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# A brief insight into the insect pest of sunflower (*Helianthus annuus* L.)

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ABSTRACT

The sunflower (*Helianthus annuus* L.) crop has the capacity to quickly adapt to numerous agroecological niches and cropping systems in the Indian subcontinent due to its wide range of adaptation. The major barrier in sunflower production is insect pest damage. It causes damages up to 35-40% damages (IYPH report, 2020). The sunflower environment is home to a wide variety of both useful and harmful insect species. Though more than fifty insect species have been reported on sunflower, cutworms (*Agrotis* spp.), leaf hoppers (*Amrasca biguttula biguttula*), plant hopper (*Empoasca* spp.), thrips (*Thrips palmi*), whitefly (*Bemuses tabaci*), defoliators (*Spilosoma obliqua*, *Spodoptera litura,* and *Plusia orichalcea*), capitulum borer (*Helicoverpa armigera*) are major pests of economic concern. With over 180 host plants, including significant crops, *Helicoverpa armigera* is one of the most devastating and polyphagous insect pests of sunflowers.

**Keywords**: Cultivation, Insect Pests, Pest management, Production, Sunflower

Sunflower, Helianthus annuus (Family: Asteraceae) is a prominent oilseed crop in India and is a native of America, grown as an annual plant. It is also referred to as "Surajmukhi" in Indian conditions and has the capacity to adapt to various agro-climatic conditions (Nirakar and Mahalik, 2008). Due to the high quantity of unsaturated fatty acids and lack of linolenic acid with high oil content (39-49%) in commercially available cultivars, sunflower oil is typically regarded as a premium oil (Geetha and Hegde, 2018). The sunflower is best suited as a spring crop or as a follow-up crop to wheat due to its relatively short growing season and is desirable for dryland crops and can be the best option in regions with little irrigation because of their drought tolerance. It also grows well with complete watering as well (Holly Davis, 2020). Domesticated sunflower crops appear to be more vulnerable to insect damage than their wild counterparts due to morphological and chemical alterations (Jarrad, 2015). Different insect pests cause various levels of damage to the sunflower crop in different regions; for example, defoliating pests can reduce the average yield of sunflower by 267.2 kg/ha whereas *Helicoverpa* alone can cause 120 kg/ha seed loss in India (Panchabhavi and Krishnamoorhty, 1978). Insect pests that attack the crop at various phases of its growth have an enormous adverse effect on the crop's profitability. Control of insect pest mainly depends on the use of chemicals but cultural and biological control is more useful than chemical control and can help in the conservation of natural enemies and also is safer for human and environmental health (Flint and Dreistadt, 1998). Adopting appropriate pest management techniques can reduce the majority of the losses caused by the pest. Farmers need to determine the necessity for any management strategies at the right time because potential risks might differ from place to region and from year to year (Nirakar *et al*., 2008). The economic threshold reflects the minimal number of insects at which management measures should be undertaken in order to prevent a large yield loss. In accordance with the type of insect and the stage of crop growth, the quantity could vary. The crop has delicate plant portions and important growth stages that must be protected from certain enemies (Juan Ignacio, 2014). In this review, we have discussed the pest of sunflower and their production and protection scenario in brief which will give a complete understanding of crops as well as help in planning management strategies to the readers and farmers.

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**Production scenario**: United States Department of Agriculture (USDA) estimates that the world sunflower production in 2022-2023 will be 50.70 million metric tons. Russia is the highest producer in the world with a production of 16.0 million metric tons and a productivity of 1.78 tons/ha. Ukraine ranks second with a production of 10 million metric tons and the European Union stands third with a production of 9.48 million metric tons (Statista). India ranks 18$^{th}$ position with an area of 1.48 million hectares and a production of 2,79,000 metric tons. Karnataka is the leading producer with an area of 7.94 lakh hectares and a production of 3.04 lakh tons followed by Orissa, Haryana, Maharashtra (Statista). Sunflower seeds are also nutritionally rich and serve as the source of many important vitamins. The nutritional information of serving size i.e. 32g is given in Table 1.

**Health benefits**: It Lowers inflammation due to the presence of Flavonoids, vitamin E, and other anti-inflammatory plant chemicals found in sunflower seeds and improves heart health as it has Monounsaturated and polyunsaturated fatty acids, both of which are good for the heart, are abundant in sunflower seeds. It also lessens the risk of cardiovascular disease, high blood pressure, and high cholesterol (Poonam Sachdev, 2022). It Boosts energy levels as vitamin B1 present in sunflower seeds can help in converting food to energy which helps in keeping active throughout the day. Selenium can increase blood flow and deliver more oxygen to the body and reduces the risk of cancer due to Beta-sitosterol, a phytosterol present in sunflower seeds that helps to prevent breast cancer. It inhibits the growth of tumour cells, decreases the size of the tumour and also prevents metastasis. It also helps in reducing diabetes and improves brain function of the brain as Seeds contain vitamin B6. Which improves mood and concentration and enhances memory. Sunflower seeds are rich in protein and fibre it making us feel full for a long time thus reducing the food intake and helping in weight loss. Sunflower seeds are a good source of thiamine which helps in the breakdown of carbohydrates and serves as a powerhouse of energy. They are a good source of iron which helps in preventing anaemia and have a potent antibacterial activity which helps in removing bacteria and germs from cells which helps to detox our body. The antibacterial and antifungal activity of the seeds prevents infection thus keeping skin clear. Since they are a source of vitamin E which is beneficial for prenatal health it is an effective source of nutrition for pregnant women (Prachi Garg, 2023).

**Crop calendar and cultivation practices followed in sunflowers**: Sunflowers can be grown in all three seasons *viz., kharif, rabi* and summer. *Kharif* crops suffer from lodging as heading coincides with heavy rain. *Rabi* sown crop will suffer from poor germination and small heads are produced. However, for better yield, it is advised to cultivate in the zaid season after *rabi. Rabi* crop is sown in December-January and it is harvested in March-April. The crop matures in 90-100 days and the farmer can get a good income by beekeeping also (Biswas, 2019). A pictorial representation of crop growing periods is shown in Table 2. For sunflower growing heavy soil is preferred and due to the enormous system of roots, deep ploughing with a moldboard plough is required. To increase yield, sunflowers must be sown on time (Juan Ignacio, 2014). Oil content declines and yield losses take place in cases of late seeding. The seed rate depends upon soil type, germination percentage, time of sowing and method of sowing. The normal seed rate required is 8-10kg/ha. Sunflowers can be sown using the planter, dibbling, single-row cotton drill, or Kera method (Duane, 2007). With a gap of 2.25 to 2.5 inches between each row, plants should be placed 9 inches apart for irrigation-fed areas and 12 inches apart for rain-fed areas. The fertilizer requirement of sunflower is 60 kg/acre of nitrogen, 40 kg/acre of phosphorous and 25 kg/acre of potassium (Shu-tian *et al.,* 2018). Though this also relies on the weather, the crop normally requires four to five irrigations. The first irrigation should be used 20 days after emergence, the second irrigation should be used 20 days later, the third irrigation should be used at head development, the fourth irrigation should be used at grain formation, and the final irrigation should be used at the milk stage (Kadasiddappa Malamasuri *et al.,* 2017). Thinning is one of the operations essential to maintain the desired plant population. For this purpose, weak or abnormal seedlings should be uprooted before the first irrigation is given. Control of weeds during the first eight weeks after emergence is crucial. Weed control can be done through hoeing and pre/post-emergence herbicide application (Goran Malidza *et al.,* 2016). Sunflower crop matures when the back of the flower head turns yellow and the leaves become greyish white and the moisture content of the seed is 30-35%. For storage, the seed moisture content should be 8-10% (Muhammed Nazar, 2018).

**Pest profiling of major pests of sunflower**: Pest-infesting sunflower mainly falls into three categories i.e., defoliators, head borers and sucking pests. Among these defoliators and sap suckers can be seen in early crop stages while head borers cause damage in late stages. Head borer is considered a major pest and among sucking pests, jassids are the major ones affecting crops. The last week of May and the first week of June marked the peak infestation of sucking pests, whiteflies, and plant hoppers, respectively. Their populations persisted into the first week of October. Semiloopers were seen among the defoliators in the second week of April, while the hairy caterpillar population peaked in the second week of October (Syed Kakakhel *et al.,* 2000). Generally, head borers are active in the mid of the year and they did not attack during Autumn and sucking pest can be seen towards the end of the year, whitefly is a serious pest in Autumn and while a higher population of plant hoppers cause more damage than whitefly.

## THE MAJOR PEST OF SUNFLOWER

**Cutworm (Agrotis ipsilon, Noctuidae, Lepidoptera)**: It is a seedling pest and more widespread, and damaging in the Northern Hemisphere than in the Southern Hemisphere. It annually reinvades temperate areas, overwintering in warmer or subtropical areas. It is distributed in Europe, China, and North America. Host range: It has a wide host range, feeding on nearly all vegetables like brinjal, tomato, and cereals like wheat, maize rice and other crops like cotton, tobacco, strawberry, sugarbeet etc. Bionomics: Eggs are deposited in clusters on foliage. Females deposit 1200-1900 eggs and the

duration is 3-6 days. Larvae are uniformly coloured on the dorsal and lateral surfaces. There are 6 larval instars. Duration is 20-40 days. Pupation occurs below ground. Pupa is dark brown and the duration is 12-20 days (Harris, 1962). The adult is fairly large in size and forewing is dark brown and the hind wing is whitish to grey. The adult pre-oviposition period is 7-10 days. Symptom: In addition to feeding on leaves, the larvae cut seedlings 1-2 inches above the soil's surface. A field with cut plants that have been dried and blown away has bare spots. Larvae can consume 400 square cm of foliage during their development. The early larval instar does not cause much damage to crops but once it attains the fourth larval stage it causes severe damage to young plants by cutting the plants from below during the night (Abdel Gawaad, 1971).

**Foliage pests**: The sunflower crop is damaged at different stages by several defoliators. Among them, the major defoliators are:

**Tobacco caterpillar (*Spodoptera litura*, Noctuidae, Lepidoptera)**: It has a wide distribution and besides India, it is present in Vietnam, Indonesia, Australia, China, Africa, Europe, the Middle East and Fiji. Host range: It is an extremely serious pest, the larvae of which can defoliate many economically important crops. It is seasonally common in annual and perennial agricultural ecosystems in tropical and temperate Asia. The host range include crops grown for food and fibre like groundnut, soybean, safflower, castor, other vegetables and plantation and forestry crops as well as some weed species (Balasubramanian *et al*., 1978). Bionomics: Eggs are laid in batches and covered with brown colour hairs on tender leaves. A single female can lay an average of 2000 eggs. The fully-grown caterpillar is green to pale brown in colour with dark marks on the body and it pupates in soil and pupal period is from 7-10 days adults are dark brown or greyish brown coloured with zigzag markings.

**Symptom**: Larvae are leaf eaters but sometimes they act as cutworms. Early instar larvae feed by scraping the chlorophyll content. Third and fourth instar larvae feed voraciously which leads to complete defoliation of leaves. During day time they hide under the soil and in severe cases the plants are completely destroyed (USDA, 2005)

**Hairy caterpillar (Spilosoma obliqua, Arctiidae, Lepidoptera)**: They are highly polyphagous pests found throughout the year. It is widely distributed in South-eastern Afghanistan, Northern Pakistan, India, Bhutan, Bangladesh and Myanmar. Host ranges: They are highly polyphagous and feed on species of plants including cereals, millets, oilseeds, vegetables, fruit crops, and fibre crops. In India, the insect is a serious pest of fibre crops, sometimes occurring in epidemic outbreaks (Sivakumar *et al*., 2020).

**Bionomics**: The adult female lays 400-1000 eggs which are light green in colour. Eggs are spherical and laid in clusters. The egg period is 8-13 days, larvae have 7 larval instars and the larval period is 30-56 days (Selvaraj *et al.,* 2015), pupation takes place in plant debris and the pupal period is 7-15 days. Adults have a crimson colour body with black dots. Wings are pinkish with numerous black spots. Adult lives for 7 days.

**Symptom**: The larvae on hatching feed on chlorophyll content up to the second instar. The attacked leaves look like dirty paper. The later instars feed gregariously leaving only the veins of leaves without green material. After finishing the foliage, they migrate to adjacent fields (Ramaiyer, 1998).

**Semi looper (*Trichoplusia ni*, Noctuidae, Lepidoptera)**: It is distributed in Southeast Asia, the Arabian Peninsula, Iran, Afghanistan, China, India, Nepal, and North America. Host range: It is a generalist insect that can feed over 160 host plants. The preferred host is crucifers such as cabbage, cauliflower, and broccoli (Rivera Vega *et al*., 2017). Also, it feeds on many other host plants like tobacco, pulses, soybean, sunflowers etc.

**Bionomics**: Eggs are laid singly on the undersurface of leaves. A female can lay about 400-500 eggs and the egg period is 3-4 days, larvae when fully grown is greenish in colour and have white longitudinal stripes on the dorsal side. The larval period is 20-3- days. Pupation takes place in leaf folds and the pupal period is 9-10 days. In adults, the forewings are greyish brown with a deep golden-yellow patch in the centre. Males can be distinguished from females by light brown hairs that lie flat against their abdomen (Shorey *et al*., 1962).

**Symptom**: Damage is caused by larvae, the first three instars feed on the lower leaf surface leaving the upper surface intact. The fourth and fifth instar on leaves cause large irregular holes and usually do not feed on the leaf margin. Feeding sites are marked by large accumulations of sticky, wet faecal matter (McEwen and Hervey, 1960).

**Sunflower beetle (*Zygogramma exclamationis*, *Chrysomelidae, Coleoptera*):** Sunflower beetles are native to North America and they feed on cultivated and wild sunflowers (Janet J Knodel, 2010). Bionomics: Eggs are laid singly on the undersurface of leaves and stem. Each female can lay about 200-2000 eggs, and larvae emerge in about one week. Larvae have 4 instars and are present in fields for about 6 weeks. They Pupate in earthen cells. Pupal stage last from 10 days to 2 weeks. Adults closely resemble the Colorado potato beetle. The head is reddish brown. The forewing is cream-coloured and has 3 dark stripes (Janet J Knodel, 2010).

**Symptom**: Both adults and larvae eat on domesticated and wild sunflowers, defoliating the plants as they go. Both larvae and adults completely destroy the plants. Adult beetles harm plants soon after waking up from their winter hibernation. Adults frequently only eat the leaf margins, however, larvae typically consume the entire leaf surface. When the number of larvae is high, damaged leaves take on a lacy appearance. Fields may become severely defoliated if there are many insects (Janet J Knodel, 2010).

**INFLORESCENCE PESTS**

**Head borer (*Helicoverpa armigera*, Noctuidae, Lepidoptera)**: It is native and widespread in Central and Southern Europe, temperate Asia and Africa, Australia and Oceania (Jones *et al*., 2019).

**Host range**: It is a polyphagous pest with having wide host range. The most important host crops are tomato, cotton, pigeon pea, chickpea, rice, sorghum, soybeans, a number of fruit trees forest trees and a range of vegetable crops (Zalucki *et al*., 1986).

**Bionomics**: Eggs are laid singly on floral parts, leaves etc. The egg period is 2-4 days. Larvae have a greenish-brown body with a yellowish head and a dark band behind the head. Larval colour darkens with successive moults for the six instars (Yamasaki *et al.,* 2009). The larval period is 18-25 days. Pupa is brownish in colour and usually pupates in the soil. The pupal period is 6-21 days. The adult is stout-bodied and the colour is variable. Females are darker usually dull orange-brown reddish brown or brick red and live for 1-2 weeks (Hardwick, 1975).

**Symptom**: It is a serious pest of sunflowers that, under typical circumstances, results in a yield loss of 20-25%. It can occasionally increase by 40-70% (Nirakar Ranasingh and Jayanta Kumar, 2008). Following a brief period of feeding on leaves, buds, and flowers, newly hatched larvae may enter the disc and feed on the maturing seed after drilling a hole in it. Inside the disc, mature larvae bore by forming visible tunnels. It moves to the next head after feeding the seed in the first head, thus reducing the crop. The toxicity of third and fourth-instar larvae is greater than that of younger ones. Greenish hues characterise the fully developed larvae (Nirakar *et al*., 2008).

**SUCKING PESTS**

**Jassids (*Amrasca biguttula biguttula*, *Cicadellidae, Hemiptera*)**: it is widespread in the Indian subcontinent covering Bangladesh, India, Nepal and Pakistan. It is also recorded in Afghanistan, Vietnam, Japan, China, Taiwan and in Pacific Island of Guam (CABI, 2021).

**Host plants**: In India, Jassids feed on sap from a wide range of plants including cotton, okra, eggplant, hibscius, and sunflower throughout the year, and on pigeon pea and cowpea during monsoon season. It also occurs on various leaves of grass, including lawns of Bermuda grass (Chandani Kamble *et al.,* 2015).

**Bionomics**: Eggs are laid on the undersurface of leaves. Eggs hatch in 6-10 days and the nymphal period is 7-9 days. Nymphs moult 5 times and adults are greenish-yellow wedge-shaped with a pair of black spots on the vertex and a spot on each of the forewings. The total lifecycle is completed in 2 weeks to 1 month. Have 6-7 generations in a year (Hanumantappa *et al*., 2011).

**Symptom**: Major sucking pest which causes crop loss of up to 46% (Basappa, 1999). Both nymphs and adults suck the sap from the undersurface of leaves. The damage is characterized by typical yellowish-white spots on leaves as a result leaves become crinkled and cup-shaped, growth gets stunted brownish red colour develops on the edges of leaves and the condition is known as "hopper burn". Seeds are also shrivelled and there is a drastic reduction in oil content (Nirakar *et al*., 2008).

**Thrips (*Scirtothrips dorsalis, Thripidae, Thysanoptera*):** It is widely distributed in Thailand, India, Japan, South Africa, West Africa and Kenya (Ramakrishna Ayyar, 1932). Host plants: It is a pest of economic significance with a broad host range, with prominent pest reports on crops including pepper, eggplant, mango, citrus, strawberry, grapes, cotton, blueberry and rose (Venette and Davis, 2004).

**Bionomics**: Eggs are minute, kidney shaped laid in slits in leaf tissues, the eggs hatch between 2-7 days. Nymphs are creamy to pale yellow in colour and resemble adults but wingless (Fig. 15). Adults are slender and lice-like. Adults are straw colour yellowish brown and elongated measuring 1 mm in length (Seal *et al*., 2009).

**Symptom**: Nymphs and adults suck the sap from leaves. This results in white patches on the upper and necrotic patches on the lower surface of the leaves. It consists of distortion of young leaflets and patchy areas of necrotic tissue that puncture and split as the leaflets grow (Sanap and Nawale, 1987).

**Whitefly (*Bemisia tabaci, Aleyrodidae, Hemiptera*):** It is a highly polyphagous genus which appears from November to February. It is originally from southern Asia and is widely distributed in Africa, Australia, China, Hawaii, Arizona, California, Florida, and Georgia (Cock, 1986).

**Host range**: It attacks more than 500 species of plants (Greathead, 1986). It is a global polyphagous pest which is

reported in plant families like solanaceae, cucurbitaceae, fabaceae etc. Weeds often serve as alternate hosts of crop pests.

**Bionomics**: Eggs are laid singly on the lower surface of leaves. Eggs hatch in a week of time and nymphs are oval scale-like and remain attached to the leaf surface (Butler *et al*., 1983). Adults are tiny moth-like with a whitish-yellow body and wings coated with milky white waxy powder (Fig. 18).

**Damage**: Nymphs and adults suck the sap usually from the undersurface of leaves and excrete honeydew. Infestation causes a medium for the growth of black moulds. Later the vitality of the plant is lowered (Berlinger, 1986). It also causes leaf chlorosis, leaf withering, premature dropping of leaves and plant death.

**Integrated pest management in sunflower**: Because of possible losses from weeds, insects, and disease, sunflowers can be a crop with a high risk of failure. Given these possible concerns, integrated pest management (IPM) must be practised by the growers. IPM is a sustainable method of managing pests that combines cultural, mechanical, biological, and chemical techniques in a way that reduces the risk to the economy, human health, and the environment while keeping the pest population below levels which results in unacceptable losses in crop quality or yield (Laurence D Charlet *et al*., 2010). The idea behind integrated pest management (IPM) is that a variety of factors interact to affect a pest's abundance. Although the efficacy of control strategies varies, the number of pests in sunflowers can be reduced and the expense of managing pest populations can be decreased without unneeded crop losses by integrating several population-regulating elements. IPM also advises the prudent use of chemical pesticides when necessary and provides methods to increase their efficiency while minimizing their negative effects on the environment and non-target organisms (Janet *et al*., 2010).

**Cultural control**: Pre-monsoon deep ploughing is done to expose the hibernating pupae to sunlight and predatory birds. The field should be kept exposed to sunlight for at least 2-3 weeks. Timely sowing and clean cultivation will help in reducing the infestation. Early planting can reduce the incidence of sucking pests. Removal and destruction of alternate weed hosts and removal of crop residues after harvest will reduce the infestation. A balanced dose of fertilizers avoids over-fertilization and under-fertilization (British Columbia, 2019). Sowing sunflower seeds on ridges of 6-8 cm in height is done in cutworm-endemic areas to prevent infestations. Intercropping the sunflower with groundnut in a 1:4 ratio reduces whiteflies, and jassids populations and intercropping with pigeon peas helps to control tobacco caterpillars (Larry D Charlet *et al*., 2018). Sow 3-4 lines of maize around the sunflower crop to monitor pests. Sowing marigolds as a trap crop @ 50 plants/acre helps in managing the head borers.

**Mechanical control**: Hand picking and collection and destruction of leaves with eggs. This can reduce the pest populations and prevent damage to crops. Destroy infested leaves which show characteristic drying symptoms. Trapping: Use of pheromone traps at the rate of 4traps/acre and use of yellow sticky traps for the control of whitefly and blue sticky trap for the control of thrips also light traps can be set up @ 1trap/acre (Nirakar *et al*., 2008). Use of mechanical barriers like nets, and screens to prevent entry of pest

**Biological control**: Release of *Trichogramma chilonis* @50,000/ha at weekly interval (Nirakar *et al*., 2008). Release of egg parasitoids like *Telenomus remus* @ 1,25,000/ha. Release of natural enemies like coccinellids, *Chrysoperla carnea* @ 1 larva/head (Basappa, 2011). Spray HaNPV 250 LE/ha + 1 kg jaggery + 200ml Sandovit or Teepal; mix it and spray in evening hours (for *Helicoverpa*). Conserve natural bio control populations like spiders, long horned grasshoppers, dragonfly, damselfly etc. Use of NPV on cloudy days@ 500 LE/ha will be effective. Spraying of Bt @ 400g/ha or 1g/lit. Spray 5% neem oil or 5% NSKE (Nirakar *et al.,* 2008). Spray *Clerodendrum inerme* dust (25%) and plant extract (10%). Release of larval parasitoids like *Apanteles* sp, *Bracon* sp. Erection of bird perches@ 10/acre (Charlet *et al*., 2018). List of natural enemies used in sunflower crop protection is given in Table 4.

**Chemical control**: Seed treatment with imidacloprid 48%FS @ 5-9 ml/kg seed and thiamethoxam 70WS @ 0.7 g a.i/kg seed for control of sucking pest (Basappa, 1999). Spray imidacloprid 17.8% SL @ 40 ml/acre diluted in 200 lit of water. Spraying of dichlorvos 76% EC @ 250 ml/acre diluted in 200-400 lit of water. Form a deep furrow trench around the field and dust 2% Methyl parathion to prevent the mass migration of hairy caterpillars. List of approved insecticides for sunflower pest management is given in Table 5

**Conclusion**: Environmentally acceptable methods must be used to handle sunflower insect pests. Due to the fact that the sunflower crop draws a variety of beneficial insect species, attention must be paid to preserving the activity of potential biocontrol agents and pollinators by implementing environmentally friendly strategies like the use of biopesticides, mechanical methods, and cultural practises, which are crucial in reducing pest loads without harming the beneficial insect fauna (Basappa and Sriharan, 1999). Cultural and insecticide-based management can combine for

effective insect control. However, when planting dates are constrained or insecticide applications are poorly timed, high levels of damage make the need for a more broadly-based management strategy. For future management of sunflower pests, transgenic insect-resistant sunflowers could provide a simple technology for growers to limit the severe incidence of pests. Insecticide resistance in significant sunflower pests like *Helicoverpa armigera* and *Spodoptera litura,* which have evolved many levels of resistance to most conventional pesticides in the cotton ecosystem, must be identified early and managed. The development of location-specific integrated pest management (IPM) modules using promising biocontrol agents, botanicals, resistant cultivars, and cultural practices is required despite the evaluation of a number of potential eco-friendly integrated pest management (IPM) components. Despite the development of successful plant protection technologies, a strong extension programme without a participatory approach and a shortage of skilled extension people prevent their demonstration in the form of location-specific IPM modules. (Basappa *et al.,* 1999). Farmers must be instructed on how to monitor pest populations and use relatively simple expert systems for managing sunflower pests. Therefore, the emergence and dissemination of current knowledge is a crucial component in enabling farmers to adopt an IPM programme in Sunflower for sustainable production.

Table 1 Nutritional information of sunflower seeds

| Nutrients | Available nutrient | % Daily value |
|---|---|---|
| Calories | 186 Kcal | - |
| Total fat | 16g | 21% |
| Saturated fat | 2g | 10% |
| Trans fat | 0g | |
| Cholesterol | 0 mg | 0% |
| Sodium | 1mg | 0% |
| Potassium | 0 mg | 0% |
| Total carbohydrate | 8g | 3% |
| Dietary fiber | 4g | 14% |
| Sugar | 1g | |
| Protein | 6g | 12% |
| Vitamin E | | 37% of the RDI |
| Vitamin B6 | | 11% of the RDI |
| Folate | | 17% of RDI |
| Iron | | 6% of the RDI |
| Magnesium | | 9% of the RDI |
| Zinc | | 10% of the RDI |
| Copper | | 26% of the RDI |
| Manganese | | 30% of the RDI |
| Niacin | | 10% of the RDI |

*Percent daily values are based on a 2000 calorie diet (USDA)

Table 2 Crop calendar of sunflower

| Season | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *kharif* | | | | | | | Sowing | | Vegetative growth | Harvest | | |
| *Rabi* | Sowing | | vegetative | Harvest | | | | | | | | |
| Summer | | Harvest | | | | | | | | Sowing | vegetative | |

Table 3 Pest profile of sunflower

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Capitulum borer | | | | Capitulum borer | | | |
| | | | | Leaf hopper | | | | | | Thrips | |
| | | | | | | | | Tobacco caterpillar | | | |
| | | | | | | | Cut worm | | | | |
| | | | Semi looper | | | | Bihar hairy caterpillar | | | | |
| | | | | | Sunflower beetle | | | | | | |
| | | | | | Whitefly | | | | | | |

Table 4 Natural enemies in sunflower ecosystem (Geetha *et al*., 2018)

| Natural enemy | Taxonomic position | Host | Images of natural enemies |
|---|---|---|---|
| Ladybird beetle (*Cheilomenes sexmaculata, Coccinella transversalis*) | Coccinellidae; Colepotera | General predator |  |
| Green lace wing (*Chrysoperla zastrowi*) | Chrysopidae; Neuroptera | General predator |  |
| Brown lace wing | Hemerobiidae; Neuroptera | General predator |  |
| Predatory bug (*Eocanthecona furcellata*) | Pentatomidae; Hemiptera | Lepidopteran larvae |  |
| Spider | Aranae | General predator |  |
| Mirid bug (*Nesidiocoris tenius*) | Miridae; Hemiptera | Sucking pest (whitefly, thrips) |  |
| Mirid bug (*Cytorhinus lividipennis*) | Miridae; Hemiptera | Sucking pest (leafhoppers) |  |
| Preying mantid | Mantodea | General predator |  |

Table 5 Approved insecticides for the management of insect pests in sunflower

| Pest | Chemical | Trade name | Dosage |
|---|---|---|---|
| Leaf hopper (*Amrasca bigutulla bigutulla*) | Imidacloprid 70% WS | Samrat, Seed touch | 700g/ha |
| | Imidacloprid 17.8% SL | Confidor, Tatamida | 0.2ml/lit |
| | Thiamethoxam 30% FS (seed treatment) | Harrier, Thiogold, Taliah | 10gm |
| | Thiamethoxam 70% WS | Texan, Cruiser | 400g |
| Whitefly (*Aleurodicus dispersus*) | Inidacloprid 70%WS | Samrat, Seedtouch | 700g/ha |
| | Imidacloprid 17.8% SL | Confidor, Tatamida | 0.2ml/lit |
| | Malathion 50% EC | Himthion, Malathion | 2ml/lit |
| Thrips (*Scirtothrips dorsalis*) | Thiamethoxam 30%FS (seed treatment) | Harrier, Thiogold, Taliah | 10gm |
| | Thiamethoxam 70%FS (seed treatment) | Texan, Cruiser | 400gm |
| Bihar hairy caterpillar (*Spilosoma obliqua*) | Cypermethrin 10% EC | Cyber-10, Striker-10 | 1.5ml/lit |
| Tobacco caterpillar ( *Spodoptera litura* ) | Dichlorvos 76% EC | Nuvan, Vapona, Atgard | 250ml/acre |
| | Chlorantraniliprole 18.5%SC | Coragen, Ferterra | 3ml/10 lit |
| Capitulum borer (*Helicoverpa armigera*) | Emamectin benzoate 5 EC | Proclaim | 200ml/ha |
| | Triazophos 40EC | Fulstop- D | 1.5lit/ha |

(Central Insecticide Board, 2022)

## REFERENCES


Abdel-Gawaad A A and El-Shazli A Y 1971. Studies on common cutworm *Agrotis ipsilon* Rott. Lifecycle and habits. *Zeitschrift fuer Angewandte Entomologie*, **68**: 409-412.

Ayyar T V R 1940. *Hand book of Economic Entomology for South India.* Coimbatore, Tamil Nadu.

Bartholomew Saanu Adeleke and Olubukola Oluranti Babalola 2020. Oilseed crop sunflower (*Helianthus annuus*) as a source of food: Nutritional and health benefits. *Food Science and Nutrition*, **8**(9): 4666-4684.

Basappa H 1995. *Insect Pest Management in Sunflower-Innovative Approaches,* Directorate of Oilseed Research, Hyderabad, India.

Central Insecticide Board, 2022. https://ppqs.gov.in/central-insecticides-board.

Chandani Kamble and Tukaram Vithalaro Sathe, 2015. Incidence and host plants for *Amrasca biguttula* from Kolhapur region, India. *International Journal of Drug Development and Research*, **5**(3): 3658-3661.

Charlet L D 1992. Seasonal abundance and parasitism of sunflower beetle (Coleoptera: Chrysomelidae) on cultivated sunflower in northern great plains. *Journal of Economic Entomology*, **85**: 766-771.

Fabian Fernandez-Luqueno, Fernando Lopez Valdez, Mariana Miranda-Arambula 2014. An Introduction to Sunflower Crop. *Environmental Influences and Pest and Disease,* 18 pp.

Faqir Muhammed Anjum, Muhammed Nadeem, Muhammed Issa Khan and Shahs Hussain 2012. Nutritional and therapeutic potential of sunflower seeds. *British Food Journal*, **114**(4). DOI:10.1108/00070701211219559.

Geetha S and Hegde M G 2018. Incidence of insect pest and natural enemies in sunflower crop ecosystem. *International Journal of Current Microbiology and Applied Sciences*, **7**(9): 1593-1601.

Harris C R, Mazurek J H and White G V 1962. The life history of black cutworm, *Agrotis ipsilon* under controlled conditions. *Canadian Entomologist*, **94**: 1183-1187

Janet J Knodel, Charlet Laurence and Gavloski, John 2010. *Integrated Pest Management of Sunflower Insect Pest in Northern Great Plains.* North Dakota State University, Fargo, ND.

Jones, Christopher M, Parry, Hazel, Tay, Wee Tek, Reynolds, Don R, Chapman and Jason 2019. Movement ecology of pest *Helicoverpa armigera:* Implications for ongoing spread. *Annual Review of Entomology*, **64**: 277-295.

Kakakhel S A, Islam N, Amjad M and Malik M A 2000. Insect Pest Complex of Sunflower, *Helianthus annus* L. *Pakistan Journal of Biological Sciences*, **3**: 669-671.

Munir Ahmad, Abdul Ghaffar and Muhammed Rafiq 2013. Host plants of leaf worm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) in Pakistan. *Asian Journal of Agriculture and Biology*, **1**(1): 23-28.

Nayak S K, Nilambar Khura and Moharana R L 2022. Seasonal abundance of insect pest and natural enemies in sunflower in the Western undulation zone of Odisha, *The Pharma Innovation Journal*, **11**(5): 245-248.

Nirakar R and Mahalik J K 2008. *Insect Pests Management in Sunflower*, Orissa Review.

Ramaiyer Varatharajan, S Amar Singh, T James Kesia, O D Singh 1998. Life table of *Spilosoma obliqua* on sunflower. *International Journal of Tropical Insect Science,* **18**(04).

Rivera-Vega L J, Galbraith D A, Grozinger C M and Felton G W 2017. Host plant driven transcriptome plasticity in the salivary glands of cabbage looper (*Trichoplusia ni*). *PLoS ONE*, **12**(8): DOI:10.1371/journal.pone.0182636.

Rogers C E 1992. Insect pest and strategies for their management in cultivated sunflower. *Field Crop Research*, **30**(3-4): 301-332.

Ruchika Nandha, Harpal Singh, Kamlesh Garg and Seema Rani 2014. Therapeutic potential of sunflower seeds. *International Journal of Research and Development in Pharmacy and Life Science*, **3**: 967-972.

Selvaraj K, Gotyal B S, Satyapathy S and Ramasubramanian 2015. First record of *Protapanteles obliquae* (Wilkinson) (Braconidae: Hymenoptera) on *Spilosoma obliqua* on jute crop. *Journal of Biological Control*, **29**(3): 169-170.

Shorey H H Andres and L A Hale 1962. The biology of *Trichoplusia ni*, Life history and behaviour. *Annals of the Entomological Society of America*, **55**(5): 591-597.

Shubh Pravat Singh Yadav, Vivek Lahutiya, Prava Paudel 2022. A review on biology, ecology and management tactices of *Helicoverpa armigera* (Noctuidae, Lepidoptera). *Turkish Journal of Agriculture-Food Science and Technology*, **10**(12): 2467-2476.

# Genetic variability studies of major yield components in segregating population derived from pistillate lines of castor (*Ricinus communis* L.)

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ABSTRACT

A segregating population was developed by crossing two pistillate (female) lines of castor *viz.,* IPC-23 and IPC-21. Population behavior was studied to understand the variability for major yield and yield components. The distribution of node number, plant height and seed yield were deviated from normal distribution and it was positively skewed with significant leptokurtic curve indicating that the two parents with high seed yield were selected for population development. Positive skewness indicates that the plants with exceptionally high seed yield were isolated from the population. Difference between phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) was very low to moderate for major yield components *viz.,* number of effective spikes per plant, number of nodes to primary spike, plant height, total spike length and effective spike length indicating that phenotypic selection can be effectively used for yield improvement. High heritability and genetic advance over mean (GAM) indicated the role of additive gene action for plant height and total/effective primary spike length. Correlation of number of nodes up to the primary spike with plant height up to primary spike, and total/effective spike length was positive indicating the possibility of short-statured, early pistillate selections with long primary spikes in castor.

**Keywords**: Castor, Frequency distribution, Heritability, Phenotypic and genotypic coefficient of variance

Castor is an annual, non-edible oilseed crop with industrial value. It is cultivated in about 29 countries of tropical and sub-tropical origin. India is the secondary centre of origin of castor and a leading country in the world in terms of castor area (0.9 m. ha), production and productivity (1.2 t/ha) (2021-22). Hybrids are commercially successful in castor due to a unique two-line breeding system involving pistillate (female) and male lines (Lavanya and Solanki, 2010). Majority of the pistillate lines developed from Vijapur Pistillate-1 (VP-1) are governed by 'S' type of mechanism of sex reversal and expression of interspersed staminate flowers (ISF) (Senthilvel *et al*., 2022). Castor being a monotypic genus, generation of variability in major yield components and sex expression is restricted to intra-specific recombination breeding using dominant sources of traits followed by pedigree method of selection (Ramesh *et al.,* 2021).

Success of any breeding programme depends on the extent of trait variability in the population. Phenotypic and genotypic coefficients of variation (PCV and GCV) are useful measures to compare the variability among different characters while heritability estimates help in determining the relative amount of the heritable portion in variation (Chaudhari *et al.,* 2016). Estimates of PCV, GCV and heritability for major seed yield components and their correlations help in identifying the reliable characters for selection in segregating populations.

Studies and data documentation on population behavior for yield and yield components in castor crop specially for the segregating population developed between two pistillate lines are limited. Hence, the current study was carried out to study the segregating population behavior in the light of genetic variability, distribution and correlation between yield and its associated traits to isolate the superior segregants in an $F_2$ population of two pistillate lines, IPC-23 and IPC-21.

## MATERIALS AND METHODS

The study was carried out at the ICAR-Indian Institute of Oilseeds Research (ICAR-IIOR) located at Hyderabad. Two green stemmed pistillate lines *viz.,* IPC-23 and IPC-21 with diverse agro-morphological characters like plant height, flowering and maturity, spike length, number of capsules per spike, number of effective spikes per plant etc. were selected for the study to generate transgressive segregants in later generations. As both the parents were pistillate, ISF generated in later spike orders with increasing temperature were used to pollinate the female parent. Repeated pollinations were done to generate nearly 50 seeds for each cross. A total of 127 $F_2$ plants along with three rows each of parents, IPC-23 and IPC-21 and $F_1$ of IPC-23 x IPC-21 were raised during *rabi* 2019-20. A spacing of 90 x 60 cm was followed with 10 plants in each row. All recommended agronomic practices were followed along with timely plant protection measures to raise a healthy crop (Suresh *et al.,* 2020). Observations were recorded on morphological characters like stem color, bloom and capsule spines along with quantitative characters like number of nodes to primary raceme, plant height up to primary raceme, total and effective primary spike length, number of effective spikes/plant, seed yield (g/plant), hundred seed weight (g) and oil content (%).

The $F_2$ population data were subjected to frequency distribution and coefficients of skewness and kurtosis were estimated. Phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated for $F_2$ population using the formula given by Weber and Moorthy 1952.

Phenotypic variance (PV) = Total observed variance of $F_2$ population
Genotypic variance (GV) = Environmental variance
Environmental variance = Variance of $P_1$+Variance of $P_2$+2 (variance of $F_1$)
Heritability (Broad sense) $H_2$= Genotypic variance/ Phenotypic variance
PCV= ( 2p/ x?) x 100
GCV= ( 2g/x?) x 100

The range of variation was categorized using Sivasubramanian and Madhavamenon (1973) method of estimation. Genetic advance and heritability were calculated by the method suggested by Johnson *et al.* (1955). Correlation and frequency distribution studies were carried out using SPSS 16.0 software (Verma, 2012).

## RESULTS AND DISCUSSION

IPC-23, a mutant of DPC-9 is a very early type with an average of eight nodes to primary spike compared to 17 nodes in IPC-21 pistillate line. IPC-21 is a late, tall plant type (71 cm) with a long primary spike (65 cm) while IPC-23 is a short plant type (42 cm) with a short primary spike (18.8 cm). The F1 was of medium plant height (56.2 cm), early with low node number (10.8) and recorded maximum seed yield of 324 g/ plant.

In the present study, descriptive statistical analysis of three generations *viz.,* parents-IPC-23 (P1), IPC-21 (P2), $F_1$ and $F_2$ data of five major yield components along with seed yield per plant (g) was further used to estimate genetic variability (Table 1), correlations (Table 2) and frequency distribution (Fig.1).

The asymmetry of the distribution of quantitative characters is measured by skewness (Figure 1 and Table 1). In the present study, the skewness for six characters *viz.,* number of nodes to the primary raceme (NN), plant height up to primary spike (PHt-cm), total primary spike length (TSPL-cm), Effective primary spike length (ESPL-cm), number of effective spikes per plant (ESPP) and seed yield (SY g/plant) were significantly deviated from "0" indicating the absence of normal distribution. The coefficient of skewness for all the six characters were positive by pushing the data towards right side, indicating higher values over mean. The peakness of the normal distribution curve is measured by kurtosis. In the present study, kurtosis was positive with significant and leptokurtic for node number, plant height and seed yield, indicating the higher genetic variation of the population. Leptokurtic curves are statistical distributions having greater than three kurtosis, with a wider or flatter shape, flatter tails and have a greater chance of extremely positive or negative events. Skewed and leptokurtic distribution of quantitative traits were also observed in $F_3$ population of a cross in groundnut indicating higher genetic variability (Jignesh *et al.,* 2020).

While, for other three characters *viz.,* total primary spike length, effective primary spike length and number of effective spikes per plant, the kurtosis value were negative and non-significant mesokurtic curve indicating low genetic variation. Mesokurtic curve indicates zero kurtosis and there is no possibility of extreme and rare segregants and is almost similar to normal distribution with normal or bell curve.

The range of variation was highest for seed yield per plant (1-323.2 g/plant) followed by plant height up to primary spike (8-112 cm), total and effective primary spike length (4-74 cm) (Table 1). High mean along with high range of the traits indicated the scope for improvement through selection procedures.

The estimates of PCV were slightly higher than the corresponding GCV estimates for most of the traits indicating that phenotypic variation was mostly contributed by genetic component and with low environment component. The difference between PCV and GCV estimates was very low for number of effective spikes per plant, number of nodes to primary spike and moderate for plant height, total spike length and effective spike length revealing minimal role of environment. The difference between estimates of PCV and GCV is very high for seed yield. Thus, phenotypic selection in $F_2$ generation can be effectively used for improvement for all the major yield components (Table 1). Similar results were reported by Chaudhary *et al.* (2016) for all the major yield components and Golakia *et al.* (2007) for seed yield per plant.

Both the pistillate lines *viz.,* IPC-15, a dominant source of early flowering (<35 DAS), maturity of primary spike (<90 DAS) and plant height while IPC-21 for late flowering (>50-65 DAS), maturity (>110 DAS) and tall plant height (>70 cm) will help the breeders for selection of base line population. Ultimately, phenotypic selection for lower node number, plant height, total and effective spike length, number of effective spikes per plant in the present $F_2$ population will result in isolation of plants with desirable early maturing and short pistillate selections. A similar trend was reported earlier in advanced lines of castor selected through both pedigree (PS) and single seed descent (SSD) methods (Lavanya *et al.,* 2021).

Estimates of heritability coupled with GCV for a trait can be used for selection of the lines (Burton, 1952). Based on heritability estimates, traits may be classified as high (0.6-1), moderate (0.3-0.6) and low (<0.3) (Salihu *et al.,* 2017). In the present study, number of effective spikes per plant is the highly heritable character while all the other characters except seed yield per plant were also highly heritable. High heritability confirmed the presence of additive gene action indicating the success of direct selection for all the traits except for seed yield per plant. Similar high heritability

trends were reported for node number and plant height (Golakia *et al.,* 2007), plant height, seed yield per plant (Patel *et al.,* 2010), majority of the traits (Patel and Jaimini, 1991; Mehta and Vashi, 1997; Dapke *et al.,* 2016; Lavanya *et al.,* 2021).

However, as broad sense heritability includes both additive and non-additive gene action, prediction of phenotype based on heritability *per se* may not give clear picture. Heritability coupled with genetic advance as percent mean (GAM) may give reliable results (Johanson *et al.,* 1955). The estimates of GAM were low for node number (11.5) and highest for plant height (487.3). The estimates of heritability and GAM were high for plant height, total and effective primary spike length confirming the role of additive gene action suggesting that these traits can be directly used for selection and fixed in subsequent generations. A similar trend was observed in genetic variability estimates of 72 castor genotypes for effective spikes per plant, effective primary spike length, plant height up to primary spike etc (Chaudhari *et al.,* 2016). High GAM for plant height, spike length, number of nodes per plant and seed yield were also reported by Lakshmamma *et al.* (2005), Alemaw *et al.* (2014) and Salihu *et al.* (2017). The traits *viz.,* effective spikes per plant and node number up to primary with moderate to high heritability and low estimates of GAM indicated that the segregants were genetically diverse with a scope to further improve by selection. Low heritability and high GAM observed for seed yield per plant indicate that the trait is controlled by non-additive gene action, which limits early generation selection for seed yield in population improvement. The total superiority of the lines selected from $F_2$ population may not be retained due to different nature of gene actions that control the expression of the traits in further generations.

Table 1 Genetic variability analysis for quantitative traits in $F_2$ population of IPC-23 x IPC-21

| Trait | P1 | P2 | Mean | Min | Max | GCV | PCV | Heritability | GAM | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NN | 8.1 | 16.9 | 10.2 | 5 | 25 | 73.8 | 91.9 | 0.64 | 11.5 | 1.258** | 3.92* |
| PHt | 42.3 | 71.1 | 31.1 | 8 | 112 | 275.9 | 325.8 | 0.72 | 487.3 | 1.303** | 2.38* |
| TSPL | 18.8 | 65.0 | 28.9 | 7 | 78 | 256.6 | 309.1 | 0.69 | 392.2 | 0.613** | -0.49 |
| ESPL | 18.8 | 65.0 | 27.4 | 4 | 74 | 253.5 | 310.1 | 0.67 | 362.3 | 0.627** | -0.47 |
| ESPP | 10.9 | 5.5 | 6.7 | 1 | 20 | 156.9 | 163.9 | 0.92 | 34.2 | 1.017** | 0.88 |
| SY | 88.3 | 103.7 | 78.0 | 1 | 324.2 | 498.8 | 707.3 | 0.50 | 3995.9 | 1.486** | 2.29* |

NN-Number of nodes to the primary raceme, PHt-Plant height up to primary spike (cm), TSPL-total primary spike length (cm), ESPL-Effective primary spike length (cm), ESPP-Number of effective spikes per plant, SY-seed yield (g/plant); **- Significant at the 0.01 level. *- Significant at the 0.05 level

Table 2. Pearsons's genotypic correlation coefficients of six characters in $F_2$ of IPC-23 x IPC-21

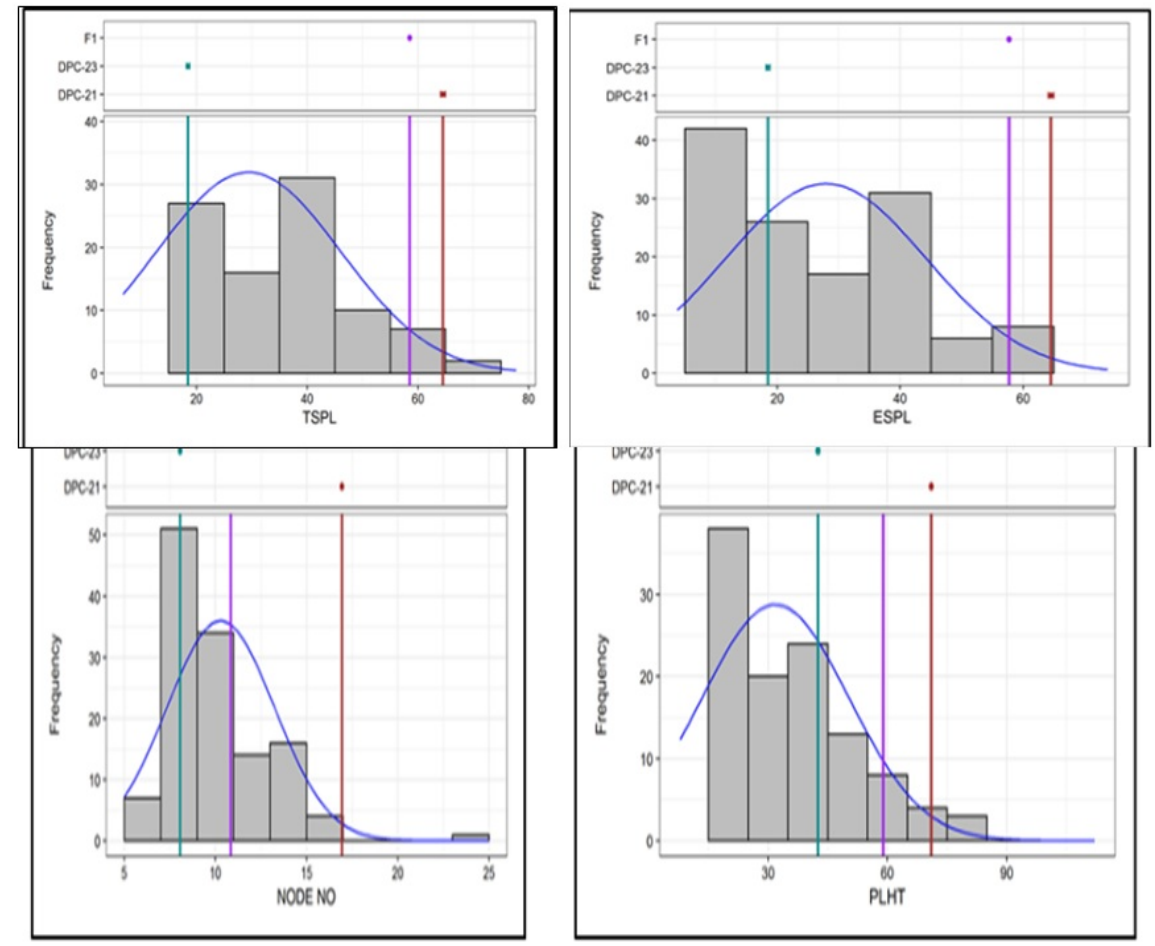
| | PHt | TSPL | ESPL | ESPP | SY |
|---|---|---|---|---|---|
| NN | 0.67** | 0.31** | 0.32** | -0.13 ns | 0.20* |
| PHT | | 0.69** | 0.69** | -0.12 ns | 0.10 ns |
| TSPL | | | 0.99** | -0.15 ns | -0.0 ns |
| ESPL | | | | -0.15 ns | 0.01 ns |
| ESPP | | | | | -0.04 ns |

NN-Number of nodes to the primary raceme, PHt-Plant height up to primary spike (cm), TSPL-total primary spike length (cm), ESPL-Effective primary spike length (cm), ESPP-Number of effective spikes per plant, SY-seed yield (g per plant)
**Significant at the 0.01 level. *. Significant at the 0.05 level, ns-non-significant

Correlation between seed yield and yield components in the present study indicated that seed yield per plant was significantly correlated with only node number. All the other traits *viz.,* number of nodes to the primary spike, plant height up to primary spike, total and effective spike length were significantly and positively correlated with each other (Table 2).

Significantly positive skewness and leptokurtic curve pattern of frequency distribution indicated heterogeneity of the population for three major characters including seed

yield. Phenotypic selection can be efficiently used to improve major yield components which have positive and significant correlations with each other except with seed yield. The present study on genetic variability of a segregating population of a pistillate x pistillate cross will aid to improve pistillate background and identify an early, short statured pistillate plant type with long primary spikes.




NODE NO-Number of nodes to the primary raceme, PLHT-Plant height up to primary spike (cm), TSPL-Total primary spike length (cm), ESPL-Effective primary spike length (cm), ESPP-Number of effective spikes per plant, SY-seed yield (g per plant)

Fig 1. Frequency distribution of yield and yield components in $F_2$ of a cross between two pistillate lines in castor

## REFERENCES

Alemaw G, Kassahun B M, Taye G and Endalamaw C 2014. Phenotypic variability in Ethiopian castor (*Ricinus communis* L.) accessions. *International Journal of Advanced Biological and Biomedical Research,* **2**(12): 2909-2914.

Chaudhari D R, Parmar V L, Dube D V, Bhakta R S, Patel A I and Lodam V A. 2016. Genetic variability and divergence study in castor (*Ricinus communis* L.). *Advancements in Life Sciences*, **5**(16): 6418-6422.

Dapke J S, Naik M R, Vaidya G B, Vanve P B, Narwade AV and Rajkumar B K 2016. Genetic variability in castor (*Ricinus communis* L.). *European Journal of Biotechnology and Bioscience*. **4**(4): 39-40.

Golakia P R, Kavani R H and Monpara B A 2007. Genetic variation and trait relationship in castor. *National Journal of Plant Improvement*, **9**(1): 60-62.

Jignesh H K, Mital D J, Ajay B C, Bera S K and John J G 2020. Effect of selection response for yield related traits in early and later generations of groundnut (*Arachis hypogaea* L.). *Crop Breeding and Applied Biotechnology,* **20** (2). https://doi.org/10.1590/1984-70332020v20n2a31.

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

Lakshmamma P, Lakshmi P, Mohan Y C and Lavanya C 2005. Genetic variability and character association in castor (*Ricinus communis* L.). *National Journal of Plant Improvement*, **7**(2), 122-130.

Lavanya C and Solanki 2010. Crop improvement of castor: The challenges ahead. In: Hegde D.M., (Ed) *Research and development in castor: present status and future strategies.* Ind. Soc. Oilseeds Res. Hyderabad. pp 36-55.

Lavanya C, Ushakiran B, Sarada C, Manjunatha T, Senthilvel S, Ramya K T and Santhalakshmi Prasad M 2021. Use of single seed descent versus pedigree selection for development of elite parental lines in castor (*Ricinus communis* L.). *Genetic Resources and Crop Evolution*, **68**: 295-305.

Mehta D R and Vashi P S 1997. Variability, heritability and genetic advance in castor. *Agricultural Science Digest,* **17**: 236.

Patel J K, Saiyed M P, Patel C G, Bhatt R K and Bhatt J P 2010. Genetic variability and correlation studies in castor (*Ricinus communis* L.). *International Journal of Agricultural Science,* **6**(1): 129-131.

Patel P S and Jaimini S N 1991. Interrelationship and path analysis of certain quantitative characters in castor. *Journal of Oilseeds Research*, **8**: 105-109.

Ramesh, Rakesh Choudhary, Mamta Nehra and Manish Kumar 2021. Combining ability analysis of newly developed male lines of castor (*Ricinus communis* L.) in Rajasthan. *Journal of Oilseeds Research*, **38**(4): 337-342.

Salihu B Z, Falusi A O, Gana A S, Adebola M O and Daudu O Y 2017. Estimation of heritability and predicted genotype mean for seed yield of castor (*Ricinus communis* L.) using Best Linear Unbiased Prediction (BLUP). *Journal of Plant Development*, **24**: 51-65.

Senthilvel S, Manjunatha T and Lavanya C 2022. Castor breeding. In: Yadav D K, Dikshit H K, Mishra G P and Tripathi S. (Eds). *Fundamentals of Field Crop Breeding.* Springer Singapore, ISBN 978-981-16-9256-7.

Sivasubramanian S and Madhavamenon P 1973. Genotypic and phenotypic variability in rice. *Madras Agricultural Journal,* **60**(8-9): 1093-1096.

Suresh G, Lavanya C, Duraimurugan P, Santhalakshmi M P, Manjunatha T, Lakshmi P, Jawahar J L and Reddy A V V 2020. *Castor: Production Technology.* 7th Revised Edition. ICAR-Indian Institute of Oilseeds Research, Hyderabad. pp. 26.

Verma J P 2012. *Data analysis in management with SPSS software.* Springer Science & Business Media.

