compliance with the instructions given below will help quick handling of the manuscript by the reviewers, editor and printers. **Manuscripts are considered for publication in the Journal only from members of the ISOR.**

General

Full-length articles, short communications, book reviews and review articles are published in the Journal. Review articles and book reviews are published usually by invitation. Full length articles and short communications should report results of original investigations in oilseeds, oil bearing plants and relevant fields of science. Choice of submitting the paper(s) either as full length paper or short communication rests with the authors. The Editor(s) or Reviewer(s) will examine their suitability or otherwise only in that specific category. Each article should be written in English correctly, clearly, objectively and concisely. All the statements made in the manuscript should be clear, unambiguous, and to the point. Plagiarism is a crime and therefore, no part of the previously published material can be reproduced exactly without prior permission from the original publisher or author(s) as deemed essential and the responsibility of this solely rests on the authors. Also, authors shall be solely responsible for the authenticity of the results published as well as the inferences drawn thereof. Telegraphic languages should be avoided. The data should be reported in a coherent sequence. Use active voice. Active voice is clear, unambiguous and takes less space. Use past tense while reporting results. Do not repeat ideas in different forms of sentences. Avoid superfluous sentences such as `it is interesting to note that', `it is evident from the table that' or `it may be concluded that' etc. Use % for percent, %age for percentage, / for per, @ for at the rate of hr for hours, sec for seconds. Indicate date as 21 January 2010 (no commas anywhere). Spell out the standard abbreviations when first mentioned eg. Net assimilation rate (NAR), general combining ability (GCA), genetic advance (GA), total bright leaf equivalents (TBLE), mean sum of squares (MSS).

Manuscript

Language of the Journal is English. Generally, the length of an article should not exceed 3,000 words in the case of full-length article and 750 words in the case of short communication. However completeness of information is more important. Each half-page table or illustration should be taken as equivalent to 200 words. It is desirable to submit manuscript in the form of soft copy either as an e-mail attachment to editorisor@gmail.com (preferred because of ease in handling during review process) or in a **compact disk (CD) (in MS Word document; double line space; Times New Roman; font size 12).** In exceptional cases, where the typed manuscript is being submitted as hard copy, typing must be done only on one side of the paper, leaving sufficient margin, at least 4 cm on the left hand side and 3 cm on the other three sides. Faded typewriter ribbon should not be used. Double space typing is essential throughout the manuscript, right from the **Title** through **References** (except tables), foot note etc. Typed manuscript complete in all respects, is to be submitted to the Editor, Journal of Oilseeds Research, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500 030. Every page of the manuscript, including the title page, references, tables, etc. should be numbered. Punctuation marks help to show the meanings of words by grouping them into sentences, clauses, and phrases and in other ways. These marks should be used in proper manner if the reader of a paper is to understand exactly the intended meaning. Receipt of the manuscript (in the form of either soft or hard copy) will be acknowledged by the editorial office of the Society, giving a manuscript number which should be quoted in all subsequent correspondence regarding that particular article.

Full-length Articles

Organization of the Manuscript

Before reading the instructions given below, the author(s) would better have a close look at the latest issue of the Journal.

Full-length article comprises the following sections.

(a) Short title
(b) Title
(c) Author/Authors
(d) Institution and Address with PIN (postal) code
(e) Abstract (along with key words)
(f) Introduction
(g) Materials and Methods
(h) Results and Discussion
(i) Acknowledgments (if any)
(j) References
(k) Tables and figures (if any)

Guidelines for each section are as follows:

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

Short Title

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

Title

Except for prepositions, conjunctions, pronouns and articles, the first letter of each word should be in capital letter. The title should be short and should contain key words and phrases to indicate the contents of the paper and be attractive. Jargons and telegraphic words should be avoided. In many cases, actual reading of the paper may depend on the attractiveness of the title.

Author/Authors

The name(s) of author(s) should be typed in capital letters a little below the title, starting from the left margin. Put an asterisk on the name of the corresponding author. **Give the Email ID of the corresponding author** as a footnote.