Weber C R and Moorthy B R1952. Heritable and non-heritable relationships and variability of oil content and agronomic characters in the $F_2$ generation of soybean crosses. *Agronomy Journal*, **44**: 202-209.

# Unravelling the G × E interactions using AMMI biplot for phenology and agro-morphological traits in linseed (*Linum usitatissimum* L.)

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ABSTRACT

In the present study, additive main effects and multiplicative interactions (AMMI) biplot analysis was used to identify stable genotypes for days to flowering, maturity, plant height and number of branches per plant to dissect GEI in linseed (*Linum usitatissimum* L.). Trials were conducted in randomized complete block design (RCBD) with two replications over three consecutive years, 2016-17, 2017-18 and 2018-19. ANOVA analysis revealed genotype and G×E interaction effects contributed significant sum of square for days to flower (97.31% and 0.56%); days to maturity (89.27% and 8.90%); plant height (98.29% and 0.70%) and number of branches per plant (86.40% and 2.41% respectively). The dissection of GE interaction for all the traits was mostly explained by the first and second principal component axis (IPCA1 and IPCA2). The SSI statistic fully sync with the results of the AMMI1 biplot analysis for all the traits of top ranked genotypes across the environments. Results of genotypes stability in AMMI1 and AMMI2 biplot analyses were shown differential response with some exceptions that indicates the different sets of genes were responsible for the cumulative expression of traits under study. In the present study environments imposed variable effects with few exceptions towards the genotype stability in both AMMI1 and AMMI2 analysis models for all the traits studied. Hence, the desirable genotypes identified in linseed for phenology and agro-morphological traits could be utilized in hybridization program and varietal recommendation under semi-arid conditions.

**Keywords**: Genotype x environment interaction, Interaction principal component analysis, Linseed

Linseed (*Linum usitatissimum* L. 2n=30, x=15), an important oilseed crop belonging to the family Linaceae and the tribe Lineae, which includes around 230 species, is the only species of this family with commercial relevance (Kumar *et al.,* 2020a, Kumar *et al.,* 2021). It is a multipurpose crop cultivated for production of stem fiber and seed oil (Kumar *et al.,* 2021). Linseed oil is a good drying oil that is used in the production of paints, inks, varnishes, and other wood treatments, waterproof fabrics, oil cloth, soap, linoleum, putty, and pharmaceuticals, among other things (Juita *et al.,* 2012; Dwivedi *et al.,* 2021). Crop is grown for fibre, oil, or both seed and oil, but it has recently gained new interest in the emerging functional food market due to higher content of digestible proteins and lignans in seeds and high content of alpha linolenic acid (ALA), an essential Omega-3 fatty acid in its oil, which accounts for up to 61 percent of total fatty acid content (Reddy *et al.,* 2013, Kumar *et al.,* 2020a, Kumar *et al.,* 2021). In terms of area, India is second after Canada, and third in terms of production. Linseed is mostly produced as an oilseed crop in India, covering approximately 3.2 lakh ha and producing 1.74 lakh metric tonnes (Faostat, 2018). The average yield is quite low when compared to the global average yield (Faostat, 2018). Low productivity could be attributed to a narrow genetic base and the lack of high-yielding varieties, cultivation in marginal lands, and vulnerability to biotic and abiotic stressors. As a result of rising demand, there is an urgent need for cultivars with desired characteristics. Before designing a suitable breeding strategy for genetic improvement, the development of high yielding varieties necessitates the study of genotypes throughout time for phenology and yield component attributes.

Stability is an important criterion in breeding techniques, and it can be handled by phenotypic manifestation of features in the relevant environment (Rad *et al.,* 2013). Several statistical approaches for analysing plant stability have been presented, with the goal of dissecting GEI and stable trait expression across environments. AMMI is one such promising technique for analysing MET data and interpreting complex GEI interactions. It may show the interaction pattern graphically and indicate the contexts for evaluating the various genotypes (Kumar *et al.,* 2020a, 2020b). In the present investigation, 50 genotypes of linseed were evaluated by the AMMI analysis and the SSI statistics for selection of genotypes in terms of days to flowering, maturity, plant height and number of branches per plant. The objectives of this study were to dissect GEI for phonological and yield component traits in 50 linseed genotypes using AMMI

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analysis and to detect stable and superior genotypes across the environments (years) for future use in breeding programs.

## MATERIALS AND METHODS

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

**Field experiments and observations recorded**: The genotypes were sown in randomized complete block design (RCBD) with 2 replications. Each genotype was represented by 2 rows of 2 m length with distance of 30 cm between rows and 10 cm between plants in a row. Thinning was performed after 21 days of germination to maintain plant geometry. From sowing till harvesting, all the recommended agronomic package of practices was followed to raise the good crops. Five plants were randomly selected and tagged for taking observations. The observations were recorded for quantitative traits such as days to flowering, maturity, plant height and number of branches per plant.

**Statistical analysis**

**Analysis of AMMI model**

The AMMI model for the i$^{th}$ genotype in the j$^{th}$ environment is (Zobel *et al*., 1988)

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

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

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

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

where, $PC_1$ and $PC_2$ are the scores of 1$^{st}$ and 2$^{nd}$ IPCs respectively; and $\theta_1$ and $\theta_2$ are percentage sum of squares explained by 1$^{st}$ and 2$^{nd}$ principal component interaction effect respectively. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASI scores indicate a more stable genotype across environments.

Simultaneous stability index (SSI) incorporate mean and stability index in a single criteria and calculated as: SSI = rASI + rY where, rASI is the rank of ASI and rY is the rank of mean yield of genotypes across environments. This index considered the rank of AMMI stability index (ASI) and rank of genotypes based on average yield across environments (Farshadfar *et al.,* 2011). The AMMI and stability indices were determined using R statistical software, version 3.4.1 (R Development Core Team, 2020).

## RESULTS AND DISCUSSION

**AMMI analysis of variance**: The AMMI model retrieves the part of the sum of squares that determines the G×E interaction, which is called the standard portion (the genotype and environment effect), and a residual part, which corresponds to unpredictable and uninterpretable responses from the model (Cornelius *et al.,* 1996). The present AMMI analysis indicated the genotypic effect scores comparatively more scattered than the environmental effect scores, demonstrating that variability due to the genotype is moderately greater than the variability caused by environmental effects (Figs 1a, 1b, 1c and 1d). The AMMI analysis of number of days to flower over the environments showed that 97.31% significant sum of squares was explained by the genotype and 0.56% was attributable to the G×E interaction effects respectively (Table 2). The significant sum of square of genotype and G×E interaction effects of 89.27% and 8.90% respectively reported for days to maturity. For plant height, significance of 98.29% total sum of squares was justified by genotype and 0.70% by GEI while significance sum of square of 86.40% and 2.41% contributed by genotype and GEI effects respectively for branches per plant in linseed. AMMI analysis of variance showed the large genotype and G×E interaction percentage

for the sum of squares for all the traits studied. It indicates the significant differences existed among the genotypes and the environments showed differential response against the genotypes. Mean sum of squares were found significant for the genotypes for biomass yield, harvest index, test weight and genotype x environment interaction for test weight and seed yield by Berti *et al.* (2010) in linseed. Lirie *et al.* (2013) were also observed highly significant differences exist among the genotypes and environment for seed yield and significant for genotype, environment and genotype x environment interaction for oil content and oil yield in linseed. Genotype and environment were found highly significant differences for the plant height, day to flower, seeds per-capsule and seed yield while genotype and environment exhibits significant differences only for plant height, day to flower and seed yield as investigated by Soto-Cerda *et al.* (2013) in linseed. Alem and Tadesse (2014) elucidated AMMI analysis and found genotype x environment and environment were shown significant differences for seeds per boll while Tadesse *et al.* (2017) found that significant differences among genotype, environment and genotype x environment interaction for the seed yield in linseed. Similarly Chobe and Ararsa (2018) studied in linseed and observed highly significant differences were exists among themselves for genotype, environment and genotype x environment interaction for seed yield. Kumar *et al.* (2020a) performed AMMI analysis using 50 diverse linseed genotypes and found highly significant differences prevails among genotype for number of bolls per plant, number of seeds per boll, seed yield per plant and oil content (%) while genotype x environment interaction for number of bolls per plant, number of seeds per boll and seed yield per plant. The partitioning of GE interaction for days to flower, maturity, plant height and number of branches per plant which was mainly explained by the first and second principal component axis (IPCA1 and IPCA2) with 86.50% and 13.50%; 92.10% and 7.90%; 86.80% and 13.20% and 84.30% and 15.70% of GEI sum of squares respectively (Table 2). The present G x E partitioning was fully agreement with the previous study of Tadesse *et al.* (2017) for seed yield and number of bolls per plant, number of seeds per boll, seed yield per plant and oil content (%) by Kumar *et al.* (2020a) in linseed.

**Stability and genotypes performance:** The genotypic mean, ASI, SSI and relative rankings of genotypes on the basis of yield and stability are presented in Table 3 and 4. Low value of ASI reflects the more stability of genotype and low GEI (Kumar *et al.,* 2020a, Kumar *et al.,* 2020b). Low ASI value were observed of genotypes Suyog, IC96491, Kirtika, Pusa-3, Padmini, IC96460, Janki, IC56363, IC96461; Shekhar, Suyog, Baner, IC56365, Meera and Kirtika, Sheela, IC96461, Baner, Suyog for days to flower, maturity, plant height and number of branches per plant respectively (Tables 3 and 4). Higher rY and smaller rASI ranking could be considered as desirable SSI value for rankings of suitable genotype for days to flower, maturity and plant height. Conversely, lower rY combined with lower rASI ranking was the case of identification of desirable genotype for the number of branches per plant in the linseed. SSI represents genotypic superiority in the sense of general or wide adaptation. Based on SSI and mean rank, genotypes Suyog, IC96491, IC96473, EC41528, Shival; Padmini, IC96460, IC56363, IC96461, Shival and Suyog, Sharda, Sweta, S-36, Kiran were best for days to flower, maturity and plant height respectively. Neela, Sheela, LC-54, LC-27 and Garima were desirable genotypes for number of branches per plant. SSI statistics revealed Suyog, IC96491, IC96473, EC41528, Shival; Padmini, IC96460, IC56363, IC96461, Shival and Suyog, Sharda, Sweta, S-36, Kiran were most efficient genotypes for days to flower, maturity and plant height respectively. Similarly, Neela, Sheela, LC-54, LC-27 and Garima were desirable genotypes for number of branches per plant in linseed. The similar statistics used previously by (Tadesse *et al.,* 2017) for seed yield and Kumar *et al.* (2020a) for number of bolls per plant, number of seeds per boll, seed yield per plant and oil content (%) to delineate the stable genotypes in linseed.

When we evaluated environments independently, AMMI1 (Figs 1a, 1b, 1c and 1d) also depicted the stability of genotype for days to flower, maturity, plant height and number of branches per plant across the years. In present study, Shival, IC96491, IC96473, EC41528, Suyog, Kirtika for days to flower and Shival, Padmini, IC96460, IC56363, IC96461, IC96473, EC41528 for days to maturity were most desirable genotypes. Genotypes Suyog, Sharda, Sweta, S-36, Kiran, Shekhar for plant height and IC54970, IC56363, IC56365, IC96460, Mukta, Gaurav, Padmini, IC96461, Parvati, Rashmi, Suyog, LC-54 for number of branches per plant were most efficient genotypes in linseed (Figs 1a, 1b, 1c and 1d). Moreover genotypes like Pratap Alsi-1, Nagarkot; Subhra; Mukta, Hira, Pratap Alsi-1 and Surabhi, EC41528 were highly unstable for days to flower, maturity, plant height and number of branches per plant respectively from biplot of AMMI1 analysis (Figs 1a, 1b, 1c and 1d). AMMI1 analysis identified genotypes Shival, IC96491, IC96473, EC41528, Suyog, Kirtika and Shival, Padmini, IC96460, IC56363, IC96461, IC96473, EC41528 were most desirable genotypes for days to flower and days to maturity respectively. Genotypes Suyog, Sharda, Sweta, S-36, Kiran, Shekhar for plant height and IC54970, IC56363, IC56365, IC96460, Mukta, Gaurav, Padmini, IC96461, Parvati, Rashmi, Suyog, LC-54 for number of branches per plant were most efficient genotypes in linseed.

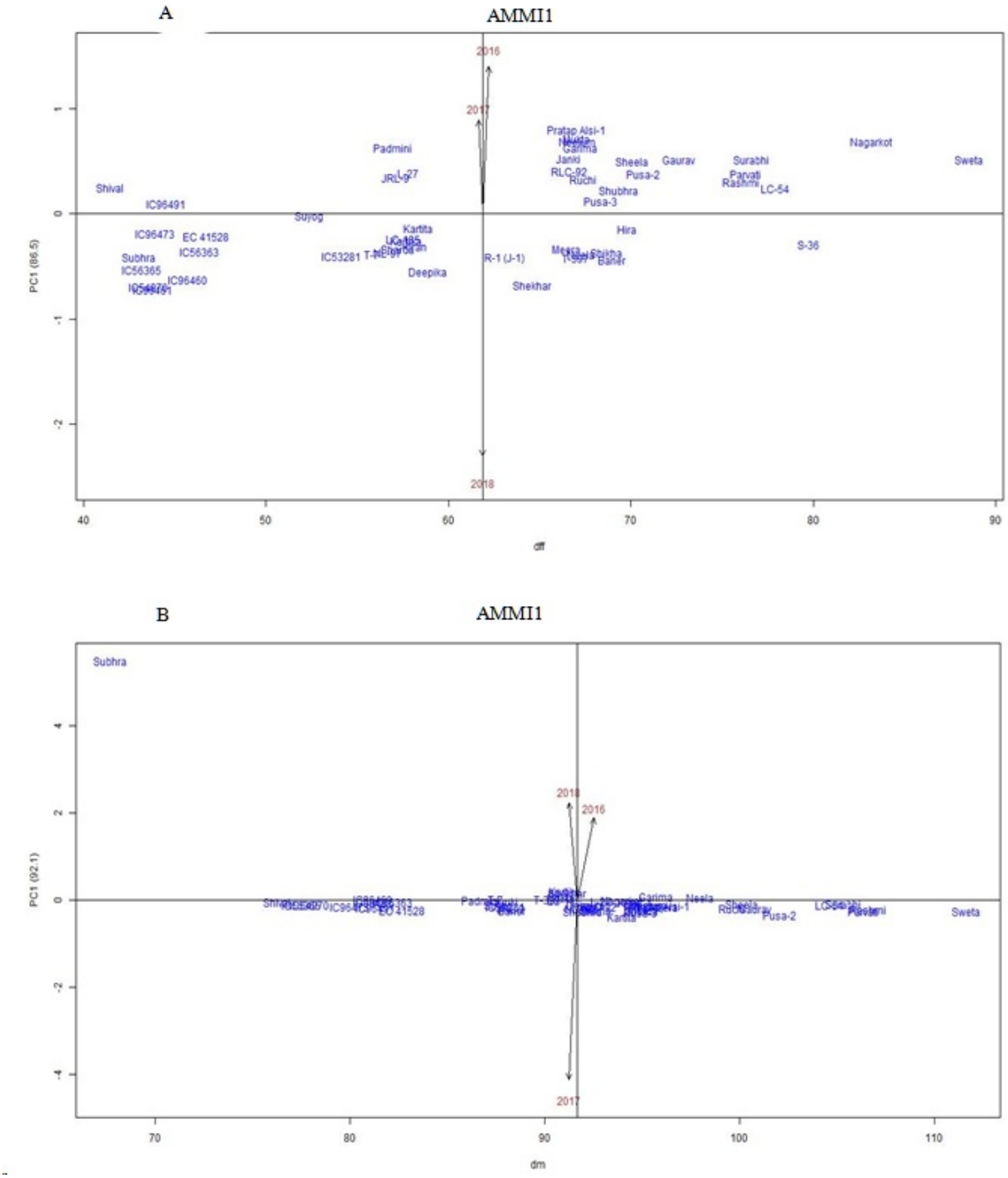


Fig. 1. AMMI biplot showing AMMI1 for a. days to flower and b. maturity of 50 linseed genotypes

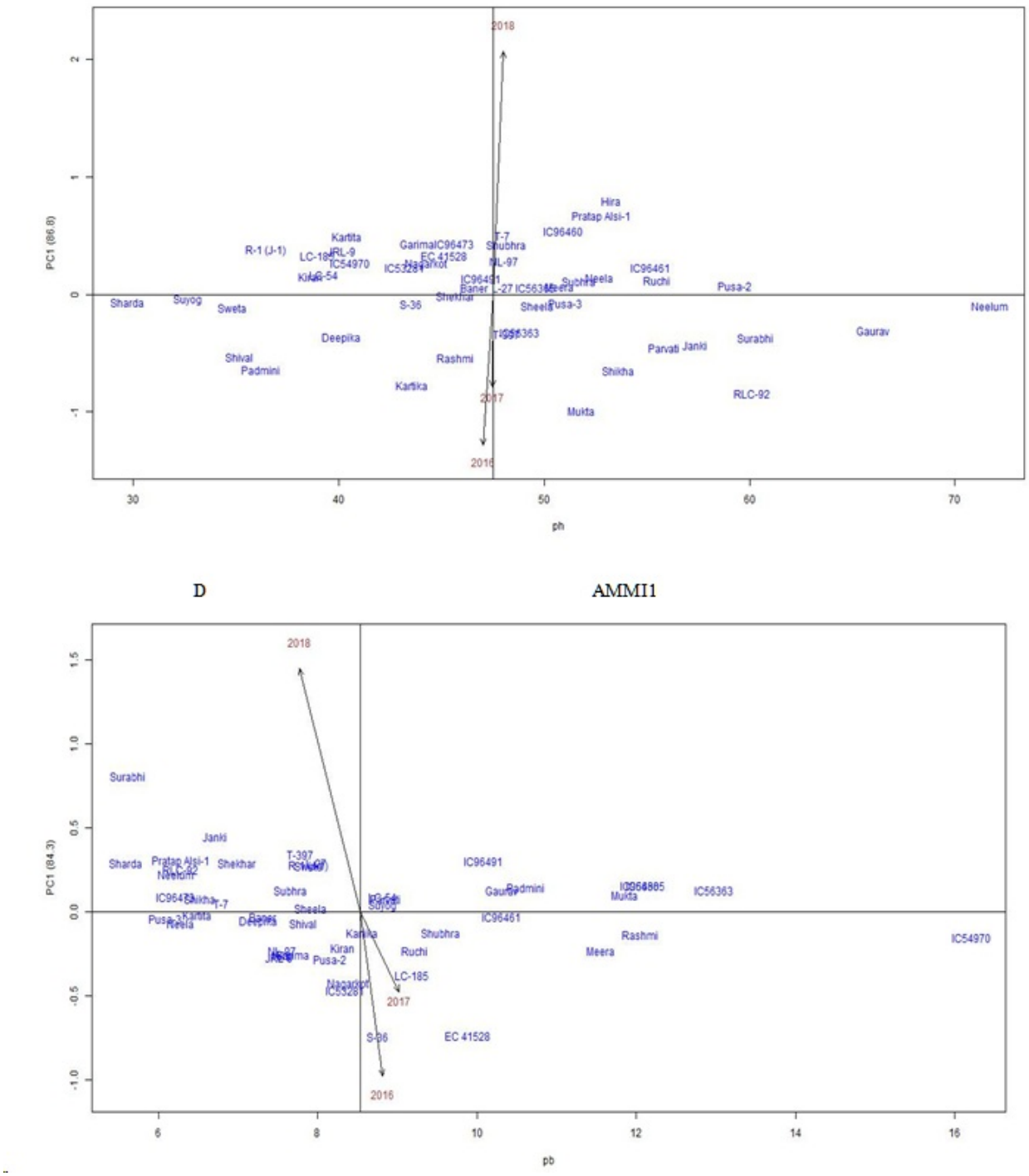


Fig. 1. AMMI biplot showing AMMI1 for c. plant height and d. number of branches per plant of 50 linseed genotypes

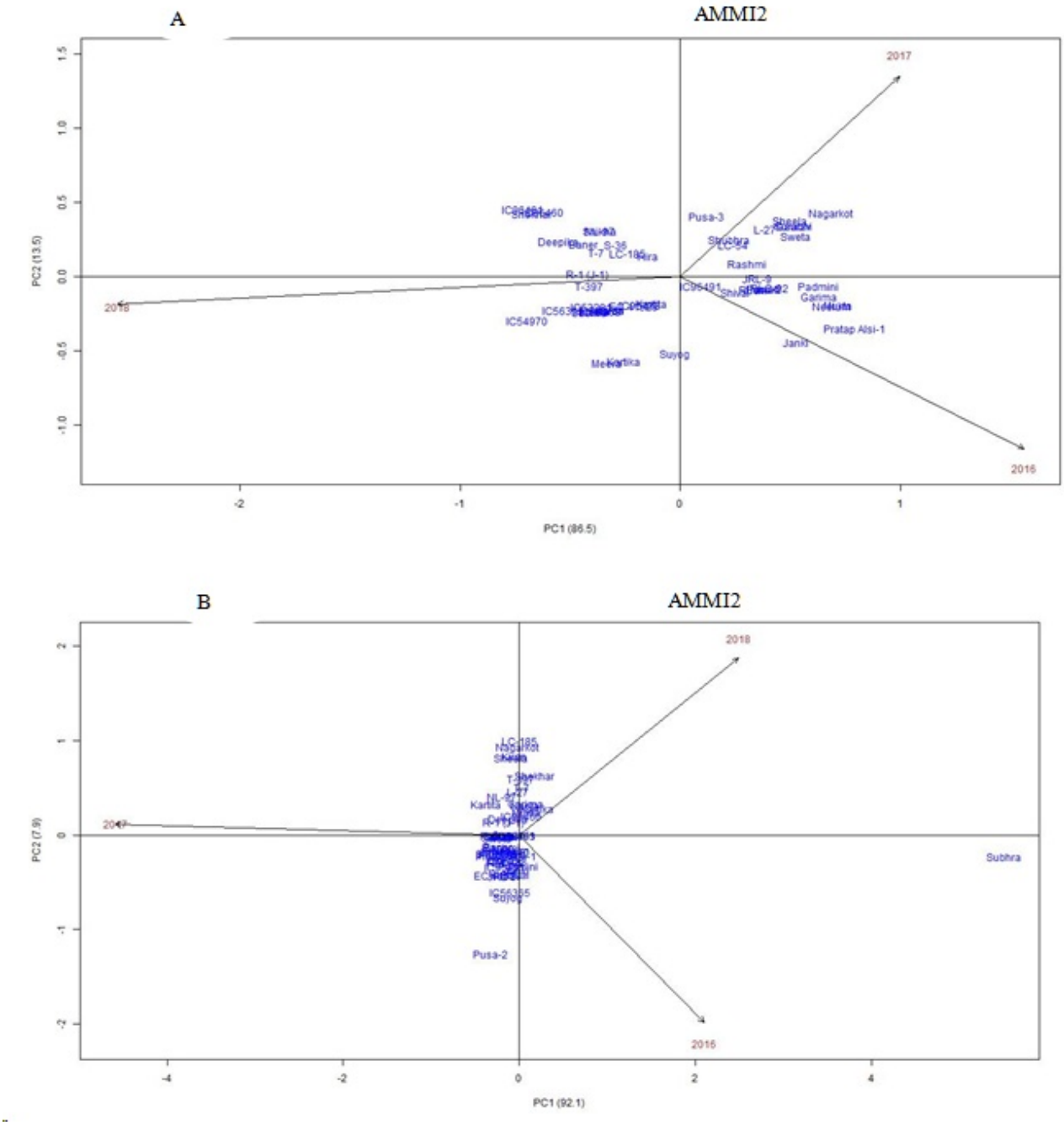


Fig. 2. AMMI biplot showing AMMI2 or interaction biplot graph for a. days to flower and b. days to maturity of 50 linseed genotypes

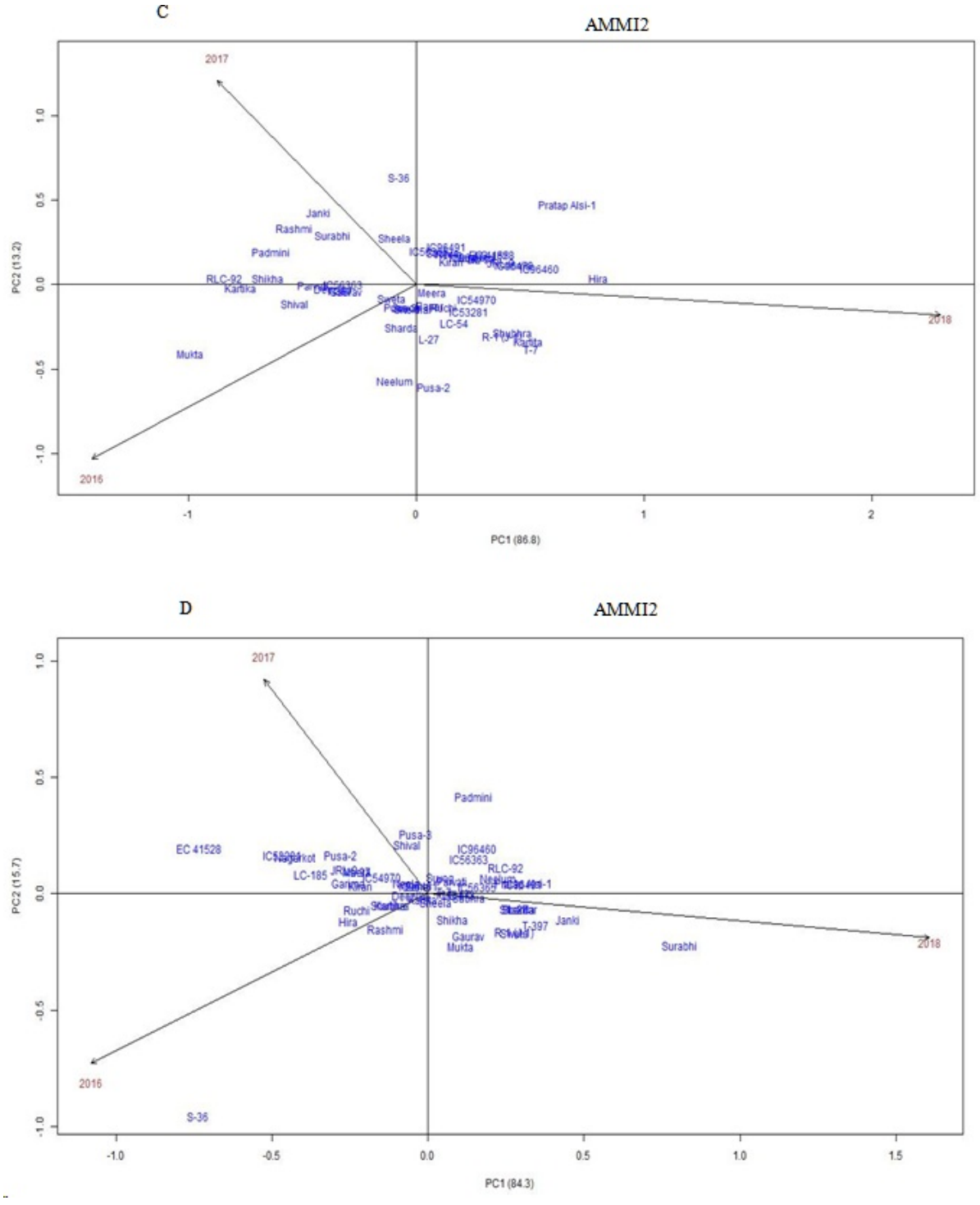


Fig. 2. AMMI biplot showing AMMI2 or interaction biplot graph for c. plant height and d. number of branches per plant of 50 linseed genotypes

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

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

Table 2 AMMI analysis of variance of phenology and agro-morphological traits for 50 linseed genotypes

| | Days to flower | | | | | | | Days to maturity | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sources of variation | Degree of freedom | Sum of squares | Mean sum of squares | F value | Pr (>F) | % explained | % accumulated | Sum of squares | Mean sum of squares | F value | Pr (>F) | % explained | % accumulated |
| Environment (E) | 2 | 16 | 8.06 | 0.03 | 0.9747 | 0.04 | | 109.20 | 54.61 | 0.50 | 0.65 | 0.45 | |
| Rep(E) | 3 | 850 | 283.33 | 5497.36 | <2e-16*** | 2.07 | | 325.20 | 108.40 | 1280.11 | <2e-16*** | 1.33 | |
| Genotype (G) | 49 | 39928 | 814.85 | 15809.97 | <2e-16*** | 97.31 | | 21790.40 | 444.70 | 5251.38 | <2e-16*** | 89.27 | |
| G×E interaction | 98 | 231 | 2.35 | 45.66 | <2e-16*** | 0.56 | | 6.28 | 0.06 | 1.54 | <2e-16*** | 8.90 | |
| IPCA1 | 50 | 199.47 | 3.99 | 77.40 | 0.00 | 86.50 | 86.50 | 2002.09 | 40.04 | 472.84 | 0.00 | 92.10 | 92.10 |
| IPCA2 | 48 | 31.14 | 0.65 | 12.59 | 0.00 | 13.50 | 100.00 | 170.87 | 3.56 | 42.04 | 0.00 | 7.90 | 100.00 |
| Residuals | 147 | 8 | 0.05 | | | 0.02 | | 12.40 | 0.08 | | | 0.05 | |
| | Plant height | | | | | | | Branches per plant | | | | | |
| Environment (E) | 2 | 49.10 | 24.53 | 0.47 | 0.66 | 0.23 | | 89.64 | 44.82 | 1.65 | 0.33 | 5.61 | |
| Rep(E) | 3 | 156.50 | 52.16 | 916.12 | <2e-16*** | 0.73 | | 81.56 | 27.19 | 522.68 | <2e-16*** | 5.10 | |
| Genotype (G) | 49 | 21016.60 | 428.91 | 7533.20 | <2e-16*** | 98.29 | | 1381.72 | 28.20 | 542.11 | <2e-16*** | 86.40 | |
| G×E interaction | 98 | 150.60 | 1.54 | 27.00 | <2e-16*** | 0.70 | | 38.62 | 0.39 | 7.58 | <2e-16*** | 2.41 | |
| IPCA1 | 50 | 130.74 | 2.61 | 45.93 | 0.00 | 86.80 | 86.80 | 32.58 | 0.65 | 12.53 | 32.58 | 84.30 | 84.30 |
| IPCA2 | 48 | 19.89 | 0.41 | 7.28 | 0.00 | 13.20 | 100.00 | 6.05 | 0.13 | 2.42 | 6.05 | 15.70 | 100.00 |
| Residuals | 147 | 8.40 | 0.06 | | | 0.04 | | 7.65 | 0.05 | | | 0.48 | |

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

Table 3 Average number of days to flower and maturity of linseed (Y) and other stability parameters: Additive Main effects and Multiplicative Interaction (AMMI) stability Index (ASI), rankings of mean performance (rY), rankings of ASI (rASI) and Simultaneous Selection Index (SSI)

| | Days to flower | | | | | Days to maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Genotype | Y | ASI | rY | rASI | SSI | Y | ASI | rY | rASI | SSI |
| Baner | 68.97 | 0.3793 | 13 | 33 | 46 | 88.367 | 0.21646 | 34 | 41 | 75 |
| Deepika | 58.87 | 0.4814 | 28 | 40 | 68 | 92.100 | 0.12281 | 26 | 22 | 48 |
| EC 41528 | 46.77 | 0.1820 | 41 | 7 | 48 | 82.700 | 0.21954 | 41 | 43 | 84 |
| Garima | 67.23 | 0.5481 | 18 | 43 | 61 | 95.733 | 0.07435 | 13 | 12 | 25 |
| Gaurav | 72.63 | 0.4494 | 8 | 35 | 43 | 100.833 | 0.18002 | 7 | 35 | 42 |
| Hira | 69.80 | 0.1259 | 11 | 5 | 16 | 94.833 | 0.18002 | 18 | 34 | 52 |
| IC53281 | 54.17 | 0.3498 | 39 | 28 | 67 | 88.000 | 0.13211 | 37 | 26 | 63 |
| IC54970 | 43.60 | 0.6026 | 47 | 47 | 94 | 77.967 | 0.09826 | 47 | 18 | 65 |
| IC56363 | 46.37 | 0.3146 | 42 | 20 | 62 | 82.233 | 0.03925 | 42 | 4 | 46 |
| IC56365 | 43.23 | 0.4606 | 48 | 39 | 87 | 77.533 | 0.10537 | 48 | 20 | 68 |
| IC96460 | 45.73 | 0.5426 | 43 | 41 | 84 | 81.233 | 0.03046 | 44.5 | 2 | 46.5 |
| IC96461 | 43.80 | 0.6224 | 46 | 49 | 95 | 81.233 | 0.03925 | 44.5 | 5 | 49.5 |
| IC96473 | 43.93 | 0.1600 | 45 | 6 | 51 | 80.033 | 0.12799 | 46 | 25 | 71 |
| IC96491 | 44.57 | 0.0816 | 44 | 2 | 46 | 81.333 | 0.15032 | 43 | 29 | 72 |
| Janki | 66.60 | 0.4605 | 24 | 38 | 62 | 88.067 | 0.03671 | 36 | 3 | 39 |
| JLS-9 | 57.13 | 0.3028 | 35 | 19 | 54 | 88.300 | 0.18012 | 35 | 36 | 71 |
| Kartika | 57.67 | 0.2349 | 32 | 12 | 44 | 91.033 | 0.18974 | 30.5 | 38 | 68.5 |
| Kirtika | 58.37 | 0.1162 | 29 | 3 | 32 | 93.967 | 0.34666 | 20 | 49 | 69 |
| Kiran | 58.20 | 0.2703 | 30 | 15 | 45 | 94.400 | 0.08033 | 19 | 16 | 35 |
| LC-27 | 57.80 | 0.3389 | 31 | 27 | 58 | 92.900 | 0.03929 | 22 | 6 | 28 |
| LC-185 | 57.57 | 0.2056 | 33 | 9 | 42 | 91.033 | 0.07883 | 30.5 | 14 | 44.5 |
| LC-54 | 77.90 | 0.2101 | 4 | 10 | 14 | 104.633 | 0.10568 | 5 | 21 | 26 |
| Meera | 66.47 | 0.2991 | 25 | 18 | 43 | 96.133 | 0.12799 | 11 | 24 | 35 |
| Mukta | 67.03 | 0.6198 | 20 | 48 | 68 | 90.833 | 0.06986 | 32 | 11 | 43 |
| Nagarkot | 83.18 | 0.5940 | 2 | 45 | 47 | 93.933 | 0.07516 | 21 | 13 | 34 |
| Neela | 67.30 | 0.3367 | 17 | 26 | 43 | 98.000 | 0.06695 | 10 | 10 | 20 |
| Neelum | 67.07 | 0.5977 | 19 | 46 | 65 | 95.300 | 0.09083 | 14 | 17 | 31 |
| NL-97 | 56.67 | 0.3192 | 37 | 22 | 59 | 91.767 | 0.18599 | 28 | 37 | 65 |
| Padmini | 56.93 | 0.5430 | 36 | 42 | 78 | 86.733 | 0.02706 | 40 | 1 | 41 |
| Parvati | 76.30 | 0.3300 | 6 | 25 | 31 | 106.367 | 0.23344 | 3 | 44 | 47 |
| Pratap Alsi-1 | 67.00 | 0.6886 | 21 | 50 | 71 | 95.967 | 0.13952 | 12 | 28 | 40 |
| Pusa-2 | 70.70 | 0.3300 | 9 | 24 | 33 | 102.067 | 0.31990 | 6 | 48 | 54 |
| Pusa-3 | 68.33 | 0.1182 | 15 | 4 | 19 | 94.933 | 0.24580 | 17 | 47 | 64 |
| R-1 (J-1) | 63.07 | 0.3634 | 27 | 32 | 59 | 95.100 | 0.16358 | 15 | 30 | 45 |
| Rashmi | 76.03 | 0.2624 | 7 | 14 | 21 | 106.600 | 0.18980 | 2 | 39 | 41 |
| RLC-92 | 66.67 | 0.3522 | 23 | 29 | 52 | 92.800 | 0.13543 | 23 | 27 | 50 |
| Ruchi | 67.37 | 0.2858 | 16 | 16 | 32 | 99.633 | 0.17267 | 9 | 32 | 41 |
| S-36 | 79.73 | 0.2554 | 3 | 13 | 16 | 92.233 | 0.18002 | 25 | 33 | 58 |
| Sharda | 57.23 | 0.2925 | 34 | 17 | 51 | 94.967 | 0.21779 | 16 | 42 | 58 |
| Sheela | 70.10 | 0.4364 | 10 | 34 | 44 | 100.133 | 0.10242 | 8 | 19 | 27 |
| Shekhar | 64.60 | 0.5865 | 26 | 44 | 70 | 91.167 | 0.17100 | 29 | 31 | 60 |
| Shikha | 68.67 | 0.3192 | 14 | 21 | 35 | 92.600 | 0.20673 | 24 | 40 | 64 |
| Shival | 41.47 | 0.2195 | 50 | 11 | 61 | 76.300 | 0.04908 | 49 | 8 | 57 |
| Shubhra | 69.37 | 0.1974 | 12 | 8 | 20 | 91.967 | 0.23845 | 27 | 45 | 72 |
| Subhra | 43.03 | 0.3589 | 49 | 31 | 80 | 67.700 | 5.06843 | 50 | 50 | 100 |
| Surabhi | 76.63 | 0.4494 | 5 | 36 | 41 | 105.333 | 0.07931 | 4 | 15 | 19 |
| Suyog | 52.37 | 0.0738 | 40 | 1 | 41 | 87.633 | 0.12728 | 38 | 23 | 61 |
| Sweta | 88.53 | 0.4534 | 1 | 37 | 38 | 111.633 | 0.24069 | 1 | 46 | 47 |
| T-397 | 66.97 | 0.3586 | 22 | 30 | 52 | 90.133 | 0.04980 | 33 | 9 | 42 |
| J-7 | 55.80 | 0.3296 | 38 | 23 | 61 | 87.500 | 0.04794 | 39 | 7 | 46 |

Table 4 Average of plant height and number of branches per plant (Y) and other stability parameters: Additive Main effects and Multiplicative Interaction (AMMI) stability Index (ASI), rankings of mean performance (rY), rankings of ASI (rASI) and Simultaneous Selection Index (SSI)

| Genotype | Plant height | | | | | Branches per plant | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Y | ASI | rY | rASI | SSI | Y | ASI | rY | rASI | SSI |
| Baner | 46.63 | 0.0547 | 28 | 3 | 31 | 7.32 | 0.024 | 36 | 4 | 40 |
| Deepika | 40.13 | 0.3180 | 41 | 30 | 71 | 7.25 | 0.047 | 37 | 7 | 44 |
| EC 41528 | 45.17 | 0.2898 | 32 | 27 | 59 | 9.88 | 0.618 | 12 | 48 | 60 |
| Garima | 43.83 | 0.3726 | 34 | 35 | 69 | 7.68 | 0.215 | 31 | 32 | 63 |
| Gaurav | 66.00 | 0.2687 | 2 | 25 | 27 | 10.32 | 0.113 | 9.5 | 19 | 28.5 |
| Hira | 53.27 | 0.6932 | 11 | 48 | 59 | 7.55 | 0.216 | 33.5 | 33 | 66.5 |
| IC53281 | 43.23 | 0.2016 | 37 | 21 | 58 | 8.35 | 0.394 | 22 | 47 | 69 |
| IC54970 | 40.57 | 0.2314 | 38 | 23 | 61 | 16.22 | 0.125 | 1 | 22 | 23 |
| IC56363 | 48.83 | 0.2780 | 21 | 26 | 47 | 12.98 | 0.114 | 2 | 20 | 22 |
| IC56365 | 49.60 | 0.0577 | 20 | 4 | 24 | 12.12 | 0.133 | 3 | 23 | 26 |
| IC96460 | 50.97 | 0.4712 | 17 | 43 | 60 | 12.05 | 0.137 | 4 | 24 | 28 |
| IC96461 | 55.20 | 0.2006 | 9 | 20 | 29 | 10.32 | 0.024 | 9.5 | 3 | 12.5 |
| IC96473 | 45.63 | 0.3726 | 31 | 36 | 67 | 6.22 | 0.077 | 46.5 | 14 | 60.5 |
| IC96491 | 46.93 | 0.1197 | 27 | 16 | 43 | 10.08 | 0.257 | 11 | 42 | 53 |
| Janki | 57.37 | 0.3762 | 6 | 37 | 43 | 6.72 | 0.380 | 40 | 46 | 86 |
| JLS-9 | 40.17 | 0.3233 | 40 | 32 | 72 | 7.52 | 0.226 | 35 | 34 | 69 |
| Kartika | 43.57 | 0.6696 | 35 | 47 | 82 | 8.55 | 0.103 | 20 | 16 | 36 |
| Kirtika | 40.40 | 0.4285 | 39 | 39 | 78 | 6.48 | 0.013 | 42 | 1 | 43 |
| Kiran | 38.67 | 0.1360 | 44 | 18 | 62 | 8.32 | 0.181 | 23 | 26 | 49 |
| L-27 | 48.00 | 0.0655 | 25 | 7 | 32 | 7.98 | 0.245 | 25 | 38 | 63 |
| LC-185 | 38.97 | 0.2898 | 43 | 28 | 71 | 9.18 | 0.316 | 15 | 44 | 59 |
| LC-54 | 39.27 | 0.1482 | 42 | 19 | 61 | 8.82 | 0.077 | 17.5 | 13 | 30.5 |
| Meera | 50.73 | 0.0585 | 18 | 5 | 23 | 11.55 | 0.192 | 7 | 28 | 35 |
| Mukta | 51.80 | 0.8643 | 14 | 50 | 64 | 11.85 | 0.094 | 6 | 15 | 21 |
| Nagarkot | 44.23 | 0.2251 | 33 | 22 | 55 | 8.38 | 0.361 | 21 | 45 | 66 |
| Neela | 52.70 | 0.1276 | 13 | 17 | 30 | 6.28 | 0.058 | 44 | 9 | 53 |
| Neelum | 71.70 | 0.1111 | 1 | 15 | 16 | 6.22 | 0.190 | 46.5 | 27 | 73.5 |
| NL-97 | 48.07 | 0.2496 | 24 | 24 | 48 | 7.55 | 0.192 | 33.5 | 29 | 62.5 |
| Padmini | 36.20 | 0.5537 | 46 | 44 | 90 | 10.62 | 0.140 | 8 | 25 | 33 |
| Parvati | 55.84 | 0.3930 | 7 | 38 | 45 | 8.85 | 0.067 | 16 | 11 | 27 |
| Pratap Alsi-1 | 52.77 | 0.5780 | 12 | 46 | 58 | 6.28 | 0.257 | 44 | 41 | 85 |
| Pusa-2 | 59.30 | 0.1040 | 5 | 13 | 18 | 8.15 | 0.238 | 24 | 37 | 61 |
| Pusa-3 | 51.03 | 0.0641 | 16 | 6 | 22 | 6.08 | 0.053 | 48 | 8 | 56 |
| R-1 (J-1) | 36.47 | 0.3300 | 45 | 33 | 78 | 7.88 | 0.235 | 27.5 | 35 | 62.5 |
| Rashmi | 45.70 | 0.4693 | 29.5 | 42 | 71.5 | 12.05 | 0.117 | 5 | 21 | 26 |
| RLC-92 | 60.13 | 0.7284 | 4 | 49 | 53 | 6.28 | 0.213 | 44 | 31 | 75 |
| Ruchi | 55.50 | 0.1032 | 8 | 11 | 19 | 9.22 | 0.193 | 14 | 30 | 44 |
| S-36 | 43.50 | 0.1073 | 36 | 14 | 50 | 8.75 | 0.640 | 19 | 49 | 68 |
| Sharda | 29.70 | 0.0672 | 50 | 8 | 58 | 5.58 | 0.245 | 50 | 40 | 90 |
| Sheela | 49.67 | 0.0893 | 19 | 9 | 28 | 7.92 | 0.022 | 26 | 2 | 28 |
| Shekhar | 45.70 | 0.0228 | 29.5 | 1 | 30.5 | 6.98 | 0.245 | 38 | 39 | 77 |
| Shikha | 53.60 | 0.5649 | 10 | 45 | 55 | 6.52 | 0.067 | 41 | 12 | 53 |
| Shival | 35.20 | 0.4629 | 47 | 41 | 88 | 7.82 | 0.066 | 29 | 10 | 39 |
| Shubhra | 48.17 | 0.3693 | 22.5 | 34 | 56.5 | 9.55 | 0.103 | 13 | 17 | 30 |
| Subhra | 51.67 | 0.1037 | 15 | 12 | 27 | 7.65 | 0.111 | 32 | 18 | 50 |
| Surabhi | 60.30 | 0.3214 | 3 | 31 | 34 | 5.62 | 0.683 | 49 | 50 | 99 |
| Suyog | 32.67 | 0.0413 | 49 | 2 | 51 | 8.82 | 0.034 | 17.5 | 5 | 22.5 |
| Sweta | 34.83 | 0.0964 | 48 | 10 | 58 | 7.88 | 0.235 | 27.5 | 36 | 63.5 |
| T-397 | 48.17 | 0.2933 | 22.5 | 29 | 51.5 | 7.78 | 0.290 | 30 | 43 | 73 |
| J-7 | 47.97 | 0.4384 | 26 | 40 | 66 | 6.78 | 0.043 | 39 | 6 | 45 |

The AMMI2 biplot or interaction biplot between IPCA2 versus IPCA1 showed that genotypes R-1 (J-1) and T-397 were the most desirable genotypes as it posses high stability and early flowering habit (Fig. 2a). IC96491 was the most stable genotype for days to flower. Genotypes Nagarkot and Pratap Alsi-1 were unstable for days to flower (Fig 2a). AMMI2 analysis model for days to maturity showed that, Subhra was the most efficient genotype (Fig. 2b). R-1 (J-1) and Deepika were most stable genotypes identified for the maturity duration (Fig. 2b). Genotypes LC-185, Nagarkot, Pusa-2, Kiran and Sheela were unstable for days to maturity (Fig 2b). Meera was the most stable genotype identified for plant height. RLC-92, Kartika, Shikha, Parvati, Shival, IC56363, Deepika, Gaurav and Padmini were the most desirable genotypes as it posses shorter plant height and stability over the years (Fig. 2c). The genotypes Mukta, S-36, Pratap Alsi-1, Neelum and Pusa-2 were unstable for plant height in linseed (Fig. 2c). The genotypes Deepika, Sheela and Neela were most stable for number of branches per plant (Fig 2d). Pratap Alsi-1, Neelum, RLC-92, IC56365 and Parvati were most desirable as it posses higher number of branches with more stability while S-36 and Padmini were unstable for number of branches per plant in linseed (Fig. 2d). Similarly, AMMI2 interaction biplot showed that R-1 (J-1) and T-397 for early flowering while Subhra for days to maturity were the most efficient genotypes. RLC-92, Kartika, Shikha, Parvati, Shival, IC56363, Deepika, Gaurav and Padmini were the most desirable genotypes for dwarf plant height. Desirable genotypes like Pratap Alsi-1, Neelum, RLC-92, IC56365 and Parvati were identified for number of branches per plant in linseed. Results of AMMI1 and AMMI2 biplot analyses were differs for most of the genotypes for days to flower, maturity, plant height and number of branches per plant with some exceptions that indicates the different sets of genes and effect of environment on the cumulative expression of traits under study. The contribution of AMMI2 or interaction biplot to GEI sum of squares was in conformity with the previous studies of Lirie *et al.* (2013) for seed yield, oil content and oil yield, Alem and Tadesse (2014) for seeds per boll, Tadesse *et al.* (2017) for seed yield, Chobe and Ararsa (2018) for seed yield and Kumar *et al.* (2020a) for number of bolls per plant, number of seeds per boll, seed yield per plant and oil content (%) in linseed.

Environments with IPCA1 scores nearly or equal to zero have small contribution to the interactions and accordingly have large contribution to the stability of genotypes (Oliveira *et al.,* 2009; Akter *et al.,* 2014). The AMMI1 biplot graph of days to flower, plant height and number of branches per plant showed that environments 2017 (more), 2016 (moderate) and 2018 (low) contributed for stability of genotypes in linseed (Figs 1a, 1c and 1d respectively). Environments 2016 and 2018 were more and 2017 as moderate contributor of stability for days to maturity in AMMI1 biplot analysis (Fig. 1b). The AMMI2 biplot or interaction biplot graphs showed environments 2016, 2017 and 2018 were contributed more towards the GxE interaction hence less towards the stability of genotypes for all the characters studies (Figs 2a, 2b, 2c and 2d respectively). Outliers are common phenomenon when genotypes are evaluated over years under field conditions which posses challenges for studying the genotype x environment interactions, however robust AMMI models which uses the combination of robust fit and robust SVD approaches (Ajay *et al.,* 2021) can be used for precise estimation of GEI even in the presence of outliers. AMMI2 or interaction biplot may be more accurate to extract GEI variation as it contains information of two IPCAs and greater pattern proportion compared to the AMMI1. This model is simple and elucidates the stability, genotypic performance, genetic variance between genotypes, and the environments that optimize varietal performance (Miranda *et al.,* 2009). AMMI1 and AMMI2 biplot analysis revealed environments have different response for genotype stability for days to flower, maturity, plant height and number of branches per plant. This showed that differential response of environments play significant role in stability of genotypes towards the phenotypic trait expression in linseed (Alem and Tadesse, 2014; Tadesse *et al.,* 2017; Chobe and Ararsa, 2018; Kumar *et al.,* 2020a).

AMMI model is effective as it contributes to a large portion of the GEI sum of squares and separate the main and interaction effects. The results showed that the AMMI1 and AMMI2 biplot models had differential response for days to flower, maturity, plant height and number of branches per plant in sight of genotype performance across the environments. This indicated that trait is governed by different sets of genes on the cumulative expression of phenotypic traits variation. Variable results were obtained for environmental contribution towards the genotype performance in both AMMI1 and AMMI2 analysis indicated differential response of environment for all the traits studied. The results of SSI statistic agreed with the results of the AMMI1 biplot models for days to flower, maturity, plant height and number of branches per plant of top ranked genotypes in all environments. Conclusively, genotype Suyog was most desirable genotype for multiple traits like days to flower, plant height and number of branches per plant; Kirtika for days to flower and number of branches per plant; Shival for days to flower and maturity; IC96461 for days to maturity and number of branches per plant while, Baner for plant height and number of branches per plant respectively.

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## REFERENCES

Ajay B C, Ramya K T, Abdul Fiyaz R, Govindaraj G, Bera S K, Narendra Kumar, Gangadhar K, Praveen Kona, Singh G P and Radhakrishnan T 2021. R-AMMI-LM: Linear-fit Robust-AMMI model to analyze genotype-by environment interactions. *Indian Journal of Genetics and Plant Breeding*, **81** (1):87-92.

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

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

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

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

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

Dwivedi S K, Satyaraj Guru R K and Panda S. 2021. Foliar application of plant growth regulators on growth, yield and economics of linseed (*Linum usitatissimum* L.). *Journal of Oilseeds Research*, **38**(2): 195-198.

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

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

Jambhulkar N N, Bose L K and Singh O N 2014. "AMMI stability index for stability analysis," in CRRI Newsletter, January-March 2014, ed. T. Mohapatra (Cuttack, Orissa: Central Rice Research Institute), 15.

Juita, Dlugogorski B Z, Kennedy E M and Mackie J C 2012. Low temperature oxidation of linseed oil: a review. *Fire Science Reviews,* 1:3.

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

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

Kumar M, Patel M, Chauhan R, Tank C and Solanki S 2020a. Deciphering genotype x environment interactions by AMMI method for yield and component traits in linseed (*Linum usitatissimum* L.). *Journal of Oilseeds Research*, **37**(2): 120-133.

Kumar M, Patel M, Chauhan R, Tank C and Solanki S 2021. Delineating multivariate divergence, heritability, trait association and identification of superior omega-3-fatty acid specific genotypes in linseed (*Linum usitatissimum* L.). *Genetika*, **53**(2): 825-849.

Kumar M, Patel M P, Chauhan R M, Tank C J, Solanki S D, Gami R A, Soni N V, Patel P C, Patel P T, Bhadauria H S, Patel N B, Patel R M and Rani K 2020b. Delineating G × E interactions by AMMI method for root attributes in ashwagandha [*Withania somnifera* (L.) Dunal]. *Indian Journal of Genetics and Plant Breeding*, **80**(4): 441-449.

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

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

R Development Core Team 2020. R: A language and environment for statistical computing. *R Foundation for Statistical Computing,* Vienna, Austria. URL https://www.R-project.org/.

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

Soto-Cerda B J, Westermeyer F, In˜iguez-Luy F, Gasto´n Mun˜oz, Montenegro A and Cloutier S 2013. Assessing the agronomic potential of linseed genotypes by multivariate analyses and association mapping of agronomic traits. *Euphytica*, DOI10.1007/s10681-013-1012-1.

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

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

# Assessment of genetic variation for herbicide tolerance in sesame (*Sesamum indicum* L.) germplasm

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ABSTRACT

To assess genetic variation for herbicide tolerance in sesame, a set of 55 genotypes were sprayed with imazethapyr@75g ai/ha on the 18th day after sowing at seedling stage. A control plot without herbicide spray was maintained. The injury caused due to Imazethpyr spray was recorded visually on 1-5 scale and the survival rate was calculated on 7th, 10th, 13th and 15th day after treatment. The herbicide injury rating ranged from 2-4.8 on 7th day after herbicide spray (DAHS), to 3.7 -5.0 on the 15th DAHS. The survival rate progressively decreased from 7th DAHS to 15th DAHS in most genotypes. The genotype, NIC-8261 was the most sensitive genotype expressing the symptoms of herbicide injury at a very early stage. On the 15th DAHS, only 10 genotypes *viz.,* CO-1, OTS-2, SI-328, SI-3171, NIC-16106, G-53, SI-1769, TC-25, RT-146 and NIC-8317 had a survival rate ranging from 27 to 39%. The subset of 10 genotypes was further evaluated for growth and yield attributes to assess the effect of imazethapyr spray on them. Imazethpyr spray resulted in delayed flowering and adversely caused a reduction in plant height, number of capsules per plant, seeds per capsule, thousand seed weight and seed per single plant in the sesame genotypes. The findings of the present study indicated that Imazethpyr@75gai/ha applied as a post-emergence herbicide at seedling stage was toxic to sesame and caused adverse effects on sesame growth and yield, by reducing the plant height, capsule production, thousand seed weight and also caused a delay in flowering. The response of sesame genotypes to Imazethpyr application was variable suggesting that genetic variability exists for herbicide tolerance in the germplasm, which need to be studied intensively.

**Keywords**: Genetic variation, Herbicide tolerance, Imazethpyr, Sesame

Sesame (*Sesamum indicum* L.) is one of the well-known oilseed crops with chromosome number 2n = 26. It belongs to the family Pedaliaceae. It is called as 'Queen of oilseeds' because of its high oil quality and shelf life period. Sesame seeds contain about 50 per cent of oil, which is rich in antioxidants and different fatty acids like oleic acid (43%), linoleic acid (35%), palmitic acid (11%) and stearic acid (7%). The crop is tolerant to drought conditions and suitable for well-drained soils. The crop can be grown in various agro-climatic conditions of India. In addition to the complex genetic factors, there are several biotic and abiotic stresses that adversely affect the production and productivity of sesame crop. One such major production challenge that negatively influences sesame yield is the presence of weeds. The effect of weeds on sesame establishment has been well recorded. Weeds can cause yield reductions in sesame ranging from 65% to 100% and it needs a critical weed free period of up to 50 days after planting (Singh *et al.,* 1992; Balyan *et al.,* 1993 and Grichar *et al.,* 2011). With weak seedling vigour, limited competitive ability, and lack of inexpensive and affordable labour, use of pre-emergence and post emergence herbicides is essential for sesame production. Most commonly used herbicides in sesame include alachlor, imazethapyr, diuron, fluchloralin, linuron and pendimethalin. Use of herbicides has proven to be more effective in controlling weeds than manual labour or hand weeding. However, in addition to controlling weeds, herbicides also affect the crop growth with phytotoxicity effects ranging from severe stunting to lethality. Cultivation of superior high yielding varieties coupled with herbicide tolerance can help reducing the cost of cultivation and result in higher profitability to sesame farmers. Screening the sesame germplasm is essential for assessing the natural variability and identifying potential donors for desirable yield component traits and herbicide tolerance for utilization in plant breeding programme (Rajitha *et al.,* 2021).

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## MATERIALS AND METHODS

The present investigation was carried out during summer season of 2022 at the Department of Oilseeds, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University (TNAU), Coimbatore. A set of 55 sesame

genotypes (maintained at Department of Oilseeds, TNAU) were used. The experiment was laid out in a completely randomized block design during summer, 2022. The genotypes were raised in two replications along with an untreated control plot for comparing the effect of herbicide on sesame growth and yield. Each genotype was raised in a single row of three meters length with a spacing of 30 cm between rows and 10 cm between plants, following the recommended agronomic package of practices during the experimental period. The herbicide Imazethpyr was sprayed as a post emergence application at the dose of 75g active ingredient per hectare (a.i/ha) on 17$^{th}$ day after sowing in the replicated plots. In the control plot (CP), one hand weeding was done on 17$^{th}$ day to maintain the weed free condition and no herbicide application was taken up. *Trianthema portulacastrum* was the major weed species in the experimental plot.

Based on the symptoms expressed, the genotypes were scored for the herbicide injury rating on 7$^{th}$, 10$^{th}$, 13$^{th}$ and 15$^{th}$ day after herbicide spray (DAHS) following a 1-5 scale: 1-highly tolerant (no burning/chlorosis of leaves), 2-tolerant (minor burning/chlorosis of leaves), 3-moderately tolerant (moderate burning /chlorosis of leaves), 4-sensitive (severe burning/chlorosis of leaves) and 5-highly sensitive (complete burning of leaves leading to plant mortality). All the plants in a row were scored individually on a 1-5 scale in the Imazethpyr treated plots (ITP) and the mean was taken as the herbicide injury score. The survival rate of genotypes was recorded on 15$^{th}$ and 21$^{st}$ DAHS as the ratio of number of surviving plants after and before herbicide application and expressed in percentage.

The genotypes for which the mean survival rate was 25% and above in the treatment plot was selected for further agro-morphological characterization. Seven quantitative characters were recorded based on descriptors of sesame (IPGRI and NBPGR, 2004) in the treatment and control plot to assess the impact of herbicide application on growth and yield traits of sesame genotypes, which included plant height, days to 50% flowering, days to maturity, number of capsules per plant, number of seeds per capsule, thousand seed weight and seed yield per plant (g). Basic descriptive statistics such as mean, range, and standard deviation for herbicide injury scores and survival rate of the 55 genotypes were calculated using Excel software. The formula (1-ITP/CP)*100 was used to calculate the percentage of reduction caused due to Imazethpyr spray on growth and yield parameters in the treated plots compared to the control plot.

## RESULTS AND DISCUSSION

The damage symptoms expressed in the genotypes treated with the herbicide ranged from yellowing, necrosis, growth reduction, burning of leaves, wilting and mortality in severe cases. In some genotypes, the damage symptoms progressively increased over a 15 day time period. A few genotypes showed yellowing followed by sudden wilting and mortality. The surviving plants began to recover gradually from the 15$^{th}$ day after herbicide spray. All the genotypes survived on the 7$^{th}$ day after the herbicide spray with two genotypes recording a herbicide injury rating on a 1-2 scale, 35 genotypes on a 2-3 scale, 17 genotypes on a 3-4 scale and one genotype on 4-5 scale. On the 10$^{th}$ day after the treatment, 29 genotypes showed a damage rating of 2-3 scale, 25 genotypes exhibited a damage rating on 3-4 scale, and one genotype was highly susceptible recording a damage rating of 4-5 scale. On the 13$^{th}$ day after treatment, only seven genotypes showed a damage rating of 2-3 scale, while the remaining genotypes expressed a susceptible to highly susceptible reaction to herbicide spray. On the 15$^{th}$ day after herbicide treatment, four genotypes namely CO-1, OTS-2, SI-328 and SI-3171 were moderately tolerant recording a damage rating of 3-4 scale, while the remaining genotypes recorded high herbicide injury scores of 4-5 and exhibited a susceptible to highly susceptible reaction. The mean herbicide injury scores recorded for each genotype at 7$^{th}$ and 15$^{th}$ day after herbicide spray are presented in Fig. 1. Grichar *et al.* (2009) reported that yellow splotching, necrosis of leaves, stunting were the common symptoms noticed in sesame up to 10 days after herbicide application, after which the sesame plants showed recovery. Sharma *et al.* (2018) reported that the herbicide injury score in a set of 180 lentil genotypes ranged from 1.5 to 5.0 after 14 days after Imazethpyr spray and recovery symptoms were observed after 30 days after the spray. Based on the visual scoring, a majority of them (122 genotypes) were classified as sensitive to highly sensitive genotypes.

The genotype NIC-8261 was highly sensitive to herbicide spray and was very early to show the herbicide injury symptoms. It recorded the least survival rate of 7% by the 7$^{th}$ DAHS. For the other genotypes, the survival rate ranged from 50 to 100% on 7$^{th}$ DAHS, 33 to 100% on 10$^{th}$ DAHS and 38 to 100% on 13$^{th}$ DAHS. As the symptoms progressed, a severe reduction in survival rate was observed by 15$^{th}$ DAHS with the survival rate ranging from 0-39%. On the 15$^{th}$ DAHS, the herbicide spray caused complete lethality of 15 genotypes, 12 genotypes recorded a survival rate less than 20%, 14 genotypes had a survival rate of less than 30% and five genotypes had a survival rate of less than 40%. The mean survival rates recorded for each genotype at 7$^{th}$ and 15$^{th}$ day after herbicide spray are presented in Fig 2. Out of the 55 genotypes, only 10 genotypes *viz.,* CO-1, OTS-2, SI-328, SI-3171, NIC-16106, G-53, SI-1769, TC-25, RT-146 and NIC-8317 had a mean survival rate greater than 25%.

These 10 genotypes were used for further evaluation to assess the effect of imazethapyr spray on growth and yield parameters in sesame. The effect of Imazethpyr spray on growth and yield parameters are presented in Table 1. The

mean reduction in plant height was 33.8 cm in the Imazethpyr sprayed plots compared to the control plot. The reduction in plant height ranged from 20.5 cm (SI-3171) to 52.4 cm (SI-328). Imazethapyr spray on 18$^{th}$ day after sowing resulted in a delay in the 50% flowering on an average by nine days. While the minimum delay of two days was observed in the genotype TC-25, a maximum delay in flowering by 13 days was observed in the genotype S-861. The number of capsules per plant also decreased in the herbicide treated plot, with a mean reduction of 27.2%. The reduction in capsules per plant ranged from 2.3% (TC-25) to 55.0% (SI-328). The seeds produced per capsule were also lesser in the herbicide treated plot compared to the control plot ranging from 0.8% (TC-25) to 23.1% (NIC-16106). The mean number of seeds produced per capsule in the herbicide treated plot was 50.1, while it was 54.5 seeds per capsule in the control plot. The reduction in thousand seed weight ranged from 2.1% (G-53) to 24.1% (RT-146) with a mean reduction to the tune of 11.5% compared to the control plot. The mean seed yield recorded per plant showed a reduction of 30.7%. A wide variation for seed yield per plant was observed with a maximum reduction recorded in the genotype S-861 (60.5%) followed by OTS-2 (55.7%) and CO-1 (55.3%). The least reduction in the seed yield per plant was recorded by TC-25 (12.6%). Among the 10 genotypes, reduction for plant height, capsules per plant and seed yield per plant was highly pronounced in the genotype CO-1, while TC-25 showed the least adverse effect for growth and yield traits after Imazethpyr spray. While most of the surviving genotypes were moderate to poor yielders, they exhibited relatively lesser adverse effect due to Imazethpyr spray compared to CO-1, which was superior in terms of its yield performance. Although CO-1 recorded a lower herbicide injury scoring and better survival rate, the remarkable adverse impact of Imazethpyr in CO-1 may be due its slow recovery after the injury stress experienced at an early stage of its growth period.

The application of Imazethpyr caused a delay in flowering and had adverse effects on all growth and yield parameters *viz.,* plant height, capsule production, seeds per capsule, thousand seed weight and seed yield. Similar results were also observed in sesame by Grichar *et al.* (2001) and Singh *et al.* (2018). In comparative analysis of the impact of soil applied herbicides on sesame growth and yield Grichar *et al.* (2001a) reported that Imazethpyr when applied as a pre-emergence herbicide caused a significant reduction in plant stand, plant height and seed yield in sesame and was selectively toxic to sesame. Singh *et al.* (2018) evaluated five herbicides *viz.,* pendimethalin, imazethapyr, oxyfluorfen, metribuzin and imezemox for weed control in sesame. All these herbicides when used alone or in combination as pre-emergence application caused a reduction in plant height, particularly the reduction in plant height was significant due to the Imazethpyr spray at 60g ai/ha.

A similar adverse effect of Imazethpyr application on vegetative growth, flowering and yield parameters was also observed in a few other dicot plants. For instance, delay in flowering caused by Imazethpyr spray was reported in chickpea (Gaur *et al.,* 2013; Taran *et al.,* 2013) and lentils (Sharma *et al.,* 2018), which was attributed to the slow growth rate of the crops in the herbicide treated plots. Reduction in plant height due to Imazethpyr spray was also reported in chickpea (Taran *et al.,* 2013) and lentils (Sharma *et al.,* 2018). Findings of Royuela *et al.* (2000) and Gaston *et al.* (2002) suggested that Imazethpyr spray caused starvation and blockage of ALS catalyzed reactions leading to fermentative metabolism, thereby inhibiting of growth of plants. The significant reduction in number of pods per plant and seed weight in chickpea due to Imazethpyr spray were attributed to reduced crop growth rate, and reduced reproductive phase caused due to delayed flowering (Sharma *et al.,* 2018; Maalouf *et al.,* 2016). The adverse effect of Imazethpyr treatment on seed yield was pronounced with a reduction to the tune of 32.3% in lentils (Sharma *et al.,* 2018).

Several pre-emergence and post-emergence herbicides are used to control weeds in sesame cultivation. However, the results of herbicide application are not consistent as conflicting results have been reported in the evaluation of these herbicides. The effect of herbicides on weeds and sesame growth varies with the type of herbicide, dose, formulation, time of application, soil moisture, soil texture and pH, intensity of rainfall during germination and early vegetative phase (Smith, 1989; Martin, 1995; Grichar *et al.,* 2001a and Grichar *et al.,* 2001b). Till date, there is no post-emergence herbicide that is capable of controlling weeds without causing injury to sesame. Imazethpyr, which belongs to the class of imidazolinone herbicides is presently used on a commercial scale as both pre-emergence and post emergence herbicide. It controls the weeds by inhibiting a key enzyme, acetolactate synthase (ALS) involved in the biosynthetic pathway of branched chain amino acids such as valine, leucine and isoleucine. Existence of natural genetic variation for tolerance to imidazolinone herbicides has been reported in crops such as rice, wheat, maize, oilseed rape, sunflower (Tan *et al.,* 2005), chickpea (Gaur *et al.,* 2013), field pea (Hanson and Thill, 2001) and lentils (Sharma *et al.,* 2018). The present study showed that Imazethpyr herbicide when applied at very early stage causes phytotoxicity in sesame affecting the survival rate and establishment; however, the genotypes differed in their response to herbicide application in terms of growth and yield traits suggesting the genetic variation for tolerance to herbicides in sesame. Evaluating a larger set of germplasm would unveil the possibility of identifying herbicide tolerant genotypes in sesame.

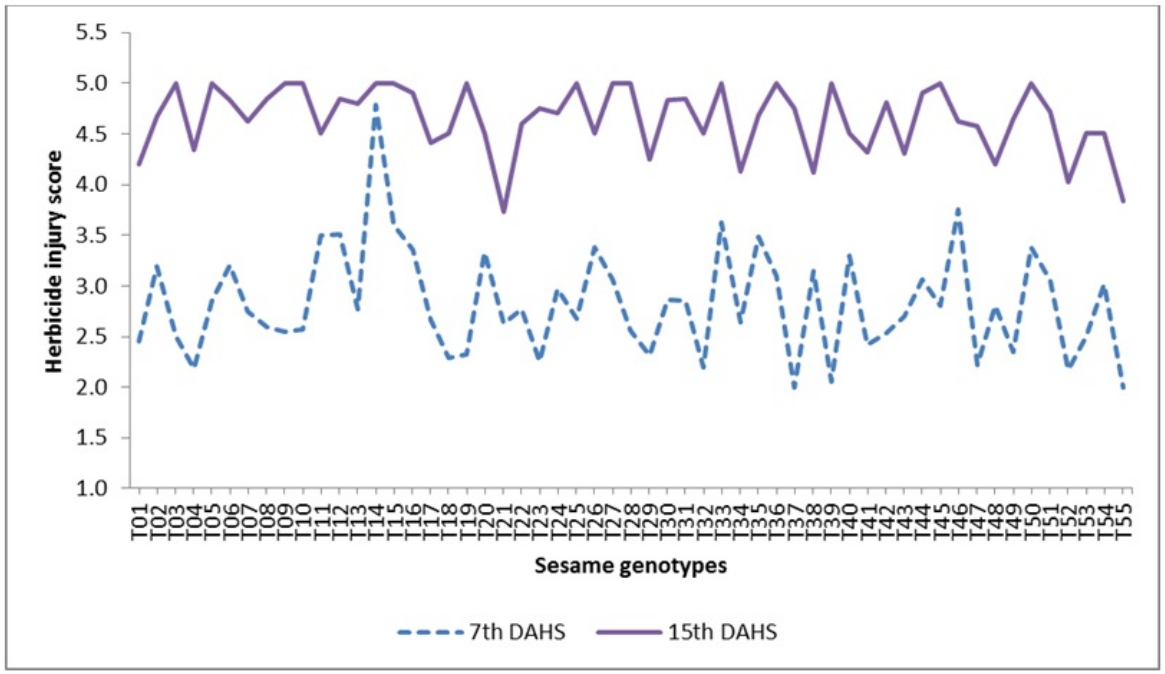


Fig. 1. Herbicide injury score of sesame genotypes at different time intervals in Imazethpyr herbicide treated plots

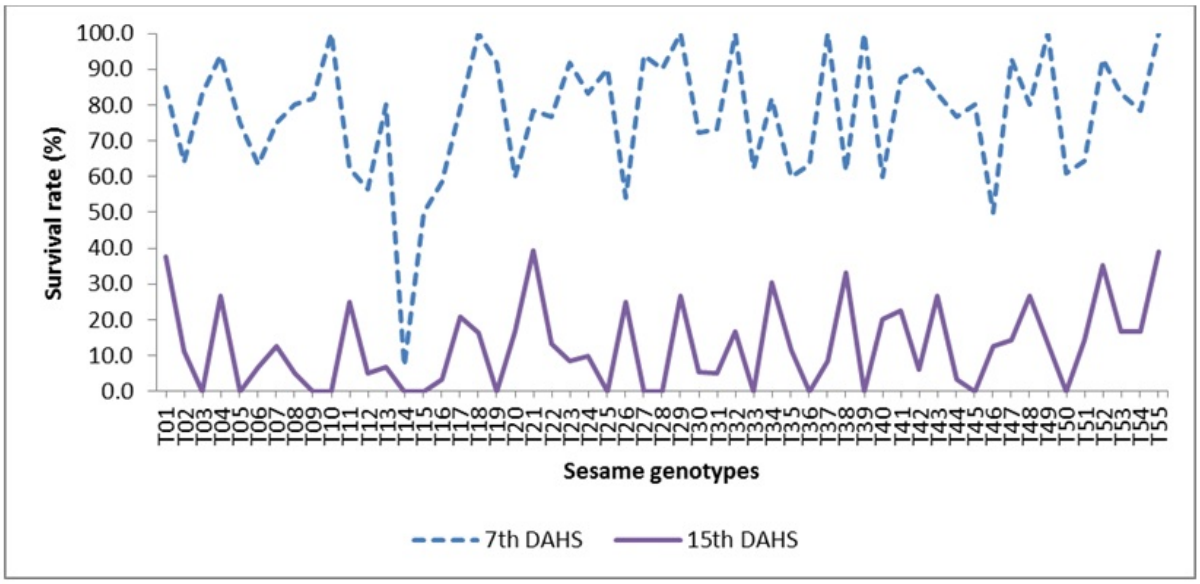


Fig. 2. Survival rate of the sesame genotypes at different time points after herbicide spray

Table 1 Effect of Imazethpyr herbicide spray on agro-morphological and yield contributing traits in sesame

| Code | Genotype | PH | | | DFF | | | CPP | | | SPC | | | TSW | | | SYP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CP | ITP | % redn | CP | ITP | Delay | CP | ITP | % redn | CP | ITP | % redn | CP | ITP | % redn | CP | ITP | % redn |
| T01 | NIC -16106 | 131.6 | 93.3 | 29.1 | 41 | 53 | 12 | 119.8 | 82.2 | 31.4 | 59.2 | 45.5 | 23.1 | 2.4 | 2.2 | 8.3 | 6.8 | 5.4 | 20.2 |
| T04 | G-53 | 127.0 | 83.4 | 34.3 | 43 | 57 | 14 | 94.7 | 83.9 | 11.4 | 55.2 | 49.0 | 11.2 | 2.7 | 2.6 | 2.1 | 5.2 | 4.2 | 18.9 |
| T21 | OTS-2 | 112.0 | 74.3 | 33.7 | 45 | 58 | 13 | 115.2 | 80.0 | 30.6 | 53.6 | 50.8 | 5.2 | 2.6 | 2.5 | 4.3 | 7.9 | 3.5 | 55.7 |
| T29 | SI-1769 | 107.6 | 79.7 | 25.9 | 45 | 55 | 10 | 139.4 | 109.3 | 21.6 | 56.4 | 52.8 | 6.4 | 2.6 | 2.3 | 10.5 | 4.5 | 3.9 | 13.3 |
| T34 | TC-25 | 102.1 | 74.2 | 27.3 | 45 | 47 | 2 | 113.0 | 110.4 | 2.3 | 49.2 | 48.8 | 0.8 | 3.2 | 2.6 | 19.1 | 6.5 | 5.7 | 12.6 |
| T38 | RT-146 | 115.7 | 79.2 | 31.6 | 45 | 54 | 9 | 109.6 | 79.1 | 27.9 | 55.6 | 54.0 | 2.9 | 3.1 | 2.3 | 24.1 | 6.5 | 5.1 | 21.8 |
| T43 | NIC-8317 | 136.3 | 84.3 | 38.2 | 48 | 56 | 8 | 103.8 | 97.3 | 6.3 | 60.5 | 56.1 | 7.3 | 2.9 | 2.4 | 17.2 | 8.1 | 5.7 | 30.1 |
| T48 | SI-328 | 155.4 | 73.9 | 52.4 | 43 | 50 | 7 | 130.4 | 58.7 | 55.0 | 52.4 | 47.6 | 9.2 | 2.9 | 2.6 | 9.8 | 8.0 | 5.8 | 27.6 |
| T52 | SI-3171 | 107.0 | 85.1 | 20.5 | 45 | 50 | 5 | 138.4 | 79.5 | 42.6 | 50.0 | 46.1 | 7.8 | 3.0 | 2.7 | 10.4 | 7.9 | 3.8 | 51.6 |
| T55 | CO-1 | 174.0 | 95.3 | 45.2 | 45 | 56 | 11 | 155.6 | 88.3 | 43.3 | 52.8 | 50.0 | 5.3 | 3.0 | 2.7 | 8.9 | 11.5 | 5.1 | 55.3 |
| | Minimum | 102.1 | 73.9 | 20.5 | 41.0 | 47.0 | 2 | 94.7 | 58.7 | 2.3 | 49.2 | 45.5 | 0.8 | 2.4 | 2.2 | 2.1 | 4.5 | 3.5 | 12.6 |
| | Maximum | 174.0 | 95.3 | 52.4 | 48.0 | 58.0 | 14 | 155.6 | 110.4 | 55.0 | 60.5 | 56.1 | 23.1 | 3.2 | 2.7 | 24.1 | 11.5 | 5.8 | 55.7 |
| | Mean | 126.9 | 82.2 | 33.8 | 44.5 | 53.5 | 9 | 122.0 | 86.9 | 27.2 | 54.5 | 50.1 | 7.9 | 2.8 | 2.5 | 11.5 | 7.3 | 4.8 | 30.7 |

PH- Plant height (cm); DFF-Days to 50% flowering; CPP-Capsules per plant; SPC-Seeds per capsule; TSW-Thousand seed weight (g); SYP-Seed yield per plant (g); CP-Control plot; ITP-Imazethpyr treated plot; % redn-% reduction

## REFERENCES


Balyan R, Kumar S, Malik R, and Panwar R 1993. Post-emergence efficacy of atrazine in controlling weeds in pearl-millet. *Indian Journal of Weed Science*, **25**:7-11.

Gaston S, Zabalza A, González E M, Arrese-Igor C, Aparicio-Tejo P M and Royuela M 2002. Imazethapyr, an inhibitor of the branched-chain amino acid biosynthesis, induces aerobic fermentation in pea plants. *Physiologia Plantarum*, **114** (4): 524-532.

Gaur P M, Jukanti A K, Samineni S, Chaturvedi S K, Singh S, Tripathi S, Singh I, Singh G, Das T K and Aski M 2013. Large genetic variability in chickpea for tolerance to herbicides imazethapyr and metribuzin. *Agronomy*, **3**(3): 524-536.

Grichar W J, Sestak D C, Brewer K D, Besler B A, Stichler C R and Smith D T 2001a. Sesame (*Sesamum indicum* L.) tolerance and weed control with soil-applied herbicides. *Crop Protection*, **20**(5): 389-394.

Grichar W J, Sestak D C, Brewer K D, Besler B A, Stichler C R and Smith D T 2001b. Sesame (*Sesamum indicum* L.) tolerance with various postemergence herbicides. *Crop Protection*, **20**(8): 685-689.

Grichar W J, Dotray PA and Langham D R 2009. Sesame (*Sesamum indicum* L.) response to preemergence herbicides. *Crop Protection*, **28**(11): 928-933.

Grichar W J, Dotray P A and Langham D R 2011.Weed control and the use of herbicides in sesame production, herbicides, theory and applications, Marcelo Larramendy (Ed.), InTech, Available from: http://www.intechopen.com/ books/ herbicides-theory-andapplications/weed-control-and-the-use-of-herbicides-in-sesame-production.

Hanson B D and Thill DC 2001. Effects of imazethapyr and pendimethalin on lentil (*Lens culinaris*), pea (*Pisum sativum*), and a subsequent winter wheat (*Triticum aestivum*) crop. *Weed Technology*, **15**(1):190-194.

IPGRI and NBPGR 2004. Descriptors for sesame (Sesamum spp.). International Plant Genetic Resources Institute, Rome, Italy, National Bureau of Plant Genetic Resources, New Delhi, India.

Maalouf F, Patil S B, Rajendra K, Hamwieh A, Goyal A and Kumar S 2016.Breeding for post emergence herbicides in cool season food legumes.Amman, Jordan: International Center for Agricultural Research in the Dry Areas (ICARDA).

Martin C. 1995. Development of an effective weed control system for sesame in the Northern Territory. *Proceedings of Sesame Workshop,* Darwin and Katherine, New Territory.

Rajitha D, Srikanth T, Padmaja D and Kiran Babu T 2021. Genetic variability and heritability studies among genotypes of sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **38**(1) : 43-48,

Royuela M, Gonzalez A, Gonzalez E M, Arrese-Igor C, Aparicio-Tejo P M and Gonzalez-Murua C 2000. Physiological consequences of continuous, sublethal imazethapyr supply to pea plants. *Journal of Plant Physiology*, **157**(3): 345-354.

Sharma S R, Singh S, Aggarwal N, Kaur J, Gill R K, Kushwah A, Patil S B and Kumar S. 2018. Genetic variation for tolerance to post-emergence herbicide, imazethapyr in lentil (*Lens culinaris* Medik.). *Archives of Agronomy and Soil Science*, **64**(13): 1818-1830.

Singh A, Bisen R and Tiwari A 2018. Genetic variability and character association in sesame (*Sesamum indicum* L.) genotypes. *International Journal of Current Microbiology and Applied Sciences*, **7**(11): 2407-2415.

Singh D, Dagar J and Gangwar B 1992. Investation by weeds and their management in oilseed crops. *Agricultural Reviews*, **13**(3): 163-175.

Smith A 1989. Degradation, fate, and persistence of phenoxyalkanoic acid herbicides in soil. *Reviews of Weed Science*, **4**: 1-24.

Tan S, Evans R R, Dahmer M L, Singh B K and Shaner D L 2005. Imidazolinone?tolerant crops: history, current status and future. *Pest Management Science*, **61**(3): 246-257.

Taran B, Holm F and Banniza S 2013. Response of chickpea cultivars to pre-and post-emergence herbicide applications. *Canadian Journal of Plant Science*, **93**(2): 279-286.

# Growth and yield performance of castor hybrids under different methods of planting and fertility levels in North Gujarat Agro-climatic region

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ABSTRACT

A field experiment was conducted to evaluate the yield performance of castor hybrids under different methods of planting and fertility levels at Agronomy Instructional Farm, C P College of Agriculture, Sardarkrushinagar, Gujarat in loamy sand soil. The experiment consisted eight treatment combinations with two hybrids (GCH 7 and GCH 8), two planting methods (Direct seed sowing and Transplanting) and two fertility levels(75% RDF and 100% RDF) were undertaken in randomized block design with factorial concept and replicated four times. Significantly higher number of capsules (88.63) on primary spike, seed yield per plant (686.30 g), 100-seed weight (32.49 g), number of spikes (20.01) per plant, seed yield (3220 kg/ha) and stalk yield (5340 kg/ha) were recorded with GCH 8 hybrid. In planting methods, significantly higher number of capsules (89.09) on primary spike, seed yield per plant (688.65 g), number of spikes (19.60) per plant, seed yield (3230 kg/ha), stalk yield (5361 kg/ha) and available P2O5 (48.7 kg/ha) and S (13.01 mg/kg) after harvest of crop were recorded under direct seed sown castor. 100% RDF registered significantly higher plant height (86.14 cm) at harvest, number of nodes (18.58) per plant, number of capsules (88.60) on primary spike, length of primary (74.57 cm) spikes, seed yield per plant (688.53 g), 100-seed weight (32.00 g), number of spikes (19.66) per plant, seed yield (3190 kg/ha), stalk yield (5281 kg/ha) and available N, P2O5and S (156 kg/ha, 49.8 kg/ha and 13.35 mg/kg, respectively).

**Keywords**: Castor, Fertility levels, Hybrid, Planting methods and transplanting

Castor (*Ricinus communis* L., 2n=20, Family: Euphorbiaceae) is an industrially important non edible oilseed crop widely cultivated in the arid and semi-arid regions of the world. In the year 2020-21, Gujarat is leading castor growing state in India covering 6.52 lakh ha area with 13.45 lakh tonnes production and 2062 kg/ha average productivity. The area under castor in India was 8.87 lakh ha with 16.47 lakh tonnes of production and an average productivity of 1856 kg/ha (Anonymous, 2021; Chauhan *et al.,* 2021). Castor production is higher in Gujarat state because most of the farmers are growing hybrids under irrigated conditions and they are adopted the scientific cultivation methods suggested to them. As per recommendation, farmers are advised to grow castor with wider spacing of 150 cm × 120 cm in north Gujarat agro-climatic region. The farmers having more fertile soils, go for even wider spacing of 150 cm × 150 cm, 180 cm × 150 cm, 180 cm × 180 cm and even more. Castor is a hardy crop which survives in a wide range of ecology. Basically, castor grows throughout the warm temperate and tropical region, it flourishes under varieties of climatic conditions that its range cannot easily be defined. Castor is basically a long-day plant, but is adaptable with fewer yields to a wind range of photoperiod. However, castor flower normally on both a short 12-hour and a long 18-hour day, but at 9-hours growth and development were severely retarded (Weiss, 1983). The productivity of castor is low due to poor crop management practices and low resource allocation coupled with lack of high yielding improved hybrids adaptive under diverse environmental condition. Both low and excess application of fertilizers hinders crop performance and pollutes the soil environment. Hence, balance nutrient supply is a key factor for realizing high yield and profits with different fertility levels in a particular region. So, it become imperative to find out the performance of hybrids under various levels of fertilizer dose and also assess their economic feasibility. Since last two decades hybrid vigour species is being exploited on commercial scale and hybrids *viz.,* GCH 3, GAUCH 1, GCH 2, GCH 4, GCH 5, GCH 7 and GCH 8 have been released for cultivation in Gujarat state, respectively. At present, castor hybrid GCH 4, GCH 5, GCH 7 and GCH 8 are cultivated in Gujarat. GCH 7 is high yielding hybrid and resistant to wilt disease, nematodes and tolerant to root rot disease and GCH 8 is high yielding and resistant to wilt disease. Propagation of castor using seedlings started in plastic bags or root plugs has been studied as an alternative for regions with short-growing seasons (Severino *et al.,* 2012; Ramesh *et al.,* 2021). The castor is sown through seeds and seeds are precious and scare at most of the time. It is also recommended to sow castor through dibbling. Sometimes no seed is germinated at the dibble and gap remain. The gap is directly related to economical loss to the farmers. If this gap is filled through resowing of seed, the next crop is almost delayed by 25-30

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days. To overcome this challenge, if some castor seed are grown in plastic sleeves at the time of sowing of castor in field and on the need based transplanting of bag seedling hence, this gap could be filled.

## MATERIALS AND METHODS

A field experiment was conducted during *kharif* season 2020-21 at Agronomy Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar, Gujarat. Geographically, Sardarkrushinagar is situated at 24°19' North latitude and 72°19' East longitude with an elevation of 154.52 m above MSL and located in the North Gujarat Agro-climate region. Climate of this region is sub-tropical monsoon type and falls under semi-arid region. Soil of the experimental field was loamy sand in texture, low in organic carbon (0.32 %) and available nitrogen (136 kg/ha), medium in available phosphorus (46.7 kg/ha), available potash (247 kg/ha) and available sulphur (10.5 mg/kg) having pH value of 7.2. The experiment consisted eight treatment combinations with two hybrids (GCH 7 and GCH 8), two planting methods (Direct seed sowing and transplanting) and two fertility levels (75% RDF and 100% RDF) of randomized block design with factorial concept and replicated four times. The seedling was raised in nursery poly bags. The soil was mixed well with FYM with a ratio of soil and FYM was 3:1. Castor hybrid GCH 7 and GCH 8 seeds were dibbled in open furrows at the depth of 4.5-5.0 cm. The crop was sown by keeping 150 cm inter and 120 cm intra row spacing. At the same time castor hybrid GCH 7 and GCH 8 were sown in nursery bags for raising seedling of castor for transplanting treatment. 21 days old seedlings were transplanted in field as per the treatment in earmarked plots. The recommended dose of fertilizer for castor crop was N180, P40, K0 and S20 kg/ha. Full dose of phosphorus, sulphur and 25% dose of nitrogen fertilizers were applied just before planting and seeding as basal application through urea, DAP and bentonite sulphur and remaining 75% of nitrogen was applied at 30-35 DAS/DAT, 60-65 DAS/DAT and 90-95 DAS/DAT. First irrigation was given after sowing and before transplanting of crop. Remaining irrigations were given as per crop requirement. Total eight irrigations were applied during the life period of the crop. The data recorded for various parameters during the course of investigation were statistically analyzed by a procedure appropriate to the design of experiment as described by Gomez and Gomez (1984). The significance of difference was tested by "F" test at 5 per cent level. The critical difference was calculated when the differences among treatment were found significant under "F" test.

## RESULTS AND DISCUSSION

**Growth and yield attributes**: Number of nodes (18.03) per plant was recorded significantly higher with castor hybrid GCH 7 (Table 1) because this hybrid is taller as compared to castor hybrid GCH 8 resulting more internodes. These results are in concurrence with those reported by Narkhede *et al.* (1984) and Jat and Desai (2020). Number of capsules on primary spike (88.63), seed yield per plant (686.30 g), 100-seed weight (32.49 g) and number of spikes per plant (20.01) was significantly higher with GCH 8 as compared to GCH 7. The increased seed yield per plant of castor hybrid GCH 8 could mainly be attributed to comparatively higher number of spikes per plant and 100 seed weight of this hybrid as compare to GCH 7. Several workers have also been reported the variation among the genotypes of castor yield and growth characteristics (Senthil Kumar and Venkatachalam, 2018). Castor hybrid GCH 7 has recorded lower number of spikes per plant because this hybrid has taken more number of days to maturity as compared to GCH 8 and has experienced more vegetative growth and the new branches which are vegetative sinks, has shaded the primary leaves. This shading might have impaired the production of the racemes. Similar findings of production of spikes per plant in hybrids were reported by Chauhan and Yakadri (2004), Raj *et al.* (2010) and Jat and Desai (2020). Plant height at harvest (cm) and length of primary spike (cm) were found non-significant due to different hybrids. Plant height at harvest, no. of nodes per plant, length of primary spike and 100 seed weight were found numerically higher with direct seed sown crop and remained statistically unaffected due to different planting methods. Significantly higher no. of capsules on primary spike (88.63), seed yield per plant (689 g) and no. of spike per plant (19.60) were found under direct seed sown castor (Table 2). The increasing trend in seed yield per plant, no. of spike per plant, no. of capsules on primary spike might be due to the reason that root growth of transplanted castor is less as compared to direct seed sowing castor so uptake of nutrients is less as compared to direct seed sowing castor, hence transplanted castor has short height and short growth resulting in less yield as compared to direct seed sown castor. Rodriguez and Vazquez (2019) found that the castor root architecture, horizontal and vertical distribution, proliferation of secondary and lateral roots is influencing much on the growth and development of castor plant. Data presented in Table 1 indicated that the plant height at harvest (86.14 cm), no. of nodes per plant (18.58), no. of capsules on primary spike (88.60), length of primary spike (74.57 cm), seed yield per plant (688.53 g), 100-seed weight (32.00 g) and no. of spikes per plant (19.66) were found significantly higher due to 100% RDF. This increasing trend in above mention parameters due to the reason that sufficient supply of nutrients might have enhanced growth promoting substance, which led to accelerated cell division and elongation and ultimately resulted in luxuriant vegetative growth in term of plant height, no. of nodes per plant, length

of primary spike, no. of capsules on primary spike, seed yield per plant, 100-seed yield, spikes per plant (Rana *et al.,* 2006 & Jat and Desai (2020).

**Yield performance and soil fertility status**: Higher seed yield (3220 kg/ha) and stalk yield (5340 kg/ha) were found significantly under GCH 8 (Table 2). In planting methods significantly higher seed yield (3230 kg/ha) and stalk yield (5361 kg/ha) were produced under direct seed sown castor. 100% RDF recorded significantly higher seed yield (3190 kg/ha) and stalk yield (5281 kg/ha) in different fertility levels. Increase in seed yield and stalk yield due to GCH 8, direct seed sowing and 100% RDF because GCH 8 hybrid produced higher number of spikes, highest branches and higher 100-seed weight as compared to GCH 7. Reducing seed and stalk yield in transplanted castor because after transplanting of castor, castor plant suffers from environmental shock and they take time for recover in normal condition and root growth of transplanted castor is less as compared to direct seed sowing hence uptake of nutrient is less resulting in less yield. (Rodriguez andVazquez, 2019, Senthil Kumar and Venkatachalam, 2018). Variation in available N, $P_2O_5$, $K_2O$ and S in soil after harvest of crop found non-significant due to various hybrids (Table 3). Available $P_2O_5$ (48.7 kg/ha) and S (13.01 mg/kg) was found significant due to direct seed sown castor. Significantly higher value of available N (156 kg/ha), $P_2O_5$ (49.8 kg/ha), and S (13.35 mg/kg) in soil were found under 100% RDF fertilized castor.

It can be concluded that castor hybrid GCH 8 directly sown through seed and should be fertilized by 100% recommended dose of fertilizer for getting higher yield in loamy sand soil of north Gujarat.

Table 1 Effect of hybrids, planting methods and fertility levels on growth and yield attributes of castor

| Treatments | Plant height at harvest (cm) | No. of nodes /plant | Length of primary spike (cm) | No. of capsules on primary spike |
|---|---|---|---|---|
| Hybrids | | | | |
| H1: GCH 7 | 84.73 | 18.03 | 70.78 | 82.97 |
| H2:GCH 8 | 81.48 | 16.58 | 73.82 | 88.63 |
| SEm ± | 1.67 | 0.35 | 1.44 | 1.85 |
| CD (P=0.05) | NS | 1.04 | NS | 5.44 |
| Methods of planting | | | | |
| P1: Direct seeds sowing | 84.06 | 17.67 | 74.30 | 89.09 |
| P2: Transplanting | 82.14 | 16.94 | 70.30 | 82.50 |
| SEm ± | 1.67 | 0.35 | 1.44 | 1.85 |
| CD (P=0.05) | NS | NS | NS | 5.44 |
| Fertility levels | | | | |
| F1: 75% RDF | 80.06 | 16.03 | 70.03 | 83.00 |
| F2: 100% RDF | 86.14 | 18.58 | 74.57 | 88.60 |
| SEm ± | 1.67 | 0.35 | 1.44 | 1.85 |
| CD (P=0.05) | 4.92 | 1.04 | 4.23 | 5.44 |

Table 2 Effect of hybrids, planting methods and fertility levels on yield attributes and yield of castor

| Treatments | Seed yield /plant (g) | 100-seed weight (g) | No. of spikes/ plant | Seed yield (kg/ha) | Stalk yield (kg/ha) |
|---|---|---|---|---|---|
| Hybrids | | | | | |
| H1: GCH 7 | 626.69 | 29.79 | 16.85 | 2908 | 4716 |
| H2:GCH 8 | 686.30 | 32.49 | 20.01 | 3220 | 5340 |
| SEm ± | 16.61 | 0.46 | 0.31 | 83.75 | 168.64 |
| CD (P=0.05) | 48.84 | 1.34 | 0.92 | 246.30 | 495.98 |
| Methods of planting | | | | | |
| P1: Direct seeds sowing | 688.65 | 31.81 | 19.60 | 3230 | 5361 |
| P2: Transplanting | 624.35 | 30.47 | 17.26 | 2897 | 4695 |
| SEm ± | 16.61 | 0.46 | 0.31 | 83.75 | 168.64 |
| CD (P=0.05) | 48.84 | NS | 0.92 | 246.30 | 495.98 |
| Fertility levels | | | | | |
| F1: 75% RDF | 624.47 | 30.28 | 17.20 | 2937 | 4775 |
| F2: 100% RDF | 688.53 | 32.00 | 19.66 | 3190 | 5281 |
| SEm ± | 16.61 | 0.46 | 0.31 | 83.75 | 168.64 |
| CD (P=0.05) | 48.84 | 1.34 | 0.92 | 246.30 | 495.98 |

Table 3 Effect of hybrids, planting methods and fertility levels on soil fertility status after harvest of castor

| Treatments | Available nutrients | | | |
|---|---|---|---|---|
| | N (kg/ha) | $P_2O_5$ (kg/ha) | $K_2O$ (kg/ha) | S (mg/kg) |
| Hybrids | | | | |
| H1: GCH 7 | 148 | 46.6 | 247 | 12.34 |
| H2:GCH 8 | 152 | 48.1 | 251 | 12.81 |
| SEm ± | 2.8 | 0.9 | 5.9 | 0.3 |
| CD (P=0.05) | NS | NS | NS | NS |
| Methods of planting | | | | |
| P1: Direct seed sowing | 153 | 48.7 | 252 | 13.01 |
| P2: Transplanting | 147 | 46.0 | 245 | 12.14 |
| SEm ± | 2.8 | 0.9 | 5.9 | 0.3 |
| CD (P=0.05) | NS | 2.6 | NS | 0.78 |
| Fertility levels | | | | |
| F1: 75% RDF | 144 | 44.9 | 241 | 11.80 |
| F2: 100% RDF | 156 | 49.8 | 256 | 13.35 |
| SEm ± | 2.8 | 0.9 | 5.9 | 0.3 |
| CD (P=0.05) | 8.3 | 2.6 | NS | 0.78 |

## REFERENCES


Anonymous 2021. Ministry of Agriculture, Government of India.

Chauhan S and Yakadri Y 2004. Sowing date and genotype effects on performance of *rabi* castor (*Ricinus communis* L.) in Alfisols. *Journal of Research*, **32**(2): 90-92.

Chauhan J S, Choudhury P R and Singh K H 2021. Production, varietal improvement programme and seed availability of annual oilseeds in India: Current scenario and future prospects. *Journal of Oilseeds Research*, **38**(1): 1-18.

Gomez K A and Gomez A A 1984. *Statistical Procedures for Agricultural Research* (2nd Ed). John Wiley and Sons Interscience Publication, New York, USA.

Jat A L and Desai A G 2020. Growth, productivity behavior and economics of castor (*Ricinus communis* L.) hybrids as influenced by different fertility levels under North Gujarat agro-climatic region. *Annals of Arid Zone,* **59**(3&4): 101-105.

Narkhede B N, Patil A B and Deokar A B 1984. Varietal response to plant densities and nitrogen application in castor. *Journal of Oilseeds Research*, **1**(2): 109-114.

Ramesh, Rakesh Choudhary, Mamta Nehra and Manish Kumar 2021. Combining ability analysis of newly developed male lines of castor (*Ricinus communis* L.) in Rajasthan. *Journal of Oilseeds Research*, **38**(4): 337-342.

Raj A D, Patel B S and Mehta R S. 2010. Effect of furrow irrigation and hybrid varieties on growth, yield and water use efficiency of castor (*Ricinus communis* L.). *International Journal of Tropical Agriculture,* **28**(1-2): 117-122.

Rana D S, Giri G and Panchuri D K 2006. Evaluation of castor genotypes for productivity, economics, litter fall and changes in soil properties under different levels of inter-row spacing and nitrogen. *Indian Journal of Agronomy*, **51**(4): 318-322.

Rodriguez O A V and Vazquez A P 2019. Seedling characteristics of three oily species before and after root pruning and transplant. *Plants,* **8**(258): 1-19.

Senthil Kumar G and Venkatachalam S R 2018. Effect of spacing and spike maintenance for yield maximization in castor (*Ricinus communis* L.). *International Journal of Chemical Studies*, **6**(2): 1834-1836.

Severino L S, Dick L A, Marco B, Candido M J D, Chen G, Crosby W, Xiaohua He T D, Lakshmamma P, Lavanya C, Machado O L T, Mielke T, Milani M, Miller T D, Morris J B, Morse S A, Navas A A, Soars D J, Sofiatti V, Wang M L, Zanotto M D and Zielder H 2012. A review on the challenges for increased production of castor. *Agronomy Journal*, **104**(4): 853-880.

Weiss E A 1983. *Oilseed crops.* Longman Group Ltd, 31-99 pp.

# Evaluation of suitable method of composting castor shell and stalk

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ABSTRACT

The experiments on evaluating composting method with different treatments were conducted for four consecutive years at the Castor-Mustard Research Station, S D Agricultural University, Sardarkrushinagar during 2018-21 the nutrient composition of composted castor shell and stalk were examined. The results indicated that composted fresh castor shell or shredded stalk compost (approx. 1000 kg) treated with cow dung (100 kg) + urea solution (4 kg/200 L water) + SSP (5 kg) along with microbial consortium @ 1 kg resulted in highest N, P, K content and micronutrient content (Fe, Mn, Zn and Cu). The cost of production of compost was ₹ 6.81 per kg of shell and ₹ 6.76 per kg stalk respectively.

**Keywords**: Castor shell, Castor stalk, Compost, Micronutrients, Nutrient content

Castor (*Ricinus communis* L.) is grown in tropical and subtropical regions of the world and cultivated in about 30 different countries including India, China, Brazil, Thailand, Philippines and Russia. As non-edible industrial oilseed crop. Castor is widely cultivated oilseed crop in semi-arid and arid areas and India is the world leader in castor area, production and productivity. Castor is cultivated in India in about 0.81 m ha area with 1.79 mt production and an average productivity of 2228 kg/ha. Gujarat is the leading castor growing state in India, besides, Andhra Pradesh, Rajasthan, Tamil Nadu, Karnataka and Orissa, having 6.5 lakh hectares cultivated area (84%) with 15.5 lakh tonnes production (68 %) and 2371 kg/ha average productivity (Anonymous, 2022; Patel *et al.,* 2021). Castor seed contains approximately 45-55% oil and 15-20% protein. The castor oil has more than 700 uses, ranging from medicine and cosmetics to biodiesel, plastics and lubricants, especially due to high viscosity and boiling and low melting points therefore demanded by the industries in most of industrial countries of world (Salihu *et al*., 2014). Castor seed meal is also a source of protein, but due to presence of 'ricin' toxin it is unsuitable as a feed constituent and used as manure. Cultivation of castor generates two main by-products: stalk (stem) and shell (husks) after harvesting and processing of the produce. For each ton of castor seed, 2.15 ton of castor stalk and 0.35 ton of shell are produced. As per rough estimates, in India every year 2.86 mt castor stalk (castor stalk is about 65 % of total biomass) and around 8 lakh tones of castor shell are produced which is of no use other than burning due to their high calorific values. Its shell and stalk contains nitrogen, phosphorus, potassium, manganese, zinc, copper, iron and other essential plant nutrients (Agarwal *et al*., 2015). The lignin rich composition of these biological wastes make them non-suitable for quick composting like pulse waste (Shah *et al*., 2015; Zhang *et al.,* 2019). In India and other developing countries growing castor, the castor shell and stalk could be used as soil amendment and manure to improve soil structure, enhance nutrient recycling, supplement to chemical fertilizer and alternate source of in-situ source of plant nutrients (Livleen *et al.,* 2016). Composting could be an alternative to use these biological castor wastes into nutrient rich compost by following suitable method and quantification of nutrient content is not properly understood. Keeping this in view, the present study was conducted to study of nutrient enrichment as a result of composting of castor shell and stalk.

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## MATERIALS AND METHODS

After the harvest of castor crop, the castor shell and stalk composts were prepared from different materials at Castor-Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar, Gujarat. Each year the composting experiment was conducted in two different sets of similar treatments of stalk and husk biomass. Composting was done by using the following treatments:

**A. For castor shell compost**
T1: Shredded castor shell + 10% dung slurry
T2: T1 + 2% urea solution + 0.5% SSP (weight basis)
T3: T1 + microbial consortium @ 1 kg/t
T4: T2 + microbial consortium @ 1 kg/t
**B. For castor stalk compost**
T1: Shredded castor stalk + 10% dung slurry
T2: T1 + 2% urea solution + 0.5% SSP (weight basis)
T3: T1 + microbial consortium @ 1 kg/t
T4: T2 + microbial consortium @ 1 kg/t

The dimension of each heap was maintained as 15 ft x 3.5ft x 3.0 ft for castor shell compost and 15 ft x 4.0ft x 4.0

ft for stalk compost initially. The initial mass of compost used for the study was nearly 1 ton. The compost was turned on every fortnight. The compost was kept moist by sprinkling water on weekly intervals. The five composting samples with one suntreated check sample were taken before watering or before turning of compost heaps for studying various parameters. pH and EC of compost was measured as per standard method, while Micro-Kjeldhal method was used for estimating total N, di-acid digests for P and K using spectrophotometer and flame photometer, respectively (Jackson, 1973). During composting, the temperature of the compost pile (depth of the pile was 3 ft) was measured in the upper (10 cm below the top of the pile), middle and lower (10 cm above the bottom of the pile) parts at every fortnight. The compost samples were dried at 65°C for determination of pH, total nitrogen, total phosphorus, total potassium and micro nutrients were based on the method used by (Zhang *et al*., 2019).

## RESULTS AND DISCUSSION

**Effect on temperature**: Temperature is an important indicator for monitoring the composting process. The average value of temperature indicated that in case of castor shell the temperature increased and reached to highest level of 69.3°C within 3 weeks and continued for nearly next four weeks with a slight decrease (Fig. 1). This could be due to increase in the number of microbial population until the food was available. . The temperature started rising in sixth week and reached to the elevated value during seventh week. This could be due to change in the microbial dynamics during the period. The thermophilic microbes could have consumed all available food and new mesophilic microbes could have able to feed on previously dead and debris of microbes and the partial decomposers and relatively complex biomass. In case of castor stalk, the temperature increased gradually and reached at its peak during sixth and seventh week and decreased gradually (Fig. 2). The rate of increase and decrease in temperature in the heaps were almost identical. The slower increase in temperature could be due to wide packing gaps does not allow temperature to rise, once the gaps between castor stalk reduces by softening the plant tissues, the temperature increased. The slow increase in temperature could facilitate congenial condition for different microbes to act on the castor stalk and carry on the decomposition process. Once, the temperature reached maxima, there could be change in the population dynamics. The slow decrease in temperature could also allow complex biological biomass to participate in the process of microbial decomposition. The organic acids and ammonia produced during the process of composting have antagonistic effect on pathogens and hardly and dormant seeds of weeds. The temperature of 60-70°C that is sufficient enough to destroy many diseases causing agents, harmful insects and weed seeds (Kakde, 2017). Between 50 and 60 days after composting, due to reduced temperature and the accumulation of soluble organic matter, microbial activity increased again leading to another stage of temperature rise in the compost pile, and after 60 days of composting, the temperature slowly decreased. Greyish appearance of actinomycetes in large cluster was also visible and it could decompose more resistant materials in a pile such as lignin, cellulose, starches, proteins and waxes during the later stages of decomposition (Fig. 3 and Fig. 4).

**Effect on pH**: The pH of shell compost increased just after composting upto 3$^{rd}$ week (except T1), after 7$^{th}$ week of composting it decreased gradually while, the pH of stalk compost increased just after composting but after that sharply decreased and attained almost steady value after 6-7 weeks onwards. The pH of final castor shell compost was in neutral range for the treatments T3 and T4 indicating addition of microbes helped in reducing the compost pH by producing organic acids which further helped in the process of composting of shell. While in case of castor stalk, the pH of compost increased during the first week in all the treatments and then declined sharply up to 3$^{rd}$ week and slight lowered during 4$^{th}$ week. The pH was found increasing from 4$^{th}$ week and reached to maxima during 6$^{th}$ week (T1), 5$^{th}$ week (T2), 7$^{th}$ week (T4 and T3). Afterwards it decreased slowly. In all the treatments the final compost pH was found neutral in reaction. Composting microbes use carbon as energy source and nitrogen for growth (protein synthesis). During the early stages of decomposition, organic acids were formed, and this acidic condition favoured the growth of fungi and disintegration of lignin and cellulose. This changes in pH might be due to the breakdown of phenolic acid compounds in the raw materials, as well as the breakdown of proteins and amino acids by microbes (Fig 5 and 6).

**Effect on EC**: The data of electrical conductivity (EC) of composted shell and stalk, decreased gradually after 4th week (Except T1) (Fig 2 to 5). The decrease in EC value could be due to synthesis of more electrically inert compound or formation of stable salts, organic compounds or chelates (Table 1 and 2).

**Effect on nutrient content**: The N and P content of final castor shell compost was found maximum 1.5 % and 0.9 %, respectively while in castor stalk it was 1.2 % and 0.6 %, respectively in the treatment T4 in both the cases (Table 3, 4 and Fig. 7, 8). The micronutrient cations also increased by the process of composting in both the cases. The highest

value of Fe, Mn, Zn and Cu was 6514, 160, 52 and 22 ppm, respectively in castor shell compost while in case of castor stalk were 1966, 173, 52.5 and 19 ppm, respectively (Table 3 and 4).

On the basis of correlation studies, in the castor shell compost, N was positively correlated with Fe (0.992**), Mn (0.995**), Zn (0.980*) and Cu (0.960*). While Ps and K could not express any significant correlation with nutrients under study. Fe content was positively correlated with Mn (0.997**) and Zn (0.956*); Mn content was positively correlated with Zn (0.974*) and Cu (0.958*) while Cu content was positively correlated with Zn content (0.996 **) (Table 5). In the castor stalk compost, N was positively correlated with Fe (0.998**) and Zn (0.964*). While phosphorus and potassium could not express any significant correlation with nutrients under study. Iron content was positively correlated with Zn (0.970*); manganese content was positively correlated with Zn (0.957*) (Table 6). This could be due to composting is done by the addition of composting microbes, urea and single super phosphate at the time of compost heap preparation. The nitrogen and phosphorous addition in compost helped in increasing the number of microbes by providing easily utilizable forms ($NO_{3-}$, $NH_4^+$, and $H_2PO_4^-$, $HPO_{4--}$ and organic forms) to the microbes (Singh and Longkumer, 2018). The Compost quality varies with the kind of raw organic materials (feedstock), the composting process used, and the state of biological activity. The treatment T4 received additional supply of composting microbes (mostly thermophylic), readily available nitrogen and phosphorus in form of urea and single super phosphate to multiply and grow in their numbers. Considering the average nutrient value of castor shell or shredded stalk compost, the maximum N, P and K content and micronutrient cations like Fe, Mn, Zn and Cu was found in treatment T4. This might be caused by the mineralization of organic matter during composting, loss of $CO_2$, and evaporative loss of water driven by heat production during the oxidation of organic matter. After complete composting process, Treatment T4 (castor shell or shredded stalk + 10 % cow dung + 2% urea solution (200 L ) + 0.5% SSP + microbial consortium) is found highest final weight (yield) of compost heap. The cost of production of compost was ₹ 6.81 per kg of shell compost while ₹ 6.76 per kg for stalk compost. Through composting, organic chemicals in the shell were transformed by microbes into a stable, usable, and high value-added compost product, which helps prevent environmental pollution. Such products not only provide nutrients for plant growth but also improve soil properties, such as nutrients increase in soil and physical properties improvement of soil (Ramaswamy *et al*., 2010).