Institution and Address

This matter will come below the name(s) of the author(s). Name of the Laboratory/Department, followed by the name of the Institution/Organization/University where the work reported in the paper was carried out shall come below the name(s) of author(s). Complete postal address, which should include city/town, district, and state, followed by PIN (postal) code is to be furnished. In case any author has left the above address, this should be indicated as a footnote.

Abstract

The paragraph should start with the word Abstract (in bold font). The abstract should comprise brief and factual summary or salient points of the contents and the conclusions of the investigation reported in the paper and should refer to any new information therein. As the abstract is an independent entity, it should be able to convey the gist of the paper in a concise manner. It will be seen by many more people than will read the paper. The abstract, as concise as possible, should not exceed 250 words in length. Everything that is important in the paper must be reflected in the abstract. It should provide to the reader very briefly the rationale, objectives or hypothesis, methods, results and conclusions of the study described in the paper. In the abstract, do not deflect the reader with promises such as 'will be discussed' or 'will be explained'. Also do not include reference, figure or table citation. At first mention in the abstract, give complete scientific name for plants and other organisms, the full names of chemicals and the description of soil order/series. Any such names or descriptions from the abstract need not be repeated in the text. It must be remembered that the abstracting journals place a great emphasis on the abstract in the selection of papers for abstracting. If properly prepared, they may reproduce it verbatim.

"Key words" should, follow separately after the last sentence of the abstract. "Key words" indicate the most important materials, operations, or ideas covered in the paper. Key words are used in indexing the articles.

Introduction (To be typed as side-heading, starting from the left-hand margin, a few spaces below the key words)

This section is meant to introduce the subject of the paper. Introduction should be short, concise and indicate the objectives and scope of the investigation. To orient readers, give a brief reference to previous concepts and research. Limit literature references to essential information. When new references are available, do not use old references unless it is of historical importance or a landmark in that field. Emphasis should be given among other things on citing the literature on work done under Indian conditions. Introduction must include: (a) a brief statement of the problem, justifying the need for doing the work or the hypothesis on which the work is based, (b) the findings of others that will be further developed or challenged, and (c) an explanation of the approach to be followed and the objectives of the research described in the paper. If the methods employed in the paper are new, it must be indicated in the introduction section.

Materials and methods (To be typed as side-heading, starting from the left-hand margin, a few spaces below the introduction)

This part of the text should comprise the materials used in the investigation, methods of experiment and analysis adopted. This portion should be self-explanatory and have the requisite information needed for understanding and assessing the results reported subsequently. Enough details should be provided in this section to allow a competent scientist to repeat the experiments, mentally or in fact. The geographical position of soil site or soils used in the experiment or site of field trial should be identified clearly with the help of coordinates (latitude & longitude) and invariably proper classification according to Soil Taxonomy (USDA), must be indicated to the level of Great-group, Suborder or Order as far as possible. Specify the period during which the experiment(s) was conducted. Send the article after completion of the experiment(s) not after a gap of 5 years. Instead of kharif and rabi use rainy and winter season respectively. Please give invariably the botanical names for local crop names like raya, bajra moong, cholam etc. Botanical and zoological names should confirm to the international rules. Give authorities. Go through some of our recent issues and find out the correct names. Give latest correct names from authentic source. For materials, give the appropriate technical specifications and quantities and source or method of preparation. Should a product be identified by trade name, add the name and location of the manufacturer or a major distributor in parenthesis after the first mention of the product. For the name of plant protection chemicals, give popular scientific names (first letter small), not trade names (When trade name is given in addition, capitalize the first letter of the name). Known methods of analysis should be indicated by referring to the original source, avoiding detailed description. Any new technique developed and followed should be described in fair detail. When some specially procured or proprietary materials are used, give their pertinent chemical and physical properties. References for the methods used in the study should be cited. If the techniques are widely familiar, use only their names in that case.