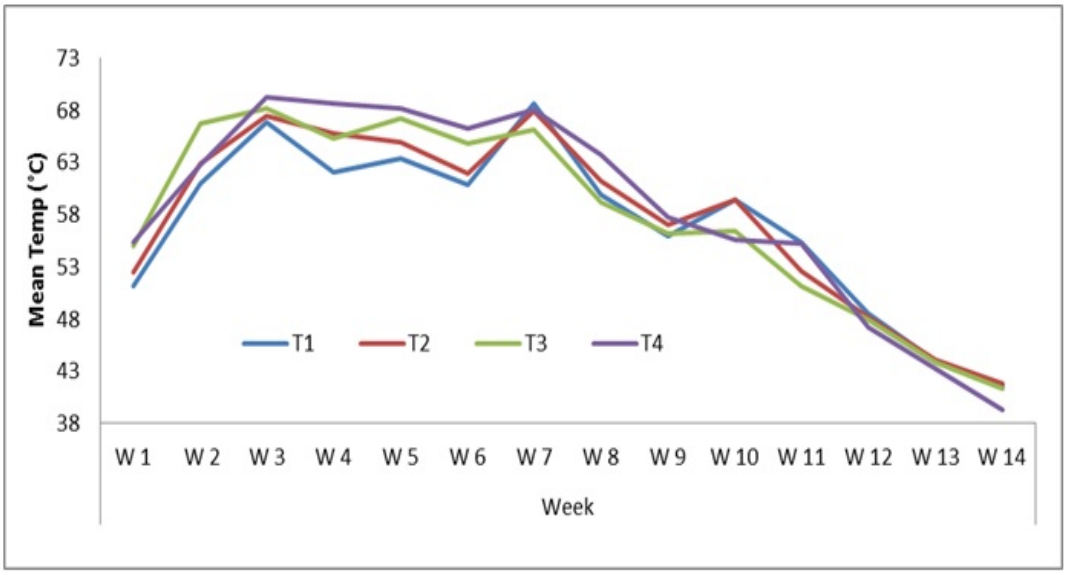


Fig. 1. Effect of different treatments on temperature (°C) of castor shell compost heaps (4 year mean value)

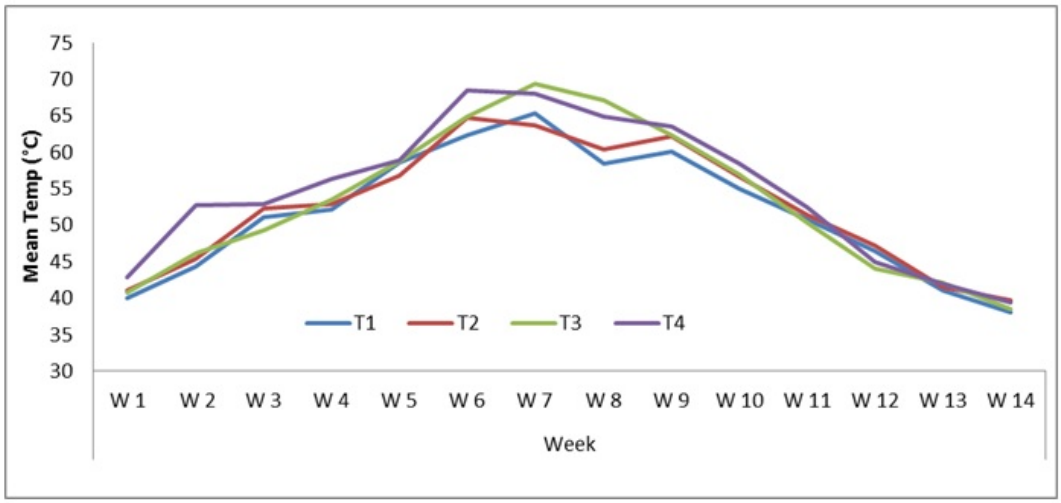


Fig. 2. Effect of different treatments on temp (°C) of castor stalk compost heaps (4-year mean value)

Fig. 3. Cross section view of castor shell compost heap (Treatment T4) at 60 days

Fig. 4. Cross section view of castor stalk compost heap (Treatment T4) at 60 days

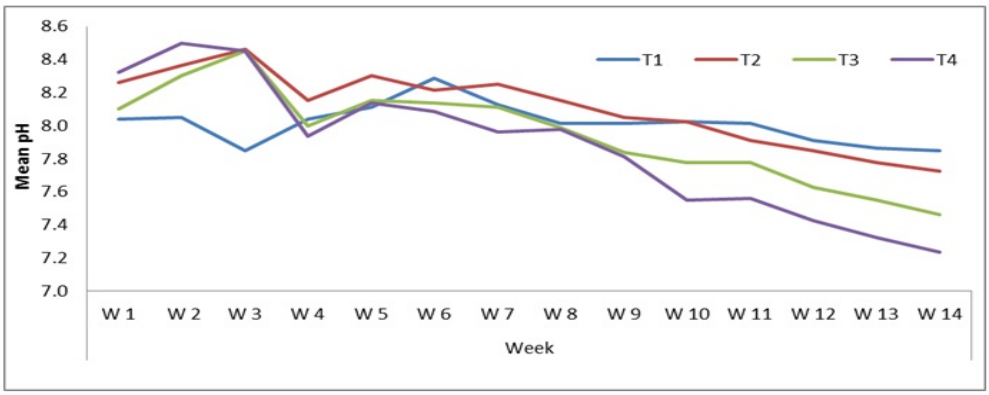


Fig. 5. Effect of different treatments on pH of castor shell compost heaps (4 year average value)

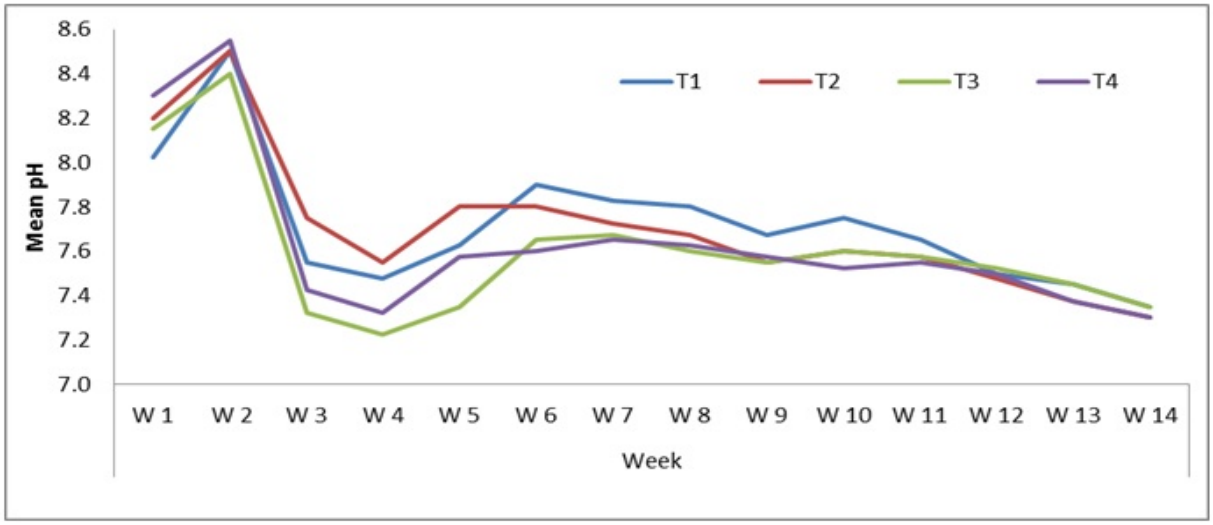


Fig. 6. Effect of different treatments on pH of castor shredded stalk compost heaps (4 year average value)

Fig. 7. Finally prepared castor shell compost

Fig. 8. Finally prepared castor stalk compost

Table 1 Effect of different treatments on EC ($dSm^{-1}$) of castor shell composting (4 years average value)

| Treatments | Week | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W 1 | W 2 | W 3 | W 4 | W 5 | W 6 | W 7 | W 8 | W 9 | W 10 | W 11 | W 12 | W 13 | W 14 |
| T1: Castor shell + 10% dung slurry | 3.4 | 3.8 | 3.8 | 3.9 | 4.0 | 4.0 | 4.1 | 4.1 | 3.8 | 3.5 | 3.3 | 3.3 | 3.0 | 2.9 |
| T2: T1 + 2% urea solution + 0.5% SSP (weight basis) | 3.9 | 4.0 | 4.1 | 4.3 | 4.1 | 4.1 | 3.7 | 3.5 | 3.3 | 3.1 | 2.9 | 2.6 | 2.5 | 2.4 |
| T3: T1 + microbial consortium @ 1 kg/t | 3.7 | 4.1 | 4.2 | 4.3 | 4.1 | 3.9 | 3.7 | 3.5 | 3.3 | 3.0 | 2.7 | 2.4 | 2.2 | 2.1 |
| T4: T2 + microbial consortium @ 1 kg/t | 4.1 | 4.2 | 4.3 | 4.3 | 4.2 | 4.0 | 3.8 | 3.5 | 3.2 | 2.9 | 2.7 | 2.4 | 2.2 | 2.1 |

Table 2 Effect of different treatments on EC ($dSm^{-1}$) of castor stalk composting (4 years average value)

| Treatments | Week | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W 1 | W 2 | W 3 | W 4 | W 5 | W 6 | W 7 | W 8 | W 9 | W 10 | W 11 | W 12 | W 13 | W 14 |
| T1: Shredded castor stalk + 10% dung slurry | 3.2 | 2.9 | 2.9 | 2.8 | 2.8 | 2.9 | 2.9 | 3.0 | 2.7 | 2.7 | 2.5 | 2.3 | 2.2 | 2.1 |
| T2: T1 + 2% urea solution + 0.5% SSP (weight basis) | 3.6 | 3.7 | 3.7 | 3.4 | 3.2 | 3.0 | 2.8 | 2.6 | 2.4 | 2.2 | 2.0 | 1.7 | 1.6 | 1.5 |
| T3: T1 + microbial consortium @ 1 kg/t | 3.3 | 3.4 | 3.3 | 3.0 | 2.8 | 2.7 | 2.6 | 2.4 | 2.2 | 2.0 | 1.7 | 1.6 | 1.4 | 1.3 |
| T4: T2 + microbial consortium @ 1 kg/t | 3.4 | 3.2 | 3.2 | 2.9 | 2.8 | 2.7 | 2.6 | 2.4 | 2.2 | 2.0 | 1.7 | 1.5 | 1.4 | 1.3 |

Table 3 Average nutrient content in castor shell compost heaps as influenced by different treatments and production cost

| Treatments | N (%) | P (%) | K (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) | Production cost (Rs/kg) |
|---|---|---|---|---|---|---|---|---|
| T1: Castor shell + 10% dung slurry | 0.9 | 0.7 | 1.5 | 4967 | 118 | 34 | 14 | 8.03 |
| T2: T1 + 2% urea solution + 0.5% SSP (weight basis) | 1.2 | 0.8 | 1.5 | 5802 | 138 | 40 | 16 | 7.24 |
| T3: T1 + microbial consortium @ 1 kg/t | 1.2 | 0.7 | 1.6 | 5909 | 142 | 41 | 17 | 7.21 |
| T4: T2 + microbial consortium @ 1 kg/t | 1.5 | 0.9 | 1.6 | 6514 | 160 | 52 | 22 | 6.81 |
| Initial | 0.6 | 0.4 | 0.8 | 1750 | 79 | 31 | 11 | - |

Table 4 Average nutrient content in castor stalk compost heaps as influenced by different treatments and production cost

| Treatments | N (%) | P (%) | K (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) | Production cost (Rs/kg) |
|---|---|---|---|---|---|---|---|---|
| T1: Shredded castor stalk + 10% dung slurry | 0.5 | 0.5 | 0.7 | 920.0 | 111.8 | 43.5 | 16.0 | 7.54 |
| T2: T1 + 2% urea solution + 0.5% SSP (weight basis) | 0.9 | 0.6 | 0.6 | 1553.0 | 124.8 | 47.8 | 17.0 | 6.99 |
| T3: T1 + microbial consortium @ 1 kg/t | 1.0 | 0.6 | 0.7 | 1636.8 | 136.8 | 47.8 | 16.5 | 6.88 |
| T4: T2 + microbial consortium @ 1 kg/t | 1.2 | 0.6 | 0.7 | 1966.3 | 173.0 | 52.5 | 19.3 | 6.76 |
| Initial | 0.3 | 0.4 | 0.4 | 315.8 | 72.3 | 28.5 | 7.3 | - |

Table 5 Correlation metrics of different parameters of composting of castor shell

| Parameters | N | P | K | Fe | Mn | Zn | Cu |
|---|---|---|---|---|---|---|---|
| N | | | | | | | |
| P | 0.853NS | | | | | | |
| K | 0.707NS | 0.302NS | | | | | |
| Fe | 0.992** | 0.785NS | 0.750NS | | | | |
| Mn | 0.995** | 0.798NS | 0.770NS | 0.997** | | | |
| Zn | 0.980* | 0.870NS | 0.731NS | 0.956* | 0.974* | | |
| Cu | 0.960* | 0.844NS | 0.763NS | 0.934NS | 0.958* | 0.996** | 1.000 |

Table 6 Correlation metrics of different parameters of composting of castor stalk

| Parameters | N | P | K | Fe | Mn | Zn | Cu |
|---|---|---|---|---|---|---|---|
| N | | | | | | | |
| P | 0.906NS | | | | | | |
| K | -0.000NS | -0.333NS | | | | | |
| Fe | 0.998** | 0.913NS | -0.052NS | | | | |
| Mn | 0.897NS | 0.628NS | 0.299NS | 0.890NS | | | |
| Zn | 0.964* | 0.798NS | 0.018NS | 0.970* | 0.957* | | |
| Cu | 0.807NS | 0.549NS | 0.091NS | 0.820NS | 0.941NS | 0.935NS | 1.000 |

The castor growing farmers are recommended to utilize by-product of castor crop i.e. stalk and shell by heap method of composting using either castor shell or shredded stalk compost (1 tons) + cow dung (10%) + urea solution (4 kg/200 L water) + SSP (5 kg) along with microbial consortium @ 1 kg. The compost heaps need turning 6 times at fortnight interval and watering to keep them moist. The final castor shell compost has an average N, P, K content (1.5, 0.9 and 1.6%) while the castor shredded stalk compost has an average N, P, K content (1.2, 0.6 and 0.7%) which could be used as a source of nutrients in raising the crops sustainably.

## REFERENCES


Agarwal R, Chaudhary M and Singh J 2015. Waste management initiatives in India for human wellbeing. *European Scientific Journal*, **11**(10) 105-127.

Anonymus 2022. *State- wise area, production and productivity of castor seeds in India, 2019-20 to 2021-22*. The Solvent Extractors Association of India.

Jackson M L 1973. *Soil chemical analysis.* New Delhi: Prentice Hall of India Pvt. Ltd. 498p.

Livleen S, Satish D L, Indra M M, Archna S and Annapurna K 2016. Rural composting for improvement of soil health and sustainable agriculture. *Agri Res & Tech: Open Access J*. **1**(5): 105-112.

Kakde S V 2017. Biodegradation of agricultural residues and oily waste, their effect on vegetable crop yield. *International Journal of Science and Research,* **6** (7): 681-687.

Patel D K, Patel D A, Patel J R and Patel K V 2021. Generation mean analysis for seed yield and its component traits in five crosses of castor (*Ricinus communis* L.). *Journal of Oilseeds Research*, **38**(1): 25-36.

Ramaswamy J, Prasher S O, Patel R M, Hussain S A and Barrington S F 2010. The effect of composting on the degradation of a veterinary pharmaceutical. *Bioresource Technology*, **101**(7): 2294-2299.

Salihu B Z, Gana A K and Apuyor B O 2014. Castor oil plant (*Ricinus communis* L.): Botany, ecology and uses. *International Journal of Science and Research*, **5**(6): 1333-1340.

Singh R K and Longkumer T E 2018. *Compost: The black gold.* Krishi Vigyan Kendra -Phek, ICAR - NRC on Mithun, Porba, Phek, Nagaland, 112p.

Shah S K, Patel C J, Rathore B S and Desai A G 2015. Evaluation of castor stem residues for cellulose and lignin content. *International Journal of Agriculture, Environment & Biotechnology*, **8**:2, 331-334.

Varshney A C, Bhoi K L and Mehta B P 1987. Evaluation of crop residues of north Gujarat. *Biological Wastes*, **19** (3): 227-231.

Zhang J, Ying Y and Yao X 2019. Effects of turning frequency on the nutrients of *Camellia oleifera* shell co-compost with goat dung and evaluation of co-compost maturity. *PLOS One*, **14**(9): e0222841.

# Seed priming with antioxidants improves physiological parameters in sunflower cv. Co-2 under unfavourable germination conditions

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ABSTRACT

The results of studying the effects of sunflower seed priming with 4 different antioxidants at 2 different concentrations under three unfavourable germination are presented in this paper. The goal of the study was to determine the impact of antioxidants on the physiological performance of sunflower seeds under favourable and different unfavourable germination conditions. The findings showed that seed germination was more stressed at 40°C and 100% RH. The effect of stress was minimized by seed priming with Butylated hydroxy toluene 0.1% followed by Butylated hydhydroxy toluene 2 % by recording 7 and 4 per cent higher germination over control. The seedling growth parameters viz., root and shoot length, seedling dry matter production and vigour indices were influenced negatively by NaCl 0.1 % stress condition. Under unfavourable germination conditions, seed priming with Butylated Hydroxytoluene (BHT) at 0.1 per cent, followed by α- Tocopherol at 0.5 per cent, and Ascorbic acid at 1.0 per cent, was observed to improve seedling growth characteristics.

**Keywords**: Antioxidants, Butylated hydroxytoluene, Germination and vigour, Seed priming, Sunflower

Sunflower (*Helianthus annuus* L.) is a common oilseed crop of India with wider utility. It is used as a source of edible oil and as raw material for agri - based industry. The seed contains 45-50% good quality oil. Crop production depends heavily on the planting of high quality seeds. Rapid and uniform emergence is almost important on which stand establishment is based. Absolute longevity depends on initial seed quality, vigour and proper storage. Oil seeds are very sensitive to the harsh environmental conditions. It is hypothesized that their oil content readily oxidizes which deteriorate the seeds in storage (Wilson and Mc Donald, 1986). In ancient days, various seed treatments were practiced as initial production techniques for improved productivity. One programmatic approach to increase crop production is seed invigouration (Farooq *et al.,* 2006). Seed invigouration strategies include hardening, osmo hardening, osmo conditioning, hydropriming, hormonal priming, matri-priming and others (Windauer *et al.,* 2007).

Seed priming is one of the physiological methods, which improves seed performance and provides faster and synchronized germination. Priming is frequently used to hasten germination and promote uniformity of different crops, especially in difficult emerging conditions (McDonald, 2000; Halmer, 2004; Chowdary *et al.,* 2021). Seed priming influences germination rate, seed vigour, and seedling development in addition to the percentage of seeds that germinate under various ecological conditions.

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This technique has become a common seed treatment that can increase the percentage and uniformity of germination or seedling emergence, mainly under unfavourable environmental conditions (Halmer, 2004).Upon rehydration, primed seeds may exhibit faster rates of germination, more uniform emergence, greater tolerance to environmental stress and reduced dormancy in many species (Khan, 1992). Therefore, there is a strong interest in the seed industry to find suitable priming agent(s) that might be used to increase the tolerance of plants under adverse field conditions (Job *et al.,* 1997; Langhi *et al.,* 2021).

Behairy *et al.* (2012) observed that seeds primed with antioxidants creased germination and seedling shoot length under salt stress as compared with not treated seeds in a sunflower. In sunflower seed priming with antioxidants has beneficial effects on germination even at lower temperatures (Bailly *et al.,* 2000). Seed priming with the solution of antioxidant substances performed prior to accelerated ageing had a positive effect on the length of both roots and shoots (Draganic, 2012). The aim of this study was to observe whether priming with an aqueous solution of antioxidants has an effect on sunflower seed performance under unfavourable germination conditions.

## MATERIALS AND METHODS

**Experimental materials**: Pure seeds of the Co-2 cultivar of sunflower, to understand the physiological mechanisms of adaptation to different stress during the seed germination were collected from the Department of Oilseeds, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore which formed the base material for the study. Uniform sized seeds were selected. The sunflower

hybrid Co-2 seeds were primed with different antioxidant solutions for 12 hrs. T1-α-Tocopherol 0.5 %, T2-α-Tocopherol 1.0 %, T3-Ascorbic acid 0.5 %, T4-Ascorbic acid 1.0 %, T5-Glutathione 0.05 %, T6-Glutathione 0.1 %, T7-Butylated hydroxytoluene 0.1 %, T8-Butylated hydroxytoluene 0.2 %, T9-Control. After the expiry of soaking duration, the seeds were dried back to their original moisture content and tested for various seed quality parameters. Thus all 9 treatments were considered as a factor (1). Primed seeds were subjected to three unfavourable germination conditions along with favourable germination conditions as the trials for germination conditions were conducted in four set of temperatures with relative humidities. C1- 25± 2°C and 95± 3% RH, C2- 40°C and 100% RH, C3- 15°C and 100% RH, C4-Pre- moistened media with NaCl 0.1% solution + 25± 2°C and 95± 3% RH. Thus all the 4 conditions considered as sub factor (2). Optimal conditions with respect to light and moisture were maintained for proper germination and development of seedlings. The physiological parameters were measured to evaluate the response of Co-2 cultivar to high temperature stress.

**Methodology**: The details of each observation recorded in three replications have been given below:

**Germination (%) (ISTA, 2020)**: The germination test was conducted with 4x100 seeds each using a paper medium. The germination set up has been placed in a germination room maintained at 25 ± 2°C and 95 ± 3 per cent relative humidity. At the end of 10 days of the germination period recommended as per ISTA (2020), the seedlings were evaluated. Based on the mean number of normal seedlings developed, the mean germination was expressed in percentage.

**Abnormal seedling (%)**: The seedlings were evaluated. Based on the mean number of abnormal seedlings developed, the mean abnormal seedlings were expressed in per cent.

**Root length (cm)**: Ten normal seedlings were selected at random from each replication and the length of the root was measured from the collar region to the tip of the primary root and the mean was expressed in centimeter.

**Shoot length (cm)**: Ten normal seedlings were selected at random from each replication and the distance between the collar regions to the tip of the primary leaf was measured and the mean was expressed in centimeter.

**Total seedling length (cm)**: On the day of the final count, 10 normal seedlings were randomly selected from the germination test. The length between the collar region and the tip of the primary shoot was measured as the shoot length, and the length between the collar region and tip of the primary root was measured as the root length. The total seedling length (TSL) was calculated by adding the shoot and root lengths together (ISTA, 2020) and the average seedling length for each genotype in all replications and treatment combinations were recorded. The values of TSL were used for calculations of seedling vigour index (SVI) -I.

**Seedling dry matter production (g/10 seedlings)**: After measuring the root and shoot length, the ten normal seedlings in each replication were shade dried for 24 h and then in a hot air oven maintained at 70±1°C for 48 h. Then, they were cooled for 30 min in a desiccator which contained calcium chloride and then weighed in an electronic balance. The mean weight was expressed as dry matter production of 10 seedlings in gram.

**Vigour index I (Abdul-Baki and Anderson, 1973)**: Vigour index (VI) was computed using the following formula and expressed as a whole number.

Vigour index I = Germination percentage × Seedling length (cm)

**Vigour index II**: The Vigour index was computed by using the following formula and expressed in whole numbers (Abdul-Baki and Anderson, 1973).

Vigour index II = Germination (%) dry weight of 10 seedlings

**Experimental design and statistical analyses**: The data of the experiment were collected and arranged in a factorial completely randomized design with four levels of Factor 1 (Treatments) and 19 levels of Factor 2 (Conditions). Three replications for all the treatment combinations were applied in which 100 seeds per replication were used. Analysis of variance (ANOVA) from the data was employed to compute variable effects in both the factors and their interaction. Significant differences between means of treatments, conditions, and interactions were calculated using the least significant difference and compared the means exercising Tukey's test at $P \leq 0.05$.

## RESULTS AND DISCUSSION

**Effect of priming treatments**: Priming with antioxidants expressed a significant influence on germination and abnormal seedling %. The difference in germination % and abnormal seedling (%) was statistically significant due to priming treatments. Among the treatments, irrespective of germination conditions provided, (T7) Butylated hydroxyl toluene 0.1% recorded the highest germination of 79 % and minimum abnormal seedling (19%) followed by (T5) Glutathione 0.05% (78 %) germination and 20 % abnormal seedlings. Minimum germination (71%) and maximum

abnormal seedlings (25 %) were observed in control (T9) (Table 1 and 2). Similar findings were reported by Ghassemi-golezani *et al*. (2008) in lentil.

A significant variation in shoot length and root length was observed due to priming treatments. A longer root was measured when the seeds were primed with (T1) α-Tocopherol 0.5 % up to 30.5 cm while, (T9) control seeds measured the shortest root of 26.3 cm. The longest shoot was recorded in the seeds primed with (T7) Butylated hydroxytoluene 0.1% of 20.7cm followed by (T1) α-Tocopherol 0.5% (20.1cm) and (T5) Glutathione 0.05% (19.9cm) shoot length when compared to (T9) control with only 17.9cm (Table 3). Similarly, the result obtained by Draganic *et al.* (2012) notified that seed priming with different combinations of antioxidants resulted in an increase in root length over the control in medium vigour seeds.

Seedling dry matter production was significantly influenced by priming treatments. Among the treatments, irrespective of germination conditions provided, (T7) Butylated hydroxytoluene 0.1% recorded the maximum seedling dry matter production (0.324 g 10 seedlings -1) which was on par with (T2) α-Tocopherol 1% (0.318 g 10 seedlings-1). Whereas, (T9) control recorded minimum seedling dry matter production with only 0.293 g 10 seedlings-1 (Table 4). Similar findings were reported by Pandita and Nagarajan (2000) in tomato and Sowmya *et al.* (2013) in cucumber. The results of vigour indices for priming treatment. Irrespective of germination conditions provided, (T7) Butylated hydroxytoluene 0.1% recorded the highest vigour index I (3995) and vigour index II (25.7) when compared to control (T9) with only 3156 vigour index I and 20.8 vigour index II.

**Effect of germination conditions**: Researchers have emphasized that seed priming mitigates the adverse effects of different stress factors (Chiu *et al.,* 1995). Hence, present studies were undertaken to assess the physiological performance of sunflower seeds under favourable and different unfavourable germination conditions.

The difference in germination % and abnormal seedling (%) was statistically significant due to germination conditions. Among the germination conditions, (C2) 40°C + 100% RH exerted more stress on germinating seeds by recording only 72% when compared to the favourable condition of (C1) 25±2°C + 95±3% RH with 81% germination. Whereas, maximum abnormal seedlings were recorded in (C3) at 15°C + 100% RH (25% ) due to the impact of stress on germinating seeds when compared to favourable condition of (C1) 25±2°C + 95±3% RH with only 18% (Table 1). The unfavourable germination condition that exerted a minimum effect on the germination was (C4) NaCl 0.1 % with less abnormal seedling at 22 % (Table 1 and 2).

The unfavourable germination condition that exerted a minimum impact on the germination was (C3) 15°C and 100% RH with 75% germination and in the case of abnormal seedling, it was in (C4) NaCl 0.1% i.e. 22% when compared to normal favourable condition (C1). The significant variation in shoot length and root length were observed due to germination conditions Among the stress conditions, (C4) NaCl 0.1% exerted more stress on root length by recording only 27.1 cm when compared to the favourable condition of (C1) 25±2°C and 95±3% RH with (30.3 cm). Among different unfavourable germination conditions, more reduction in shoot length was observed in (C4) NaCl 0.1% by recording only 17.6 cm when compared to the favourable condition of (C1) 25±2°C and 95±3% RH with 20.7cm (Table 3). Numerous researchers have established that seed priming with an osmotic solution, especially under suboptimal temperature conditions, stimulates seed germination of sunflower (Smok *et al.,* 1993), maize, wheat, barley, soya bean (Bodsworth and Bewley, 1981), and sweet maize (Sung and Chang, 1993).

Seedling dry matter production was significantly influenced by germination conditions. Among the germination conditions, (C4) NaCl 0.1% showed reduction in seedling drymatter production with 0.284 g 10 seedlings -1. Whereas, a favourable condition of (C1) 25±2°C and 95±3% RH recorded 0.344 g 10 seedlings-1. The unfavourable germination condition exerted minimum influence on the dry weight of seedlings was (C2) 40°C and 100 % RH with 0.323 g 10 seedlings -1 with a reduction of 6 per cent than normal favourable condition (C1) (Table 4). It may be due to the greater susceptibility of primed seeds to stress is related to the effect of priming and drying on the protection mechanisms encompassing free radical and peroxide-scavenging enzymes, such as superoxide dismutase, catalase, and glutathione reductase (Chojnowski *et al.,* 1997). It was same as previous studies carried out by Chhetri *et al.* (1993) in french bean, peas, lentil, and millet, Draganic (2012) in sunflower.

The results of vigour indices for germination conditions. Among the germination conditions, (C4) NaCl 0.1 % also showed the highest impact of stress on germinating seeds by recording only 3306 vigour index I and vigour index II by recording only (21) when compared to favourable condition of (C1) 25±2°C and 95±3% RH with 4157 vigour index I and vigour index II (28) (Fig.1 and 2). Saline condition showed a reduction in physiological parameters in canola, and it was observed by Hemmat Katab (2007).

**Interaction effect of priming treatments and germination conditions**: From the interaction effect, it was observed that seed primed using (T5) Glutathione 0.05% observed the highest germination (82 per cent).Which was 15.85 % more over control seed under (C3) 15°C + 100 % RH whereas seed primed with (T7) Butylated hydroxy toluene 0.1%

observed minimum abnormal seedling per cent 17 per cent. Whereas, (T6) Glutathione 0.1 % recorded the highest abnormal seedling per cent 31 % under (C2) 40°C and 100% RH (Table 1 and 2). However, the interaction between priming treatments and germination conditions was found to be non-significant for root length but significant for shoot length, hence highest shoot length of 21.5 cm was obtained when seeds primed with (T7) Butylated hydroxytoluene 0.1% were subjected to (C2) 40°C and 100 % RH. Which is 11.16 per cent higher than the (T9) control (19.5).

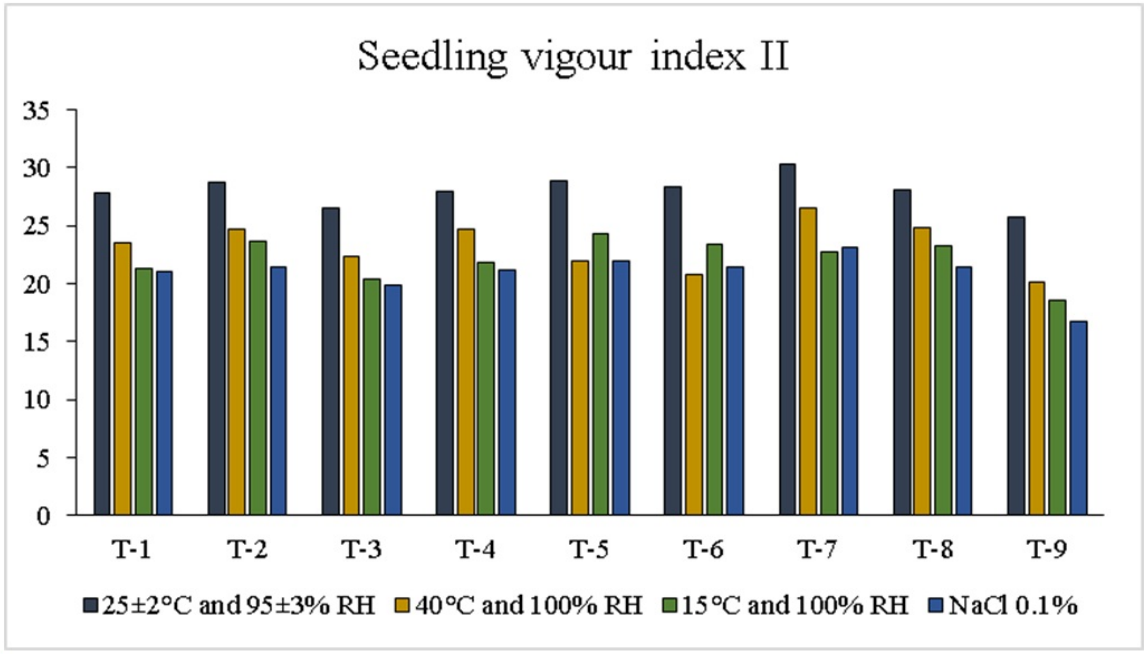


Fig.1. Effect of seed priming with antioxidants on vigour index I under favourable and unfavourable germination conditions in sunflower cv. Co-2

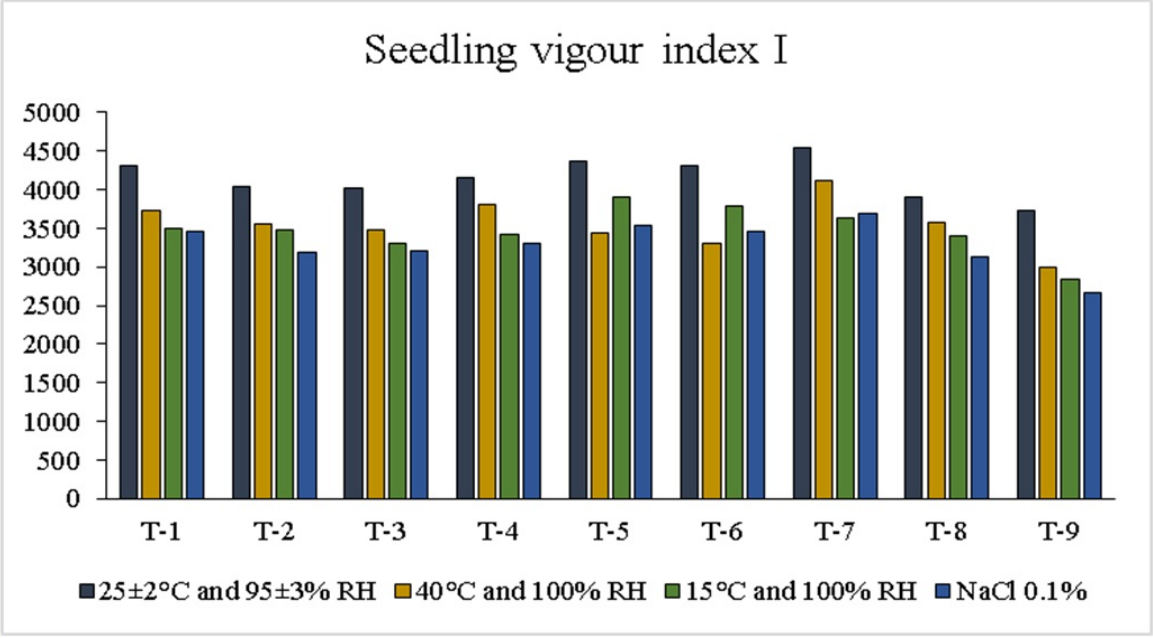


Fig.2. Effect of seed priming with antioxidants on vigour index II under favourable and unfavourable germination conditions in sunflower cv. Co-2

Table 1 Effect of seed priming with antioxidants on germination (%) and abnormal seedling (%) under favourable and unfavourable germination conditions in sunflower cv.CO2

| Treatments (T) | Germination conditions (C) | | | |
|---|---|---|---|---|
| | Germination (%) | | | |
| | (C1) 25±2°C and 95±3% RH | (C2) 40°C and 100% RH | (C3) 15°C and 100% RH | (C4) NaCl 0.1% |
| T1 - α-Tocopherol 0.5% | 80 (63.44) | 72 (58.05) | 71 (57.42) | 73 (58.70) |
| T2 - α-Tocopherol 0.1% | 82 (64.90) | 75 (60.00) | 78 (62.03) | 74 (59.34) |
| T3 - Ascorbic acid 0.5% | 78 (62.03) | 70 (56.79) | 70 (56.79) | 71 (57.42) |
| T4 - Ascorbic acid1.0% | 81 (64.16) | 76 (60.67) | 73 (58.70) | 74 (59.34) |
| T5 - Glutathione 0.05% | 84 (66.42) | 68 (55.55) | 82 (64.90) | 77 (61.34) |
| T6 - Glutathione 0.1% | 83 (65.65) | 65 (53.73) | 80 (63.44) | 76 (60.67) |
| T7 - Butylated hydroxy toluene 0.1% | 85 (67.22) | 79 (62.73) | 74 (59.34) | 78 (62.03) |
| T8 - Butylated hydroxy toluene 0.2% | 81 (64.16) | 76 (60.67) | 78 (62.03) | 75 (60.00) |
| T9- Control | 79 (62.73) | 67 (54.94) | 69 (56.17) | 68 (55.55) |
| Mean | 81 (64.16) | 72 (58.05) | 75 (60.00) | 74 (59.34) |
| | T | C | T x C | |
| SEd | 0.41 | 0.27 | 0.82 | |
| CD (P=0.05) | 0.81** | 0.54** | 1.62** | |

(* and ** represented the differences were significant at the 5 and 1 % levels and values in parentheses ( ) are arc sine transformed values)

Table 2 Effect of seed priming with antioxidants on abnormal seedling (%) under favourable and unfavourable germination conditions in sunflower cv. Co-2

| Treatments (T) | Germination conditions (C) | | | |
|---|---|---|---|---|
| | Abnormal seedling (%) | | | |
| | (C1) 25±2°C and 95±3% RH | (C2) 40°C and 100% RH | (C3) 15°Cand 100% RH | (C4) NaCl 0.1% |
| T1 - α-Tocopherol 0.5% | 20 (26.57) | 24 (29.33) | 29 (32.58) | 23 (28.66) |
| T2 - α-Tocopherol 0.1% | 18 (25.10) | 19 (25.84) | 22 (27.97) | 22 (27.97) |
| T3 - Ascorbic acid 0.5% | 22 (27.97) | 26 (30.66) | 30 (33.21) | 26 (30.66) |
| T4 - Ascorbic acid1.0% | 19 (25.84) | 20 (26.57) | 27 (31.31) | 22 (27.97) |
| T5 - Glutathione 0.05% | 16 (23.58) | 28 (31.95) | 18 (25.10) | 19 (25.84) |
| T6 - Glutathione 0.1% | 17 (24.35) | 31 (33.83) | 20 (26.57) | 20 (26.57) |
| T7 - Butylated hydroxy toluene 0.1% | 15 (22.79) | 17 (24.35) | 26 (30.66) | 18 (25.10) |
| T8 - Butylated hydroxy toluene 0.2% | 19 (25.84) | 20 (26.57) | 22 (27.97) | 25 (30.00) |
| T9- Control | 17 (24.35) | 25 (30.00) | 31 (33.83) | 27 (29.33) |
| Mean | 18 (25.10) | 23 (28.66) | 25 (30.00) | 22 (27.97) |
| | T | C | T x C | |
| SEd | 0.14 | 0.09 | 0.28 | |
| CD (P=0.05) | 0.28** | 0.18** | 0.56** | |

(* and ** represented the differences were significant at the 5 and 1 % levels and values in parentheses ( ) are arc sine transformed values)

Table 3 Effect of seed priming with antioxidants on seedling root and shoot length (cm) under favourable and unfavourable germination conditions in sunflower cv. Co-2

| Treatments (T) | Germination conditions (C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Root length (cm) | | | | Shoot length (cm) | | | |
| | (C1) 25±2°C + 95±3% RH | (C2) 40°C and 100% RH | (C3) 15°C and 100% RH | (C4) NaCl 0.1% | (C1) 25±2°C and 95±3% RH | (C2) 40°C and 100% RH | (C3) 15°C and 100% RH | (C4) NaCl 0.1% |
| T1 - α-Tocopherol 0.5% | 32.3 | 31 | 29.8 | 28.7 | 21.5 | 20.8 | 19.5 | 18.6 |
| T2 - α-Tocopherol 0.1% | 28.7 | 27.6 | 26.8 | 25.3 | 20.5 | 19.9 | 18.5 | 17.7 |
| T3 - Ascorbic acid 0.5% | 30.8 | 29.7 | 28.3 | 27.4 | 20.8 | 20 | 18.8 | 17.9 |
| T4 - Ascorbic acid1.0% | 31.7 | 30.6 | 29.2 | 28.1 | 19.6 | 19.4 | 17.6 | 16.5 |
| T5 - Glutathione 0.05% | 30.9 | 29.8 | 28.4 | 27.5 | 21.2 | 20.7 | 19.2 | 18.3 |
| T6 - Glutathione 0.1% | 31.2 | 30.3 | 28.7 | 27.8 | 20.7 | 20.4 | 18.7 | 17.6 |
| T7 - BHT 0.1% | 31.5 | 30.7 | 29 | 28.1 | 22 | 21.5 | 20 | 19.1 |
| T8 - BHT 0.2% | 28.4 | 27.5 | 25.9 | 25.8 | 20.2 | 19.5 | 17.8 | 16.8 |
| T9- Control | 27.4 | 25.8 | 24.6 | 23.6 | 19.8 | 18.8 | 16.6 | 15.6 |
| Mean | 30.3 | 29.2 | 27.8 | 26.9 | 20.7 | 20.1 | 18.5 | 17.6 |
| | T | C | T x C | | T | C | T x C | |
| SEd | 0.18 | 0.12 | 0.36 | | 0.13 | 0.09 | 0.26 | |
| CD (P=0.05) | 0.35** | 0.23** | NS | | 0.25** | 0.17** | 0.51* | |

(* and ** represented the differences were significant at the 5 and 1 % levels)

Table 4 Effect of seed priming with antioxidants on seedling dry matter production (g 10 seedlings -1) under favourable and unfavourable germination conditions in sunflower cv. Co-2

| Treatments (T) | Germination conditions (C) | | | |
|---|---|---|---|---|
| | Seedling dry Matter (g) | | | |
| | (C1) 25±2°C + 95±3% RH | (C2) 40°C and 100% RH | (C3) 15°C and 100% RH | (C4) NaCl 0.1% |
| T1 - α-Tocopherol 0.5% | 0.348 | 0.327 | 0.3 | 0.288 |
| T2 - α-Tocopherol 0.1% | 0.35 | 0.329 | 0.302 | 0.29 |
| T3 - Ascorbic acid 0.5% | 0.34 | 0.319 | 0.292 | 0.28 |
| T4 - Ascorbic acid1.0% | 0.346 | 0.325 | 0.298 | 0.286 |
| T5 - Glutathione 0.05% | 0.344 | 0.323 | 0.296 | 0.284 |
| T6 - Glutathione 0.1% | 0.341 | 0.32 | 0.293 | 0.281 |
| T7 - BHT 0.1% | 0.356 | 0.335 | 0.308 | 0.296 |
| T8 - BHT 0.2% | 0.347 | 0.326 | 0.299 | 0.287 |
| T9- Control | 0.325 | 0.3 | 0.269 | 0.245 |
| Mean | 0.344 | 0.323 | 0.295 | 0.282 |
| | T | C | T x C | |
| SEd | 0.002 | 0.001 | 0.004 | |
| CD (P=0.05) | 0.004** | 0.002** | NS | |

(* and ** represented the differences were significant at the 5 and 1 % levels)

The interaction between antioxidant treatments and germination conditions was found to be non-significant for seedling dry matter (Table 4). The interaction effect showed that seed primed with (T7) Butylated hydroxy toluene 0.1% recorded highest vigour index I (4124) which was 25.92 % more over (T9) control and vigour index II (26.5) which was 23 % more over control (T9) under (C2) 40°C and 100% RH. Interaction effect showed that seed primed with (T7) Butylated hydroxy toluene 0.1% recorded highest vigour index II (26.5) which was 23 % more over control (T9) under (C2) 40°C and 100 % RH (Fig.1 and 2). Thus the present study revealed that the better performance of seedlings even under stress condition that could possibly be due to antioxidant treatment providing protection against stress at low level of concentration and certain biochemical strategies were used to enhance salt tolerance in plants, including the control of ion transfer from roots to leaves, the distribution of ions into cellular compartments, the synthesis of osmotic regulators, changes in photosynthesis and cell membranes, and the induction of antioxidative enzymes and certain plant hormones (Nakamura *et al.,* 2002).

Under favourable germination conditions of 25±2°C and 95±3% RH also the influence of Butylated hydroxytoluene 0.1 % was much more pronounced followed by Glutathione 0.05 % with an increase in germination by 6 and 5 per cent respectively over control seeds. There was a corresponding decline in abnormal seedling production also due to the above treatments. However, it was evident from the study that no antioxidant priming treatment could improve the performance of germination and seedling growth attributes under unfavourable germination conditions as that of favourable condition of 25±2°C and 95±3% RH Seed priming with either Butylated hydroxytoluene 0.1 % or α-Tocopherol 0.5 % and Ascorbic acid 1.0 % had alleviated the effect of unfavourable germination condition stress by increasing the germination, seedling growth and vigour indices through not up to the level of performance in stress free favourable germination condition.

Illustrations: To find out the effect of antioxidants on the physiological performance of sunflower seeds under favourable and different unfavourable germination conditions, a laboratory experiment was conducted where the seeds of sunflower cv. Co-2 was primed with eight antioxidants and subjected to three unfavourable germination conditions and favourable germination conditions of 25 ± 2°C and 95±3% RH were maintained as the control for comparison. The results revealed that 40°C and 100 % RH exerted more stress on seed germination. The effect of stress was minimized by seed priming with Butylated hydroxytoluene 0.1% followed by Butylated hydhydroxytoluene 2 % by recording 7 and 4 per cent higher germination over control. The seedling growth parameters *viz.,* root and shoot length, seedling dry matter production and vigour indices were influenced negatively by NaCl 0.1% stress condition. Seed priming with Butylated hydroxy toluene 0.1% followed by α-Tocopherol 0.5 % and Ascorbic acid 1.0 % found to have positive influence on the enhancement of seedling growth attributes under unfavourable germination conditions.

## REFERENCES


Abdul Baki, A A and Anderson J D, 1973. Vigor determination in soybean seed by multiple criteria 1. *Crop science*, **13**(6), pp.630-633.

Bailly C, Benamar A, Corbineau F and Côme D, 2000. Antioxidant systems in sunflower (*Helianthus annuus* L.) seeds as affected by priming. *Seed Science Research*, **10** (1), pp.35-42.

Behairy R T, El-Danasoury M and Craker L, 2012. Impact of ascorbic acid on seed germination, seedling growth, and enzyme activity of salt-stressed fenugreek. *Journal of Medicinally Active Plants*, **1**(3), pp.106-113.

Bodsworth S and Bewley J D 1981. Osmotic priming of seeds of crop species with polyethylene glycol as a means of enhancing early and synchronous germination at cool temperatures. **Canadian Journal of Botany, 59**(5), pp.672-676.

Chhetri D R, Rai A S and Bhattacharjee A, 1993. Chemical manipulation of seed longevity of four crop species in an unfavourable storage environment. *Seed Sci. & Technol.,* **21**: 31-44.

Chiu KY, Wang C S and Sung J M, 1995. Lipid peroxidation and peroxide?scavenging enzymes associated with accelerated aging and hydration of watermelon seeds differing in ploidy. *Physiologia Plantarum,* **94**(3), pp.441-446.

Chojnowski M, Corbineau F and Côme D, 1997. Physiological and biochemical changes induced in sunflower seeds by osmopriming and subsequent drying, storage and aging. *Seed Science Research*, **7**(4), pp.323-332.

Draganic I and Lekic S 2012. Seed priming with antioxidants improves sunflower seed germination and seedling growth under unfavorable germination conditions. *Turkish Journal of Agriculture and Forestry*, **36**(4), pp.421-428.

Farooq M, Basra S M A, Afzal I and Khaliq A, 2006. Optimization of hydropriming techniques for rice seed invigoration. *Seed Science and Technology*, **34**(2), pp.507-512.

Ghassemi-golezani K, Aliloo, A A, Valizadeh M and Moghaddam M, 2008. Effects of hydro and osmo-priming on seed germination and field emergence of lentil (*Lens culinaris* Medik.). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **36**(1), pp.29-33.

Halmer P 2004. Methods to improve seed performance in the field. *Handbook of Seed Physiology*, pp.125-65.

Khattab H 2007. Role of glutathione and polyadenylic acid on the oxidative defense systems of two different cultivars of canola seedlings grown under saline conditions. *Australian Journal of Basic and Applied Sciences*, **1**(3), pp.323-334.

ISTA 2020 *International Rules for Seed Testing.* International Seed Testing Association. Bassersdorf, Switzerland.

Job C, Kersulec A, Ravasio L, Chareyre S, Pepin R and Job D, 1997. The solubilization of the basic subunit of sugarbeet seed 11-S globulin during priming and early germination. *Seed*

*Science Research*, **7**(3), pp.225-244.

Khan A A 1992. Preplant physiological seed conditioning. *Horticultural Reviews*, **13**(1), pp.131-181.

Langhi A M, Patel S R, Narwade A V, Patel R K, Chaudhari K N and Chhatrola H N 2021. Studies on genotype x environment interactions of sunflower hybrids (*Helianthus annuus* L.). *Journal of Oilseeds Research*, **38**(2): 211-221

Mc Donald M B 2000. Seed priming. In: Black, M., Bewley, J.D. (eds) *Seed Technology and Its Biological Basis* : 287-325

Nakamura I, Murayama S, Tobita S, Bong B B, Yanagihara S, Ishimine Y and Kawamitsu Y, 2002. Effect of NaCl on the photosynthesis, water relations and free proline accumulation in the wild Oryza species. *Plant Production Science*, **5**(4), pp.305-310.

Pandita V K and Shantha N 2000. Osmopriming of fresh seed and its effect on accelerated ageing in Indian tomato (*Lycopersicon esculentum*) varieties. *Indian Journal of Agricultural Sciences,* **70**(7), pp.479-480.

Smok M A, Chojnowski M, Corbineau F and Côme D, 1993. Effects of osmotic treatment on sunflower seed germination in relation with temperature and oxygen. *Basic and Applied Aspects of Seed Biology*, **3**:1033-1038.

Yasaswini Chowdary B, Lakshmi Prayaga, Narender Reddy S, Eshwari K B, Meena H P and Srikanth B 2021. Effect of water stress on physiological traits of sunflower (*Helianthus annuus* L.) restorer lines. *Journal of Oilseeds Research*, **38**(1): 54-58.

Windauer L, Altuna A and Benech-Arnold R, 2007. Hydrotime analysis of Lesquerella fendleri seed germination responses to priming treatments. *Industrial Crops and Products*, **25**(1), pp.70-74.

# Integration of bioagent, Bacillus subtilis Bbv57 and fungicides for the management of foliar diseases of groundnut (*Arachis hypogaea* L.)

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ABSTRACT

Groundnut or Peanut (*Arachis hypogaea* L.) is a major oilseed crop widely grown in major tropical and sub-tropical regions of the world. Disease occurrence pose a major threat in groundnut cultivation. Among the biotic stresses, foliar fungal diseases viz., early leaf spot (ELS) caused by *Cercospora arachidicola* Hori, late leaf spot (LLS) caused by *Phaeoisariopsis personata* (Berk. & Curt.) V.Arx (=*Mycosphaerella berkeleyi* Jenkins) and rust caused by *Puccinia arachidis* Speg. are the most widely distributed and economically important diseases of groundnut and account for more than 50% yield loss. Field experiments were conducted during *kharif* 2021 and *rabi*/summer 2021-22 for the management of foliar diseases in groundnut using bioagent, *Bacillus subtilis* Bbv57 talc formulation and fungicides. The results of the field experiment conducted during *kharif* 2021 revealed that seed treatment with *Bacillus subtilis* Bbv57 talc formulation @ 10 g/kg seed followed by foliar spray of Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/l at 40 and 60 DAS was effective in managing the foliar diseases of groundnut with the late leaf spot (20.9 PDI) and rust (12.3 PDI) as compared to control which recorded late leaf spot of 71.4 PDI and rust of 52.1 PDI respectively. The maximum pod yield of 2361 kg/ha and haulm yield of 2764 kg/ha were observed in the effective treatment; whereas minimum pod yield of 1836 kg/ha and haulm yield of 1984 kg/ha were observed in the control. Similar trend was observed during *rabi*/summer 2021-22.

**Keywords**: Groundnut, Integrated Disease Management, Late leaf spot, Rust

Groundnut (*Arachis hypogaea* L.) is an important oilseed, food and feed crop of India contributing about 24% and 29% to total area and production of oilseeds respectively (Birthal et al., 2010). It is an important oilseed crop with high levels of proteins, carbohydrates, vitamins and minerals contained within seeds. The major groundnut growing areas are Gujarat, Andhra Pradesh, Tamil Nadu, Rajasthan and Maharashtra which contributes around 90% of the area and production. Groundnut is cultivated as *kharif* (rainfed or monsoon season) and *rabi*-summer (irrigated) crop and well drained, sandy soils are best suited for production (Tilak and Bhat, 2021).

The groundnut crop in general experiences several serious biotic and abiotic challenges that limit pod yields (Chaudhari *et al.,* 2021). Diseases of groundnut reduce the yield and quality and increase the production cost wherever the crop is grown. Among the groundnut diseases, late leaf spot caused by *Phaeoisariopsis personata* and rust caused by *Puccinia arachidis* are the foremost serious fungal diseases and account for more than 50% yield loss (Nataraja *et al.,* 2014). The late leaf spot usually appears at 55 to 60 days after sowing and causes more than 50% loss in pod and haulm yield (Hegde *et al.,* 2016). The combined infection of rust and leaf spots cause losses to the tune of 90%. Alternaria leaf blight is another fungal disease causing blighting of groundnut leaves. Reduction in pod and haulm yield was reported as 25.3% and 53.0% respectively (Eswara Reddy and Venkateswara Rao, 1999).

Application of chemical fungicides is considered as the preferred disease management strategy among the farmers and their indiscriminate application have serious adverse effect on beneficial insects, human health and surrounding environment. Biological control had attained importance in modern agriculture for disease control (Balode, 2010). Since the efficacy of bio-control agents in disease abatement has been inconsistent due to their inability to maintain a critical threshold population necessary for sustained bio-control activity, bio-control with antagonistic microorganism alone could not be an entire replacement for management strategies currently employed. The increasing problems by continued usage of pesticides and failure of individual IPM components to reduce the pest population necessitates the event of IPM modules that involves the synergistic integration of IPM components. The success and sustainability of IDM strategy, especially with resource poor farmers, greatly depends on their involvement in helping generate locally specific techniques and solutions suitable for their particular farming systems and integrating control components that are ecologically sound and readily available to them. Hence, the present research was undertaken to evaluate the bioagent, Bacillus subtilis Bbv57 talc formulation and fungicides for the management of foliar diseases of groundnut.

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## MATERIALS AND METHODS

Field experiments were conducted during *kharif* 2021 and *rabi*/summer 2021-2022 for the management of foliar diseases in groundnut using bioagent, Bacillus subtilis Bbv57 talc formulation and fungicides. The field experiments were conducted at Coconut Research Station, Aliyarnagar, Tamil Nadu Agricultural University (Longitude: 77.49°E Latitude: 10°N MSL- 260 MSL). The field experiments were laid out in Randomized Block Design with seven treatments and three replications. The groundnut variety Co 2 was used for the field experiments. The plot size was 5.0 m x 4.0 m and spacing of 30 cm x 10 cm was adopted. The treatments were imposed as per the schedule. Seeds were treated with bioagent Bacillus subtilis Bbv57 talc formulation @ 10 g/kg or fungicide Tebuconazole 2DS @ 1.5 g/kg. Foliar application was done with fungicides Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/l or Azoxystrobin 22.9% @ 1 g/l or at 40 and 60 DAS or Tebuconazole 25.9%EC @ 1 ml/l or Difenoconazole 11.4%EC @ 1 ml/l or B. subtilis @ 1 g/l. Two rounds of spraying were made at 40 DAS and 60 DAS. The treatment schedule is as follows: T1: Seed treatment with Bacillus subtilis Bbv57 @ 10 g/kg + foliar spray of Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/l at 40 and 60 DAS; T2 : Seed treatment with B. subtilis @ 10 g/kg + Foliar spray of Azoxystrobin 22.9% @ 1 g/l at 40 and 60 DAS; T3 : Seed treatment with B. subtilis @ 10 g/kg + Foliar spray of Tebuconazole 25.9% EC @ 1 ml/l at 40 and 60 DAS; T4 : Seed treatment with B. subtilis @ 10 g/kg + Foliar spray of Difenoconazole 11.4%EC @ 1 ml/l at 40 and 60 DAS; T5 : Seed treatment with Tebuconazole 2 DS @ 1.5 g/kg + Foliar spray of B. subtilis @ 1 g/l at 40 and 60 DAS; T6 : Seed treatment with Tebuconazole 2 DS @ 1.5 g/kg + FS of Tebuconazole 25.9%EC @ 1 ml/l at 40 and 60 DAS and T7 : Untreated control

The plots not treated with fungicides or bioagent served as the control. The disease intensity of foliar diseases viz., late leaf spot (LLS) and rust were recorded for each treatment at the time of physiological maturity by random selection of 25 plants per plot for each treatment. Modified 1-9 disease scale was used for scoring late leaf spot and rust diseases of groundnut (Subramanyam *et al.,* 2008).

Per cent disease index (PDI) was calculated using formula

$$PDI = \frac{\text{Sum of numerical ratings}}{\text{No. of plants observed x Maximum disease grade}} \times 100$$

The pod yield and haulm yield were recorded for each treatment. The data were statistically analyzed by Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

**Field evaluation of bioagent and fungicides for the management of foliar diseases of groundnut during *kharif* 2021**: The results of the field experiment conducted during *kharif* 2021 revealed that seed treatment with *Bacillus subtilis* talc formulation @ 10 g/kg seed followed by foliar spray of Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/l at 40 and 60 DAS was effective in managing the foliar diseases of groundnut with the late leaf spot of 20.9 PDI and rust of 12.3 PDI respectively. Seed treatment with B. subtilis @ 10 g/kg seed followed by foliar spray of Tebuconazole 25.9%EC @ 1 ml/l at 40 and 60 DAS ranked next with late leaf spot of 24.7 PDI and rust of 18.4 PDI respectively (Table 1). Grichar *et al.* (2010) reported that tebuconazole was effective for the management of leaf spot disease in groundnut.

Seed treatment with Tebuconazole 2 DS @ 1.5 g/kg seed followed by foliar application of *B. subtilis* @ 1 g/l at 40 and 60 DAS recorded late leaf spot of 31.6 PDI and rust of 24.3 PDI respectively. The fungicides *viz.,* azoxystrobin, chlorothalonil and tebuconazole were found to be effective for the management of leaf spot and stem rot in groundnut (Hagan *et al.,* 2010). In the control, maximum late leaf spot of 71.4 PDI and rust of 52.1 PDI were observed (Table 1).

Integrated management of diseases by combining chemical and biological method would be an effective method for the management of diseases compared to adopting single method. The maximum pod yield of 2361 kg/ha and haulm yield of 2764 kg/ha were observed in the effective treatment T1; whereas minimum pod yield of 1836 kg/ha and haulm yield of 1984 kg/ha were observed in the control (Table 1). The effect of seed treatment in increasing the pod yield was reported by several workers. Dandnaik *et al.* (2009) reported that seed treatment with hexaconazole gave higher pod yield in groundnut.

**Field experiment for the management of foliar diseases of groundnut during *rabi*/summer 2021-22**: The results of the field experiment conducted during *rabi*/summer 2021-22 revealed that seed treatment with *Bacillus subtilis* talc formulation @ 10 g/kg seed followed by foliar spray of Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/l at 40 and 60 DAS was effective in managing the foliar diseases of groundnut with the late leaf spot of 16.7 PDI and rust of 10.8 PDI. In the untreated control, late leaf spot of 66.3 PDI and rust of 42.6 PDI respectively were recorded (Table 2). Reduction of foliar disease severity in linseed was observed by treating seeds with Carbendazim + Thiram (De *et al*., 2003; Ramkishore and Singh, 2008). Dudi and Lodha (2003) observed the efficacy of seed treatment in peanut against seedling diseases. Dutta and Das (2002) highlighted the significant disease reduction of collar rot in tomato.

Table 1 Effect of fungicides and bioagents for the management of foliar diseases of groundnut - Trial I (*kharif* 2021)

| S.No. | Treatments | Late leaf spot (PDI) | Rust (PDI) | Pod yield (kg/ha) | Haulm yield (kg/ha) |
|---|---|---|---|---|---|
| T1 | Seed treatment with Bacillus subtilis Bbv57 @ 10 g/kg + FS of Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/l at 40 & 60 DAS | 20.9 (22.3) | 12.3 (15.6) | 2361 | 2764 |
| T2 | Seed treatment with B. subtilis @ 10 g/kg + FS of Azoxystrobin 22.9% @ 1 g/l at 40 & 60 DAS | 27.3 (29.6) | 21.6 (24.3) | 2172 | 2616 |
| T3 | Seed treatment with B. subtilis @ 10 g/kg + FS of Tebuconazole 25.9%EC @ 1 ml/l at 40 & 60 DAS | 24.7 (26.1) | 18.4 (21.6) | 2284 | 2739 |
| T4 | Seed treatment with B. subtilis @ 10 g/kg + FS of Difenoconazole 11.4%EC @ 1 ml/l at 40 & 60 DAS | 25.1 (27.4) | 20.7 (23.2) | 2246 | 2643 |
| T5 | Seed treatment with Tebuconazole 2 DS @ 1.5 g/kg + FS of B. subtilis @ 1 g/l at 40 & 60 DAS | 31.6 (33.2) | 24.3 (27.9) | 1953 | 2158 |
| T6 | Seed treatment with Tebuconazole 2 DS @ 1.5 g/kg + FS of Tebuconazole 25.9%EC @ 1 ml/l at 40 & 60 DAS | 30.2 (32.7) | 22.9 (25.4) | 1969 | 2266 |
| T7 | Untreated control | 71.4 (69.6) | 52.1 (49.7) | 1836 | 1984 |
| | CD(P=0.05) | 1.86 | 2.43 | 84.69 | 38.47 |
| | SE(d) | 0.89 | 1.22 | 41.37 | 18.63 |

*Mean of three replications Var : Co-2

Table 2 Effect of fungicides and bioagents for the management of foliar diseases of groundnut - Trial II (*rabi*/summer 2021-22)

| S. No. | Treatments | Late leaf spot (PDI) | Rust (PDI) | Pod yield (kg/ha) | Haulm yield (kg/ha) |
|---|---|---|---|---|---|
| T1 | Seed treatment with Bacillus subtilis Bbv57 @ 10 g/kg + FS of Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/l at 40 & 60 DAS | 16.7 (19.2) | 10.8 (12.3) | 2421 | 2711 |
| T2 | Seed treatment with B. subtilis @ 10 g/kg + FS of Azoxystrobin 22.9% @ 1 g/l at 40 & 60 DAS | 21.3 (24.6) | 16.2 (18.4) | 2213 | 2478 |
| T3 | Seed treatment with B. subtilis @ 10 g/kg + FS of Tebuconazole 25.9%EC @ 1 ml/l at 40 & 60 DAS | 18.4 (21.3) | 13.6 (15.7) | 2396 | 2683 |
| T4 | Seed treatment with B. subtilis @ 10 g/kg + FS of Difenoconazole 11.4%EC @ 1 ml/l at 40 & 60 DAS | 19.6 (22.4) | 14.7 (16.9) | 2374 | 2658 |
| T5 | Seed treatment with Tebuconazole 2 DS @ 1.5 g/kg + FS of B. subtilis @ 1 g/l at 40 & 60 DAS | 25.2 (28.7) | 20.3 (22.7) | 1963 | 2198 |
| T6 | Seed treatment with Tebuconazole 2 DS @ 1.5 g/kg + FS of Tebuconazole 25.9%EC @ 1 ml/l at 40 & 60 DAS | 23.7 (26.5) | 18.4 (20.6) | 1992 | 2231 |
| T7 | Untreated control | 66.3 (62.4) | 42.6 (34.1) | 1842 | 2063 |
| | CD(P=0.05) | 1.82 | 1.64 | 68.36 | 52.71 |
| | SE(d) | 0.94 | 0.76 | 33.72 | 27.46 |

*Mean of three replications Var : Co2

Seed treatment with *B. subtilis* @ 10 g/kg seed followed by foliar application of Tebuconazole 25.9%EC @ 1 ml/l at 40 and 60 DAS ranked next with late leaf spot of 18.4 PDI and rust of 13.6 PDI respectively (Table 2). Wann et al. (2011) reported that leaf spot disease in groundnut could be managed using fungicides. Integrated disease management of foliar and soil borne diseases with fungicides, castor cake and *Trichoderma* in groundnut was reported by Jadon *et al.* (2017). They reported that lowest incidence of soil borne diseases was observed in seed treatment with mancozeb and seed treatment with tebuconazole compared to untreated control. The maximum pod yield of 2421 kg/ha and haulm yield of 2711 kg/ha were observed in the effective treatment T1. The minimum pod yield of 1842 kg/ha and haulm yield of 2063 kg/ha were observed in the control (Table 2). Hagan *et al.* (2010) documented that groundnut yield was higher with the fungicide azoxystrobin than with the other fungicide programs.

Seed treatment with *Bacillus subtilis* Bbv57 talc formulation @ 10 g/kg of seed followed by foliar spray of Tebuconazole 50% + Trifloxystrobin 25% @ 1 g/l at 40 and 60 DAS was found to be effective in managing the late leaf spot and rust diseases of groundnut with increased pod yield and haulm yield.

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REFERENCES

Balode A. 2010. Effect of tricodermin, biological product against Botrytis in horticultural crops. *Acta horticulture*, **877**: 1583-1588.

Birthal P S, Parthasarathy Rao P, Nigam S N, Bantilan M C S, Bhagavatula S. 2010. Groundnut and Soybean Economics in Asia: Facts, Trends and Outlook. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, p. 92.

Chaudhari P B, Shah S K, Chaudhary K V, Chaudhary S F and Desai A G 2021. Effect of potassium on chemical composition, uptake and soil properties of groundnut (*Arachis hypogaea* L.) grown in loamy sand soil. *Journal of Oilseeds Research*, **38**(1): 49-53.

Dandnaik B P, Patil D T, Chavanand M H, Dandnaik A B. 2009. Chemical control of stem rot of groundnut caused by *Sclerotium rolfsii. Journal of Mycology and Plant Pathology*, **39**: 185.

De R K, Dwivedi R P, Udit Narain. 2003. Biological control of lentil wilt caused by *Fusarium oxysporum* fsp. lentis. *Annals of Plant Protection Sciences*, **11**: 46-52.

Dudi J, Lodha P C. 2003. Compatibility of seed dressing fungicides with rhizobium in groundnut. National seminar: *Stress Management in Oilseeds*, 2003, Jan 28-30, p. 24-25.

Dutta P, Das B C. 2002. Management of collar rot of tomato by *Trichoderma* spp. and chemicals. *Indian Phytopathology*, **55**: 235-237.

Eswara Reddy N P, Venkateswara Rao K. 1999. Chemical control of *Phaeospariopsis* leaf spot of groundnut. *J. Plant Dis. and Prot*, **106**: 507-511.

Grichar W J, Jaks A J, Woodward J. 2010. Using prothioconazole plus tebuconazole for foliar and soil borne diseases control in Texas peanut. *Crop Management*. CM--0405-02-RS.

Hagan A K, Campbell H L, Bowen K L, Wells L, Goodman R. 2010. Managing early leaf spot and stem rot with reduced fungicide inputs on disease resistant peanut cultivars. *Peanut Science,* **37**: 129-136.

Hegde Y R, Ravichandran S, Keshgond R. 2016. Bioefficacy of new molecules against fungal foliar diseases of groundnut. *Journal of Pure and Applied Microbiology*, **10**: 635.

Jadon K S, Thirumalaiswamy P P, Vinod Kumar, Koradia V G, Padavi R D. 2017. Integrated management of major foliar and soil borne diseases of pea nut (*Arachis hypogeae* L.) with fungicides, *Trichoderma* and Castor cake. *Int. J Curr. Microbiol. App. Sci*, **6**(12): 1884-1899.

Nataraja M V, Jadon K S, Holajjer P, Thirumalaisamy P P, Jasrotia P, Ram Dutta. 2014. *Integrated Pest and Disease Management in Groundnut.* Directorate of Groundnut Research, Technical bulletin, p. 19.

Ramkishore R, Singh J. 2008. Evaluation of fungicides against *Fusarium oxysporum* fsp. lentis of linseed. *Anals of Plant Protection Sciences*, **16**: 165-167.

Subrahmanyam P, McDonald D, Waliyar E, Reddy L J, Nigam S N, Gibbons R W, Thind T S. 2008. Screening methods and sources of resistance to rust and late leaf spot of groundnut (In En. Summaries in En, Fr, Sp, and Pt.). Information Bulletin no. 47. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 2008, p. 24.

Tilak I S and Bhat R S 2021. High yielding mutants from the introgression lines of groundnut (*Arachis hypogaea* L.). *Journal of Oilseeds Research*, **38**(2): 132-136.

Wann D Q, Tubbs R S, Culbreath A K. 2011. Genotype and approved fungicides evaluation for reducing leaf spot diseases in organically-managed peanut. *Plant Health Progress.* (October): PHP-2010-1027-01-RS, 2011.

# Exploration of *Bacillus* species and AMF in the management of sesame root rot (*Macrophomina phseaolina*) and leaf blight (*Alternaria sesame*)

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ABSTRACT

Sesame is liable to be infected by various pathogenic fungi like leaf blight and root rot at all the stages of crop growth. The present study was carried out to evaluate the effect of bio-agents on managing the diseases in sesame. Seed treatment with Bacillus subtilis (TNAU-Bs1) @ 20 ml/kg seed + soil application of VAM @ 50 kg/ha at 15 DAS + foliar application of liquid formulation of *B. amyloliquefaciens* (TNAU-PP-CC-B-0171) @ 0.75% on 45 DAS was found to record very less leaf blight (18.12 PDI) and root rot incidence (4.24%) by recording 62.58 and 90.39 per cent disease reduction over control respectively in *rabi* season. Similar kind of results were obtained during *kharif* season which recorded the minimum root rot incidence (6.92%), leaf blight (14.98 PDI) by recording 64.55 and 85.05 per cent disease reduction over control respectively.

**Keywords**: *Bacillus subtilis, B. amyloliquefaciens,* VAM, Root rot and leaf blight, Sesame

Sesame (*Sesamum indicum* L.) is one of the important oil seed crop grown in many parts of the world. It is also known as queen of oil seeds. In India the crop is generally known as Til. It is rich source of antioxidants such as sesamin, sesamol and sesamoline (Shyu and Hwang, 2002). The sesame seeds are rich source of edible oil (50%), protein (20%), oleic acid (47%) and linolenic acid (39%). The long shelf life of sesame seed oil is due to the presence of sesamol. In Tamil Nadu, sesame is grown in 51.3 thousand ha with an annual production of 28.6 thousand tonne and productivity of 558 kg/ha. Though India is the largest producer and exporter of sesame in the world, the productivity is lower than the world average yield of sesame.

Sesame crop is affected by many diseases like root rot, Alternaria leaf blight, Cercospora leaf spot, wilt, stem blight, powdery mildew, bacterial leaf spot and phyllody (Jayaramachandran *et al.,* 2021; Sangeetha *et al.,* 2021). Among the diseases, root rot caused by *Macrophomina phaseolina* is a major problem causing significant economic constraints to sesame production worldwide. Sesame root rot pathogen has wide host range and it has the capacity to produce sclerotia, pycnidia and pycnidiospores that may persist in soil for several years (Pande *et al.,* 2004). The pathogen is seed borne and temperature of 20-30° C and high humid conditions favoured the disease. This disease causes severe losses right from seedling to maturity stages (Khan, 2007). Among the foliar diseases, leaf blight caused by Alternaria sesame is the major disease of sesame attacks all parts of the plant in all stages. Symptoms includes small, dark brown, water soaked, round to irregular lesions, with concentric rings, 1-8 mm in diameter appears on the leaves. Under excessive soil and atmospheric humidity, the spot could increases in size and number.

Since sesame seed and oil are in high demand for its utilization in different industries due to their high unsaturated fatty acids (USFA) and methionine content, focus has been shifted to safer alternatives to chemical fungicides in recent years. Therefore, bio-control has attained importance in modern agriculture to restrain the hazards of intensive use of chemicals for disease control. Among the bio-control agents, Bacillus has become the bacterium of the choice for its versatility and ability to contain a large number of plant pathogens in diverse environments (Malleswari, 2014). However, due to fluctuations in environment, the efficacy of bio-control agents is inconsistent due to their inability to colonize maintain threshold population and multiply in Rhizosphere (Gupta *et al.,* 2018).

The biological activities and population of introduced antagonist generally decline with time after their application and thus making the beneficial response for short duration. Therefore, bio control with antagonistic microorganisms alone could not be a complete replacement for conventional chemical based management strategies currently being employed. To enhance and extend the desired responses, the environment growing rhizophere needs to be altered to selectively favour the activities of the introduced biocontrol agent and this can be solved by the addition of specific substrates. Combination of bio control agents and growth stimulating substrates like mycorrhizae are known to inhibit pathogens and hence they are considered as attractive management strategy over the conventional methods for plant disease management.

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Soil amendments like VAM application are known to improve the nutrient status and tilth of the soil. In addition they also increase the microbial activity of applied bio-control agents suppresses pathogen. AMF can also enhance resistant to root rot pathogens (Borowics, 2001). Also being bio-control agents can proliferate, colonize and protect the newly formed plant parts to which they are not applied. This work is therefore aimed to study the combined application of biocontrol agents and mycorrhizae application on the disease control. In addition the population of bioagents over the period of crop growth was also enumerated.

## MATERIALS AND METHODS

An experiment was conducted in the new farm of Regional Research Station, Vridhachalam, Cuddalore, Tamil Nadu during 2021-2022 *kharif* and *rabi* to study the effect of bacterial antagonists and VAM application on the management of leaf blight and root rot of sesame under field conditions. A plot size of 5 x 4 m with four treatments and six replications in Randamized Block Design using the susceptible variety Co-1 was executed.

T1- The sesame seeds (var. Co1) were treated with *Bacillus subtilis* (TNAU-Bs 1) @ 20 ml/kg dried under shade and sown in the field. The VAM was applied @ 50 kg/ ha, after mixing with 100 kg of FYM broadcasting evenly at 15 days after sowing (DAS). There after foliar application of Bacillus amyloliquefaciens (TNAU - PP- CC- B-0171) @ 0.75% on 45 DAS was sprayed.

**Isolation of *Bacillus subtilis* from the soil**: Ten grams of soil sample was suspended in 90 ml of sterile distilled water. The soil suspension was heat shocked at 60o C for one hr in a water-bath to kill non-spore forming organisms (Ubalua, 2014). A loopful each of the soil suspension was inoculated by streaking on nutrient agar medium. The inoculated plates were incubated aerobically at 37°C for 24 hrs and examined for the appearance of colonies. The colonies that exhibited cultural characteristics typical of *Bacillus* species i.e. round or irregular; thick and opaque; cream-colored colonies were sub-cultured onto nutrient agar slants for subsequent identification.

**Assessment of AMF spore**: AM fungi were isolated by the wet sieving and decanting technique as described by Gerdemann and Niclson (1963). A set of sieves with pores sizes of 400, 315, 250, 160, 71 and 63 mM were counted using binocular microscope at 5X. Sporocarps were kept on wet Whatman No. 1 filter papers in Petri dishes. VA mycorrhizae sporocarps were collected. Two hundred sporocarps were added as a soil drench near sesame plants after transplanting. In T2, sesame seeds (var. Co1) were treated with carbendazim @ 2g/kg and sown in the field. The carbendazim @ 1g/l solution was drenched near the root zone of the sesame on 15 DAS. Thereafter foliar application of mancozeb @ 1 kg/ ha on 45 DAS was done. In T3, all the practices generally followed by farmers were done in time (Recommended dose of fertilizers). The fourth treatment was maintained as control (Only water was irrigated) (T4).

The seed treatment with *B.subtilis* and carbendazim were done individually 24 h prior to sowing. VAM (TNAU commercial talc formulation) were applied to the soil individually a week before sowing. The crop was raised as per the agronomic practices given in the TNAU Crop Production Guide (2019) and observations of disease incidence were recorded one week after the last foliar spray.

**Observations:** The germination percentage was assessed on 15 days after sowing. The root rot disease incidence was recorded at the time of physiological maturity (50 days after sowing) by counting the number of infected plants and total number of plants Per cent disease incidence was calculated using the formula

$$Disease\ incidence = \frac{Number\ of\ infected\ plants}{Total\ number\ of\ plants} x\ 100$$

The observations on disease severity was recorded by 0-5 scale (Kushwaha and Kaushal, 1970) for leaf blight and presented in table and per cent disease index (PDI) was calculated by following the AICRP (Sesame and Niger) disease ratings.

| Disease grade | Description | Disease Reaction |
|---|---|---|
| 0 | No visible symptoms | Immune |
| 1 | 1 to 10 % leaf area infected | Resistant |
| 2 | 2 to 20 % leaf area infected | Moderately resistant |
| 3 | 21 to 30 % leaf area infected | Moderately susceptible |
| 4 | 31 to 40 % leaf area infected | Susceptible |
| 5 | More than 40 % leaf area infected | Highly susceptible |

PDI =

Sum of numerical ratings x 100/Maximum grade

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Total Number of leaves scored

**Statistical analysis**: All the readings were taken in triplicate, unless it was specifically mentioned. The results were represented as mean ±standard deviation (SD) using one way analysis of variance (ANOVA) and was compared with Duncan Multiple Range Test ($p<0.05$ confidence level). SPSS for windows (Ver.2.1, IBM SPSS Inc., Chicago, IL) software was used for all the statistical analysis.

## RESULTS AND DISCUSSION

**Incidence of root rot (Per cent) and Leaf blight (PDI)**: In *kharif* season the results of the experimental trial showed that the treatment (T1 ) comprising of seed treatment with *B. subtilis* (TNAU-Bs1) @ 20 ml/kg + soil application of VAM @ 50 kg/ ha at 15 days after sowing (DAS) + Foliar application of liquid formulation of *B. amyloliquefaciens* (TNAU-PP-CC-B-0171) @ 0.75% on 45 DAS was found to record very less leaf blight (14.98 PDI) and root rot incidence (6.92%) by recording 64.55 and 85.05 per cent disease reduction over control respectively. Whereas the treatment (T2) Seed treatment with carbendazim @ 2 g/kg + soil drenching with carbendazim @ 1 g/l 15 DAS + Foliar application of mancozeb @ 1 kg/ha 45 Days After Sowing was found to record minimum leaf blight (20.18 PDI) and root rot incidence (03.48%) by recording 58.32 and 92.11 per cent disease reduction over control respectively at 50 DAS. The above explained two treatments (T1 and T2) were statistically on par with each other (Table 1). Similarly the treatment was found to record less leaf blight (16.24 PDI) and root rot incidence (6.08%) by recording 61.57 and 86.86 per cent disease reduction over control respectively. In Rabi season the experimental results revealed very less leaf blight (18.12 PDI) and root rot incidence (4.24%) by recording 62.58 and 90.39 per cent disease reduction over control respectively. Whereas the same treatment was found to record less leaf blight (20.18 PDI) and root rot incidence (03.48 %) by recording 58.32 and 92.11 per cent disease reduction over control respectively at 50 DAS.

Chung and Choi (1990) observed that *T. viride, T. harzianum* and *B. subtilis* have strong biocontrol potential against *M. Phaseolina* causing root rot of sesame and also reduced the disease incidence significantly. VA mycorrhizae was able to colonize sesame roots in soil infested by *F. oxysporum* f. sp. *sesami* than in the soil infested with *M. phaseolina* (Sahab *et al.,* 2001).VA mycorrhizal fungi protect plants by inhibiting the pathogens in sesame rhizosphere and/or reducing the pathogenic activity and improving resistance due to the increase of antifungal chitinase enzymes in roots (Dehne *et al.,* 1978). Patil *et al.,* (2003) also opined that the biological control agents were more effective and economical when applied as seed treatment than as soil treatment as observed in the present study. Similar to the present study. Biocontrol agents have a direct antagonistic activity not only by producing various metabolites, but also by inducing defence enzymes, which have recently been found to be a new way whereby plants defend themselves from pathogen attack (Bharathi *et al.,* 2004).

**Yield**: *Kharif* season was found to record high yield (684 kg/ha) with 54.68 per cent increased yield over control and also by recording high C: B ratio of 1:3.10. This treatment (T1) is statistically significant from all other treatments. The same treatment (T1) was found to record more yield (698 kg/ha) with 58.74 per cent increased yield over control and also by recording the cost benefit ratio of 1:3.22 in *rabi* season (Table 2).

Over all the incidence of root rot was less during summer season as compared to *kharif* .However maximum yield was realized in summer over *kharif* season. The yield reduction during *kharif* was due to severe incidence of root rot and blight in experimental plot .It was found that combined application of biocontrol agent and VAM for seed treatment and soil application showed the minimum disease and higher yields as compared to application of bio control agent alone and over untreated check. Balabasker (2006) reported that the application of FYM along with antagonists significantly reduced the pathogen population and root rot incidence and increases the rhizosphere population of antagonists and the biometrics of sesame. Govindappa *et al.* (2011) reported that application of biocontrol agents *viz., T. harzianum, B. subtilis* and *P. fluorescens* reduced the Fusarium wilt incidence of safflower both under greenhouse and field conditions. From this, it was inferred that seed treatment with bio control agents provided longer protection than chemicals which suppress the seed and soil-borne pathogens. The present investigation is in line with the report of Rao (2009).

VA mycorrhizae fungi also increase lignin content in root system (Ziedan *et al.,* 2010). B. subtilis showed a high reduction of pathogen growth, sporulation and sclerotial formation (Elewa *et al.,* 2011). Anis et al. (2010) also found the effectiveness of Bacillus subtilis for management of root rot in sunflower when seeds are treated. While as, fluorescent pseudomonad is also found to be effective against this pathogen by producing chitinase and β-1,3-glucanase which helps in inhibiting the growth *Fusarium oxysporum, M. phaseolina* and *Sclerotinia sclerotiorum* (Gupta *et al.,* 2006). Our finding is in consonance with those reported by Afouda *et al.* (2012) in cow pea against root rot (*M. phaseolina*) pathogen in field, reported that *B. subtilis* showed strongest antagonistic activity against *M. phaseolina* and treatment of *B. subtilis* strain A11 reduced disease incidence 89.29% over the untreated control plants. Similarly Vyas and Patel (2015) reported that soil application of talc base formulation of *B. subtilis* reduce root rot disease in chick pea caused by *M. phaseolina*. Mean while, *B. subtilis* generated a fungistatic effect probably connected to a competition for space or nutrients, instead of a toxic effect (Torres *et al.,* 2016). In our study, *B. amyloliquefaciens* was found to solubilise phosphate and it also produced enzymes like protease, cellulase and catalyse. However, it has limited antagonistic activity against *M. phaseolina*. VA mycorrhizae fungi also increase lignin content in root system (Ziedan *et al.,* 2010). The use of mixed inocula of mycorrhizal symbionts and

biocontrol agents can be more effective than the use of a single species.

**Populations of *Bacillus* species and VAM**: In *kharif* season the treatment T1 was found to record more population of antagonist (Bacillus sp.) and VAM spores in the rhizosphere soil on 40 and 80 DAS by recording Bacillus sp. as 1.46 x $10^6$ cfu and 1.86 x 106cfu / g of soil and 186 and 204 No. of VAM spores / 100 g of soil respectively.

Table 1 Effect of bacterial antagonists and VAM on the management of root rot and leaf blight

| T. No. | Treatments | Diseases Incidence 50 DAS | | | |
|---|---|---|---|---|---|
| | | *Kharif* 2021 | | *Rabi* 2022 | |
| | | Root rot* (%) | Leaf Blight (PDI)* | Root rot* (%) | Leaf Blight (PDI)* |
| 1 | Seed treatment with B. subtilis (TNAU-Bs1) @ 20 ml / kg + Soil application of VAM @ 50 kg/ ha 15 DAS + Foliar application of liquid formulation of B. amyloliquefaciens (TNAU-PP-CC-B-0171) @ 0.75% on 45 DAS | 06.92 | 14.98 | 04.24 | 18.12 |
| 2 | Seed treatment with carbendazim @ 2 g/kg + Soil drenching with carbendazim @ 1 g/ l 15 DAS + Foliar application of mancozeb @ 1 kg/ha 45 DAS | 06.08 | 16.24 | 03.48 | 20.18 |
| 3 | Farmer's practice | 22.68 | 24.42 | 30.26 | 28.86 |
| 4 | Control | 46.28 | 42.26 | 44.12 | 48.42 |
| CD (P=0.05) | | 1.12 | 2.16 | 1.09 | 2.24 |

*Mean of six replications; ST - Seed treatment; LF - Liquid formulation; DAS - Days after sowing; SA - Soil application

Table 2. Effect of bacterial antagonists and VAM on the management of root rot and leaf blight

| T. No. | Treatments | *Kharif* 2021 | | *Rabi* 2022 | |
|---|---|---|---|---|---|
| | | Yield (kg/ha) | C:B ratio | Yield (kg/ha) | C:B ratio |
| 1 | Seed treatment with B. subtilis (TNAU-Bs1) @ 20 ml / kg + Soil application of VAM @ 50 kg/ ha 15 DAS + Foliar application of liquid formulation of B. amyloliquefaciens (TNAU-PP-CC-B-0171) @ 0.75% on 45 DAS | 684 | 1:3.10 | 698 | 1:3.22 |
| 2 | Seed treatment with carbendazim @ 2 g/kg + Soil drenching with carbendazim @ 1 g/ l 15 DAS + Foliar application of mancozeb @ 1 kg/ha 45 DAS | 662 | 1:3.02 | 672 | 1:3.16 |
| 3 | Farmer's practice | 422 | 1:2.46 | 416 | 1:2.68 |
| 4 | Control | 310 | 1:1.12 | 288 | 1:1.04 |
| CD (P=0.05) | | -- | 19.86 | --- | 20.12 |

*Mean of six replications; ST - Seed treatment; LF - Liquid formulation; DAS - Days after sowing; SA - Soil application

In *rabi* season the treatment T1 was found to record more population of antagonist (*Bacillus* sp.) and VAM spores in the rhizosphere soil on 40 and 80 DAS by recording *Bacillus* sp. as 1.88 x $10^6$ cfu and 1.96 x $10^6$ cfu/g of soil and 198 and 232 No. of VAM spores/100 g of soil respectively. All other treatments were found to record very negligible quantity of population of antagonist and VAM spores. Moreover, the treatment T1 was statistically significant from all other treatment (Table 3). Our data is in accordance with Chanway *et al.* (1991), who recorded colonization of different Bacillus strains within the range 104 -105 cfu/g in the lodgepole pine rhizosphere. It enhanced vegetative parameters of chir-pine and also suppressed root rot disease and showed excellent root colonization ability. These attributes of *B. subtilis* BN1 verifies it as a potent bio-control agent against *M. phaseolina.* Santos *et al.* (2006) reported that *Bacillus* sp. is the most numerous rhizobacteria in the soil. This high presence in the soil reveals the great competitive potential, when it is present in the soil environment. The reduction in the population of the pathogen might be attributed to the activity of the increased rhizosphere population of antagonists and the toxic

metabolites produced by the bio agents and organic amendments which might have suppressed the pathogen. The mechanisms by which the antagonists act upon pathogens include antibiotic production, competitive ability, parasitism and lysis (Raaijmakers *et al.,* 1997). *B. subtilis* is an example of antagonistic bacteria that usually act through antibiosis and eventually by parasitism and competition for space and nutrients (Nagorska *et al.,* 2007). Thus it could be assumed that the combination delivery system of *B. subtilis* might have increased bacterial colonization in the rhizosphere and the various antifungal metabolites and combined action of such antibiotics. Bacillus sp. has potent plant growth promoting traits such as IAA production, phosphate solubilisation and nitrogen fixation (Senthilkumar *et al.,* 2009).

Table 3 Population of Bacillus spp. and VAM in the rhizosphere region of sesame under field condition

| T. No | Treatments | Population of *Bacillus* spp. (cfu/g of soil)* | | | | | | Population of VAM (No. of spores /100 g soil)* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Kharif* 2021 | | | *Rabi* 2022 | | | *Kharif* 2021 | | | *Rabi* 2022 | | |
| | | Before sowing ($x10^4$) | 40 DAS ($x10^6$) | 80 DAS ($x10^6$) | Before sowing ($x10^4$) | 40 DAS ($x10^6$) | 80 DAS ($x10^6$) | Before sowing | 40 DAS | 80 DAS | Before sowing | 40 DAS | 80 DAS |
| 1 | Seed treatment with *B. subtilis* (TNAU-Bs1) @ 20 ml / kg + Soil application of VAM @ 50 kg/ ha 15 DAS + Foliar application of liquid formulation of B. amyloliquefaciens (TNAU-PP-CC-B-0171) @ 0.75% on 45 Days After Sowing | 1.64 | 1.46 | 1.86 | 1.34 | 1.88 | 1.96 | 1.82 | 186.0 | 204.0 | 1.68 | 198.0 | 232.0 |
| 2 | Seed treatment with carbendazim @ 2 g/kg + Soil drenching with carbendazim @ 1 g/ l 15 DAS + Foliar application of mancozeb @ 1 kg/ha 45 Days After Sowing | 1.68 | 0.16 | 0.18 | 1.42 | 0.11 | 0.18 | 1.62 | 1.70 | 1.76 | 1.74 | 1.78 | 1.80 |
| 3 | Farmer's practice | 1.42 | 0.18 | 0.26 | 1.28 | 0.28 | 0.32 | 1.74 | 1.92 | 1.98 | 1.84 | 1.90 | 2.14 |
| 4 | Control | 1.62 | 0.05 | 0.08 | 1.26 | 0.07 | 0.09 | 1.68 | 1.74 | 1.78 | 1.72 | 1.76 | 1.82 |
| | CD (P=0.05) | NS | 0.11 | 0.14 | NS | 0.16 | 0.19 | NS | 6.88 | 6.96 | NS | 6.94 | 7.22 |

*Mean of six replications

## REFERENCES


Afouda L C A, Schulz D, Wolf G and Wydra K 2012. Biological control of *Macrophomina phaseolina* on cowpea (*Vigna unguiculata* L.) under dry conditions by bacterial antagonists. *International Journal of Biological and Chemical Sciences*, **6**(6): 5068-5077.

Balabaskar P 2006. Certain studies on the management of root rot of sesame (*Sesamumindicum* L.) incited by *Macrophomina phaseolina* (Tassi) Goid Ph.D. Thesis, Annamalai University Annamalainagar, Tamil Nadu.

Borowicz J J, Pietr S J, Stankiewcz M, Lewicka T and Zukowska Z 1992. Inhibition of fungal cellulase, pectinase and xylanase activity by plant growth-promoting fluorescent Pseudomonas spp. Bulletin *OILB SROP*, **15**: 103-106.

Chung H S and Choi W B 1992. Biological control of sesame damping-off in the field by coating seed with antagonistic *Trichoderma viride. Review of Phytopathology*, **71**(5): 321.

Dehne H W, Schonebeck F, Baltruschat H 1978. Unter such ungenzumEinfluss de endotrophen Mycorrhiza auf Pflanzenkrankheiten: 111. Chitinase- aktivitat und ornithinzyklus. (The influence of endo trophic mycorrhiza on plant disease: Chitinase activity and ornithine-cycle). *ZpflanzenkrankhPflanzenschutz*, **85**: 666-678.

Elewa I S, Sahab A F, Mostafa M H and Ziedan E H 2011. Direct effect of biocontrol agents on wilt and root-rot diseases of sesame. *Archives of Phytopathology and Plant Protection*, **44**(5): 493-504.

Govindappa M, Lokesh V, Ravishankar Rai V, Rudra Naik and Raju S G 2011. Induction of systemic resistance and management of safflower *Macrophomina phaseolina* root rot diseases by biocontrolagents. *Archives of Phytopathology and Plant Protection*, **43**: 26-40.

Gupta K N, Naik K R and Rajni Bisen. 2018. Status of sesame diseases and their integrated management using indigenous practices. *International Journal of Chemical Studies*, **6**(2): 1945-1952.

Jayaramachandran M, Ravichandran V and Vaithiyalingan R. 2021. Assessment of genetic variability and resistance against stem and root rot caused by *Macrophomina phaseolina* in segregating generations of sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **38**(1): 115-120.

Khan M S, Raj S K and Snehi S K 2007. First report of 'Candidatus phytoplasma asteris' affecting sesame cultivation in India. *Journal of Plant Pathology*, **89**: 301-305.

Kushwaha U S and Kausal P K. 1970. Reaction of sesamum varieties to *Cercospora* leaf spot in Madhya Pradesh. *Mysore Journal of Agricultural Sciences*, **4**: 228-230.

Mahesh M, Saifulla Mahammad S. Srinivasa and Shashidhar K R 2010. Integrated management of pigean pea wilt caused by *Fusarium udum. European Journal of Biological Sciences*, **2**: 1-7.

Malleswari Damam 2014. *In vitro* antagonistic activity of diverse bacterial isolates against *Macrophomina phaseolina* (Tassi) Goid. *International Journal of Current Microbiology and Applied Sciences*, **3**(5): 755-763.

Pande S, Krishna Kisore G and Narayana Rao J 2004. Evaluation of chickpea lines for resistant to dry root rot caused by *R. bataticola.* Inter. *Chickpea and Pigeon pea Newsletter*, **11**: 37-38.

Papavizas G C and Lumsden R D 1980. Biological control of soil-borne fungal propagules. *Annual Review of Phytopathology*, **18**: 389-413.

Patil S, Sriram S and Savitha M J 2011. Evaluation of non-pathogenic Fusarium for antagonistic activity against *Fusarium* wilt of tomato. *Journal of Biological Control*, **25**: 118-123.

Rajpurohit T S 2004. Studies on fungicide, plant products and bio-agents as spray in sesame disease management. *Journal of Eco-Physiology*, **6**(3-4): 87-88.

Rao M S L, Kulkarni L, Lingaraju S I and Nadaf H L 2009. Bio-priming of seeds: A potential tool in the integrated management of Alternaria blight of sunflower. *HELIA*, **32**: 107-114.

Sangeetha A, Subrahmaniyan K, Meena B and Kailashnarayan Gupta 2021. Screening of elite lines of sesame (*Sesamum indicum* L.) against major diseases. *Journal of Oilseeds Research*, **38**(3): 280-285.

Sahab A F, Elewa I S, Mostafa M H and Ziedan E H 2001. Integrated control of wilt and root-rot diseases of sesame in Egypt. *Egyptian Journal of Applied Sciences*, **16**(7): 448-462.

Ziedan E H, Elewa I S, Mostafa M H and Sahab A F 2011. Application of mycorrhizae for controlling root diseases of sesame. *Plant Protection Research Journal*, **51**(4): 355-367.

# Variability in Alternaria lini causing leaf blight disease of linseed (*Linum usitatissimum* L.)

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ABSTRACT

Alternaria blight is an important disease of linseed that hampers its productivity and oil content. The pathogen is genetically diverse showing variability in respect of cultural, morphological and pathogenic characters. Variability in seventeen isolates of Alternaria lini was carried out. Studies on cultural variability showed considerable variation among the isolates. The colony diameter varied from 46.67- 71.67 mm after 96 hrs. of incubation and most of the isolates recorded medium growth rate (50-64mm). The isolates Alt-6,Alt-7 Alt-12 showed fast growth habit (>65mm). The colony colour varied from grayish white, grey, dark olive green to grayish black. Sporulation in most of the isolates were late and concentric ring was present only in four isolates (Alt 3, Alt 8, Alt 13, Alt 14) while zonation was completely absent in other isolates. Morphologically different isolates of A. lini revealed variation with respect to mycelium width, size, shape, colour and septation of conidia. Mycelial width of most of the isolates having moderate to long width. Conidial length ranged from 24.87-33.68 µm similarly breadth of conidia ranged from 7.54-10.67 µm. Transverse septation were more than longitudinal septation. Variation in beak size ranged from 3.5-6.4 µm while colour of conidia varied from brown to dark brown colour and most of the isolates exhibited obclavate, oval to obclavate shaped conidia while one isolate appeared as oval shaped. Studies on pathogenic variations revealed that the variation observed in accordance with the latent period, lesion size, lesion shape and plant disease index. The latent period of *A. lini* isolates varied from 4.75 to 6.25 days with shortest (4.75 days) latent period recorded by isolates Alt-3 and Alt-11 and longest latent period of 6.25 days was observed in isolates Alt-6, Alt-14, Alt-16. The size of lesion varied from 2.25 to 4.75 mm and maximum lesions size (4.75 mm) was observed in isolate Alt-4 whereas minimum lesion size (2.25 mm) was observed in isolate Alt-5. The lesion produced after inoculation were elongated, oval and irregular in shape. The average number of lesions ranged from 2.75 to 4.00 with maximum number (4.00) of lesion recorded in isolate Alt-13. Plant disease index revealed that Meera and Nagarkot were more severe/virulent compare to Divya and Priyam in all the isolates.

**Keywords**: *Alternaria lini,* Cultural, Isolates, Linseed, Morphological, Pathogenic, Variability

Linseed (*Linum usitatissimum* L.) commonly known as flax is one of the most important *rabi* season oilseed crop stands next to rapeseed-mustard in area and production. It has an important position in Indian economy due to its wide industrial utility. Almost every part of the linseed plant is utilized commercially, either directly or after processing. The production and productivity of linseed in India are very low, mainly due to its cultivation in residual moisture during *rabi* season as well as due to number of biotic and abiotic stresses, to which linseed crop is exposed (Dwivedi *et al.,* 2021; Asma *et al.,* 2021). The crop is known to suffer from many fungal diseases such as powdery mildew, rust, blight, damping off, leaf spot, root rot and wilt. Alternaria blight caused by *Alternaria lini* Dey and *A. linicola* Groves and Skolko, is a major biotic stress limiting yield in hot and humid environment (Groves and Skolko, 1944). It is a facultative parasite causing blight disease that affects all the aerial parts of plant and responsible for yield losses ranging from 27.9 to 59.6 % (Day, 1933). The disease attacks both assimilative and reproductive part of the plant and causes huge amount of yield losses in terms of quality and quantity of fiber and seed. Use of resistant cultivar is a reasonable and effective method for disease management but due to development of new strain among the pathogens, resistant may be break down to susceptible one. Development of resistant cultivars requires knowledge of pathogen variation present in different regions where the crops are grown. Keeping the above facts in view, the present investigation was carried out on cultural, morphological and pathogenic behavior of *A.lini.*

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## MATERIALS AND METHODS

**Isolation and culture maintenance**: The leaf blight infected samples were collected from different Cultivar/crossing materials of linseed grown in the Research farm of Birsa Agricultural University, Ranchi, Jharkhand and the pathogen Alternaria lini was isolated on suitable media. A sum total of thirty isolations were made by following standard tissue

isolation procedure and purification is done by single spore inoculation technique (Keitt, 1915). After proving pathogenecity test seventeen isolates of *A. lini* were selected and designated as Alt-1, Alt-2, Alt-3, Alt-4, Alt-5, Alt-6, Alt-7, Alt-8, Alt-9, Alt-10, Alt-11, Alt-12, Alt-13, Alt-14, Alt-15, Alt-16, Alt-17, respectively for observing variability in the pathogen using cultural, morphological and pathological parameter.

**Cultural variation**: Mycelial culture (5 mm dia) of the seventeen isolates of *A. lini* were taken from the margin of actively growing colonies, centrally inoculated in the Petri plates in three replications. The inoculated plates were incubated at 25±2°C in BOD incubator under diffused light. Pure cultures of each isolate were subjected to detailed cultural characteristics *viz.,* radial growth (colony diameter in mm), colony morphology (colony colour, colony texture and mycelial dispersion) after 10 days of incubation. Based on the time taken for completion 90 mm radial growth of test pathogen in Petri plate, the isolates were classified into three groups, fast growing (>65 mm after 96hr of incubation), medium growing (50-64mm after 96hr of incubation) and slow growing (<50 mm after 96hr of incubation). Observation on sporulation was recorded on the basis of time taken for spore formation and number of spores/isolate. On the basis of time taken for sporulation, isolates were categorized into 2 groups *viz.,* sporulation within 48 hrs (early) and sporulation more than 48hrs (late).

**Morphological variation**: For morphological studies, culture of the tested isolates were flooded with 10 ml distilled water gently scrapped with Camel hair brush for obtaining spore suspension and counted under five random microscopic fields (40 X) and averaged. The sporulation frequency was categorized as No. of spores/microscopic field is 0= nil sporulation; <10 = poor; 10-20 =fair; 20-30 =good; >30 = excellent (Ginoya and Gohel, 2015). For microscpoic examination of conidia stage and ocular micrometer were used to measure the length, breadth, beak length and number of septa based on 15 observations for each structure, recorded from 5 different slides of 3 randomly selected individuals from each slide.

**Pathogenic variation**: In order to confirm the virulence levels of *A. lini* isolates, seeds of linseed cv. Meera, Nagarkot, Divya and Priyam susceptible/resistant to *Alternaria blight* (*A. lini*) were surface sterilized with 0.1 % $HgCl_2$ and sown (@ 20 seeds/pot) in the earthen pots (30 cm dia.) filled with steam sterilized potting mixture of soil: sand: FYM (2: 1: 1) under glass house conditions. After two weeks, ten healthy seedlings per pot were maintained, watered regularly for further growth and development. The spore-cum-mycelial suspensions of *A. lini* test isolates were prepared separately from 10 days pure culture, by flooding with 5-10 ml sterile distilled water. Three pricks were given on the top, middle and lower portion of the leaves and the conidial suspension (1×105 spores/ml) applied to the pin pricked leaves with the help of sterilized cotton swabs. To ensure humid microclimatic conditions, the inoculated plants were covered with transparent polythene bags for two days until symptoms appeared. Observations were taken on incubation period (number of days taken for appearance of first symptoms), lesion size (mm) and number of lesions.

## RESULTS AND DISCUSSION

**Variability in colony growth**: The cultural variability of 17 isolates of *A. lini* on potato dextrose agar medium revealed that, there was significant difference with respect to colony diameter, colony colour, and appearance of colony texture margin, sporulation and presence of concentric circle. These studies resulted that all the isolates showed remarkable variation in terms of colony diameter ranged from 46.67 mm to 74.67 mm. Among 17 isolates, 3 isolates (Alt-6, Aly-7, Alt-12) recorded colony diameter more than 65 mm after 96 hrs. of incubation and considered as fast growing isolates , 9 (Alt-1, Alt-2, Alt-3, Alt-4, Alt-5, Alt-8, Alt-9, Alt-10, Alt-13, Alt-14, Alt-15, Alt-16, Alt-17) isolates recorded colony diameter ranging from 50-64 mm and considered as medium growing isolates whereas only one isolate (Alt-11) recorded colony diameter of < 50 mm after 96 hrs. of incubation and considered as slow growing isolates (Table 1). The present finding is in accordance with the findings of Verma and Singh (2017) studied the cultural variability of twelve isolates of *A. lini* on five different nutrient media and observed that radial growths of A.lini ranged from 25mm to 60mm after 7 days of inoculation with maximum radial growth on isolates collected from Berhampur (W.B) whereas isolate obtained from Kanpur (U.P) showed minimum radial growth.

**Variability in colony color**: With respect to colony color, grayish white, grey, dark olive green and grayish black colour were observed (Table 2). Among the seventeen isolates, 3 isolates (Alt-1, Alt-8, Alt-13) exhibited grayish white colonies, 6 isolates (Alt-2, Alt-3, Alt-11, Alt-15, Alt-16, Alt-17) showed grey coloured colony, 7 isolates (Alt-4, Alt-5, Alt-6, Alt-9, Alt-10, Alt-12, Alt-14) appeared as dark olive-green colonies and only one isolate Alt- 7 resulted grayish black colony throughout the growth. Similarly, Charpe *et al.* (2014) recorded observations on colony colour of *A. lini* and reported that 5 isolates exhibited olivacious to black coloured colony, 4 isolates produced light grey to brown coloured colonies and only one isolate resulted dark grey colony colour.

**Variability in colony texture and zonation**: Texture of colony varied from fluppy, to thick cottony mycelial growth and result revealed that eight isolates exhibited fluppy texture/growth whereas 4 isolates showed cottony colony growth on PDA media. Margin was smooth in 7 isolates Atl-1, Alt-2, Alt-3, Alt-13, Alt-14, Alt-15, Alt-16, Alt-17) whereas 3 isolates (Alt-7, Alt-8, Alt- 13) showed wavy margin. Rest of the 7 isolates depicted rough margin (Table 2). The results are in agreement with Verma and Singh (2017) as they found that appearance of the colonies showed variable result from cottony, fluffy, feathery to compressed and thin texture with rough to smooth margin in different culture of *A. lini.*

With respect to zonation/appearance of concentric rings only four isolates (Alt-3, Alt-8, Alt-13, Alt-14) showed zonation while in the remaining isolates the zonation was completely absent (Table 2). The result are in accordance with the studies conducted by Mohsin *et al.* (2016) on Alternaria porri the causal agent of purple blotch of onion and Verma and Singh (2017) on *A. lini* the causal agent of Alternaria blight of linseed.

**Variability in sporulation**: On the basis of time taken for spore formation only 6 isolates (Alt-4, Alt-6, Alt-7, Alt-9, Alt-12 and Alt-15) were sporulated early i.e. sporulation within 48 hrs whereas rest were sporulated late i.e. sporulation more than 48 hrs of incubation. The result on number of spore/isolates on microscopic field induced variable result as excellent, fair and poor sporulation. Five isolates (Alt-4 Alt-5, Alt-9, Alt-10 and Alt-14) depicted excellent/abundant (>30 spore/microscopic field) sporulation, 6 isolates (Alt-2, Alt-6, Alt-7, Alt-12, Alt-13 and Alt-15) resulted fair/moderate (10-20 spores/microscopic field) whereas rest 6 isolates were sporulated poor/scanty (<10 spores/microscopic field) (Table 2; Fig. 3). Similarly, Charpe *et al.* (2014) investigated the sporulation intensity of *A. lini* and resulted slow growing isolates had sparse sporulation whereas profusely growing isolates had abundant sporulation. Jankar *et al.* (2017) and Shingne *et al.* (2020) also reported similar variation in the sporulation intensity of the isolates of Alternaria.

**Variability in conidia**: Studies on morphological variability of isolates unveiled that all isolates showed significant variation in morphological characters which included mycelium width, shape, size, colour and septation of conidia (Table 3; Fig. 2). The mycelium width ranged from 8.02 ?m to 6.31 µm with maximum in Alt-2 and Alt-13 while minimum was observed in Alt-7. The mycelium width produced by isolated pathogen was similar to the description given by Day (1933) and Sharma *et al.* (2015). In the present studies, wide variation was recorded in size and septation of conidia. The conidial length ranged from 24.87 µm to 33.68 µm with largest in Alt-9 and Alt-3 and smallest in Alt-7 similarly, breadth of conidia ranged from 7.54 ?m to 10.67 µm with maximum in Alt-3 and Alt-9 and minimum in Alt-7 and Alt-8. Study on septation of conidia resulted that transverse septa (2-7) are more than longitudinal septa (0-3) with maximum transverse septa (3-7) in Alt-11 and minimum (2-4) in Alt-16. Kumar and Biswas (2019) have also found the wide variability in multilocus isolates of *A. lini* (blight of linseed) in term of septation (2-7) and size (20.32-28.25 ×3.76-7.55µm). Verma and Singh (2017) were obtained conidial variability with 23.26-45.72 µm conidial length and 6.76-17.01 µm width with number of septa present 1.86 to 5.60 among twelve isolates of *A. lini* (blight of linseed). Variation in beak size was also recorded which ranged from 3.5- 6.4 µm having minimum (3.5 µm) in Alt-5 and Alt-17 and maximum (6.4 µm) in Alt-2. These reports are in agreement with the findings of Charpe *et al.* (2014) recorded the beak length of *A. lini* ranged from 2.3-15.6 µm. Nine isolates of *A. lini* produced brown coloured conidia whereas the colour was dark brown in rest of the eight isolates. In respect to shape of conidia ten isolates produced obclavate conidia, six isolates produced oval to obclavate conidia while only one isolate Alt-4 produced oval shaped conidia.

**Pathogenic variability of *A. lini***: Studies on pathogenic variations revealed that variation observed in accordance with the latent period, lesion size, lesion shape and plant disease index (Table 4; Fig. 4). With respect to incubation/latent period, *A. lini* isolates varied from 4.75 to 6.25 days in which shortest (4.75 days) latent period was recorded by the isolates Alt-3, Alt-11 and longest latent period of 6.25 days was observed in isolates Alt-6, Alt-14, Alt-16. Majority of isolates showed 5.75- 6 days of incubation period. Distinct differences in number of lesion and size were seen among the isolates of *A. lini.* Number of lesion varied from 2.75 to 4.00 with the maximum average number (4.00) of lesion recorded in isolate Alt-13 and minimum number (2.75) of lesion observed in 5 isolates (Alt-4, Alt-5, Alt-7, Alt-10 and Alt-12). The size of lesion varied from 2.25 to 4.75 mm with maximum lesions size (4.75 mm) was observed in isolate Alt-4 and minimum (2.25 mm) in isolate Alt-5. In respect to lesion shape, 4 isolates produced elongated lesions, 7 isolates produced oval lesions and 6 isolates produced irregular lesions (Fig. 5).

According to plant disease index Meera and Nagarkot were susceptible with more disease compared to Divya and Priyam, with severity ranging from 10.99% (Divya) to 30.44% (Meera) (Table 4). Similarly, Kumar and Biswas (2019) studied pathogenic variability of *A. lini* on 11 isolates and found the maximum disease severity with 52.12% in leaves and 39.10% in bud were recorded on plant inoculated by Nj isolate indicating most virulent and Nr isolate was found least virulent showing 48.36% on leaves and 37.78%

on buds. Moshin *et al.* (2016) recorded the pathogenicity of 27 different *A. porri* isolates and found test isolates exhibited variations in size of the lesions (2.77 to 7.55 mm) produced on onion leaves. Meena *et al.* (2014) also studied pathogenic variability of *Alternaria alternata* (KEISSLER), and observed that isolate Aa-1 was highly pathogenic on Isabgol cv. RI-89 under artificial inoculation conditions showing 52.12% disease intensity followed by Aa-3, Aa-2, Aa-4 and Aa-5 isolates at 4-5 days of incubation.