Results and Discussion (To be typed as a side-heading, a few spaces below the matter on "Materials and Methods")

This section should discuss the salient points of observation and critical interpretation thereof in past tense. This should not be descriptive and mere recital of the data presented in the tables and diagrams. Unnecessary details must be avoided but at the same time significant findings and special features should be highlighted. For systematic discussion, this section may be divided into sub-sections under side-heading and/or paragraph side heading. Relate the results to your objectives. While discussing the results, give particular attention to the problem, question or hypothesis presented in the introduction. Explain the principles, relationships, and generalizations that can be supported by the results. Point out any exceptions. Explain how the results relate to previous findings, support, contradict or simply add as data. Use the Discussion section to focus on the meaning of your findings rather than recapitulating them. Scientific speculation is encouraged but it should be reasonable and firmly founded in observations. When results differ from previous results, possible explanations should be given. Controversial issues should be discussed clearly. References to published work should be cited in the text by the name(s) of author(s) as follows: Mukherjee and Mitra (1942) have shown or It has been shown (Mukherjee and Mitra, 1942)..... If there are more than two authors, this should be indicated by et al. after the surname of the first author, e.g., Mukherjee et al. (1938).

Always conclude the article by clearly crystallizing the summary of the results obtained along with their implications in solution of the practical problems or contribution to the advancement of the scientific knowledge.

Acknowledgments (To be typed as given above, as a side-heading, well below the concluding portion of Conclusions)

The author(s) may place on record the help, and cooperation, or financial help received from any source, person or organization. This should be very brief, and omitted, if not necessary.

References (To be typed as above, as side heading below Acknowledgement)

The list of references must include all published work referred to in the text. Type with double line spacing. Do not cite anonymous as author; instead cite the name of the institute, publisher, or editor. References should be arranged alphabetically according to the surnames of the individual authors or first authors. Two or more references by the same author are to be cited chronologically; two or more in the same year by the letters a, b, c, etc. All individually authored articles precede those in which the individual is the first or joint author. Every reference cited in the article should be included in the list of References. This needs rigorous checking of each reference. Names of authors should not be capitalized.

The reference citation should follow the order: author(s), year of publication, title of the paper, periodical (title in full, no abbreviations, italics or underlined), volume (bold or double underlining), starting and ending pages of the paper. Reference to a book includes authors(s), year, title (first letter of each word except preposition, conjunction, and pronouns in capitals and underlined), the edition (if other than first), the publisher, city of publication. If necessary, particular page numbers should be mentioned in the last. Year of publication cited in the text should be checked with that given under References. Year, volume number and page number of each periodical cited under "References" must be checked with the original source. The list of references should be typed as follows:

Rao C R 1968. *Advances in Statistical Methods in Biometrical Research*, pp.40-45, John Wiley & Sons, New York.
Kanwar J S and Raychaudhuri S P 1971. *Review of Soil Research in India*, pp 30-36. Indian Society of Soil Science, New Delhi.
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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.
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AICRP on Soybean 1992. *Proceedings of 23rd Annual Workshop of All-India Co-ordinated Research Project on Soybean*, held during 7-9 May 1992 at University of Agricultural Sciences, Bangalore, Karnataka, National Research Centre for Soybean, Indore, pp.48.
Devakumar C. 1986. Identification of nitrification retarding principles in neem (*Azadirachta indica* A.Juss.) seeds. Ph D Thesis, Indian Agricultural Research Institute, New Delhi.

Reference to unpublished work should normally be avoided and if unavoidable it may be mentioned only in the text.

Short Communication

Conceptually short communication is a first report on new concept, ideas and methodology which the author(s) would wish to share with the scientific community and that the detailed paper would follow. Short Communication is akin to an advance booking for the report on the findings. Short communications may include short but trend-setting reports of field or laboratory observation(s), preliminary results of long-term projects, or new techniques or those matters on which enough information to warrant its publication as a full length article has still not been generated but the results need to be shared immediately with the scientific community. The style is less formal as compared with the "full-length" article. In the short communications, the sections on abstract, materials and methods, results and discussion, and conclusion are omitted; but the material is put concisely in the same sequence but without formal sections. The other instructions are the same as in the case of the full-length articles.

Tables

Tables should not form more than 20% of the text. Each table should be typed on separate sheet and should have on the top a table number (in Arabic numerals *viz.* 1, 2, 3 etc.) and a caption or title which should be short, but sufficiently explanatory of the data included in the table. Information in the table should never duplicate that in the text and vice versa. Symbols (asterisks, daggers, etc. or small letters, *viz.*, a, b, etc.) should be used to indicate footnotes to tables. Maximum size of table acceptable is what can be conveniently composed within one full printed page of the journal. Over-sized tables will be rejected out-right. Such tables may be suitably split into two or more small tables.