Table 1 Colony diameter/ Radial growth of *Alternaria lini* isolates on PDA

| Isolates | Colony diameter in mm | | | Growth rate |
|---|---|---|---|---|
| | 48 hrs | 72 hrs | 96 hrs | |
| Alt-1 | 22.83 | 40.67 | 59.00 | Medium* |
| Alt-2 | 15.83 | 36.87 | 53.67 | Medium |
| Alt-3 | 27.83 | 43.17 | 60.67 | Medium |
| Alt-4 | 19.83 | 37.50 | 53.33 | Medium |
| Alt-5 | 18.50 | 40.50 | 60.33 | Medium |
| Alt-6 | 21.50 | 44.83 | 65.50 | Fast |
| Alt-7 | 30.50 | 46.83 | 71.67 | Fast |
| Alt-8 | 11.50 | 30.67 | 50.67 | Medium |
| Alt-9 | 15.50 | 45.33 | 60.67 | Medium |
| Alt-10 | 19.67 | 38.50 | 53.33 | Medium |
| Alt-11 | 15.50 | 40.83 | 46.67 | Slow |
| Alt-12 | 13.83 | 46.50 | 74.67 | Fast |
| Alt-13 | 18.50 | 46.33 | 61.33 | Medium |
| Alt-14 | 20.50 | 44.67 | 61.67 | Medium |
| Alt-15 | 24.83 | 40.83 | 57.00 | Medium |
| Alt-16 | 19.67 | 45.67 | 62.67 | Medium |
| Alt-17 | 22.83 | 30.83 | 51.67 | Medium |
| Sem (±) | 0.28 | 0.31 | 0.50 | |
| CD at 5% | 0.83 | 0.90 | 1.45 | |
| CV(%) | 2.50 | 1.32 | 1.48 | |

*Fast growth: Isolates having radial growth more than 65mm after 96 hrs of incubation; *Medium growth: Isolates having radial growth 50-64 mm after 96 hrs of incubation; *Slow growth: Isolates having radial growth less than 50 mm after 96 hrs of incubation

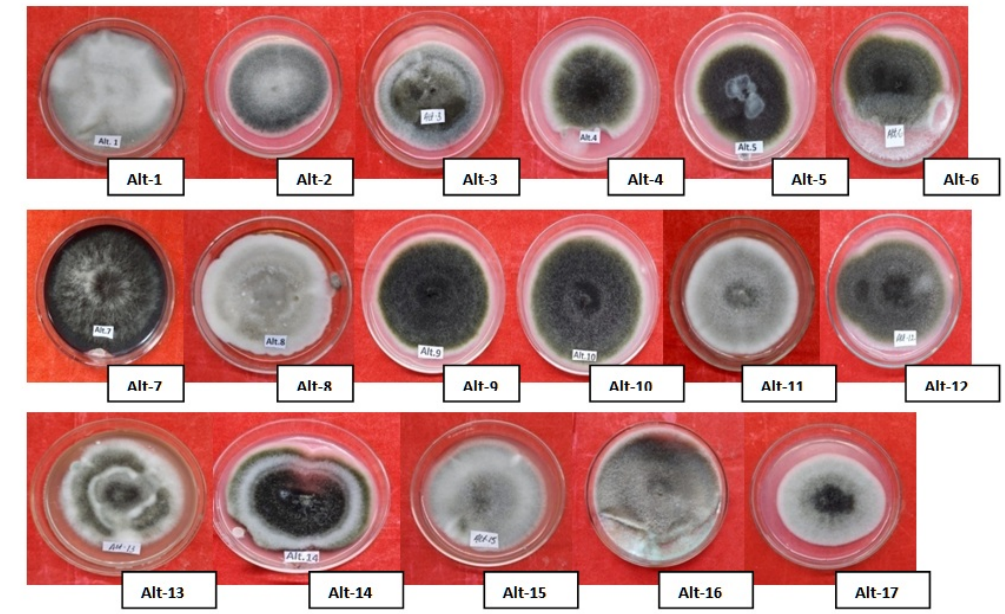


Fig. 1. Variability in cultural characters of *Alternaria lini*

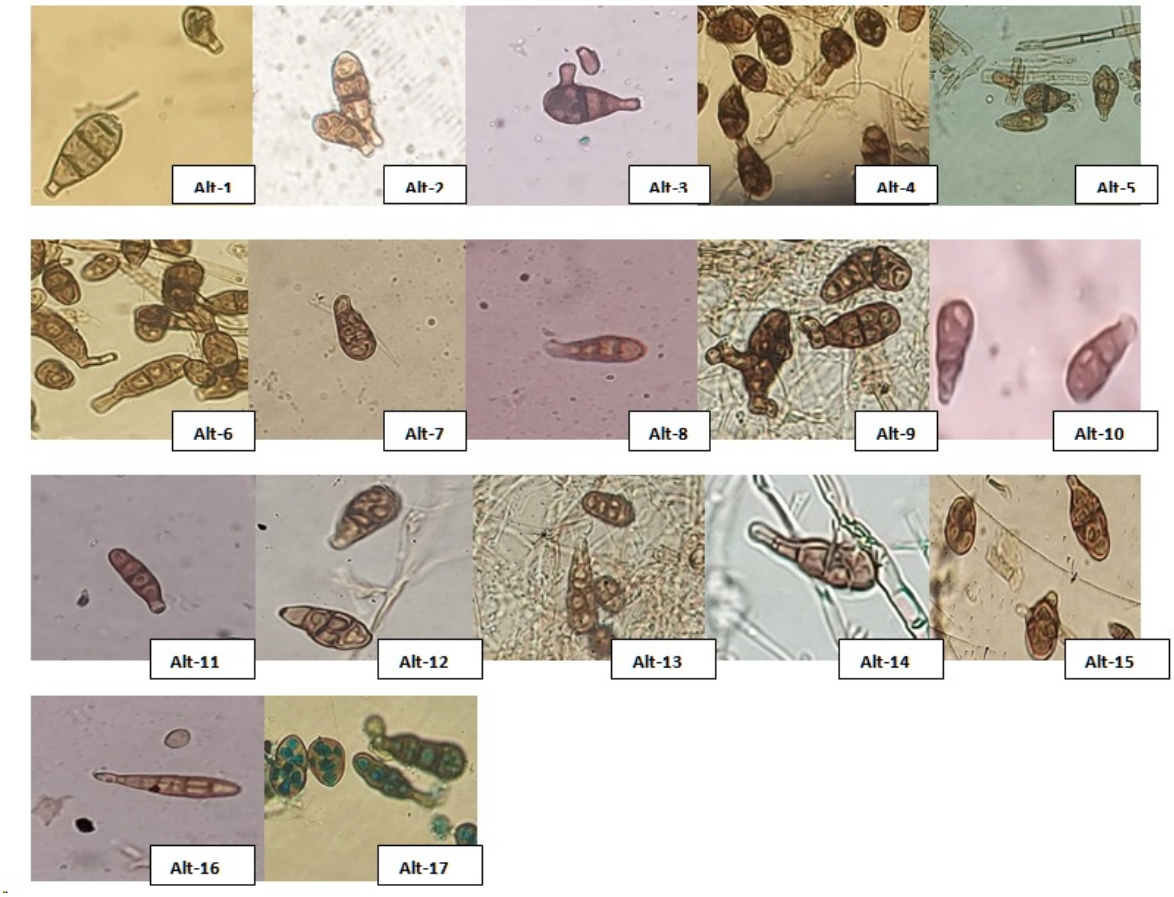


Fig. 2. Morphological variability among the isolates of *A. lini*

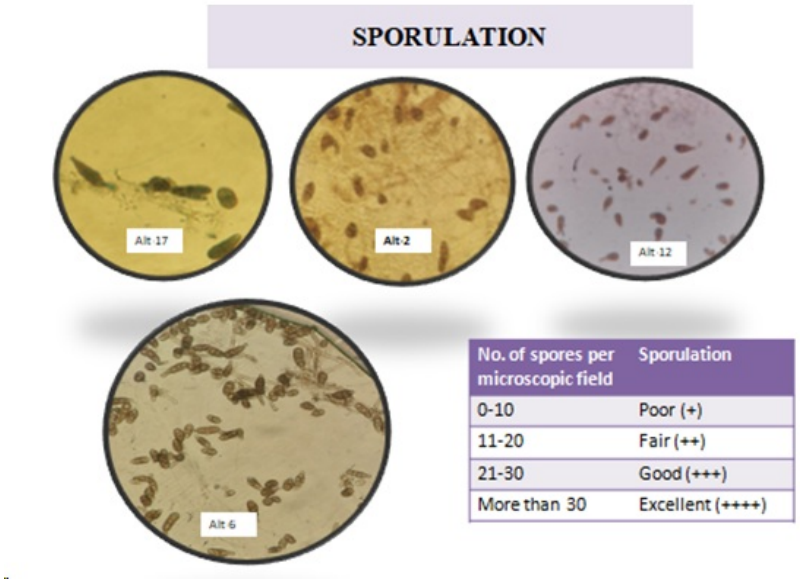


Fig. 3. Variability in sporulation of *A. lini* isolates

Table 2 Cultural variability among the isolates of *Alternaria lini* on PDA

| Isolates | Colony colour | Appearance of growth | Margin | Sporulation Time | Sporulation Number | Concentric Ring/ Zonation |
|---|---|---|---|---|---|---|
| Alt-1 | Grayish white | Fluppy | Smooth | Late | ++ | Absent |
| Alt-2 | Grey | Fluppy | Smooth | Late | + | Absent |
| Alt-3 | Grey | Fluppy | Smooth | Late | +++ | Present |
| Alt-4 | Dark olive green | Fluppy | Rough | Early | ++++ | Absent |
| Alt-5 | Dark olive green | Fluppy | Rough | Late | +++ | Absent |
| Alt-6 | Dark olive green | Fluppy | Rough | Early | ++++ | Absent |
| Alt-7 | Grayish black | Cottony | Wavy | Early | ++++ | Absent |
| Alt-8 | Grayish white | Cottony | Wavy | Late | + | Present |
| Alt-9 | Dark olive green | Fluppy | Rough | Early | ++++ | Absent |
| Alt-10 | Dark olive green | Fluppy | Rough | Late | + | Absent |
| Alt-11 | Grey | Cottony | Rough | Late | + | Absent |
| Alt-12 | Dark olive green | Fluppy | Rough | Early | ++++ | Absent |
| Alt-13 | Grayish white | Cottony | Wavy | Late | ++ | Present |
| Alt-14 | Dark olive green | Fluppy | Smooth | Late | + | Present |
| Alt-15 | Grey | Fluppy | Smooth | Early | ++++ | Absent |
| Alt-16 | Grey | Fluppy | Smooth | Late | + | Absent |
| Alt-17 | Grayish white | Fluppy | Smooth | Late | + | Absent |

Early sporulation within 48 hrs  Late sporulation more than 48 hrs

Table 3 Morphological variability of conidia among the isolates of *Alternaria lini*

| Isolates | Mycelium width(µm) | Conidial Length (µm) | | Conidial Breadth (µm) | | Colour | Shape | Septation | | Average beak size (µm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean | | | Transverse | Longitudinal | |
| Alt-1 | 7.85 | 20.48-35.84 | 27.70 | 5.12-14.08 | 8.59 | Brown | Obclavate | 2-5 | 0-3 | 3.8 |
| Alt-2 | 8.02 | 18.08-37.65 | 28.97 | 5.37-11.77 | 8.54 | Dark Brown | Obclavate | 3-6 | 0-2 | 6.4 |
| Alt-3 | 7.16 | 25.60-40.96 | 33.48 | 7.16-15.36 | 10.67 | Dark brown | Obclavate | 2-5 | 0-2 | 3.8 |
| Alt-4 | 7.16 | 20.48-35.84 | 29.72 | 6.40-15.36 | 9.07 | Dark Brown | Oval | 3-4 | 0-3 | 4.8 |
| Alt-5 | 7.50 | 16.64-38.91 | 30.36 | 5.63-15.36 | 9.16 | Brown | Oval to Obclavate | 3-6 | 0-3 | 3.5 |
| Alt-6 | 6.48 | 23.04-35.84 | 28.70 | 6.40-10.24 | 8.53 | Dark brown | Oval to Obclavate | 2-6 | 0-2 | 4.8 |
| Alt-7 | 6.31 | 20.48-30.72 | 24.87 | 5.12-12.80 | 7.54 | Dark brown | Obclavate | 2-5 | 1-2 | 3.8 |
| Alt-8 | 6.82 | 21.24-33.28 | 26.14 | 5.12-11.52 | 7.76 | Brown | Obclavate | 3-6 | 1-3 | 4.6 |
| Alt-9 | 7.68 | 22.01-40.96 | 33.68 | 5.12-15.36 | 10.57 | Dark brown | Oval to Obclavate | 2-5 | 1-2 | 4.3 |
| Alt-10 | 7.33 | 19.2-35.84 | 26.96 | 5.42-15.36 | 8.25 | Brown | Obclavate | 2-6 | 0-2 | 4.6 |
| Alt-11 | 6.99 | 20.48-40.96 | 28.67 | 5.12-16.64 | 8.11 | Brown | Obclavate | 3-7 | 0-3 | 5.2 |
| Alt-12 | 6.82 | 20.48-36.24 | 27.16 | 6.40-14.08 | 8.37 | Brown | Obclavate | 2-5 | 1-3 | 5.1 |
| Alt-13 | 8.02 | 21.24-35.84 | 28.99 | 5.12-10.24 | 9.04 | Brown | Oval to Obclavate | 3-6 | 0-3 | 4.6 |
| Alt-14 | 7.16 | 25.60-40.96 | 30.20 | 6.20-16.64 | 9.13 | Dark brown | Obclavate | 2-6 | 0-2 | 5.1 |
| Alt-15 | 7.33 | 23.04-33.28 | 28.15 | 6.14-12.8 | 8.99 | Brown | Oval to Obclavate | 2-6 | 0-2 | 4.6 |
| Alt-16 | 7.50 | 17.92-33.28 | 26.11 | 5.12-10.24 | 7.85 | Dark Brown | Obclvate | 2-4 | 1-2 | 5.1 |
| Alt-17 | 7.16 | 22.01-35.84 | 28.29 | 6.65-11.52 | 8.77 | Brown | Oval to Obclavate | 3-6 | 0-2 | 3.5 |

Table 4 Pathogenic variability among the isolates of *Alternaria lini*

| Isolates | Latent period (No. of days) | Average no. of lesions | Lesion size (mm) | Lesion shape | Disease intensity | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Meera | Nagarkot | Divya | Priyam |
| Al-1 | 5.50 | 3.50 | 3.25 | Elongated | 21.73 | 20.44 | 10.99 | 11.77 |
| Al-2 | 5.50 | 3.00 | 3.50 | Oval | 23.05 | 24.33 | 14.33 | 12.55 |
| Al-3 | 4.75 | 3.25 | 4.00 | Elongated | 26.27 | 27.55 | 15.99 | 14.99 |
| Al-4 | 5.75 | 2.75 | 4.75 | Elongated | 29.44 | 27.66 | 15.99 | 15.99 |
| Al-5 | 5.50 | 2.75 | 2.25 | Oval | 21.33 | 22.44 | 13.66 | 12.66 |
| Al-6 | 6.25 | 3.50 | 3.00 | Oval | 30.33 | 28.77 | 16.88 | 15.66 |
| Al-7 | 6.00 | 2.75 | 2.50 | Oval | 28.33 | 26.33 | 14.99 | 14.11 |
| Al-8 | 5.75 | 3.00 | 3.00 | Irregular | 24.33 | 22.88 | 12.88 | 12.55 |
| Al-9 | 6.50 | 3.00 | 3.00 | Elongated | 29.33 | 28.11 | 15.33 | 15.77 |
| Al-10 | 7.00 | 2.75 | 3.75 | Oval | 21.33 | 21.77 | 12.88 | 13.55 |
| Al-11 | 4.75 | 3.25 | 2.75 | Oval | 23.44 | 23.10 | 11.88 | 12.11 |
| Al-12 | 6.00 | 2.75 | 3.75 | Irregular | 27.77 | 26.88 | 15.33 | 14.77 |
| Al-13 | 5.75 | 4.00 | 3.25 | Irregular | 20.44 | 21.61 | 11.66 | 12.77 |
| Al-14 | 6.25 | 3.50 | 2.75 | Irregular | 30.44 | 28.55 | 15.77 | 14.88 |
| Al-15 | 6.00 | 3.00 | 3.50 | Irregular | 22.44 | 22.66 | 14.33 | 12.55 |
| Al-16 | 6.25 | 3.75 | 3.75 | Irregular | 23.11 | 24.11 | 12.44 | 11.88 |
| Al-17 | 5.50 | 3.50 | 2.75 | Oval | 22.77 | 21.33 | 12.22 | 12.88 |
| SE(m)± | | | | | 0.31 | 0.35 | 0.36 | 0.36 |
| CD at 5% | | | | | 0.89 | 1.02 | 1.06 | 1.04 |
| CV% | | | | | 2.14 | 2.49 | 4.55 | 4.60 |


Fig. 4. Pathogenic variability of *A. lini* isolates on different cultivars


Fig. 5. Lesion shape on host plant

## REFERENCES

Asma H H, Ajithkumar K, Savitha A S, Yenjerappa S T, Govindappa M R and Krishnamurthy D 2021. Studies on host range of *Alternaria* spp. causing blight disease in linseed. *Journal of Oilseeds Research*, **38**(3): 300-302.

Charpe A M, Bhoye B B and Gade R M 2014. Fungistasis of *Trichoderma* culture filtrates against *Alternaria lini* that causes bud blight of linseed. *Journal of Plant Disease Sciences*, **9**: 86-90.

Dey P K 1933. An Alternaria blight of linseed of plant. *Indian Journal of Agricultural Sciences*, **111**: 881-896.

Dwivedi S K, Satyaraj Guru R K and Panda S 2021. Foliar application of plant growth regulators on growth, yield and economics of linseed (*Linum usitatissimum* L.). *Journal of Oilseeds Research*, **38**(2): 195-198.

Ginoya C M and Gohel N M 2015. Cultural and morphological variability among the isolates of *Alternaria alternata* (fr.) Keissler, incitant of fruit rot of chilli. *International Journal of Plant Protection*, **8**: 118-125.

Groves J W and Skolko A J 1944. Note on seed borne fungi, II. *Alternaria. Canadian J. Res*., **22**: 217- 234.

Jankar K D, Bagde E D and Tatte R R 2018. Morphological and pathogenic variation of *Alternaria alternata* causing fruit rot of chilli. *International Journal of Chemical Studies*, **6**: 843-848.

Keitt G W 1905. Technique of isolating fungi. *Phytopathology*, **5**: 266-269.

Kumar N and Biswas S K 2019. Molecular and pathogenic variability of multilocus isolates of *Alternaria lini* Dey cause *Alternaria blight* in linseed (*Linum usitatissimum* L.). *Journal of Pharmacognosy and Phytochemistry*, **8**: 1360-1364.

Meena R K, Sharma S S and Singh S 2014. Studies on variability in *Alternaria alternata* (Kessler) causing leaf blight of Isabgol (*Plantago ovata*). *SAARC Journal of Agriculture*, **12**: 63-70.

Moshin S M, Islam M R, Ahmmed A N F, Nisha H A C and Hasanuzzaman M 2016. Cultural, morphological and pathogenic characterization of *Alternaria porri* causing purple blotch of onion. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*. **44**: 222-227.

Sharma R B, Arjariya A and Singh R 2015. Blight disease of linseed with its effects on oil quality and ethnomedicinal control. *Periodic Research*, **4**: 22-26.

Shingne A W, Bagade A R, Usendi P N and Gir G K 2020. Morphological, cultural and pathological variation of *Alternaria alternata* causing leaf spot of niger. *International Journal of Current Microbiology and Applied Sciences*, **9**: 3300-3306.

Verma A K and Singh R B 2017. Cultural and Morphological variability of *Alternaria lini* isolates causing blight of linseed. *International Journal of Research in Agricultural Sciences*, **7**: 361-372.

# Screening of two native isolates of entomopathogenic nematodes, *Heterorhabditis indica* and *Heterorhabditis bacteriophora*, for temperature and moisture stress tolerance

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ABSTRACT

Entomopathogenic nematodes (EPNs) are obligate parasites infecting a wide range of insect species and are one of promising biocontrol agents with potential in insect pest management. Temperature and soil moisture play an important role for their sustenance in soil and their efficiency varies greatly under different climatic conditions. The present study was aimed to study the effect of temperature and soil moisture on survival, infectivity and reproduction of two EPNs *viz., Heterorhabditis indica* and *H. bacteriophora.* The IJs of both the EPNs were exposed to different temperatures and soil moisture levels. Results revealed that survival of both EPNs effected at 5ºC. Survival of *H. indica* decreased from 54% to 29% after exposure to 5ºC for 48 h. None of the EPNs survived at 35ºC and 40ºC. Infectivity and reproduction potential of both the EPNs tested was highest at 30ºC. No decrease in infectivity was observed with increase in exposure time to different temperatures in both the EPN species. Slight decrease in reproductive potential was observed in *H. bacteriophora* when exposed to 30ºC for 48h. None of the tested EPNs infected Galleria mellonella larva at 5ºC, 35ºC and 40ºC. Both the EPNs tested showed high infectivity at soil moistures more than 10%. Minimum infection was observed at soil moistures below 10%. Our study revealed that temperature range of 20ºC-30ºC and soil moisture of >10% was found optimum for survival, infectivity and reproduction of the tested EPNs. Both the EPNs in this study showed similar temperature and moisture requirements.

**Keywords**: Entomopathogenic nematodes, Infectivity, Soil moisture, Survival, Temperature

Entomopathogenic nematodes (EPNs) belonging to the family Steinernematidae and Heterorhabditidae are proven as effective bio-agents against wide range of insect pests especially insects belonging to orders Coleoptera (Marianelli et al., 2017) and Lepidoptera (Gokte-Narkhedkar *et al.,* 2018). Pathogenicity of EPNs has also been reported on pest like Castor capsule borer, *Conogethes punctiferalis* (Bandaru *et al.,* 2020) and Serpentine leaf miner, *Liriomyza trifolii* (Gayatri *et al.,* 2019) which are difficult to reach by any other management practices. These deadly killers are equipped with symbiotic bacteria (Xenorhabdus for Steinernema and Photorhabdus for Heterorhabditis) which kill their insect hosts by causing septicemia or blood poisoning. Third stage juvenile is the infective stage (IJs) and only stage which is present in soil and actively seeks an insect host using host emitted chemical cues (Chaisson and Hallem, 2012). At this stage, IJs can survive for longer periods in absence of host, favorable climatic factors etc., and is similar to dauer stage present in most of the free living nematodes (Crook, 2014). EPNs infect their host through natural openings like mouth, anus spiracles (Steinernematids) and also through cuticle (Heterorhabditids). After killing the host, both nematodes and bacteria multiply on host body contents and after successful completion of 2-3 generations, thousands of infective juveniles (IJs) emerge out of the insect cadaver in search of a new host (Shapiro-Ilan *et al.,* 2012). EPNs are influenced by a number of biotic and abiotic factors in their natural habitat and among them, temperature has an important role directly effecting survival and persistence in soil (Chen *et al.,* 2003; Ali *et al.,* 2010; Shapiro-Ilan *et al.,* 2011). Every nematode species has their optimal temperature threshold and it vary between genus, species and strains (Pervez *et al.,* 2008; Sharmila *et al.,* 2018). In general, most of the EPNs are sensitive to extreme temperatures (below 0°C and above 40°C) in soil (Berry *et al.,* 1997; Kaya 1977; Patil *et al.,* 2018) and when exposed, their ability to infect an insect host changes drastically (Susurluk 2008). Temperature also influences the olfactory preferences and host seeking behavior of EPNs. For instance, when exposed to 15°C, *Steinernema carpocapsae* shown attraction towards chemical elicitors, methyl acetate and 2-propanone, whereas both the compounds acted as repellants when exposed to temperature above 25°C (Lee *et al.,* 2016). In another instance, infectivity of EPNs, *Steinernema* spp. and *Heterorhabditis indica* towards greater wax moth, *Galleria mellonella* varied to a greater extent

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when exposed to different temperatures. None of them showed infectivity below 10°C and above 35°C (Lalramnghaki *et al.,* 2016).

Another key element influencing survival of EPNs is soil moisture. It is one of the important soil parameters which is crucial for nematode movement, particularly while finding a host to infect and field efficacy of EPNs is highly dependent on soil moisture levels. Using EPNs is a feasible biocontrol option in areas where soil moistures are maintained either by uniform rainfall or good irrigation facilities (Blatt and Barry, 2020). Ubiquitous distribution of EPNs facilitated their isolation from different agro-ecological regions and native isolates have the ability to withstand prevailing climatic conditions in their region (Redmond and Potter, 2010). A soil moisture equivalent to 75% of field capacity and temperature of 25°C was found optimum for successful infection on Mediterranean fruit fly, *Ceratitis capitata* third instar by *S. carpocapsae* isolate ALL and *Heterorhabditis* sp., isolate RSC01 with more than 90% larval mortality (Rhode *et al.,* 2010). Similar observations were made by Shaurab *et al.,* 2015 when *H. bacteriophora* isolate AS1 showed highest infectivity rate at a soil moisture of 10% and temperature of 25°C on third instar of *C. capitata* (Shaurab *et al.,* 2015). Highest infectivity was observed in sandy soil whereas it decreased in silt and clay soils. Evaluation of native isolates is essential to see their adaptability to prevailing climatic conditions when applied in field during pest management programs and under storage conditions. The present study was aimed at evaluating the optimum temperature and soil moistures for the successful infection and reproduction of in two native isolates of Heterorhabditis, *H. indica* and *H. bacteriophora.* Hence, present study has been proposed to observe the survival, infectivity and reproduction of IJs of *H. indica* and *H. bacteriophora* on *G. mellonella* after exposing to different temperatures and soil moistures.

## MATERIALS AND METHODS

**Nematode cultures**: Two entomopathogenic nematodes, *Heterorhabditis indica* and *H. bacteriophora* were used in this study. Nematode cultures were procured from National Institute of Plant Health Management (NIPHM), Hyderabad, India. The nematode cultures were multiplied on late instar greater wax moth larvae before proceeding for bioassay. Wax moth larvae killed due to EPN infection were incubated for 2-3 days and placed on white's trap for emergence at temperature 25 ± 1ºC (Woodring and Kaya, 1988). Infective juvenile (IJs) emergence started from 10$^{th}$ day and fresh nematode suspension containing 100% active IJs were used for bioassays.

**Insect cultures**: Greater wax moth, Galleria mellonella larvae were used in bioassays. The insect cultures were collected from naturally infested honey combs and were multiplied on honey combs and artificial diet (Birah *et al.,* 2008) at a temperature of 27±2°C and relative humidity of 60-70%. After adult emergence, male and female moths were collected and released into bottles lined with bloating paper for egg laying. To improve oviposition, 10% honey solution was given as diet for adult moths. Eggs were collected and inoculated into freshly prepared artificial diet for hatching and further larval development. After 7-10 days, late instar larvae were collected and used in bioassays.

**Bioassay to evaluate IJs survival at different temperatures**: To evaluate the effect of temperature on survival of two test entomopathogenic nematodes, *Heterorhabditis indica* and *H. bacteriophora,* IJs of both EPNs were exposed to eight different temperatures (5, 10, 15, 20, 25, 30, 35 and 40ºC) at BOD (model?) for two time periods (24 and 48 h). The bioassay was performed in 50 mm glass Petri plates. Each Petri plate was added with 4 ml of nematode suspension containing approximately 2000 IJs and were sealed with parafilm to expose to different temperatures. After temperature treatment, the Petri plates were left at room temperature for IJ recovery for 24 h and live nematodes were counted by taking aliquots of how many ml? from treated nematode suspensions. IJ were considered as alive based on their normal movement or movement upon gentle probing with a needle (Glazer, 1992). Each treatment was replicated 5 times per temperature, exposure time and nematode species.

**Bioassay to evaluate IJs infectivity at different temperatures**: To study the effect of temperature on infectivity of IJs, their host penetration and development were studied after temperature treatment. The IJs were treated with different temperatures for different time periods as per the previous procedure mentioned and treated IJs were inoculated on late instar larvae of greater wax moth @ 100 IJs per larva and plates were incubated at room temperature. Five larvae were used per Petri plate and five replicates were used per temperature, exposure time and nematode species. Petri plates were checked daily for insect mortality and dead larvae were counted and incubated at 25±1ºC for 3 days. Larvae were then dissected and insect tissue was digested by adding freshly prepared 0.8% pepsin solution (pH 1.8-2) and development of first generation hermaphrodites inside insect cadaver (Glazer and Lewis, 2000) was observed.

**Bioassay to study reproduction of EPNs after exposure to different temperatures**: Reproduction of both EPNs were evaluated with final IJs emerged per insect cadaver subsequent to treatment with different temperatures. The treated IJs were used for infecting wax moth larvae as detailed above. Five larvae were used per Petri plate and

each treatment was replicated thrice. Dead larvae were incubated for 2-3 days at 25±1ºC and they were placed on white's trap (White, 1927) for IJ emergence. IJs emergence started from 10th day after insect mortality. IJs emerged were collected for every 5 days till the IJs emergence stopped and the number of IJs emerged were counted to determine the reproduction/multiplication rate of EPNs.

**Bioassay to evaluate IJs infectivity at different soil moisture**: The bioassay was performed with sandy loam soil (>75% sand) at a temperature of 25±2°C. The soil was autoclaved before performing the bioassay. Bioassay was performed in 12- well tissue culture plates (5 ml arena) and six soil moistures (3, 5, 7, 10, 15, 20% w/w) were tested. For each soil moisture treatment, 50 µl of distilled water with 100 IJs was placed at bottom of well and added with (pre-wetted) soil to obtain the desired soil moisture. At the top, one Galleria larva was added into each well and plate was sealed and inverted. The plates were inverted for every few hours to achieve uniform distribution of IJs and prevent the larval movements to the top (Yadav, 2012). Three plates were used for each moisture treatment and soil without IJs was used as control. The plates were checked for larval mortality at 24, 48 and 72 hours after treatment.

**Statistical analysis**: Data was subjected to Factorial ANOVA to observe the individual and interactive effect of nematode species, temperatures and exposure times on IJ survival, infectivity and nematode reproduction. Similarly, individual and interactive effects of soil moisture levels, exposure time and nematode species on infectivity was determined using factorial ANOVA. Factors with significant difference in their means were compared using Fisher's least significant difference test at 5% level of significance.

## RESULTS AND DISCUSSION

**IJs survival at different temperatures**: Two EPN species, Heterorhabditis indica and *H. bacteriophora* were exposed to eight different temperatures (5, 10, 15,20, 25, 30, 35 and 40ºC) to test their survival after 24 and 48 hours of exposure. Results revealed that there is significant difference between two nematode species on survival of infective juveniles ($F(1,120) = 31.8$, $p < 0.01$). Highest survival percentage was observed at temperature of 20ºC (89 %) and survival percentage is on par for 15 ºC and 25 ºC; 10 ºC and 30ºC. There is 42 % of survival at low temperature (5ºC) and both the EPNs showed around 80% survival with wide survival temperature ranging from 10ºC to 30ºC (Fig.1). At temperatures above 35ºC, chance of survival is minimal. Significant interaction has been observed between temperature and exposure time ($F(7,128) = 6.5$ and LSD =2.729) directly effecting the survival of EPNs.

**IJs infectivity at different temperatures**: Penetration of IJs of both tested EPN species reduced with increase in temperature. There is no significant difference in infectivity between the EPNs tested at different temperatures. But significant difference in penetration and development has been observed among different temperatures ($F(7,128) =$ and LSD =2.63) inferring that different temperatures effected the level of infectivity. No interaction was observed between exposure time and other factors tested in this study.

**Reproduction of EPNs after exposure to different temperatures**: Reproduction of both EPNs was effected with increase in temperature. Significant difference was observed at different temperatures and their interactive effects with other factors ($F(7,64) = 4445.6362$ and LSD =6.173 & $F(7,64) =3.6$ and LSD 8.729 respectively) and no significant difference was observed between EPNs species with respect to reproduction. Similarly, with increase in exposure time, decrease in progeny production was observed in both EPNs ($F(7,64) =5.45$ and LSD 8.729) (Fig.2).

**Moisture stress tolerance**: Different moisture levels and exposure period ($F(5,72) =48.0926$ and LSD 3.77 ; $F(5,72) =2.26$ and LSD 9.23) and their interaction showed significant difference in infectivity of tested EPNs ($F(5,72) =145.9$ and LSD 5.33). Whereas no significant difference in infectivity was observed between the EPN spp. tested. Interaction effect of EPN spp. and soil moisture levels was also found to be non-significant.

Entomopathogenic nematodes (EPNs) are well known bio-agents for their insect extermination abilities and are capable of attacking a wide range of insect taxa. Temperature plays an important role in their survival, infectivity, development and reproduction. The optimal temperatures for sustenance of a EPNs varies with species and strains that enable them to survive at variable habitat (Pervez *et al.,* 2015). For successful execution of any biocontrol agent in an integrated pest management module, understanding the effect of different biotic and abiotic factors is of prime importance. Under field conditions, temperature and soil moisture inflict a greater impact on survival, infectivity and persistence of EPNs and evaluating virulent native isolates is one important task before proceeding for mass production. In our study, we evaluated the effect of temperature on IJ survival, infectivity and reproduction; and effect of soil moisture on IJs infectivity of two EPNs, Heterorhabditis indica and *H. bacteriophora*. With increase in temperature from 5ºC to 30ºC, survival of both the EPN species increased with 25ºC being the best temperature for survival. None of IJs survived at temperature ?35ºC. IJs, when exposed to 5ºC for more than 24 hours, survival of IJs reduced from 54 to 29% in *H. indica*.

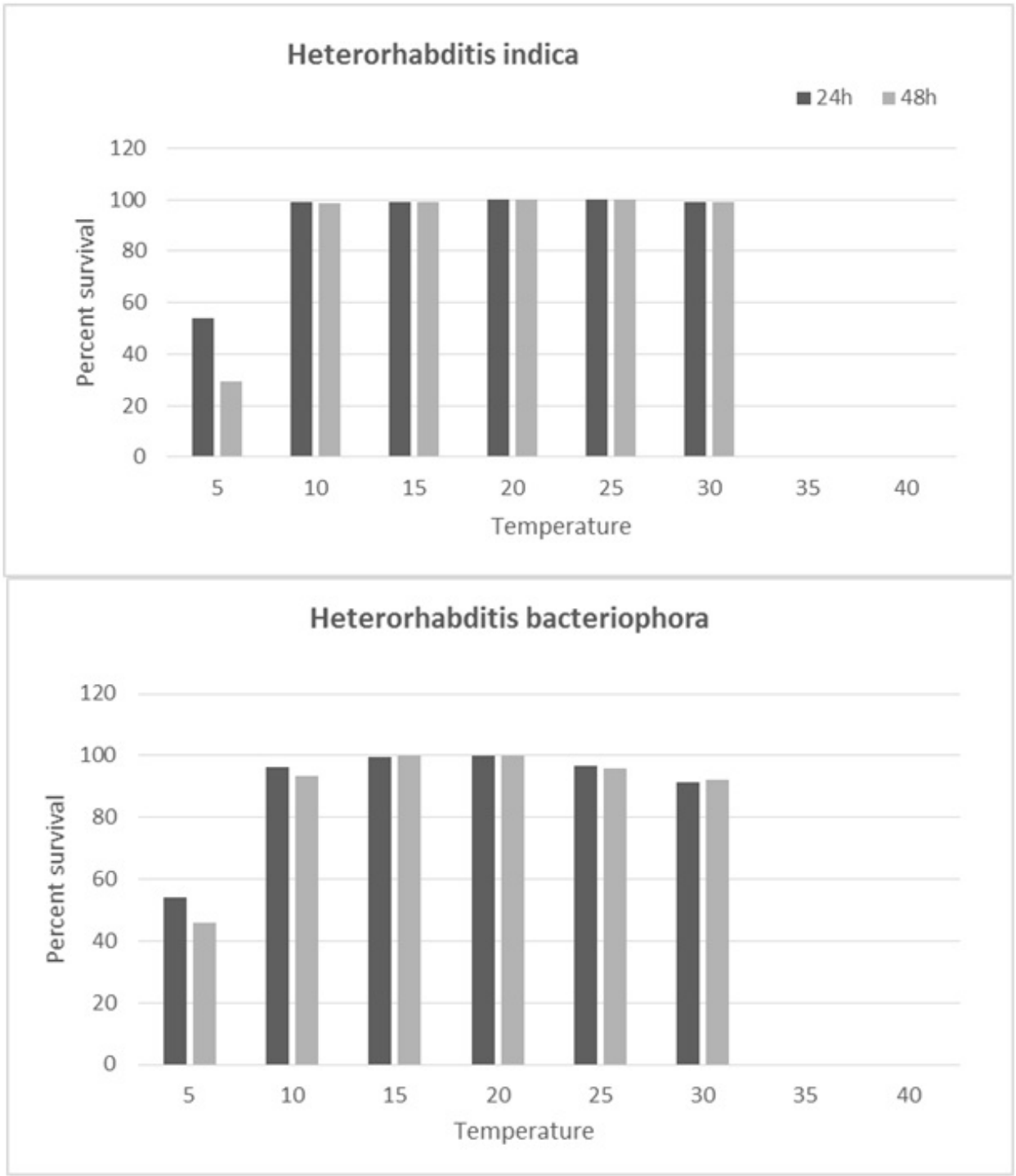


Fig. 1. Influence of different temperatures (5, 10, 15, 20, 25, 30, 35 and 40ºC) for two exposure time periods (24 and 48 h).) on survival of two EPN species *Heterorhabditis indica* and *Heterorhabditis bacteriophora*

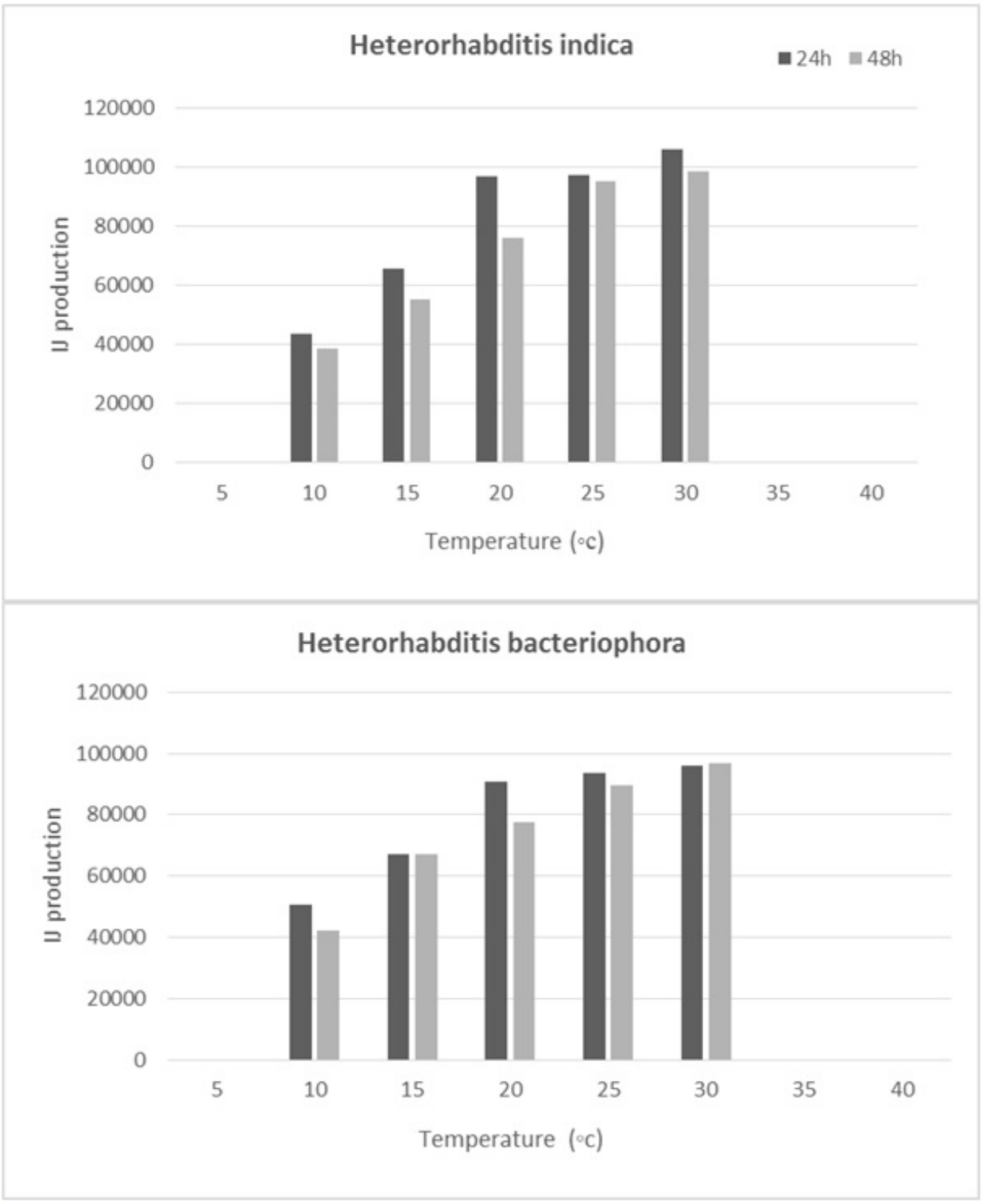


Fig. 2. Influence of different temperatures (5, 10, 15, 20, 25, 30, 35 and 40ºC) for two exposure time periods (24 and 48 h).) on IJ production of two EPN species *Heterorhabditis indica* and *Heterorhabditis bacteriophora*

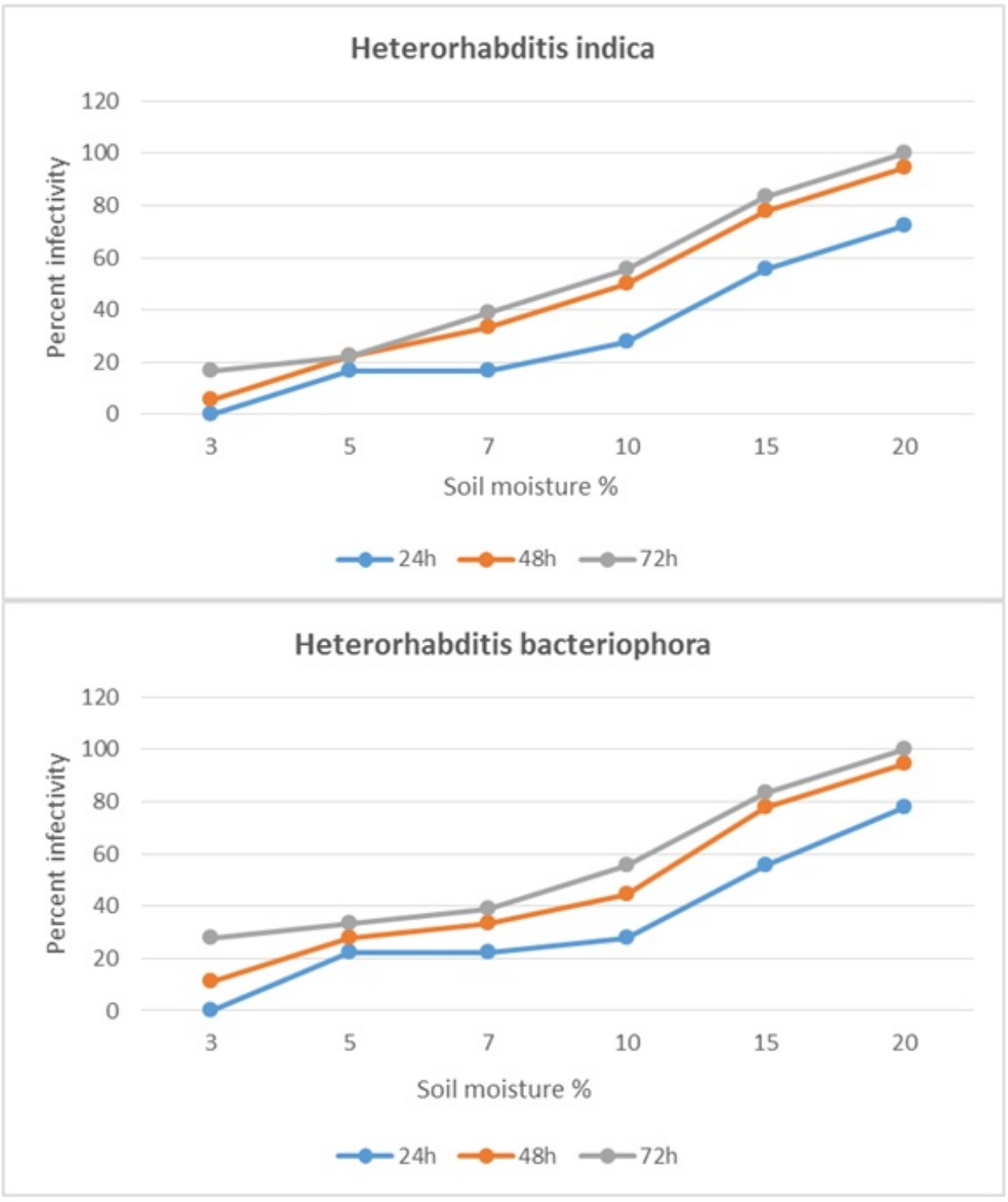


Fig. 3. Influence of different soil moistures (5, 10, 15, 20, 25, 30, 35 and 40ºC) for three exposure time periods (24, 48 and 72 h) on infectivity of two EPN species *Heterorhabditis indica* and *Heterorhabditis bacteriophora*

In contrary to our results, Patil *et al.* (2018) recorded survival of *H. indica* at temperatures 35ºC and 37ºC but not at 40ºC indicating that optimal temperatures varies with strains and habitat from which they were isolated (Patil *et al*., 2018). Accumulation of saturated fatty acids and non-reducing sugars like trehalose is responsible for heat tolerance in many organisms including EPNs (Grewal *et al.,* 2006). In a study conducted by Fanelli *et al.* (2021), differential Expression of heat shock protein HB-hsp90-1gene was observed in IJs and hermaphrodites of *H. bacteriophora*. The study concluded that HB-hsp 90-1gene modulated the acclimation to increased temperatures and also the post treatment recovery of IJs to infect wax moth larvae (Fanelli *et al.,* 2021). Our study agrees with previous studies concluding that independent of time of exposure, too high or too low temperatures effect the survival of EPNs.

In this study we have also assessed the effect of temperature on infectivity of EPNs on wax moth larvae. Highest infectivity (> 80%) was observed at a temperature of 30ºC followed by 25 ºC in both the EPNs tested. At very low (5ºC) or very high temperatures (35ºC/40ºC), no infection was observed. Similar observations were made by Pervez *et al.* (2015) where maximum mortality of Conogethes punctiferalis was found at 30°C followed by 25°C and Heterorhabditis spAt 30°C, H. indica caused 100% insect mortality at 24 h after infection indicating 30°C is the most favorable temperature for successful infection of insect (Lalramnghaki *et al.,* 2016). In this study, highest progeny production was observed at 30ºC in both EPNs whereas slight reduction in progeny production was observed when infected with IJs exposed to 48 h.

We have also studied the effect of soil moisture on infectivity of both the tested EPNs. Infectivity of both the EPNs tested increased at 10% and more soil moisture and highest infectivity was observed at 20% soil moisture (Fig.3). Blatt and Barry made similar observations when four EPN products were evaluated for their ability to infect at different soil moistures (6, 8, 10 and 15%) and soil depths (3, 5 and 7cm). Heterorhabditis bacteriophora showed high infectivity in wax moth larva at more than 15% soil moisture buried at 5 and 7 cm depths when compared to soil moistures less than 10%. In contrast, *Steinernema* spp. showed highest infectivity at lower moisture tested than higher moistures (Blatt and Barry, 2020). Cruising behavior of *Heterorhabditis* spp. along with morphological traits like smaller body length require more soil moisture for their movement even at higher depths. Low soil moisture may hinder movement of nematodes as nematodes always need a thin film of water around them for their movement.

Our study concludes that temperature and soil moisture serve as essential factors for EPNs sustenance in environment and understanding these factors is very much essential for successful utilization of native EPN isolates in pest management programmes.

## REFERENCES


Ali H, Ahmad S and Safiullah J S 2010. Efficacy of different control methods against oriental fruit fly, *Bactrocera zonata* (Saunders). *ARPN Journal of Agricultural and Biological Science*, **5**: 1-3.

Bandaru G, Duraimurugan P and Chunduri S. 2020. Virulence of entomopathogenic nematodes against castor capsule borer *Conogethes punctiferalis* (Guenée). *Indian Journal of Entomology,* **82**(1): 200-205.

Berry R E, Liu J and Groth E 1997. Efficacy and persistence of *Heterorhabditis marelatus* (Rhabditida: Heterorhabditidae) against root weevils (Coleoptera: Curculionidae) in strawberry. *Environmental Entomology*, **26**: 465-470

Birah A, Chilana P, Shukla U K and Gupta G P 2008. Mass rearing of greater wax moth (*Galleria mellonella* L.) on artificial diet. *Indian Journal of Entomology*, **70**(4): 389-392.

Blatt S E and Barry S 2020. Movement and infectivity of entomopathogenic nematodes in sandy loam soil from a carrot field in Nova Scotia: a laboratory study. *Journal of the Acadian Entomological Society*, 16.

Chaisson K E and Hallem E A 2012. Chemosensory behaviors of parasites. *Trends in Parasitology,* **28**(10): 427-436

Chen S, Li J, Han X and Moens M 2003. Effect of temperature on the pathogenicity of entomopathogenic nematodes (*Steinernema* and *Heterorhabditis* spp.) to *Delia radicum*. *BioControl*, **48**: 713-724.

Crook M 2014. The dauer hypothesis and the evolution of parasitism: 20 years on and still going strong. *International Journal for Parasitology*, **44**: 1-8.

Fanelli E, Troccoli A, Tarasco E and De Luca F 2021. Molecular characterization and functional analysis of the Hb-Hsp 90-1 gene in relation to temperature changes in *Heterorhabditis bacteriophora. Frontiers in Physiology*, **12**: 615-653.

Gayatri B and Duraimurugan P. 2019. Bio-efficacy of *Heterorhabditis bacteriophora* (Rhabditida: Heterorhabditidae) against serpentine leafminer, *Liriomyza trifolii* Burgess (Diptera: Agromyzidae) in oilseed crops. *Journal of Biological Control*, **33**(2): 169-172.

Glazer I 1992. Survival and efficacy of Steinernema carpocapsae in an exposed environment. *Biocontrol Science and Technology,* **2**(2): 101-107.

Glazer I and Lewis E E 2000. Bioassays for entomopathogenic nematodes. *Bioassays of entomopathogenic microbes and nematodes,* CABI Publishing, pp. 229-247.

Gokte-Narkhedkar N, Bhanare K, Nawkarkar P, Chilliveri P, Fand B B and Kranthi S 2019. Parasitic potential of entomo-pathogenic nematode *Heterorhabditis indica* against two Lepidopteran insect pests of cotton, *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fabricious). *Phytoparasitica*, **47**(1): 31-41.

Grewal P S, Bornstein-Forst S, Burnell A M, Glazer I and Jagdale G B 2006. Physiological, genetic, and molecular mechanisms of chemoreception, thermobiosis, and anhydrobiosis in entomopathogenic nematodes. *Biological Control*, **38**: 54-65.

Kaya H K 1977. Development of the DD-136 strain of Neoaplectana carpocapsae at constant temperatures. *Journal of Nematology*, **9**(4): 346.

Lalramnghaki H C, Vanlalhlimpuia V and Lalramliana 2016. Effect of temperature on the infectivity of entomopathogenic nematodes (Steinernematidae and Heterorhaditidae) isolated from Mizoram, *Northeastern India. Science Vision*, **16**(1): 21-26.

Lee J H, Dillman A R and Hallem E A 2016. Temperature-dependent changes in the host-seeking behaviors of parasitic nematodes. *BMC Biology,* **14**: 36.

Marianelli L, Paoli F, Torrini G, Mazza G, Benvenuti C, Binazzi F and Priori S 2018. Entomopathogenic nematodes as potential biological control agents of *Popillia japonica* (Coleoptera, Scarabaeidae) in Piedmont Region (Italy). *Journal of Applied Entomology*, **142**(3): 311-318.

Patil J, Gowda M T, Vijayakumar R and Verghese A 2018. Fluctuating temperature: A cause for survival and development of entomopathogenic nematodes, *Heterorhabditis indica* and *Steinernema carpocapsae. Indian Journal of Experimental Biology*, **56**: 327-333.

Pervez R, Ali S S and Ahmad R 2008. Effect of temperatures on the emergence of entomopathogenic nematodes. *International Journal of Nematology*, **18**(1): 25-28.

Rashid P, Eapen S J, Devasahayam S and Jacob T K 2015. Effect of temperature on the infectivity of entomopathogenic nematodes against shoot borer (Conogethes punctiferalis Guen.) infesting ginger (Zingiber officinale Rosc.). *Journal of Biological Control*, **29**(4): 187-193.

Redmond C T and Potter D A 2010. Incidence of turf damaging white grubs (Coleoptera: Scarabaeidae) and associated pathogens and parasitoids on Kentucky golf courses. *Environmental Entomology*, **39**: 1838-1847

Rohde C, Moino Jr A, da Silva M A, Carvalho F D and Ferreira C S 2010. Influence of soil temperature and moisture on the infectivity of entomopathogenic nematodes (Rhabditida: Heterorhabditidae, Steinernematidae) against larvae of *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae). *Neotropical Entomology*, **39**(4): 608-611.

Shapiro-Ilan D I, Han R and Dolinksi C 2012. Entomopathogenic nematode production and application technology. *Journal of Nematology*, **44**(2): 206.

Shapiro-Ilan D, Leskey T C and Wright S 2011. Virulence of eEntomopathogenic nNematodes to pPlum cCurculio, Conotrachelus nenuphar: Effects of Sstrain, tTemperature, and sSoil Type. *Journal of Nematology*, **43**: 187-195.

Sharmila R. Priya M S, Subramanian S, Poornima K and Pandiyan M 2018. Review on ecology of entomopathogenic nematodes. *Journal of Entomology and Zoology Studies*, **6**(4): 1086-1093.

Shaurub E H, Soliman N A, Hashem A G and Abdel-Rahman A M 2015. Infectivity of four entomopathogenic nematodes in relation to environmental factors and their effects on the biochemistry of the Medfly *Ceratitis capitata* (Wied.) (Diptera: Tephritidae). *Neotropical Entomology*, **44**(6): 610-618.

Susurluk A 2008. Influence of temperature on the vertical movement of the entomopathogenic nematodes *Steinernema feltiae* (TUR-S3) and *Heterorhabditis bacteriophora* (TUR-H2) and infectivity of the moving nematodes. *Nematology,* **10**(1):137-141.

White G F 1927. A method for obtaining infective nematode larvae from cultures. *Science,* **66**: 302-303.

Woodring J L and Kaya H K 1988. *Steinernematid and heterorhabditid nematodes: a handbook of biology and techniques.* Southern Cooperative Series Bulletin, USA.

Yadav A K 2012. Soil moisture effects on the activity of three entomopathogenic nematodes (Steinernematidae and Heterorhabditidae) isolated from Meghalaya, India. *Journal of Parasitic Diseases*, **36**(1): 94-98.

# Identification of resistant sources for gall fly, *Asphondylia sesami* Felt (Diptera: Cecidomyiidae) in sesame

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ABSTRACT

The incidence of the gall fly, *Asphondylia sesami* Felt (Diptera: Cecidomyiidae) is common during flowering period of sesame during two seasons. The sesame genotypes (n=60) were screened for A. sesami during two season 1 and 2. In season 1, two genotypes, ISWG-20-05 and IIOS-1103 were found free from *A. sesami* incidence. The sesame genotypes (n=60) graded for *A. sesami* as resistant (59 genotypes), moderately resistant (1 genotype) based on incidence. In season 2, two genotypes, SES-K-20-2015 and IC-16239 were found free from *A. sesami* incidence. The sesame genotypes (n=60) graded for *A. sesami* as resistant (29 genotypes), moderately resistant (22 genotypes), moderately susceptible (8 genotypes) and susceptible (1 genotype) based on incidence. To summarize, 28 genotypes were resistant to *A. sesami* in both season 1 (2021) and 2 (2022) and the resistant genotypes can be used as donor in future breeding programmes.

**Keywords**: Sesame, Gall fly, Population, Incidence, Genotypes, Reaction, Seasons

Sesame (*Sesamum indium* L.) has earned a poetic label 'Queen of Oilseeds' due to high quality polyunsaturated stable fatty acid, which restrains oxidative rancidity. It has other nutritional and medicinal benefits like anti-cancer, anti-diabetic, anti-inflammatory, and regulates cholesterol. The present growth rate of domestic oilseed production is not sufficient to fulfil the rising demand. Under such circumstances, serious research efforts are required to enhance the production and productivity using latest breeding tools to mine and utilize the germplasm with desired traits (Kumhar and Rajani Bisen. 2021). Biotic stresses are a major constraint for increasing the production and productivity of this crop. Insect pests are responsible for quantitative and qualitative yield reduction in sesame (Muzaffar *et al.,* 2002). An updated checklist of insect pests of sesame is provided, with 201 species included. Among these, the Cicadellidae with 20 species and Pentatomidae with 19 species are the predominant ones followed by Noctuidae (14), Miridae (11) and Chrysomelidae (10). Quantitative damage due to insect pests' infestation in sesame was reported to be between 5-50% of the total sesame production in Africa (Muzaffar *et al.,* 2002). Globally, yield loss in sesame due to insect pest infestation was reported to be 25% with most of the injury inflicted during flowering stage (Weiss, 2000; Vamshi *et al.,* 2021).

In India, the damage due to insect pests is also one of the major factors causing low productivity in sesame (Biswas *et al.,* 2001). The leaf webber/capsule borer (*Antigastra catalaunalis* Duponchel), leafhopper (*Orosius albicinctus* Distant), gall fly (*Asphondylia sesami* Felt), whitefly and mirid bug are a major constraint for increasing the production and productivity of this crop (Boopathi and Sujatha, 2022). *Asphondylia sesami* (Diptera: Cecidomyiidae) is mostly restricted to Southern India and East Africa (Ahuja *et al.* 2001). The sesame gall midge reported as a major pest from Maharashtra (India). The incidence of the pest is common during flowering period of sesame and number of generation will be increased due to staggered sowing as well as inclusion different verities of sesame (Baskaran *et al.,* 1997). Unfortunately, there are very few control strategies for management of the biotic stresses. Researchers are probably working on more eco-friendly management methods, such as plant resistance. Host plant resistance can be a suitable method for pest control within integrated pest management strategies. There is an urgent need to use indigenous sesame germplasm/advanced breeding lines to build genomic resources to discover genetic variants for genetic enhancement of sesame especially for control of *A. sesami.* Therefore, the project is aimed to identify sources of resistance to *A. sesami.* This information will be utilized in the resistance breeding programmes.

## MATERIALS AND METHODS

The present study was carried out in the research farm of ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad, Telangana, India at an altitude of 540 m, 17º19'17" N latitude and 78º24'51" E longitude and has a tropical agro-climate. For the two seasons (2021 and 2022), field experiments were conducted in 60 advanced breeding lines of sesame in randomized block design (RBD) with three replication. The net plot size was 2 × 5 m with spacing

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of 40 × 30 cm row to row and plant to plant, respectively. All the recommended agricultural practices were followed in raising the crop. No plant protection measure was taken throughout the crop season. Observation on the incidence of *A. sesami* was recorded at weekly intervals starting from initial appearance to final disappearance or up to harvest. Observations on the incidence were recorded from 10 randomly selected plants by counting number of infested capsules. The percentage of galled capsules per cultivar was used for analysis of variance. Means were separated using Fisher's protected Least Significant Difference test, at 5% probability level. All statistical analyzes were performed using SPSS software (Version 26.0, IBM Corporation, Armonk, NY, USA). The resistance was categorised by the scale of 0-10 (resistance), 11-20 (moderately resistance), 21-30 (moderately susceptible), 31-50 (susceptible) and above 50 (highly susceptible) used by Solanki *et al.* (2006) for categorising resistance for leaf webber, and capsule borer in sesame was used.

## RESULTS AND DISCUSSION

The incidence of the *A. sesami* is common during flowering period of sesame during two seasons (Fig. 1). The sesame genotypes (n=60) were screened for *A. sesami* during two season 1 and 2 (Fig. 2). In season 1, percent incidence of *A. sesami* varied from 0 to 10.12 (Fig. 2a). Two genotypes, ISWG-20-05 and IIOS-1103 were found free from *A. sesami* incidence. The highest *A. sesami* incidence was noted in GT 10 (10.12%). The sesame genotypes (n=60) graded for *A. sesami* as resistant (59 genotypes), moderately resistant (1 genotype) based on incidence (Table 1).

In season 2, percent incidence of *A. sesami* varied from 0 to 32.0 (Fig. 2b). Two genotypes, SES-K-20-2015 and IC-16239 were found free from *A. sesami* incidence. The highest *A. sesami* incidence was noted in ISWG-20-05 (28.0%), IIOS-1102 (28.0%) and SES-K-20-2011 (32.0%). The sesame genotypes (n=60) graded for *A. sesami* as resistant (29 genotypes), moderately resistant (22 genotypes), moderately susceptible (8 genotypes) and susceptible (1 genotype) based on incidence (Table 2).

Earlier, Ogwal *et al.* (2003) reported that among breeding lines in Uganda. Genotype Sesim2, a commercial variety in Uganda showed moderate resistance to sesame gall midge compared with other local variety. Orientation of insects towards the plant is influenced by plant architecture and colour, but the colour stimulus plays the most important role. Ranganatha *et al.* (2013) reported the use tolerant varieties like RT-46, Swetha, RT-103, OMT-26, RT-127, Hima and RT-125 for management of *A. sesami.*

To summarize, 28 genotypes such as SES-K-20-2015, IC-16239, SEL-S-2018-1002, SES-K-20-3007, SEL-S-2018-1003, SEL-S-2018-1010, SES-K-20-2012, SES-K-20-2019, RT-372, SES-K-20-1055, SES-K-20-1056, IIOS-20-3013, SES-K-20-2013, SES-K-20-1057, SES-K-20-1059, SES-K-20-2001, SES-K-20-2008, SES-3-19-3014, Julang sesame, Long knog-2, Lathua local, SES-K-20-2025, SES-K-20-1052, SES-K-20-2017, SES-K-20-1061, SES-K-20-1064, SES-K-20-2024, SES-K-20-2027 were resistant to *A. sesami* in both seasons and the resistant genotypes can be used as donor in future breeding programmes. However, further research is suggested to identify the DNA markers for resistance, mapping, QTL analysis and transfer of resistant genes/map segments using a backcross breeding approach coupled with marker assisted selection and also to study the genetic inheritance of resistance.

Table 1 Reaction of sesame genotypes to gall fly under open field conditions during season 1 (2021)

| Category | Per cent gall fly incidence | Number of sesame genotypes | Genotypes |
|---|---|---|---|
| Resistant | 0-10% | 59 | ISWG-20-05, IIOS-1103, IIOS-1101, IIOS-1102, RT-372, SEL-S-2018-1002, SEL-S-2018-1003, SEL-S-2018-1010, SES-S-19-1013, SES-S-19-1037, SES-K-20-1050, SES-K-20-1051, SES-K-20-1052, SES-K-20-1054, SES-K-20-1055, SES-K-20-1056, SES-K-20-1057, SES-K-20-1058, SES-K-20-1059, SES-K-20-1060, SES-K-20-2001, SES-K-20-2008, SES-K-20-2011, SES-K-20-2012, SES-K-20-2014, SES-K-20-2015, SES-K-20-2016, SES-K-20-2017, SES-K-20-2018, SES-K-20-2019, SES-K-20-2020, SES-3-19-3014, IIOS-3103, Julang Sesame, Long Knog-1, Long Knog-2, CT-23, CT-51, CT-55, IC-16239, SES-K-20-1045, Lathua Local, SES-K-20-2009, SES-K-20-1072, SES-K-20-3007, SES-K-20-2010, SES-K-20-2013, SES-K-20-2021, SES-K-20-3002, SES-K-20-1061, SES-K-20-1063, SES-K-20-1062, SES-K-20-1064, SES-K-20-2022, SES-K-20-2023, SES-K-20-2024, SES-K-20-2025, SES-K-20-2026 and SES-K-20-2027 |
| Moderately resistant | 11-20% | 1 | GT 10 |
| Moderately susceptible | 21-30% | - | - |
| Susceptible | 31-50% | - | - |
| Highly susceptible | >50% | - | - |
| Total | - | 60 | - |

Fig. 1. Nature of damage and symptoms of *Asphondylia sesami*

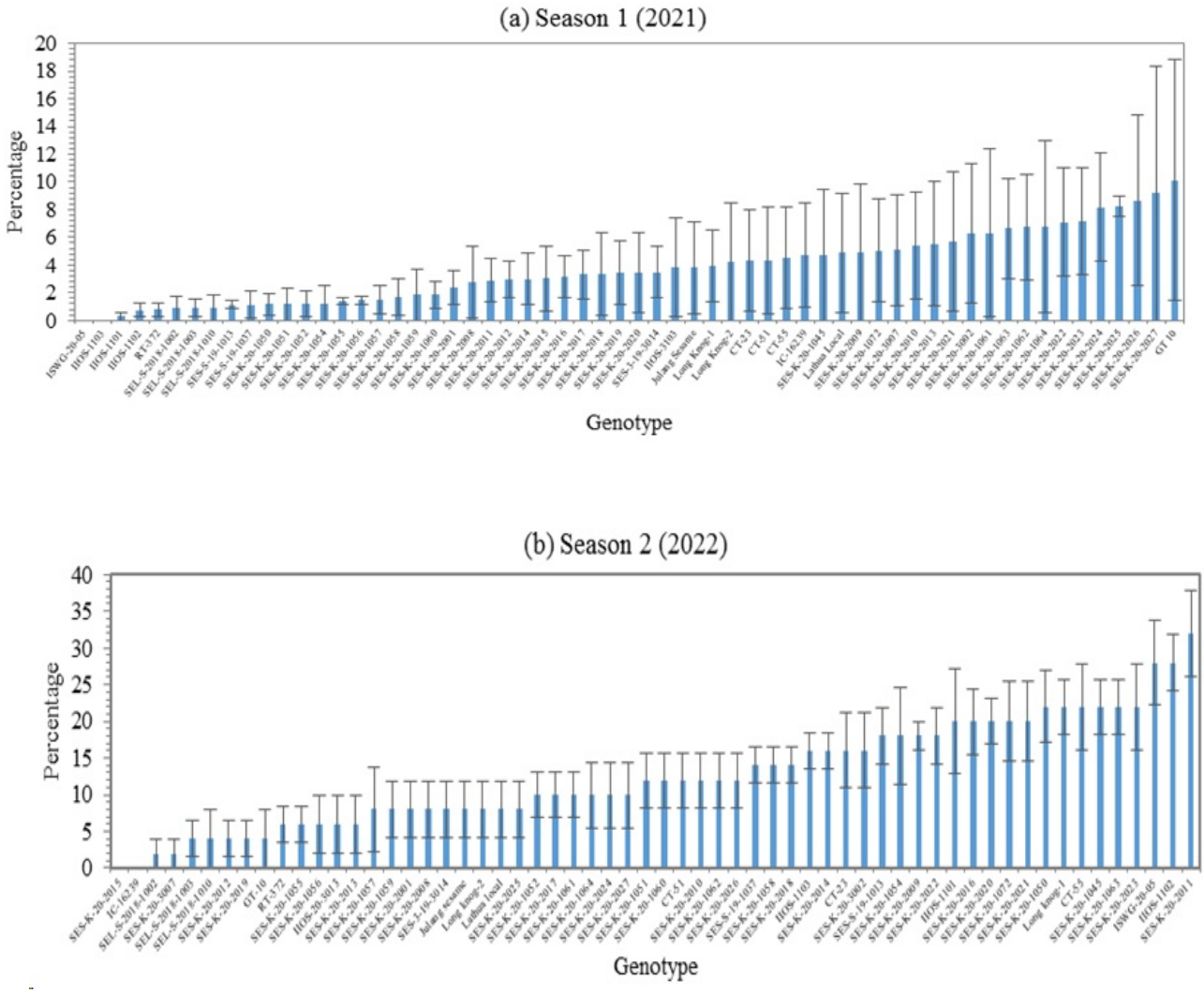


Fig. 2. Reaction of sesame genotypes to *Asphondylia sesami* during (a) season 1 (2021) and (b) season 2 (2022)

Table 2 Reaction of sesame genotypes to gall fly under open field conditions during season 1 (2022)

| Category | Per cent gall fly incidence | Number of sesame genotypes | Genotypes |
|---|---|---|---|
| Resistant | 0-10% | 29 | SES-K-20-2015, IC-16239, SEL-S-2018-1002, SES-K-20-3007, SEL-S-2018-1003, SEL-S-2018-1010, SES-K-20-2012, SES-K-20-2019, GT-10, RT-372, SES-K-20-1055, SES-K-20-1056, IIOS-20-3013, SES-K-20-2013, SES-K-20-1057, SES-K-20-1059, SES-K-20-2001, SES-K-20-2008, SES-3-19-3014, Julang sesame, Long knog-2, Lathua local, SES-K-20-2025, SES-K-20-1052, SES-K-20-2017, SES-K-20-1061, SES-K-20-1064, SES-K-20-2024, SES-K-20-2027 |
| Moderately resistant | 11-20% | 22 | SES-K-20-1051, SES-K-20-1060, CT-51, SES-K-20-2010, SES-K-20-1062, SES-K-20-2026, SES-S-19-1037, SES-K-20-1058, SES-K-20-2018, IIOS-1103, SES-K-20-2014, CT-23, SES-K-20-3002, SES-S-19-1013, SES-K-20-1054, SES-K-20-2009, SES-K-20-2022, IIOS-1101, SES-K-20-2016, SES-K-20-2020, SES-K-20-1072, SES-K-20-2021 |
| Moderately susceptible | 21-30% | 8 | SES-K-20-1050, Long knog-1, CT-55, SES-K-20-1045, SES-K-20-1063, SES-K-20-2023, ISWG-20-05, IIOS-1102 |
| Susceptible | 31-50% | 1 | SES-K-20-2011 |
| Highly susceptible | >50% | - | - |
| Total | - | 60 | - |

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REFERENCES

Ahuja D B and Kalian R K 2001. Seasonal incidence of gall fly, *Asphondylia sesami* and efficacy of various nee, based formulation, against it on sesame. *Indian Journal of Entomology*, **63**(4): 409-412.

Baskaran R K, Mahadevan N R, Sathiyanadam V K and Thangavelu S 1997. Approaches prevention and control of sesame pests. Recent Advances in Entomological Research. Regional Research Station. Tamil Nadu Agricultural University, pp. 133-136.

Biswas G C, Kabir S M H and Das G P 2001. Insect pest of sesamum (*Sesamum indicum* Linn.) in Bangladesh, their succession and natural enemies. *Indian Journal of Entomology*, **63**: 117-124.

Boopathi T and Sujatha M 2022. Emerging insect pests of sesame under changing climate scenario. Vikaspedia, India Development Gateway, Ministry of Electronics and Information Technology, Government of India, India. doi: https://vikaspedia.in/agriculture/crop-production/integrated-pest-managment/ipm-for-oilseeds/ipm-strategies-for-sesame/emerging-insect-pests-of-sesame-under-changing-climate-scenario.

Kumhar S R and Rajani Bisen 2021. Genetic analysis and diversity studies in sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **38**(4): 329-336.

Muzaffar A T, Rab D K, Maqsood A R and Imtiaz A N 2002. Insect pests associated with sesame at Tando Jam. *Pakistan Journal of Applied Science*, **2**(7): 723-726.

Ogwal S, Anyanga W, Odul C and Oumo J 2003. Screening of sesame breeder's lines for resistance/ tolerance to gall midge and sesame webworb insect pests of sesame. NAROARTP2 Annual Report 2002-2003. National Agricultural Research Organisation, Ministry of Agriculture Animal Industry and Fisheries, Kampala, Uganda.

Ranganatha A R G, Jyotishi A, Deshmukh M R, Bisen R, Panday A K, Gupta K N, Jain S and Paroha S 2013. Improved Technology for Maximizing Production of Sesame. All India Coordinated Research Project on Sesame and Niger, Indian Council of Agricultural Research, JNKVV Campus, Jabalpur, Madhya Pradesh, India. 28p.

Solanki Z S, Singh I, Rajpurohit T S and Ahuja D B 2006. Combining ability and heterosis for stem and root rot and leaf webber/capsule borer in sesame. *Indian Journal of Crop Science*, **1**(1-2): 171-174.

Vamshi P, Ramya K T, Santhalakshmi M P, Ramana J V and Kumhar S R 2021. Genetic variability studies for yield and yield attributes in breeding lines of sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **38**(3): 240-243.

Weiss E A 2000. *Oil Seed Crop,* 2nd Edition, Blackwell Science Inc.

# Evaluation of integrated pest management module for major insect pests of castor in Tamil Nadu

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ABSTRACT

Field trials were conducted during *kharif* season of 2016 and 2017 to evaluate the integrated pest management (IPM) module against major insect pests of castor in comparison with farmer's practice and untreated control. The IPM module *viz.,* application of Btk @ 1 g/l for management of semilooper (*Achaea janata*), monitoring of tobacco caterpillar (*Spodoptera litura*) using pheromone trap (@ 4/acre from 30 DAS to November) and collection and destruction of gregarious stages of defoliators, application of flubendiamide 39.35 SC @ 0.2ml/l (for tobacco when foliar damage reaching 25%) and profenofos 50 EC @ 1ml/l (for capsule borer and or leafhopper when damage is reaching 10%) was found effective against insect pests in castor. After the treatment, mean population of semilooper (0.75 larva/plant), tobacco caterpillar (1.75 larva/plant), hairy caterpillar (0.67 larva/plant), capsule borer (1.02%), leafhopper (5.77 numbers/3 leaves/plant), and thrips (3.50 thrips/spike) was low in IPM module. Per cent parasitization by *Microplitis maculipennis* on semilooper larvae was highest (55.9%) in untreated control plots followed by IPM module plots (22.77%). Highest seed yield of 1770 kg/ha with favourable B:C ratio of 2.68 recorded from IPM module plot.

**Keywords**: Castor, Economics, Insect pests, Integrated pest management, Natural enemies

Castor (*Ricinus communis* L.) is a non-edible oilseed crop cultivated in the semi-arid and arid regions in India. Castor is grown on 15.62 million hectares worldwide, with 6.96 lakh ha in India being the largest area. India produces 1.88 million metric tonnes of castor annually, with a mean productivity of 1962 kg/ha in 2022 (www.statista.com). The pest and disease complex in agricultural crops, particularly castor, has evolved due to environmental changes and intensive farming practices. Castor semilooper, *Achaea janata* Linnaeus is a specific and major pest in all regions where castor is a major dryland crop (Basappa and Lingappa, 2001; Duraimurugan *et al.,* 2015), tobacco caterpillar, *Spodoptera litura* Fabricius. is a polyphagous pest causing severe damage to foliage and inflorescence when its attack is sporadic. Other leaf feeding lepidopterans include tussock moth, *Euproctis fraterna* Moore, spiny caterpillar, *Ariadne* (=Ergolis) *merione* Cramer, slug caterpillar, *Parasa lepida* (Cramer), in all cultivated areas. Shoot and capsule borer, *Conogethes* (=Dichocrocis) *punctiferalis* (Guen.) is a major pest of castor during capsule development. Among the sucking pests leafhopper, *Empoasca flavescens* F. is a major pest. Due to change in climatic conditions the thrips posing major threat in castor cultivation and there are six species of thrips which attack castor crop (Basappa, 2003). Only the cotton thrip, *Scirtothrips dorsalis* Hood attained a status of major pest in recent years. It is estimated that castor yields are reduced by 17.2 to 63.3% due to the insect pests during *kharif* season (Lakshminarayanana and Duraimurugan, 2014). Although insecticidal control is one of the common means against the insect pests in castor. Use of chemical insecticides in indiscriminate manner will leave considerable toxic residues on the castor ecosystem (Duraimurugan and Lakshminarayana, 2018). Hence, use of organic amendments, plant products and microbial orgin insecticides can be the novel approaches to manage the pest complex in castor. The role of integrated pest management in castor pest management has obvious advantages in terms of effectiveness, safety to non target organisms and cost of cultivation with special reference to plant protection cost (Duraimurugan and Vimala Devi, 2021). Hence, keeping the above point in view, present investigation was undertaken to evaluate the integrated pest management module against major insect pests of castor under field condition.

## MATERIALS AND METHODS

Field trial was conducted during *kharif* 2016 and 2017 at Tapioca and Castor Research Station, Yethapur, Tamil Nadu to evaluate the IPM module in comparison with farmer's practice and untreated control as check. Castor hybrid, YRCH-1 was used with the spacing of 90 x 90 cm by adopting large field plot of 2000 $m^2$. In IPM module plot the treatments consists of application of Btk@1g/l for management of semilooper, monitoring of *Spodoptera litura*

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using pheromone trap @ 4/acre from 30 DAS to November and collection and destruction of gregarious stages of defoliators, application of flubendiamide 39.35 SC @ 0.2ml/l (for *S. litura* when foliar damage reaching 25%) and profenofos 50 EC @ 1ml/l (for capsule borer and or leafhopper when damage is reaching 10%. In farmer's practice, four sprays of acephate was given for pest management. In untreated control plots, YRCH-1 was planted under unprotected conditions. Observation were recorded on pest population *viz.,* defoliators (semilooper, tobacco caterpillar, hairy caterpillar), sucking pests (leafhopper, thrips, whiteflies) and capsule borer in treatments imposed plots of IPM module plot, farmers practice and untreated control plots were recorded and natural enemies count at 15 days interval on 5 plants each in 8 locations with yield data and economics. Treatment effects were analyzed using Randomized Block Design with eight replications. The data on numbers were transformed into square root values and per cent transformed into arc sine values and subjected to analysis of variance (ANOVA) through SPSS software. Pooled analysis was carried out for two years.

## RESULTS AND DISCUSSION

In IPM module plot, the semilooper (*A. janata*) population ranged from 16.80 to 21.0 larva/plant, *S litura* population ranged from 28.00 to 32.90 larva/plant, Hairy caterpillars (*Euproctis fraterna* and *Ariadne merione*) population ranged from 4.10 to 5.60 larva/plant, leafhopper population was 16.4 numbers/3 leaves/plant with hopper burn grade of 2, thrips population was 24.30 thrips/spike before adopting treatments. After the treatment mean population of semilooper (0.75 larva/plant), *S litura* (1.75 larva/plant), hairy caterpillar(0.67 larva/plant), capsule borer (1.02%), leafhopper (5.77 numbers/3 leaves/plant), and thrips (3.50 thrips/spike) was low in IPM module plot as compared to unprotected and farmers practice plots (10.70 and 14.42 semilooper larvae/plant; 30.77 and 26.97 *S. litura* larvae/plant; 3.25 and 4.87 hairy caterpillar larvae/plant; 5.50 and 7.22 per cent capsule damage due to capsule borer; 6.65 and 19.10 leafhoppers/3 leaves/plant ; thrips (17.07 and 30.55 thrips/spike ) in farmers practice plots and untreated control plots, respectively.

Table 1 Evaluation of IPM module in castor ( Pooled mean of *kharif,* 2016 and 2017)

| Module | Semilooper (No. of larvae/plant) | | | | | | M. maculipennis % parasitization | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PTC | 1 DAT | 3 DAT | 7 DAT | 14 DAT | Pooled | PTC | 1 DAT | 3 DAT | 7 DAT | 14 DAT | Pooled |
| IPM | 21.00 | 2.20 | 0.20 | 0.10 | 0.50 | 0.75 | 47.4 (43.49) | 39.50 (38.90) | 20.20 (26.65) | 8.60 (17.01) | 7.30 (15.64) | 22.77 (24.55) |
| Farmer's Practice | 16.80 | 12.20 | 10.60 | 9.80 | 10.20 | 10.70 | 44.9 (42.05) | 36.20 (36.94) | 22.30 (28.12) | 18.30 (25.27) | 14.30 (22.17) | 18.9 (28.12) |
| Untreated control | 18.20 | 21.30 | 18.00 | 12.00 | 6.40 | 14.42 | 48.3 (44.01) | 49.10 (44.48) | 56.20 (48.60) | 58.20 (49.78) | 60.10 (50.91) | 55.90 (48.44) |
| CD(P=0.05) | 5.44 | 1.33 | 1.15 | 0.86 | 0.66 | | 4.25 | 3.79 | 3.41 | 3.39 | 3.41 | |
| | Tobacco caterpillar (No.of larvae/plant) | | | | | Pooled | Apanteles parasitoid cocoon/plant | | | | | Pooled |
| IPM | 28.00 | 3.90 | 1.60 | 1.20 | 0.30 | 1.75 | 3.7 | 2.30 | 1.90 | 1.30 | 0.50 | 1.5 |
| Farmer's Practice | 32.90 | 34.00 | 31.60 | 28.20 | 29.30 | 30.77 | 2.7 | 2.00 | 1.20 | 0.50 | 0.10 | 0.95 |
| Untreated control | 30.20 | 32.60 | 28.40 | 24.30 | 22.60 | 26.97 | 4.3 | 5.60 | 6.30 | 7.20 | 7.40 | 6.62 |
| CD(P=0.05) | 2.46 | 2.56 | 2.34 | 2.05 | 2.06 | | 0.54 | 0.54 | 0.56 | 0.62 | 0.65 | |
| | Hairy caterpillar (No.of larvae/plant) | | | | | Pooled | Capsule borer (% damaged capsules) | | | | | Pooled |
| IPM | 4.90 | 1.10 | 0.90 | 0.60 | 0.10 | 0.67 | 4.3 | 2.10 | 1.30 | 0.60 | 0.10 | 1.02 |
| Farmer's Practice | 4.10 | 3.90 | 3.40 | 2.90 | 2.80 | 3.25 | 4.7 | 4.90 | 5.10 | 5.80 | 6.20 | 5.50 |
| Untreated control | 5.60 | 5.60 | 5.10 | 4.90 | 3.90 | 4.87 | 5.1 | 6.20 | 6.40 | 8.10 | 8.20 | 7.22 |
| CD(P=0.05) | 0.74 | 0.65 | 0.58 | | | | 1.01 | 0.99 | 0.99 | 1.08 | 1.10 | |
| | Leafhopper(No./ leaves/plant) | | | | | Pooled | Thrips (No. /spike) | | | | | Pooled |
| IPM | 13.6 | 8.40 | 6.90 | 4.60 | 3.20 | 5.77 | 16.3 | 6.30 | 4.90 | 2.60 | 0.20 | 3.50 |
| Farmer's Practice | 15.9 | 9.70 | 7.30 | 5.10 | 4.50 | 6.65 | 20.1 | 18.90 | 18.00 | 16.30 | 15.10 | 17.07 |
| Untreated control | 16.4 | 16.90 | 17.20 | 19.70 | 22.60 | 19.10 | 21.2 | 24.30 | 29.60 | 32.10 | 36.20 | 30.55 |
| CD(P=0.05) | 2.44 | 1.88 | 1.73 | 1.82 | 2.07 | | 3.08 | 2.97 | 3.30 | 3.42 | 3.75 | |

PTC - Pretreatment count; DAT - Days after treatment; Figures in parentheses are arc sine transformed values

Table 2 Evaluation of IPM module on seed yield and economics in castor ( Pooled mean of *kharif,* 2016 and 2017)

| | Seed yield (kg/ha) | Gross return (Rs/ha) | Cost of cultivation (Rs/ha) | Net return (Rs/ha) | CB ratio |
|---|---|---|---|---|---|
| IPM | 1770 | 70800 | 26360 | 44440 | 1: 2.68 |
| Farmer's Practice | 1080 | 43200 | 28230 | 14970 | 1 : 1.53 |
| Untreated control | 680 | 27200 | 19000 | 8200 | 1 : 1.43 |
| CD (P=0.05) | 49.06 | | | | |

Per cent parasitization by *Microplitis maculipennis* on semilooper larvae was highest (55.9%) in untreated control plots followed by IPM module plots (22.77%) as compared to farmers practice plots (18.90%). Highest (6.62 cocoon/plant) *Apantelesparasitization* recorded in untreated control plots followed by IPM module plot (1.50 cocoon/plant) and farmers practice (0.95 cocoon/plant) . Highest seed yield was recorded in IPM module plot over unprotected plot (Table. 2). The data revealed that a higher seed yield of 1770 kg/ha with favourable B:C ratio of 2.68 was recorded from IPM module plot, while lowest seed yield of 680 kg/ha with B:C ratio of 1.43 was recorded from untreated control plots. The findings of the present study was in conformity with the findings of Duraimurugan and Alivelu (2017). Hence, the IPM module *viz*., application of Btk @ 1 g/l for management of semilooper (*Achaea janata*), monitoring of tobacco caterpillar (*Spodoptera litura*) using pheromone trap (@ 4/acre from 30 DAS to November) and collection and destruction of gregarious stages of defoliators, application of flubendiamide 39.35 SC @ 0.2ml/l (for tobacco when foliar damage reaching 25%) and profenofos 50 EC @ 1ml/l (for capsule borer and or leafhopper when damage is reaching 10%) can be used for the effective and eco-friendly management of insect pests in castor.

## REFERENCES

Basappa H 2003. *Integrated Pest Management in Castor.* Directorate of Oilseeds Research (ICAR), Hyderabad.

Basappa H and Lingappa S. 2001. Damage potential of *Achaea janata* Linn. at different phenological stages of castor. *Indian Journal of Plant Protection*, **29**(1): 17-24.

Duraimurugan P and Alivelu K 2017. Development and evaluation of integrated pest Management module for castor. *Journal of Experimental Zoology, India*, **20**(Supplement 1):1389-1393.

Duraimurugan P, Sampathkumar M and Srinivas P S 2015. Calling behaviour and male response to pheromone gland extracts of castor semilooper, *Achaea janata* L. (Lepidoptera: Noctuidae). *Journal of Food, Agriculture and Environment*, **13**(2): 94-97.

Duraimurugan P and Lakshminarayana M 2018. Effect of novel insecticides to *Trichogramma chilonis* and *Snellenius maculipennis,* the potential parasitoids of castor semilooper. *Journal of Environmental Biology*, **39**: 592-596.

Duraimurugan P and Vimala Devi P S 2021. Assessment of *Bacillus thuringiensis* var. kurstaki (Bt-127) SC formulation as a component of IPM in soybean through farmer's participatory approach. *Journal of Oilseeds Research*, **38**(4): 358-361.

Lakshminarayana M and Duraimurugan P .2014. Assessment of avoidable yield losses due to insect pests in castor (*Ricinus communis* L.). *Journal of Oilseeds Research*, **31**: 140-144.

www.statista.com.

# Impact of non-monetary and low monetary inputs on yield and economics of brown sarson (*Brassica campestris* L.) under temperate hill ecology

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ABSTRACT

India imports vegetable oil to meet the domestic demand, which indicates that there is a dire need to improve the oilseed production through effective technology dissemination. To narrow down the yield gaps and achieve maximum yields, demonstrations on improved technologies related to brown sarson were conducted at 133 locations from 2016 to 2021 by the Krishi Vigyan Kendra in Kulgam district, Kashmir. The results revealed a significant improvement in yield with improved practice (IP) over farmers practice (FP). IP recorded an average yield of 13.2q/ha with a yield superiority of 28 % over FP (10.3 q/ha). The extension gap, technology gap and technology index were 2.8q/ha, 2.9q/ha and 16.4%, respectively. Though input costs were higher by ₹ 1309/ha, but, the net returns were higher by ₹ 10693/ha in IP over FP. Further, the B:C ratio was also higher in IP (2.1) as compared to that of FP (1.6).

**Keywords**: Brown sarson, Demonstration, Economics, Temperate region, Yield

The demand for edible oils is increasing very rapidly with increasing population and has been estimated to be 28.40 million tonnes by the year 2030 (Chaurasiya *et al.,* 2022). Despite being the 4th largest producer of oilseeds, India is also one of the largest importers of vegetable oils (Kumar and Tiwari, 2020). Almost 72% of the total oilseeds area is under rainfed conditions dominated by impoverished soils and marginal and small farmers. Lack of adoption of appropriate technologies, cultivation under input-starved conditions, biotic and abiotic stresses are considered as some of the major causes for low productivity of oilseeds (Anonymous, 2021; Chauhan *et al.,* 2021). Further, the yield gap between farmers' fields and ideal conditions in Kashmir valley is high. According to Sheikh *et al.* (2013) productivity of Brown Sarson is much lower (7.9 q/ha) than the potential yield of existing genotypes. To overcome the challenges in bridging the yield gaps in oilseeds, Indian Council of Agricultural Research (ICAR) through the network of research and extension institutes spread across the country, has been making special efforts over the past many years. As a part of the strategy, Frontline demonstration programme (FLD) on proven technologies is being implemented through Agriculture Science Centres (Krishi Vigyan Kendras) in each district and brown sarson is no exception.

Brown sarson is major *rabi* season crop grown after harvesting rice in Kashmir. In the Union Territory of Jammu & Kashmir, this crop occupies an area of about 65,950 hectares with a production of 58380q and an average productivity of 8.85 kg/ha (Iqbal *et al.,* 2017). With the objective to improve oilseed production and also increase farmers income in the district, Krishi Vigyan Kendra, Kulgam-SKUAST-Kashmir conducted multiple demonstrations and other extension activities in the district. The demonstrations were aimed at promoting technology capsule prepared after thorough investigation of filed level problems in the adopted villages.

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## MATERIALS AND METHODS

New technologies with better potential need a launching pad for faster dissemination. Krishi Vigyan Kendras (KVKs) at district level are part of vast network of ICAR for the purpose. In an attempt to popularise the technologies related to oilseed production, Frontline Demonstration programmes on brown sarson related technology were conducted by the KVK, Kulgam over an area of 53.3 ha at 133 locations in Kulgam district from the year 2016 to 2021. The district falls in Kashmir division of the Union Territory of Jammu & Kashmir. It is characterized by temperate climatic conditions with mild summers and harsh winters. The soil of the demonstration plots was clay loam, silt loam and loamy in texture. Before the conduct of demonstrations in 2016, a detailed SWOT analysis was carried out by Kendra scientists in the villages adopted for the purpose. The reasons of lower productivity of oilseed in the district were prioritised as late sowing, old varieties (non-monetary) and poor drainage (low monetary). At different stages of crop growth, need based capacity building programmes were conducted and need based advisories were given to the target farmers. Two practices were performed at each location over an area of 0.4 ha per demonstration *viz*., Farmers' practice (FP) and Improved practice (IP) i.e. technology capsule. The details

of the technology components used in the latter case are given in Table 1. The crop was monitored at different stages during each season and yield and economics were collected for analysis. Further, extension gap and technology gaps and technology index were computed as detailed below.

(i) Extension gap =
Demo yield - farmers' practice yield

(ii) Technology gap=
Potential yield - Demo yield

(iii) Technology Index =
$$\frac{\text{Potential yield - Demo yield}}{\text{Potential yield}} \times 100$$

(iv) Additional gains =
Additional returns (₹/ha) - additional costs (₹/ha)

Table 1 Details of Improved practice (IP ) and farmers practice (FP)

| Technology component of Improved Practice(IP) | Farmers' Practice (FP) |
|---|---|
| Improved variety (Shalimar Sarsoon 1&2) | Old varieties (Gulchin/mixture) |
| Timely sowing (5 to 15 October depending of altitude and field condition at selected location) | 15 October to 5 November |
| Pre-sowing irrigation wherever needed | Sowing on residual moisture after rice crop. |
| Opening of small drainage channels in the field to facilitate drainage of excess water during 2016-17, 2018-19 and 2020-21 | Flat beds with no drainage channels |

## RESULTS AND DISCUSSION

**Impact on crop yield**: The results of demonstrations revealed that yield varied over the years ranging from 8.9 q/ha in farmers' practice in year 2017-18 to 14.5q/ha under improved practice in year 2020-21(Table 2). This may be attributed to inclusion of new variety of brown sarsoon (Shalimar Sarsoon 2) having superior growth parameters and favourable weather conditions during the seasons. Improved practice recorded an average yield of 13.2q/ha as compared to 10.3 q/ha obtained under farmers' practice. The yield superiority ranged between 16 % and 36 %. An overall yield advantage of 28% was recorded in the improved practice. Similar results of yield advantage in rapeseed mustard from improved practice/variety were also reported by Chaudhary *et al.* (2018), Kalita *et al.* (2019), Bharat *et al.* (2020) and Prajapati *et al.* (2021).

**Gap analysis**: The gap analysis in terms of extension gap and technology gap indicates the untapped potential and impact of field level implications. The gap analysis in the present study revealed that there is a scope to enhance the oilseed production in the valley by popularizing the technologies through collaborative efforts of front line and mainstream extension functionaries. Data analysis given in Table 2 indicates an extension gap ranging between 2.0 to 3.6 q/ha with an average value of 2.8q/ha. The extension gap was lowest (2.0q/ha) during 2020-21, which may be attributed to the correlation of the cultivars to weather parameters and increase in crop production skills of farmers over the years partnership with KVK in the execution of demonstrations. On an average the extension gap was 2.8q/ha. The extension gap was lowest (2.0q/ha) during 2020-21 and was highest (3.6 q/ha) during 2019-20. This may be attributed to the correlation of the cultivars to weather parameters. Similar results were recorded by Saravanakumar (2018) in FLDs on black gram and Mubarak and Shakoor (2019) in FLDs on rice. The technology gap also varied over the years and it ranged between 1.5 to 4.4q/ha with an average value of 2.9 q/ha and technology index of 16.4% (Table 2).This indicates the influence of field level implications on the technologies developed in the research system and an untapped potential which can be realised through more rigorous technology dissemination efforts including continuous follow up, input facilitation and capacity building of farmers.

**Economic impact**: Economics was calculated by considering the input costs including seed, fertilizers, pesticides, labour etc. and output value in the market for both improved and farmers' practice. Cost of cultivation and returns per hectare showed increasing trend over the five years of demonstration programme (Fig 1 & 2) in both the cases. This was attributed to consistent increase in costs of inputs and higher value of output in the succeeding years. On an average the input costs were higher by ₹ 1309/ha in the improved practice (₹20117/ha) in comparison to farmers' practice (₹ 18778). As evident from the Fig.1 the variation in cost of cultivation was more prominent during 1$^{st}$, 2$^{nd}$ and 5$^{th}$ year of study. This was due to difference of farming practices among farmers involved in the FLD. The additional gain from improved practice ranged between ₹ 4725 in year 2016-17 to ₹16600/ha in 2019-20 averaging ₹ 9365/ha. Gross and net returns were also higher in improved practice during all the years of demonstration. Maximum net returns of ₹ 47632/ha were achieved from improved practice during 2019 -20. Net returns pooled over the years were higher in improved practice (₹ 10693/ha) over farmers' practice. The average B:C ratio was 2.1 and 1.7 for improved and farmers practice, respectively. The higher economic benefits with improved practice could be due to improved technology, timely

execution of field operations, monitoring of demonstration plots followed by on spot advisories by the Kendra returns of ₹ 47632/ha were achieved from improved practice during 2019-20. Net returns pooled over the years were ₹ 10693/ha higher in improved practice over farmer's practice. B:C ratio also indicated a similar trend. The average B:C ratio was 2.1 and 1.7 for improved and farmers practice, respectively. The higher economic benefits with improved practice could be due to improved technology, timely execution of field operations, monitoring of demonstration plots followed by onspot advisories by the Kendra. Kalita *et al.* (2019) also reported similar results during frontline demonstrations programmes on rapeseed.

Table 2 Year wise locations, area, yield and gap analysis of Frontline Demonstrations on brown sarson.

| Year | No of locations | Area covered (ha) | Grain yield (q/ha) | | % increase in yield | Extension gap | Technology gap | Technology Index (%) |
|---|---|---|---|---|---|---|---|---|
| | | | Improved Practice | Farmers' Practice | | | | |
| 2016-17 | 50 | 20 | 12.7 | 9.3 | 36 | 3.4 | 3.3 | 20.6 |
| 2017-18 | 25 | 10 | 11.6 | 8.9 | 30 | 2.7 | 4.4 | 27.5 |
| 2018-19 | 21 | 8.4 | 12.1 | 9.7 | 24 | 2.4 | 3.9 | 24.3 |
| 2019-20 | 20 | 8.0 | 14.3 | 11.3 | 32 | 3.6 | 1.7 | 10.6 |
| 2020-21 | 17 | 6.8 | 14.5 | 12.5 | 16 | 2.0 | 1.5 | 9.30 |
| Average | - | - | 13.2 | 10.34 | 27 | 2.8 | 2.9 | 16.4 |

Table 3 Economics as influenced by improved practice of brown sarson cultivation

| Year | Gross returns (₹/ha ) | | Cost of cultivation (₹/ha ) | | Net returns (₹/ha ) | | B:C ratio | | Additional gains from Improved practice (₹/ha ) |
|---|---|---|---|---|---|---|---|---|---|
| | Improved Practice | Farmers' Practice | Improved Practice | Farmers' Practice | Improved Practice | Farmers' Practice | Improved Practice | Farmers' Practice | |
| 2016-17 | 49185 | 39320 | 16780 | 14210 | 32405 | 25110 | 1.9 | 1.7 | 4725 |
| 2017-18 | 53132 | 43163 | 16780 | 14210 | 36352 | 28953 | 2.2 | 2.0 | 4829 |
| 2018-19 | 58810 | 47530 | 19340 | 19340 | 39470 | 28190 | 2.0 | 1.4 | 11280 |
| 2019-20 | 71400 | 54800 | 23768 | 23768 | 47632 | 31032 | 2.0 | 1.3 | 16600 |
| 2020-21 | 73900 | 61500 | 23920 | 22415 | 49980 | 39085 | 2.1 | 1.7 | 9390 |
| Average | 61285 | 49262 | 20117 | 18788 | 41167 | 30474 | 2.1 | 1.6 | 9365 |

*IP: Improved practice

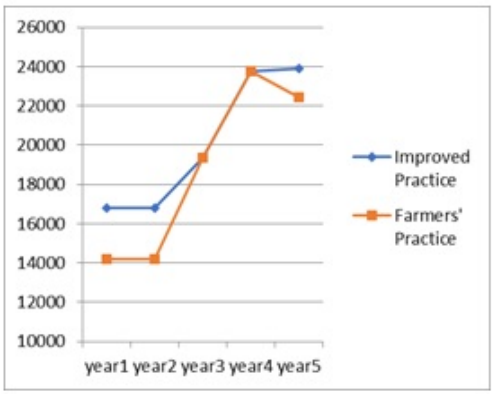


Fig. 1. Cost of cultivation (₹/ha)

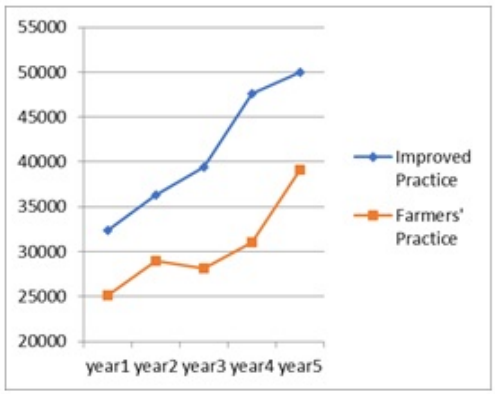


Fig. 2. Average net returns (₹/ha)

## REFERENCES


Anonymous 2021. *Status Paper on Oilseeds,* Directorate of Oilseeds Development (DOD) Government of India, Ministry of Agriculture & Farmers Welfare.

Bharat R, Rai S K, Vinod Gupta and Rahul Gupta 2020. Performance of Frontline demonstrations for increasing the productivity of Rapeseed Mustard in Jammu Region. *International Journal of Current Microbiology and Applied Sciences*, **9**(7): 3285-9321.

Chaudhary R P, Choudhary G K, Prasad R, Singh R and Chaturvedi K 2018. Impact assessment of frontline demonstration on mustard crop. *International Journal of Current Microbiology and Applied Sciences*, **7**(Special issue): 4737-4742.

Chauhan J S, Choudhury P R and Singh K H 2021. Production, varietal improvement programme and seed availability of annual oilseeds in India: Current scenario and future prospects. *Journal of Oilseeds Research*, **38**(1): 1-18.

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

Iqbal A M, Parray G A, Sheikh F A, Hussain A, Najeeb S, Bhat Z A, Shikari A B, Ganai M A, Mujtaba A, Mubarak T, Misger F A and Zargar M A 2017. Frontline demonstration programme: An effective transfer tool for adoption of *B. rapa* production technology under temperate agro climatic conditions of Kashmir Valley. *Cruciferae Newsletter*, **36**: 23-25.

Kalita S K, D S Chhonkar and Manish Kanwat 2019. Assessment of Cluster Front Line Demonstrations on Rapeseed (*Brassica campestris* L.) in Tirap District of Arunachal Pradesh. *Indian Journal of Extension Education*, **55**(3): 17-22.

Kumar V and Tiwari A 2020. Sparking Yellow Revolution in India Again. Rural pulse XXXIV. A publication of Department of Economic Analysis and Research (NABARD).

Mubarak T and Shakoor A 2019. Impact assessment of technological interventions for reducing yield gaps in rice (*Oryza sativa* L.) Under temperate hill ecology. *Journal of Krishi Vigyan*, **7**(2): 140-143.

Patel M M, Jhajharia A K, Khaddaand B S and Patil L M 2013. Frontline demonstration: An effective communication approach for dissemination of sustainable cotton production technology, *Indian Journal of Extension Education and Rural Development*, **21**: 60-62.

Prajapati K P, Patel J R, Shah S K, Gangwar G P, Tejani D N, Jat A L, Patel B K and Desai A G 2021. A new high yielding and high oil content Indian mustard variety 'GM 6' (*Banas Sona*) recommended for Gujarat state. *Journal of Oilseeds Research*, **38**(4): 337-342.

Saravanakumar S 2018. Impact of cluster frontline demonstration on black gram in western zone of Tamilnadu. *Journal of Krishi Vigyan,* **7**(1), 136-139.

Sheikh F A, Shabir A Mir, Mubarak T, Hameed-Ullah Itoo, Bhat Z A., Bhat J A, Itfaq A Mir, Angchuk P, Sumaira Shafi and Arafat Y 2013. Impact assessment of frontline demonstrations on Brown Sarson: Experience from temperate north-western Himalayan region of India. *African Journal of Agricultural Research*, **8**(23): 2956-2964.

# Dissemination and impact assessment of improved technology and scientific interventions through front line demonstrations among sesame farmers of Tikamgarh, Bundelkhand Region in Madhya Pradesh

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ABSTRACT

Frontline demonstrations are popular and one of the effective ways to disseminate the current production technology of crop husbandry among the farmers. AICRP on Sesame, Tikamgarh conducted 40 demonstrations in Tikamgarh block during *kharif* 2020 and 2021. The mean Extension Gap (EG) over years was recorded as 342 kg/ha which was more than double to the mean yield harvested under farmer's practice (FP) indicating the poor adoption of innovative technologies by farmers. Hence, still more efforts are needed to attract and change mindset of farmers towards Improved Technology (IT). The average IT was recorded as 23.5% which was much higher than desired values. Mean net return was recorded ₹34375 under IT while it was ₹12229 under FP along with average B:C ratio was calculated 2.57 under IT whereas 1.97 under FP.

**Keywords**: Crop husbandry, Farmers practice, Front line demonstration, Sesame

India is fortunate to have a wide range of oilseeds crops grown in its different agro climatic zones. Despite this advantage, India is largest importer of edible oils as its per capita consumption/year has exceeded 19.0 kg which is about 36% higher than standards for normal health. Due to the substantial gap between demand and availability of edible oil, India imported 13.42 MT which incurred ₹80000 crores currency load in 2021. (Anonymous, 2021). Present uncertain climatic scenario reduces the options of farmers to choose comparatively better input responding crops in low rainfall tracts having poor to medium fertility soils. Under such situation, farmers have limited option for *kharif* crop. Sesame is the best option in unpredictable current scenario of climate.

Sesame (*Sesamum indicum* L.) also known as Til is one of the oldest important oilseed crop of India grown in semi-arid tropics, sub-tropics and temperate regions covered 16.03 lakh ha, with total production of 7.08 lakh tones and average productivity of 442 kg/ha in 2021 (Anonymous, 2021-22). Sesame seeds contain high quality oil up to 62.7% having long shelf life due to higher linoleic content which increases resistance to oxidation and rancidity. Seed is rich source of Vitamin E, A, B1, B2, niacin, minerals and methionine amino acid along with lignans (sisamolin and sesamin) hence used for domestic as well as pharmaceutical industries.

In India, sesame is grown in *kharif, rabi* and summer season or more than one season in some states. It is mainly grown in Madhya Pradesh, Uttar Pradesh, Rajasthan, West Bengal, Andhra Pradesh, Maharashtra, Gujarat, Tamil Nadu, Odisha and Karnataka (Nagaveni *et al.,* 2021). This study intended to assess impact and disseminate and popularize improved production technology and create awareness among farmers that how modern production technologies can be helpful to increase income under uncertain climate which is regular feature of Bundelkhand region. Such efforts will change the mindset of farmers towards innovative production technologies.

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## MATERIALS AND METHODS

In total, 40 demonstrations were conducted under rainfed conditions by AICRP on Sesame, Tikamgarh district at farmers' field to create awareness among Bundelkhand's farmers towards modern production technologies for their own benefit during *kharif* 2020 and *kharif* 2021. Each demonstration was planted in 0.4 ha area with whole package/improved technology (IT) along with farmers practice (FP).

Further, whole package/ improved technology comprised of HY variety, Line sowing, fertilizers dose, weedicide and insecticides (Table 1). The data had been collected from both improved technology and farmers practice plots. Extension gap, Technology gap, Technology index and Cost- benefit ratio were calculated with the following formulae:

Extension gap (q/ha) =
(Yield of Improved technology plot (q/ha) -
Yield of farmers practice (q/ha)

Technological gap ((q/ha)) =
Potential yield (q/ha) -demonstration yield (q/ha)
Technology index (%) =
Technology gap x 100/Potential yield
Additional returns (₹) =
Demonstration returns (₹) -Farmers practice returns (₹)
Effective gain (₹) =
Additional returns (₹) - Additional cost (₹)
Incremental B:C ratio =
Additional returns (₹)/Additional cost (₹)

## RESULTS AND DISCUSSION

The results of this study indicated the substantially higher mean seed yield (612 kg/ha) were recorded under Improved Technology (IT) which was more than double to the mean yield harvested under farmers practice (FP) indicating the poor adoption of innovative technologies by farmers. Hence, concentrated efforts are required to change the mindset of farmers towards Improved Technology. (Table 2) Although, highest yield was harnessed in 2020 under both IT and its corresponding FP which may be due the effect of rainfall pattern and edaphic conditions. Results of this finding is also in agreement with Kushwaha *et al.* (2018) and Meena and Dudi (2018).

**Extension Gap**: The mean Extension Gap (EG) over years was recorded as 342 kg/ha which is almost equal to mean yield under farmers practice (FP). This indicates poor infiltration of Improved Technology (IT) among farmers and holistic approaches would be required for speedy narrow drown this gap. Above findings are in accordance with Shiv Ratan *et al.* (2021). These demonstrations are one of the most effective way to change the perception of farmers towards Improved Technology (IT). In addition to this, recurrent trainings and field visits may change the mindset of farmers. (Dayananad *et al.,* 2012; Katare *et al.,* 2011; Mitra and Samajdar, 2010).

**Technology Gap (TG)**: The average TG was found 188 kg/ha during investigation period. Rain fed condition, precipitation pattern, marginal and sub marginal soils may be the probable reason for this gap (Meena and Singh 2017 and Singh SB, 2017).

**Technological Index (TI)**: TI shows the feasibility of Improved Technology at field which will be more desirable if value would be low. The average TI was accrued as 23.5% indicating the need of rigorous efforts to fast replicate Improved Technology at farmers' fields. Findings of the current study is in accordance with Arvind kumar (2017), Balai *et al.* (2012); Iqbal *et al.* (2017), Rao *et al.* (2011) Shiv Ratan *et al.* (2020) and Shiv Ratan *et al.* (2021).

For economic parameters, cost of cultivation for IT and FP were calculated (Table 3) as per prevailing prices of inputs used and outputs. The cost of cultivation under IT ranged from ₹ 21644 to ₹ 22144 with average of ₹ 21894 while same was ranged from ₹ 12329 to ₹ 12829 with average of ₹ 12829 under FP. The average additional cost under IT was ₹ 9315 which clearly indicated the poor adoption of IT in Bundelkhand. Therefore, the need of hour is to intensify efforts through FLDs, trainings and personal visits to change the mindset of farmers towards improved technologies and scientific interventions. Mean net return over study years was recorded ₹ 34375 under IT while it was ₹ 12229 under FP which show huge difference in additional net return of ₹ 22146. It clearly indicated that farmers would have earned 62% more net income if they had adopted IT.

Further, average B: C ratios were 2.57 under IT and 1.97 under FP which is due to high quantum of produce harnessed under IT (Sharma *et al.,* 2017, Meena and Singh, 2017, Shiv Ratan *et al.,* 2020 and Shiv Ratan *et al.,* 2021).