The data in tables should be corrected to minimum place of decimal so as to make it more meaningful. Do not use full stop with CD, SEm±, 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.

Figures

Figures include diagrams and photographs. Laser print outs of line diagrams are acceptable while dot-matrix print outs will be rejected. Alternatively, each illustration can be drawn on white art card or tracing cloth/ paper, using proper stencil. The lines should be bold and of uniform thickness. The numbers and letterings must be stenciled; free-hand drawing will not be accepted. Size of the illustrations as well as numbers, and letterings should be sufficiently large to stand suitable reduction in size. Overall size of the illustrations should be such that on reduction, the size will be the width of single or double column of the printed page of the Journal. Legends, if any, should be included within the illustration. Each illustration should have a number followed by a caption typed/ typeset well below the illustration.

Title of the article and name(s) of the author(s) should be written sufficiently below the caption. The photographs (black and white) should have a glossy finish with sharp contrast between the light and the dark areas. Colour photographs/ figures are not normally accepted. One set of the original figures must be submitted along with the manuscript, while the second set can be photocopy. The illustrations should be numbered consecutively in the order in which they are mentioned in the text. The position of each figure should be indicated in the margin of the text. The photographs should be securely enclosed with the manuscript after placing them in hard board pouches so that there may not be any crack or fold. Photographs should preferably be 8.5 cm or 17 cm wide or double the size. The captions for all the illustrations (including photographs) should be typed on a separate sheet of paper and placed after the tables.

Expression of Plant Nutrients on Elemental Basis

The amounts and proportions of nutrient elements must be expressed in elemental forms e.g. for ion uptake or in other ways as needed for theoretical purposes. In expressing doses of nitrogen, phosphatic, and potassic fertilizers also these should be in the form of N, P and K, respectively. While these should be expressed in terms of kg/ha for field experiments, for pot culture studies the unit should be in mg/kg soil.

SI Units and Symbols

SI Units (System International d 'Unities or International System of Units) should be used. The SI contains three classes of units: (i) base units, (ii) derived units, and (iii) supplementary units. To denote multiples and sub-multiples of units, standard abbreviations are to be used. Clark's Tables: Science Data Book by Orient Longman, New Delhi (1982) may be consulted.

Some of these units along with the corresponding symbols are reproduced for the sake of convenience.

Names and Symbols of SI Units

Physical Symbol for SI Unit Symbol Remarks quantity physical quantity for SI Unit

Primary Units					
length	l		time	t	
metre	m		second	s	
mass	m		electric current	I	
kilogram	kg		ampere	A	
Secondary Units					
plane angle	radian	rad	Solid angle	steradian	sr
Unit Symbols					
centimetre	cm		microgram	µg	
cubic centimetre	cm^3		micron	µm	
cubic metre	m^3		micronmol	µmol	
day	d		milligram	mg	
decisiemens	dS		millilitre	mL	
degree-Celsium	°C [=(F-32)x0.556]		minute	min	

gram	g	nanometre	nm
hectare	ha	newton	N
hour	h	pascal	Pa
joule J	(= 10^7 erg or 4.19 cal.)	second	s
kelvin	K (= °C + 273)	square centimetre	cm^2
kilogram	kg	square kilometre	km^2
kilometre	km	tonne	t
litre	L	watt	W
megagram	Mg		

Some applications along with symbols

adsorption energy	J/mol (=cal/molx4.19)	leaf area	m^2/kg
cation exchange capacity	cmol (p+)/kg (=m.e./100 g)	nutrient content in plants (drymatter basis)	μg/g, mg/g or g/kg
Electrolytic conductivity	dS/m (=mmhos/cm)	root density or root length density	m/m^3
evapotranspiration rate	$m^3/m^2/s$ or m/s	soil bulk density	Mg/m^3 (=g/cm^3)
heat flux	W/m^2	specific heat	J/kg/K
gas diffusion	$g/m^2/s$ or $m^3/m^2/s$ or m/s	specific surface area of soil	m^2/kg
water flow	$kg/m^2/s$ (or) m^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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