Table.1 Components of whole package or Improved Technology of FLDs

| Technological Interventions for Whole package/ Improved Technology | |
|---|---|
| HY Varieties | TKG-306 and TKG-308 |
| Seed rate | 2.0 kg |
| Sowing | Line sowing |
| Seed treatment | Carbendazim @3g/kg seed |
| Fertilizers | 60N: 40P:20K |
| Weedicide | Quizolofop-N- ethyl (Turga Super) |
| Pesticide (Need based) | Imidacloprid and/or Profenophos |

Table 2 General Details, seed yield and other parameters for gap analyses of FLD on sesame

| Year | Number of demonstrations | Area (ha) | | Mean Yield (Kg/ha) | | Extension gap (kg/ha) | Technology gap (kg/ha) | Technology index (%) |
|---|---|---|---|---|---|---|---|---|
| | | | | IT | FP | | | |
| 2020 | 20 | 0.8 | | 645 | 274 | 371 | 155 | 19.375 |
| 2021 | 20 | 0.8 | | 579 | 266 | 313 | 221 | 27.625 |
| Total | 40 | 16 | Mean | 612 | 270 | 342 | 188 | 23.5 |

Table 3 Analysis of various economic parameters under IT as well as FP

| Year | Cost of cultivation (₹/ha) | | Mean gross returns (₹/ha) | | Net returns (₹/ha) | | B:C ratio | | Additional Cost under IT (₹/ha) | Additional gross return (₹/ha) | Additional net return (₹/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | IT | FP | IT | FP | IT | FP | IT | FP | | | |
| 2020 | 21644 | 12329 | 59312 | 25190.8 | 37668 | 12861.8 | 2.74 | 2.04 | 9315 | 34121 | 24806 |
| 2021 | 22144 | 12829 | 53226 | 24426 | 31082 | 11597 | 2.4 | 1.9 | 9315 | 28800 | 19485 |
| Mean | 21894 | 12579 | 56269 | 24808 | 34375 | 12229 | 2.57 | 1.97 | 9315 | 31461 | 22146 |

Where IT=Improved technology; FP=Farmers practice; EG=Extension gap; TG= Technology gap; TI=Technology index

## REFERENCES


Anonymous 2021. Department of food and public distribution, Ministry of consumer affairs, food and public distribution, GOI. Anonymous 2021-22, Annual Report of AICRP on Sesame & Niger, Jabalpur, Madhya Pradesh.

Balai C M, Meena R P, Meena B L and Bairwa R K 2012. Impact of front line demonstration on rapeseed-mustard yield improvement. *Indian Res. J. Ext. Edu*., **12**:113-116. Commodity Profile of Edible Oils for Sept. 2019.

Dayanand, Verma R K and Mehta S M 2012. Boosting mustard production Technology through front line demonstrations. *Indian Res. J. Ext. Edu.,* **12**:121-123.

Iqbal A M, Shikari A B, Naseer S, Nagoor S, Aziz M, Dar Z, Ali J, Ganai M A and Parry G A 2017. Participatory varietal selection in rapeseed-mustard. *Journal of Oilseed Brassica,* **8**: 201-206.

Kumar A, Yadav D K and Rana D S 2012. Rapeseed-mustard in India: Present scenario, future projection and R & D issues. *Indian Farming*, **62**(8): 14-21.

Katare S, Pandey S K and Mustafa Mohd 2011. Yield gap analysis of rapeseed-mustard through frontline demonstrations. *Agriculture Updates*, **6**(2):5-7.

Kushwaha R S, Kumar R, Kaur A, Bhadouria V S and Gupta N 2018. Impact of front line demonstration (FLD) on the yield of rapeseed-mustard in Gwalior district of MP. *Technofame*, **7**(1) 61-64.

Meena M L and Dudi A 2018. Boosting the mustard production technology through front line demonstration in Pali district of Rajasthan. *Journal of Oilseed Brassica*, **9**(2):176-181.

Mitra B and Samjadar T 2010. Yield gap analysis of rapeseed and mustard through frontline demonstration. *Agricultural Extension Review*, **22**: 16-17.

Meena M L and Singh D 2017. Technological and extension yield gaps in green gram in Pali district of Rajasthan. *Legume Research*, **40**: 187-191.

Nagaveni M, Kumar G D S and Chandana B 2021. Identification of potential districts for technology transfer in sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **38**(4): 362-368.

Rao D M, Chandrashekhar P and Neeraiah R 2011. Productivity enhancement in ground nut. *Indian Farming*, **60**: 39-40.

Ratan S, Tiwari U K, Nayak M K and Thakur S R 2020. Assessment of relative impact of improved technology and scientific interventions on the income of sesame farmers in tribal area of Bundelkhand region. *International Journal of Current Microbiology and Applied Sciences*, **9**(7): 809-813.

Ratan S, Thakur S R, Nayak M K and Singh V K 2021.Dissemination and popularization of improved technology through front line demonstrations among sesame farmers of Bundelkhand region. *International Journal of Current Microbiology and Applied Sciences*, **10**(01): 2097-2101.

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

Singh S B 2017. Yield gap analysis of rapeseed mustard through frontline demonstration under rainfed conditions in Uttarakhand. *Technofame*, **6**(1): 89-92.

# Assessment of genetic variability, correlation and path analysis in sesame (*Sesamum indicum* L.)

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ABSTRACT

The present study was attempted with thirty-eight genotypes including three checks (GT-10, TKG-22, JTS-08). The experiment was carried out in randomized block design in three replications to evaluate variability, association between various economic traits, direct and indirect effect of different characters on yield. The observations were recorded for days to 50 percent flowering, productive branches, plant height (cm), height of 1st capsule bearing node (cm), number of capsules per plant, number of seeds per capsule, capsule length(cm), inter node length (cm), days to maturity, 1000-grain weight (g), percentage of oil and yield (g/plant). Analysis of variance revealed significant differences among the genotypes for all the characters. The magnitude of phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) was larger for yield, number of productive branches, height of first capsule bearing node and number of capsule/plant and inter-node length. Genetic advance as per cent of mean for yield, number of productive branches, height of first capsule bearing node, number of capsules per plant and internode length were higher in sesame genotype. Correlation coefficient exhibited significant and high positive correlation for number of productive branches, number of capsules per plant and number of seeds per capsule and maturity. Path analysis indicated that the trait number of seeds per capsule, number of productive branches and number of capsules per plant had high direct positive effect on grain yield. These traits to be given due importance in the sesame improvement programme.

**Keywords**: Correlation, Genetic Advance, GCV, Path analysis, PCV, Sesame

Sesame (*Sesamum indicum* L.) belongs to the family Pedaliaceae, which contains 16 genera and 60 species. Only *Sesamum indicum* L. (2n = 26) was recognised as cultivated species with a wide distribution covering tropical Africa, Madagascar, Arabia, Sri Lanka, India, tropical Australia. Seeds of sesame are oval, flat and tiny with a nutty taste. It is known as the "Queen of Oilseeds" because of its oil quality. Sesame seeds contain 40 to 63 percent oil, which is high in linoleic and oleic acids (Abate and Mekbib, 2015). It has stability in oil quality due to the presence of sesamolin and sesamol, which helps in reducing the rate of oxidation.

The major growing sesame states of the country are Gujarat, Rajasthan, Orissa, Tamil Nadu, Madhya Pradesh, Karnataka, Andhra Pradesh, Uttar Pradesh, Maharashtra West Bengal, and Assam. Sesame is cultivated on 1723 thousand hectares in India, with a production of 817 thousand tonnes and an average productivity of 474 kg/ha (India stat, Ministry of agriculture, GOI, 2020-21). In case of Bihar, sesame grown in an area of 1.14 thousand hectares with an annual yield of one thousand tonnes and productivity is 874 kg/ha (India stat, Ministry of agriculture, GOI, 2020-21). The morphological variability is considerably high in sesame crop (Ramya *et al.,* 2020; Kumhar and Rajani 2021; Kumar *et al.,* 2022; Vamshi *et al.,* 2021). Genetic variability is essentially required for improvement of crop, it may be naturally present or create it through several methods. On the basis of information of genotypic and phenotypic variability along with heritability of the traits present in the population emphasise in further improvement of the crop (Rajitha *et al.,* 2021; Ramya *et al.,* 2021).

The experiment was conducted with 38 genotypes of sesame including three checks (GT-10, TKG-22 and JTS-8) at the Bihar Agriculture University farm in Sabour, Bhagalpur, Bihar, during Zaid, 2021. It comes under agro-climatic zone III A and the district is located at an elevation of 52.73 metres above mean sea level and is placed at 25° 50'N latitude and 87° 19' E longitude. Each genotype was planted in three rows of four metres with a 30 cm inter-row distance and 10 cm intra-row spacing having plot size was 3.6 sq m. Experiment was conducted in three replications in randomized block design (RBD). All the standard agricultural practises were followed during experiment. Details of the experimental material are given in Table 1. Data on yield and yield attributing characters were collected from five randomly selected plants in each replication and mean data of five plants were calculated. The traits were days to 50% flowering, number of productive branches, plant height (cm), height of first capsule bearing node (cm), number of capsules per plant, number of seeds per capsule, capsule length (cm), inter node length, days to

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maturity, 1000- seed weight (g), percentage of oil and yield (g/plant).

Table 1 List of thirty-eight genotypes of sesame

| Sl. No. | Entry | Sl. No. | Entry |
|---|---|---|---|
| 1 | GT-2 | 20 | BRT-09 |
| 2 | AT-331 | 21 | BRT-10 |
| 3 | BRT-06 | 22 | BRT-12 |
| 4 | DS-18-46 | 23 | OSM-22 |
| 5 | AT-338 | 24 | SUPRAVA |
| 6 | RT-380 | 25 | BARI-3 |
| 7 | AT-337 | 26 | BARI-4 |
| 8 | RT-382 | 27 | VS-15-07 |
| 9 | JCS-2696 | 28 | VS-15-14 |
| 10 | JLS-120 | 29 | VS-13-006 |
| 11 | AT-201 | 30 | VS-10-57 |
| 12 | DS-45 | 31 | AT-351 |
| 13 | AT-255 | 32 | AT-324 |
| 14 | TKG-523 | 33 | RT-54 |
| 15 | JLS-708 | 34 | GT-3 |
| 16 | EC-370840 | 35 | KALIKA |
| 17 | ACMS-14-7 | 36 | GT-10 (NC) |
| 18 | BRT-04 | 37 | TKG-22 (NC) |
| 19 | BRT-08 | 38 | JTS-8 (ZC) |

Genotypic and phenotypic correlation between yield and its component traits were worked out as per the method suggested by Johnson *et al.* (1955) and Al-jibouri *et al.* (1958). The significance of correlation coefficient was tested by referring to the standard table given by Fisher and Yates (1938). Path coefficient analysis was carried out as suggested by Dewey and Lu (1959).

The analysis of variance exhibited the mean sum of squares due to genotypes were highly significant for all the characters in Table 2. It indicates the presence of significant differences in the mean performance of the genotypes for each character. Results of variance revealed that all twelve characters are individually significant and similar results were observed by Kumar *et al.* (2022). Among all the characters, the high range was found for number of capsules per plant followed by plant height, days to maturity, height of 1$^{st}$ capsule bearing node, number of seeds per capsule, yield (g/plant), days to 50 % flowering, percentage of oil, number of productive branches, inter node length and capsule length. The shortest range was found for 1000-seed weight. It was observed that phenotypic variance was higher than genotypic variance for their respective characters. The highest value for genotypic variance and phenotypic variance was observed for height of first capsule bearing node. The estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for all the twelve characters studied are presented in Table 3. PCV ranged from 11.03 percent (days to50% flowering) to 32.35 percent (height of first capsule bearing node), while GCV varied from 10.77 percent (days to maturity) to 31.52 percent (height of first capsule bearing node). Higher magnitude of both PCV and GCV was recorded for height of first capsule bearing node (32.35%) and (31.52%) respectively and followed by number of productive branches, number of capsules per plant, yield and inter node length. These results were in accordance with the findings of Tripathy *et al.* (2016), Bharathi *et al.* (2015), Manjeet *et al.* (2020) and Sasipriya *et al.* (2022). The larger heritability in a broad sense will be reliable if accompanied with high genetic advances. High heritability coupled with high genetic advance as percent of mean were observed for most of the characters like yield per plant, days to 50 percent flowering, number of productive branches, plant height, height of first capsule bearing node, 1000- seed weight, number of capsules per plant and capsule length. These results were in accordance with findings of Divya *et al.* (2018), Teklu *et al.* (2014), Abate *et al.* (2015), Bharathi *et al.* (2015) and Sasipriya *et al.* (2022). Difference between the magnitude of PCV and GCV was observed for all the characters indicating that traits were least affected by environment. Similar findings were exhibited by Hamouda et al. (2016) and Kumar *et al.* (2022). It is evident that the heritability (broad sense) estimated for the twelve quantitative characters, ranged from 74.7 percent for number of seeds per capsule to 99.00 percent for 1000 seed weight. High heritability was observed for days to 50% flowering, days to maturity, 1000-grain weight and percent of oil and findings were similar to Monpara and Khairnar (2016), Kindeya (2017) and Teklu *et al.* (2017).

Correlation coefficient analysis measures the reciprocal relationship between twelve different quantitative traits to estimate the component trait on which selection may be emphasized for yield improvement. The phenotypic correlation coefficients are shown in Table 4. In most of the situations, the measures of genotypic correlation coefficients were higher than the respective phenotypic correlation coefficient. Grain yield showed positive and significant correlation with number of productive branches, number of capsules per plant and number of seed per capsule, while significant but negative correlation with days to 50% flowering, height of first capsule bearing node, internode length and days to maturity. Similar positive correlations were observed by Iqbal *et al.* (2016), Laghari *et al.* (2016), Agrawal *et al.* (2017), Abate *et al.* (2015), Monpara and Khainar (2016) and Teklu *et al.* (2014).

As the correlation coefficient may not give a complete picture of a complex relation, path analysis was done. The direct and indirect effect of different traits on yield is depicted in Table. 5. In path analysis, it was revealed that three characters had significant positive direct effect on grain yield (g/plant) were number of seeds per capsule (0.66),

number of productive branches (0.45) and number of capsule per plant (0.34) at phenotypic level. However, it exhibited high indirect effect on grain yield via number of productive branches, number of seed per capsule, number of capsule per plant, 1000-grain weight and oil content. Similar results were found by Goudappagoudra *et al.* (2011) and Kumar *et al.* (2022). Number of productive branches (0.454) was reported positive direct effect on grain yield, whereas it showed high indirect effect on seed yield via plant height, height of 1st capsule bearing node, number of capsules per plant, number of seeds per capsule, inter node length and 1000-grain weight and similar results were found by Kumar *et al.* (2022). Number of capsule per plant (0.339) was reported positive direct effect on grain yield per plant whereas exhibited high indirect effect via number of productive branches, number of capsules per plant, number of seed per capsule,1000-seed weight and oil percent. Sumathi et al. 2007 had also found similar results. Whereas, significant negative direct effect was exhibited by days to maturity (-0.427), internode length (-0.0418), plant height (-0.305) and height of 1st capsule bearing node (-0.349) and results were in accordance with Abate and Mekbib (2015), Monpara and Khaimar (2016), Kindeya (2017) and Kumar *et al.* (2022). These characters would be more effective for desired genetic improvement.

Table 2 Analysis of variance for twelve quantitative characters in Sesame

| Characters | Mean sum of squares | | |
|---|---|---|---|
| | Replications (d. f. = 2) | Genotypes (d. f. = 37) | Error (d. f. = 74) |
| Days to 50 % Flowering | 2.114035 | 59.85111** | 0.861783 |
| No. of productive branches | 0.026316 | 4.315628** | 0.199469 |
| Plant Height (cm) | 15.302720 | 1062.854310** | 41.965785 |
| Height of 1st capsule bearing node (cm) | 3.570876 | 122.460347** | 2.127093 |
| No. of capsules per plant | 177.9326 | 1294.267788** | 72.173714 |
| No. of seeds per capsule | 35.97219* | 108.366385** | 10.972914 |
| Capsule length (cm) | 0.024723 | 0.576455** | 0.016486 |
| Inter node length (cm) | 0.012087 | 1.750234** | 0.066179 |
| Days to maturity | 0.008772 | 374.698198** | 5.459222 |
| 1000- grain weight (g) | 0.003452 | 0.366458** | 0.001201 |
| Percentage of oil | 2.093745** | 47.729061** | 0.350379 |
| Yield (g/plant) | 0.122822 | 28.505008** | 1.772407 |

Table 3 Genetic parameters of twelve quantitative traits of thirty eight sesame genotypes

| Characters | $\sigma_e^2$ | $\sigma_g^2$ | $\sigma_p^2$ | ECV | GCV | PCV | $h^2$ (broad sense) | Genetic advance | Genetic advance as % mean |
|---|---|---|---|---|---|---|---|---|---|
| Number of productive branches | 0.199 | 1.372 | 1.572 | 8.402 | 22.035 | 23.583 | 87.3 | 2.255 | 42.414 |
| Plant height (cm) | 41.966 | 340.296 | 382.362 | 6.391 | 18.198 | 19.287 | 89.0 | 35.855 | 35.370 |
| Height of 1st capsule bearing node | 2.127 | 40.111 | 42.238 | 7.259 | 31.524 | 32.349 | 95.0 | 12.714 | 63.284 |
| Number of capsule/plant | 72.174 | 407.365 | 479.538 | 9.114 | 21.653 | 23.493 | 84.9 | 38.321 | 41.113 |
| Number of seeds per capsule | 10.973 | 32.464 | 43.437 | 6.189 | 10.645 | 12.313 | 74.7 | 10.147 | 18.958 |
| Capsule length (cm) | 0.016 | 0.187 | 0.203 | 4.275 | 14.384 | 15.005 | 91.9 | 0.853 | 28.403 |
| Inter node length (cm) | 0.066 | 0.561 | 0.628 | 7.577 | 22.069 | 23.333 | 89.5 | 1.460 | 42.998 |
| Days to maturity | 5.459 | 123.080 | 128.539 | 2.455 | 11.658 | 11.913 | 95.8 | 22.363 | 23.499 |
| 1000-grain weight (g) | 0.001 | 0.122 | 0.123 | 1.104 | 11.115 | 11.169 | 99.0 | 0.715 | 22.784 |
| Percentage of oil | 0.350 | 15.772 | 16.122 | 1.432 | 9.609 | 9.715 | 97.8 | 8.092 | 19.578 |
| Yield (g/plant) | 1.772 | 8.911 | 10.683 | 10.139 | 22.734 | 24.892 | 83.4 | 5.616 | 42.771 |

Table 4 Phenotypic correlation of twelve quantitative parameters for thirty eight sesame genotypes

| | NPB | PHT | HFC | NCP | NSP | CLN | INL | DTM | TW | OLP | YPP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DFF | -0.147 | 0.380* | 0.264 | -0.028 | -0.265 | 0.395* | 0.258 | 0.707** | 0.234 | 0.445** | -0.355* |
| NPB | | -0.006 | -0.141 | 0.259 | 0.431** | -0.407* | -0.134 | -0.256 | 0.091 | -0.079 | 0.612** |
| PHT | | | 0.248 | 0.002 | -0.382* | 0.112 | 0.619** | 0.202 | 0.040 | 0.267 | -0.313 |
| HFC | | | | -0.298 | -0.438** | 0.170 | 0.337* | 0.227 | -0.507** | -0.040 | -0.380* |
| NCP | | | | | 0.331* | -0.005 | -0.098 | 0.154 | 0.305 | 0.107 | 0.373* |
| NSP | | | | | | -0.190 | -0.284 | -0.371* | 0.108 | -0.038 | 0.783** |
| CLN | | | | | | | 0.212 | 0.179 | 0.185 | 0.149 | -0.284 |
| INL | | | | | | | | 0.235 | -0.222 | 0.330* | -0.451** |
| DTM | | | | | | | | | 0.193 | 0.466** | -0.455** |
| TW | | | | | | | | | | 0.365* | 0.158 |
| OLP | | | | | | | | | | | -0.299 |

R SQUQRE = 0.6609, RESIDUAL EFFECT = 0.5823

DFF-Days to 50 % flowering, NPP-Number of productive branches, PHT-Plant height (cm), HFC-Height of 1st capsule bearing node, NCP-Number of capsule/plant, NSC-Number of seeds per capsule, CLN-Capsule length (cm), INL-Inter node length (cm), DTM-Days to maturity, TW-1000-grain weight (g), OLP-Percentage of oil, YPP-Yield (g/plant)

Table 5 Direct (Diagonal) and indirect effects of component traits attributing to grain yield (g/Plant) in sesame in Phenotypic level

| | DFF | NPB | PHT | HFC | NCP | NSP | CLN | INL | DTM | TSW | OLP | YPP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DFF | -0.0412H | 0.0003 | -0.0146 | -0.0112 | 0.0009 | 0.0095 | -0.0153 | -0.0095 | -0.0287 | -0.0094 | -0.0142 | -0.3332H |
| NPB | -0.0017 | 0.2608M | 0.0337 | 0.0083 | 0.0611 | 0.0699 | -0.0517 | 0.0078 | -0.0488 | 0.0123 | -0.0179 | 0.4538H |
| PHT | -0.008 | -0.0029 | -0.0225N | -0.0057 | 0.0005 | 0.008 | -0.0026 | -0.013 | -0.0044 | -0.0008 | -0.0042 | -0.3048H |
| HFC | -0.0007 | -0.0001 | -0.0006 | -0.0024N | 0.0006 | 0.0009 | -0.0004 | -0.0008 | -0.0006 | 0.0012 | 0.0002 | -0.3497H |
| NCP | -0.0028 | 0.0289 | -0.0025 | -0.0328 | 0.1236L | 0.0423 | -0.0029 | -0.017 | 0.0112 | 0.0418 | 0.0323 | 0.3393H |
| NSP | -0.1 | 0.1159 | -0.1529 | -0.1655 | 0.1483 | 0.4327H | -0.0748 | -0.1099 | -0.152 | 0.0394 | 0.0162 | 0.6591H |
| CLN | -0.0234 | 0.0125 | -0.0073 | -0.0104 | 0.0015 | 0.0109 | -0.0629N | -0.0125 | -0.0118 | -0.0115 | -0.0073 | -0.2605M |
| INL | -0.0332 | -0.0043 | -0.0825 | -0.0479 | 0.0198 | 0.0364 | -0.0286 | -0.1434L | -0.0316 | 0.0316 | -0.0476 | -0.4182H |
| DTM | -0.0864 | 0.0232 | -0.0241 | -0.0304 | -0.0112 | 0.0436 | -0.0233 | -0.0274 | -0.1242L | -0.0235 | -0.0395 | -0.4271N |
| TSW | 0.0301 | 0.0062 | 0.0044 | -0.0661 | 0.0444 | 0.012 | 0.0241 | -0.0289 | 0.0248 | 0.1313L | 0.0412 | 0.1524N |
| OLP | -0.0659 | 0.0132 | -0.0359 | 0.0144 | -0.05 | -0.0072 | -0.0221 | -0.0636 | -0.061 | -0.0601 | -0.1916L | -0.2325M |

DFF-Days to 50 % flowering, NPP-Number of productive branches, PHT-Plant height (cm), HFC-Height of 1st capsule bearing node, NCP-Number of capsule/plant, NSC-Number of seeds per capsule, CLN-Capsule length (cm), INL-Inter node length (cm), DTM-Days to maturity, TW-1000-grain weight (g), OLP-Percentage of oil, YPP-Yield (g/plant) L-Low,N-Negligible, M-Moderate, H- High

The investigation in sesame was undertaken to understand the phenotypic and genotypic coefficient of variation, heritability, genetic advance, correlation coefficient, direct and indirect effects of attributing traits on grain yield. The analysis of variance revealed genotypes were significantly differed for all characters, thereby indicating sufficient variability for all the characters. Higher magnitude of PCV was recorded for height of 1st capsule bearing node whereas high GCV were recorded for yield (g/plant), inter node length, number of productive branches, height of 1st capsule bearing node and number of capsules per plant. High heritability coupled with high genetic advance as percent mean was observed for all the characters except number of seed per capsule and oil content. Genotypic and phenotypic correlation analysis revealed that grain yield showed positive significant association with number of productive branches, number of capsules per plant, number of seeds per capsule. Significant but negative correlation was observed for days to 50 % flowering, height of first capsule bearing node, inter node length and days to maturity. Path analysis revealed that number of productive branches, number of capsules per plant and number of seeds per capsule had high positive direct effect on grain yield.

On the basis of GCV, PCV, heritability, genetic advance, correlation and path analysis for twelve characters, selection could be more effective for the traits like number of productive branches, number of capsules per plant and number of seeds per capsule to be given more importance throughout sesame improvement programme.

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REFERENCES

Abate M 2018. Correlation and path coefficient analysis in mid-altitude sesame (*Sesamum indicum* L.) germplasm collection of Ethiopia. *Journal of Plant Science Current Research*, **2**(1): 1-7.

Abate M and Mekbib F 2015. Assessment of genetic variability and character association in Ethiopian low altitude sesame (*Sesamum indicum* L.) genotypes. *Journal of Advanced Studies in Agricultural, Biological and Environmental Sciences*, **2**(3): 55-66.

Agrawal M M, Singh S, Wawge M N, Macwana S and Sasidhara N 2017. Correlation and path analysis for seed yield and yield attributing traits in sesame germplasm (*Sesamum indicum* L). *International Journal of Chemical Studies*. **5** (4): 1099-1102.

Bharathi D, Thirumala Rao V, Venkanna V and Bhadru D 2015. Association analysis in sesame (*Sesamum indicum* L). *International Journal of Applied Biology and Pharmaceutical Technology*. **6**(1): 210-212.

Dewey J R and Lu KH 1959. Correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal*, **51**: 515-518.

Divya K, Shobha Rani T, Kiran Babu T and Padmaja D 2018. Assessment of genetic variability, heritability and genetic gain in advanced mutant breeding lines of sesame (*Sesamum indicum* L.). *International Journal of Current Microbiology and Applied Sciences*, **7** (6): 1565-1574.

Fazal A, Mustafa H S B, Hasan E U, Anwar M, Tahir M H N, Sadaqat H A 2015. Interrelationship and path coefficient analysis among yield and yield related traits in sesame (*Sesamum indicum* L.). *Nature and Science*, **13**(5): 27-32.

Fisher R A and Yates F 1963. Statistical tables for biological, agricultural and medical research. Oliver and Boyd, Edinberg.

Hamouda F E, Bashirand S G E and Ginaro M K 2016. Phenotypic and genotypic coefficients of variation and other growth attributes in sesame genotype under rain-fed conditions. *Advances in Agriculture and Agricultural Sciences*, **2**(3): 79-84.

Iqbal A, Akhtar R, Begum T and Dasgupta T 2016. Genetic estimates and diversity study in sesame (*Sesamum indicum* L.). *IOSR Journal of Agriculture and Veterinary Science,* **9**(8): 1-5.

Iqbal A, Bhattacharyya U, Akhtar R and Dasgupta T 2018. Genetic diversity computation in sesame genotypes using morphological traits and genic SSR markers. *Indian Journal of Genetics and Plant Breeding*, **78**(3): 348-356.

Ismaila A and Usman A 2014. Genetic variability for yield and yield components in sesame (*Sesamum indicum* L.). *International Journal of Science and Research*, **3**(9): 63-66.

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

Khairnar S S and Monpara B A 2013. Identification of potential traits and selection criteria for yield improvement in sesame (*Sesamum indicum* L.) genotypes under rainfed conditions. *Iranian Journal of Genetics and Plant Breeding*, **2**(2): 1-8.

Kindeya Y B 2017. Correlation and cluster analysis of white seeded sesame (*Sesamum indicum* L.) genotypes oil yield in northern Ethiopia. *African Journal of Agricultural Research*, **12**(12): 970-978.

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

Kumar Vivek, Sinha Sima, Satyendra, Sinha Sweta, Singh Ravi shanker and Singh S N 2022. Assessment of genetic variability, correlation and path analysis in sesame (*Sesamum indicum* L.). *Electronic Journal of Plant Breeding*, **13**(1): 208-215.

Kumhar S R and Rajani B 2021. Genetic analysis and diversity studies in sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **38**(4): 329-336.

Laghari J H, Mari S N, Soomro Z A, Memon H U R and Khanzada S 2016. Screening of sesame (*Sesamum indicum* L.) genotypes for yielding ability as per degree of association among yield contributing morphological features. *Sindh University Research Journal (Science Series)*, **48**(2): 241-244.

Manjeet, Verma P K, Sheoran R K, Nain M and Avtar R 2020. Evaluation of sesame (*Sesamum indicum* L.) genotypes for genetic variability based on different traits under rainfed conditions. *Electronic Journal of Plant Breeding*, **11**(1): 54-59.

Monpara B A and Khairnar S S 2016. Heritability and expected genetic gain from selection in components of crop duration and seed yield in sesame (*Sesamum indicum* L.). *Plant Gene and Trait*, **7**(2): 1-5.

Rajitha D, Srikanth T, Padmaja D and Kiran Babu T 2021. Genetic variability and heritability studies among genotypes of sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **38**(1): 43-48.

Ramya K T, Jawahar Lal J, Kumaraswamy H H and Ratnakumar P 2020. Morphological characterization of sesame germplasm. *Journal Oilseeds Research*, **37**(Special Issue): 2-3.

Ramya K T, Lavanya C, Jawaharlal J and Vishnuvardhan Reddy A 2021. Hayman's diallel analysis of elite x elite crosses in sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research,* **38**(4): 320-328.

Sasipriya S, Parimala K, Eswari K B and Balram M 2022. Studies on genetic variability in sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **39**(2): 142-145.

Tripathy S K, Mishra D R, Panda S, Senapati N, Nayak P K, Dash G B, Mohanty S K, Mohanty M R, Jena M and Pradhan K 2016. Assessment of genetic variability in sesamum (*Sesamum indicum* L). *Asian Journal of Science and Technology*, **7**(2): 2482-2485.

Vamshi P, Ramya K T, Santhalakshmi M P, Ramana J V and Kumhar S R 2021. Genetic variability studies for yield and yield attributes in breeding lines of sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research*, **38**(3): 240-243.

# Evaluation of biorational insecticides against capsule borers, *Helicoverpa armigera* and *Heliothis peltigera* (Lepidoptera: Noctuidae) on safflower

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ABSTRACT

Safflower capsule borers, *Helicoverpa armigera* (Hübner) and *Heliothis peltigera* (Denis and Schiffmüller) (Lepidoptera: Noctuidae) were considered as economically important pests of safflower. The present study was undertaken to evaluate the biorational insecticides (chlorantraniliprole 18.5 SC @ 0.15 ml/l, *Beauveria bassiana* @ 4.0 g/l, *Metarhizium rileyi* @ 4.0 g/l, commercial B.t. (Dipel) @ 2.0 ml/l, commercial neem product 1500 ppm @ 2.0 ml/l and indoxacarb 15 EC @ 0.3 ml/l) against these pests on safflower during *rabi* 2020-21 at Krishi Vigyan Kendra, Bidar, Karnataka, India. The results indicated that all the treatments were superior over untreated check in reducing the capsule borers population. Among the tested products, chlorantraniliprole was found to be effective in suppression of the capsule borers, recorded lower population (0.11 larvae per plant) with higher yield (10.47 q/ha) and benefit cost ratio (1.96) followed by indoxacarb and commercial B.t. product, recorded 0.20 and 0.23 larvae/plant, 9.44 q/ha and 8.75 q/ha and benefit cost ratio of 1.82 and 1.63, respectively.

**Keywords**: Biorational insecticides, *Helicoverpa armigera, Heliothis peltigera,* Noctuidae, Safflower

Safflower (*Carthamus tinctorius* L.) is a multipurpose crop, with unexploited potential and worldwide adaptability (Singh *et al.,* 1999; Chaitanya *et al.,* 2019). Safflower is under threat from a variety of insect pests which is a main cause for its low yield (Singh *et al.,* 1999). The crop is known to be attacked by 101 insect pest species belonging to different orders (Bharaj *et al.,* 2003; Patil and Halolli, 2005). Of these, hemipteran and lepidopteran are causing huge economic loss (Mallapur *et al.,* 1997). Among the lepidopteran, capsule borers, *Helicoverpa armigera* (Hübner) and *Heliothis peltigera* (Denis and Schiffmüller) were reported as major pests of safflower (Hanumantharaya *et al.,* 2009; Esfahani *et al.,* 2012; Akashe *et al.,* 2013).

To manage these pests, various conventional and biorational insecticides were tested (Kumar *et al.,* 1999; Biradarpatil and Jagginavar, 2016). However, use of conventional insecticides resulted in destruction of natural enemies of these pests and risk to human beings as well as environment. Alternative to conventional insecticides is use of biorational insecticides. Biorational insecticides are the toxicant that are effectively suppress the target pest and relatively non-toxic to humans or animals and does little or no hazard to the environment. In this context, the present study was undertaken to evaluate the bio-efficacy of biorational insecticides including fungal pathogens like *Beauveria bassiana* and *Metarhizium rileyi* against capsule borers (*H. armigera* and *H. peltigera*) on safflower. Previously, these fungal pathogens were not tested for their efficacy against *H. armigera* and *H. peltigera* on safflower.

A field experiment was conducted to evaluate the biorational insecticides against safflower capsule borers, *H. armigera* and *H. peltigera* on safflower during *rabi* 2020-21 at KVK, Bidar, Karnataka, India. The biorational insecticides included in the present study are chlorantraniliprole 18.5 SC @ 0.15ml/l, *Beauveria bassiana* @ 4.0 g/l, *Metarhizium rileyi* @ 4.0 g/l, commercial B.t. product @ 2.0 ml/l, commercial neem product 1500ppm @ 2.0ml and indoxacarb 15 EC @ 0.3ml/l. The experiment was laid-out in randomized complete block design (RCBD) with plot size of 5 x 5 sq. m. and each treatment was replicated three times. The safflower variety Annigeri-1 was sown with the spacing of 45 x 30 cm and raised as per the recommended package of practices. Two sprays were given during the crop period depending upon the infestation level. The insecticides were applied by using a high-volume sprayer at the rate of 500-750 litres of spray solution per hectare depending on the stage of the crop. The spray fluid was mixed with 0.1% spreader to ensure proper spreading. Observations were recorded on number of larvae per plant from ten randomly selected plants per replication. The pre-treatment count was made a day before the first spray and the post-treatment observations were recorded on 3$^{rd}$, 7$^{th}$, 9$^{th}$ and 15$^{th}$ day after each spray. The seed yield from each plot with respect to the treatments was recorded after harvest. Later, seed yield was expressed as quintal per ha. The data was analyzed

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statistically for comparing the treatments means by using OPSTAT software. The cost benefit ratio for each treatment was worked out.

The safflower capsule borers, *H. armigera* and *H. peltigera* are considered as economically important pests of safflower crop in India. In the current investigation, biorational insecticides were tested against safflower capsule borers. A day before first spray, there was no statistically significant difference between the treatments with respect to mean number of larvae per plant (Table 1). On 3rd day after first spray, the minimum number of larvae per plant was recorded in plots treated with chlorantraniliprole 18.5 SC (0.43 larvae per plant) and indoxacarb 15 EC (0.57 larvae per plant). The next best treatment was commercial B.t. product, recorded 0.83 larvae per plant and was on par with indoxacarb 15 EC. The maximum number of larvae per plant was recorded in plots treated with *M. rileyi* (0.93 larvae per plant), followed by *B. bassiana* (0.90 larvae per plant) and commercial neem product 1500ppm (0.87 larvae per plant). However, all the treatments were statistically superior over untreated check (2.10 larvae per plant) (Table 1). Same trend was observed at 7th, 9th and 15th DAS.

A day before second spray, there was no statistically significant difference between the treatments with respect to mean number of larvae per plant (Table 1). On 3rd day after second spray, the least number of larvae per plant was recorded in plots treated with chlorantraniliprole 18.5 SC (0.27 larvae per plant) and indoxacarb 15 EC (0.30 larvae per plant) as against 1.40 larvae per plant in untreated check. The next best treatment was commercial B.t. product (Dipel), recorded 0.33 larvae per plant and was on par with chlorantraniliprole 18.5 SC and indoxacarb 15 EC. The maximum number of larvae per plant was recorded in plots treated with *M. rileyi,* commercial neem product 1500ppm and *B. bassiana,* recorded 0.53, 0.52 and 0.50 larvae per plant, respectively. However, all the treatments were statistically superior over untreated check (1.20 larvae per plant) (Table 1). Similar trend was observed at 7th, 9th and 15th days after spraying. The present findings are corroborated with the findings of Biradarpatil and Jagginavar (2016) who also reported chlorantraniliprole 20 SC was found very effective in complete suppression of the pest. Further, maximum reduction in the larval population was observed in the plots treated with chlorantraniliprole 18.5 SC, recorded 87.59%.

Further, the lowest per cent of capsule damage was recorded in chlorantraniliprole 18.5 SC, recorded 13.85%. The seed yield obtained from different treatments was significantly higher compared to untreated check. Among the treatments, chlorantraniliprole 18.5 SC registered higher seed yield (10.47 q/ha), followed by indoxacarb 15 EC (9.44 q/ha) and commercial B.t. product (Dipel) (8.75 q/ha). The lesser seed yield registered in the plots treated with *M. rileyi* (7.51 q/ha) followed by commercial neem product 1500ppm (7.71 q/ha) and *B. bassiana* (8.44 q/ha) and were statistically inferior to other treatments, but superior over untreated check (3.69 q/ha) (Table 2). Similarly, Mohankumar (2015) who also recorded significantly higher seed yield in the plots sprayed with chorantraniliprole 18.5 SC, recorded 1168 kg/ha. In another study Biradarpatil and Jagginavar (2016) who also recorded significantly higher seed yield in the plots treated with chorantraniliprole 20 SC, recorded 10.68 q/ha.

Table 1 Bio-efficacy of biorational insecticides against capsule borers, *H. armigera* and *H. peltigera* (Lepidoptera: Noctuidae) on safflower

| Treatments | Dosage (ml or gm/l) | Capsule borers (No. of larvae/plant) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st spray | | | | | | 2nd spray | | | | | |
| | | DBS | 3rd DAS | 7th DAS | 9th DAS | 15th DAS | % ROC | DBS | 3rd DAS | 7th DAS | 9th DAS | 15th DAS | % ROC |
| Chlorantraniliprole 18.5 SC | 0.15 | 1.53 (1.43)a | 0.43 (0.96)a | 0.33 (0.91)a | 0.22 (0.79)a | 0.12 (0.85)a | 83.08 | 1.53 (1.24)a | 0.27 (0.87)a | 0.25 (0.85)a | 0.13 (0.80)a | 0.11 (0.78)a | 87.59 |
| Beauveria bassiana (Bb5 strain) | 4.0 | 1.67 (1.47)a | 0.90 (1.18)b | 0.77 (1.13)c | 0.60 (1.11)ab | 0.46 (0.98)b | 55.85 | 1.70 (1.30)a | 0.50 (1.00)bc | 0.33 (0.98)b | 0.37 (0.94)bc | 0.30 (0.91)b | 77.94 |
| Metarhizium rileyi (Mr2 strain) | 4.0 | 1.63 (1.46)a | 0.93 (1.20)b | 0.97 (1.21)c | 0.73 (1.04)b | 0.48 (0.98)b | 54.31 | 1.67 (1.29)a | 0.53 (1.01)c | 0.39 (1.01)b | 0.40 (0.94)c | 0.35 (0.91)b | 74.31 |
| Commercial B.t. product (Dipel) | 2.0 | 1.50 (1.41)a | 0.83 (1.15)b | 0.60 (1.04)abc | 0.49 (0.99)ab | 0.32 (0.90)ab | 65.54 | 1.47 (1.21)a | 0.33 (0.91)ab | 0.30 (0.93)ab | 0.23 (0.85)ab | 0.23 (0.85)ab | 81.46 |
| Commercial neem product 1500ppm | 2.0 | 1.60 (1.44)a | 0.87 (1.17)b | 0.73 (1.11)bc | 0.60 (1.04)ab | 0.40 (0.95)b | 60.00 | 1.63 (1.27)a | 0.52 (1.01)c | 0.37 (0.94)b | 0.40 (0.93)c | 0.33 (0.89)b | 75.15 |
| Indoxacarb 15EC | 0.3 | 1.43 (1.39)a | 0.57 (1.03)ab | 0.40 (0.95)ab | 0.43 (0.97)ab | 0.30 (0.89)ab | 73.84 | 1.53 (1.24)a | 0.30 (0.89)ab | 0.28 (0.90)ab | 0.18 (0.82)ab | 0.20 (0.83)ab | 84.31 |
| Untreated check | - | 1.30 (1.34)a | 2.10 (1.61)c | 1.60 (1.44)d | 1.63 (1.45)c | 1.17 (1.29)c | - | 1.53 (1.23)a | 1.20 (1.30)d | 1.83 (1.51)c | 1.86 (1.17)d | 1.30 (1.10)c | - |
| SEm ± | | 0.03 | 0.06 | 0.06 | 0.09 | 0.03 | | 0.03 | 0.04 | 0.02 | 0.04 | 0.04 | |
| CD at 5% | | - | 0.18 | 0.17 | 0.27 | 0.10 | | - | 0.11 | 0.17 | 0.11 | 0.12 | |
| CV (%) | | 5.86 | 8.41 | 8.79 | 14.26 | 5.56 | | 7.57 | 6.32 | 6.77 | 6.57 | 7.57 | |

- Values in parenthesis are √x+0.5 transformed; - Mean of 10 plants
- Means followed by same alphabet in columns did not differ significantly (P=0.05) by DMRT
- ROC-Reduction over control
- DBS - Days before spray; - DAS - Days after spray

The cost economics of different treatments indicated that, the maximum net return was recorded in chlorantraniliprole 18.5 SC (₹ 23565/ha) treated plots, followed by indoxacarb 15 EC (₹ 19588/ha) and commercial B.t. product (Dipel) (₹ 15550/ha). The minimum net return was recorded in *M. rileyi* (₹ 10246/ha) treated plots, followed by commercial neem product 1500ppm (₹ 10686/ha) and *B. bassiana* (₹ 14524/ha) (Table 3). The present findings are corroborated with the findings of Mohankumar (2015) who reported highest net return in plots treated with chorantraniliprole 18.5 SC, recorded ₹ 27776/ha. In another study, Biradarpatil and Jagginavar (2016) who also reported net return was highest in the chlorantraniliprole 20 SC treated plots, recorded ₹22724/ha. The cost benefit ratio was higher in chlorantraniliprole 18.5 SC (1.96), followed by indoxacarb 15 EC (1.82) and commercial B.t. product (Dipel) (1.63). The least cost benefit ratio observed in *M. rileyi* (1.42), followed by commercial neem product 1500ppm (1.43) and *B. bassiana* (1.52) (Table 3). In the present findings also, the cost benefit ratio was highest in the plots treated with chlorantraniliprole 18.5 SC, recorded 1.96. The present results are corresponding with the findings of Mohankumar (2015) who reported highest benefit cost ratio in the pots treated with chorantraniliprole 18.5 SC, recorded 2.67. In another study, Biradarpatil and Jagginavar (2016) who also reported higher cost benefit ratio in chlorantraniliprole 20 SC treated plots, recorded 1.98.

Table 2 Effect of biorational insecticides on percent capsule damage

| Treatments | Dosage (ml or gm/l) | Percent capsule damage |
|---|---|---|
| Chlorantraniliprole 18.5 SC | 0.15 | 13.85 (21.85)a |
| Beauveria bassiana (Bb5 strain) | 4.0 | 24.46 (29.63)c |
| Metarhizium rileyi (Mr2 strain) | 4.0 | 28.63 (32.34)cd |
| Commercial B.t. product (Dipel) | 2.0 | 20.36 (26.81)bc |
| Commercial neem product 1500ppm | 2.0 | 25.87 (30.55)c |
| Indoxacarb 15EC | 0.3 | 16.81 (24.20)ab |
| Untreated check | - | 34.14 (35.76)e |
| SEm ± | | 0.09 |
| CD at 5% | | 0.28 |
| CV (%) | | 5.77 |

Values in parenthesis are angular transformed
Means followed by same alphabet in columns did not differ significantly (P=0.05) by DMRT

From the above study, it can be concluded that chlorantraniliprole 18.5 SC was found to be effective in suppression of capsule borers, with enhanced seed yield and benefit cost ratio, followed by indoxacarb 15 EC and commercial B.t. product. The least effective insecticides are *M. rileyi,* followed by commercial neem product 1500ppm and *B. bassiana.*

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Table 3 Effect of biorational insecticides on seed yield and their benefit cost

| Treatments | Dosage (ml or gm/l) | Seed yield (q/ha) | Cost of protection (₹) | Total cost of cultivation (₹) | Gross returns (₹/ha) | Net return (₹/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|
| Chlorantraniliprole 18.5 SC | 0.15 | 10.47 | 1097 | 24597 | 48162 | 23565 | 1.96 |
| Beauveria bassiana (Bb5 strain) | 4.0 | 8.44 | 800 | 24300 | 38824 | 14524 | 1.59 |
| Metarhizium rileyi (Mr2 strain) | 4.0 | 7.51 | 800 | 24300 | 34546 | 10246 | 1.42 |
| Commercial B.t. product (Dipel) | 2.0 | 8.75 | 1200 | 24700 | 40250 | 15550 | 1.63 |
| Commercial neem product 1500ppm | 2.0 | 7.71 | 1280 | 24780 | 35466 | 10686 | 1.43 |
| Indoxacarb 15EC | 0.3 | 9.44 | 336 | 23836 | 43424 | 19588 | 1.82 |
| Untreated check | - | 3.69 | 0.00 | 23500 | 16974 | -6526 | 0.72 |

Market value = ₹ 4600 / q; Cost of cultivation: ₹ 23500

## REFERENCES

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

Bharaj G S, Deshpande S L and Saxena M K 2003. Field screening of safflower genotypes for resistance against safflower aphid (in) *National Seminar on Stress Management in Oilseeds* held during 28-30 January 2003 by Indian Society of Oilseed Research, at Indian Institute of Oil Seed Research, Hyderabad, 28: 126-127.

Biradarpatil K A and Jagginavar S B 2016. Bio efficacy of newer insecticides molecules against safflower capsule borer, *Helicoverpa armigera* (Hubner). *Journal of Farm Science,* **29** (1): 117-118.

Chaitanya P, Srinivas P S and Saxena A K 2019. Identification of sources against Aphid, *Uroleucon compositae* (Theobald) in safflower. *Journal of Oilseeds Research*, **36** (3): 199-202.

Esfahani M N, Alizadeh G, Zarei Z and Esfahani M N 2012. The main insect pests of safflower on Various Plant Parts in Iran. *Journal of Agriculture Science and Technology*, **2**: 1281-1289.

Hanumantharaya L, Balikai R A, Venkateshalu, Basurajappa, M P and Somanagouda G 2009. Insect pest status of safflower and their natural enemies in Karnataka. *Karnataka Journal of Agricultural Sciences,* **22** (3): 678-679.

Kumar S S R, Kulkarni G G, Basavanagouda K and Mallapur C P 1999. Insecticidal property of some indigenous plant extracts against lepidopterous pests of safflower. *Annals of Agri Bio Research,* **4** (1): 49-52.

Mallapur C P, Parameshwarappa K G, Kulkarni M S, Hulihalli W K, Kubsad V S and Gulaganji G G 1997. Pest scenario of safflower in the dry tract of Karnataka. *Journal of Oilseeds Research*, **14** (2): 300-303.

Mohankumar 2015. Biology and management of safflower leaf eating caterpillar, Perigea capensis Guen. (Lepidoptera: Noctuidae). M Sc Thesis, University of Agricultural Sciences, Dharwad.

Patil R H and Halolli S P 2005. Safflower: A unique crop for oil spices and health consequently, a better life for you (in) *Proceedings of the 6th International safflower Conference,* held during 6-10 June 2005 at Istanbul, Turkey, pp. 229-235.

Singh V, Prasad Y G and Lakshminarayana M 1999. Insect pests of safflower and their management. In: Upadhyay R K (Ed.) *IPM system in Agriculture,* Volume 5, Oilseeds. Aditya Publications, New Delhi, India, 552 p.

# Growth and instability of oilseeds in India

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ABSTRACT

Oilseeds are one of the basic necessities of human and industrial life as the edible oils are derived from the oilseeds. This study pertains to explore the growth and instability of oilseeds and extent of changes in the area, production and productivity. Traditionally, Indian cooking method is oil based particularly sesame, groundnut and sunflower. Enhancing production of oilseeds and extraction of oils are essential as it reduces imports from foreign countries. Appropriate latest technologies, minimum support prices, disseminating knowledge about the utilization of technical units, educate the farmers, proper irrigation management on drought prone areas, quality of seeds, also improves the oilseed production.

**Keywords**: Growth, Instability, India, Oilseeds

Oilseeds place pivotal role in the production of edible oils and whole oilseeds provide energy, protein and fiber and meals from these seeds are used to feed all classes of dairy cattle. Domestically, groundnut (peanut) and soybeans play a significant place in the oilseeds. Rapeseeds and sesame are the important seeds mentioned in the Indian Sanskrit 2000 B.C (Bernard, 2022). Groundnut, castor seed, sesame, soyabean, sunflower, rapeseed and mustard (Sarson and *toria/lahi*) are known as rapeseed and *rai/raya/laha* is termed as mustard), linseed, niger seed and safflower are the major nine oilseeds in the country. Realizing the significance of edible oils, the central government introduced the national Mission oilseeds and Oil palm (NMOOP) due to the 12$^{th}$ five-year plan. Expansion of oil palm areas and increasing edible oils production is one of the objectives of this scheme. This mission often organized the programme and provides financial support to educate the farmers and latest technologies. Next to USA, China, Brazil, India occupies fourth place in the production of oilseeds measuring growth and instability of oilseeds are an essential in agricultural research as it pinpoints irregularities of production (Viswanatga Reddy and Kingsly Immanuelraj, 2017; Chauhan *et al.,* 2021). The main purpose of growth of oilseeds is extraction of oils. The demand for oilseeds increased alarmingly due to the diversified use of vegetable oils, farm animal feeds, pharmaceuticals, bio-fuels and other oleo substance industrial uses. Industrial products like biodiesel, fertilizer, medicine, cosmetics, animal feeds, fibers, paint are also derived from the oilseeds. Against these underpinnings, the present study has been undertaken to measure the growth and instability of oilseeds and identifying area and yield effects on the changes in production.

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Singh and Asokan (2000) Chand and Raju (2009) Shivaj and others (2009), Sahu and Mishra (2013), Joshi and Singh (2015), Shabana (2018) also made an attempt to find the growth and instability. Gandhimathy (2020 and 2021) also studied about the instability of coconut cultivation and rice production and explores the details of area, production and productivity. Some studies throw light on food grains production whereas some studies on cereals and pulses production and spices but limited studies are available on oilseeds. Hence, in order to fulfill the research gap an attempt is made to analyze the growth and instability of oilseeds with the following objectives. i) to examine the growth of oilseeds in Peninsular India, ii) to measure the instability of oilseeds in Peninsular India, iii) to find the effects of oil production in Peninsular India iv) to find the extent of relationship between area, production and productivity of oilseeds in the Peninsular India.

This study is based on the secondary data collected from Agriculture statistics at a glance published by Directors of Economics and Statistics, Government of India. The official estimates of area, production and productivity of oilseeds were collected. The study period pertains from 1951 to 2020. To get the inferences, SPSS package 16th version and Excel is used. The instability in oilseeds production in India is measured for a long period of seven decades. Decadal growth also encompassed in this study. Appropriate statistical tools are used to draw the inferences. Compound growth rate, Mean values, Standard deviation, Coefficient of variation, Cuddy Della Valley Index, Decomposition model and regression analyses are used. Compound growth rates are used to find the decadal growth of oilseeds in India. Descriptive statistics mean values are standard variations are used to find the coefficient of variations. Cuddy Della Valley Index is widely used to find the instability index. Decomposition model helps to find area, yield and interact effects. Changes in the production are measured by

decomposition analysis. Regression analysis used to estimate the overall growth of area, production and productivity during the whole study period.

**Variables**: Area, Yield, Production

**Compound growth rate:**

$Y_t = Y_0 (1+g)^t$

$= AB^t$ where $Y_0 = A$ and $(1+g) = B$

$Yt = AB^t$

Taking log both sides

log Y = log A + t log B

i.e Y* = A*+ t B*

when $\log Y_t = y^*$ log A = A* log B = B*

This is a simple regression line in Y* and t. B* can be estimated using least squares method. Then the estimate of compound growth rate can be obtained as:

g^ = anti log B^* - 1

For expressing the compound growth rate in percentage terms g^ has to be multiplied by 100. That is

100 g^ = (anti log B^*) -1 x 100.

Coefficient of variation = Standard Deviation/ Mean x 100.

The formula for construction of Cuddy Della Valley Index (CDVI) Instability model is given as

CDVI = CV x $\sqrt{1-r^{-2}}$ where CV is coefficient of variation, is Coefficient of determination adjusted.

The range of oilseeds are given as

Low instability = between 0 and 15

Medium instability greater than 15 and lower than 30

High instability = greater than 30.

**Decomposition model**: The following decomposition model was used to find yield effects, area effects and interaction effects.

$$\Delta P = A_0 (Y_n - Y_0) + Y_0 (A_n - A_0) + \Delta A . \Delta Y; 1 = \frac{A0.\Delta Y}{\Delta P} x100 + \frac{Y0\Delta A}{\Delta P} x100 + \frac{\Delta A.\Delta Y}{\Delta P} x100$$

CAGR is widely used in agricultural domain because of its policy implications. In the era of green revolution, spectacular changes have been undertaken in agriculture field. The green revolution has made changes in the cropping pattern and intensity of crops. The impact of green revolution has positive in the next decade (1971-91), but the new industrial policy 1991 the cultivation of oilseeds reduced considerably. Overall growth of oilseeds are progressive and mild fluctuations can be seen in area, production and yield of oilseeds during the study period. Negative growth rate during 1991-2001 and 2011 and 2020. The productivity is negative during 1961-71 but all other period shows only positive growth rate. The Cuddy Della Valley Index is one of the widely used methods in measuring the instability index. Area and Productivity are more stable than the Production and the range of Instability in CDVI is less than 15 and productivity range of CDVI is more than 15 (Table 1).

Table 1 Cuddy Della Valley Index

| Attributes | Area | Production | Productivity |
|---|---|---|---|
| Mean | 20.07 | 15.84 | 728.83 |
| Standard Deviation | 5.48 | 9.14 | 253.61 |
| Coefficient of Variation | 27.29 | 57.71 | 34.80 |
| Adjusted R Squre | 0.90 | 0.90 | 0.86 |
| CDVI | 8.80 | 18.61 | 13.16 |

*Area in million ha, Production in million tonnes, Yield (kg/ha)

**Decomposition model:** Aggregate analysis for the study period of 1951-2020 explains the effects of area, yield and interactions. The components explore the interaction effects are relatively more than area and yield in the production. The effects of area and yield are closer and in explain production. Changes in the production are relatively brought out by the interaction effects i.e. area*yield.

Change in production = Area Effect (27760.47) + Yield Effect (28666.49) + Interaction Effect (43574.13)

The regression analysis is used to compute the relationship between area, production and productivity with time periods and also relationship between production and area. For every year (One Unit), 0.26 million ha of land (One Unit) for cultivation of oilseed has increased at 000 level of significance. For every year (One Unit), 0.425 million tones (One Unit) for producing oilseeds has increased at 000 level of significance. The productivity of oilseeds also rose to 11.45 yield kg per Ha (One Unit) for every year (One Unit). Productions of oilseed with area are

regressed in order to find the correlation between area and production. The result shows that every one unit increase of area, 1.57 unit of production had increased. All the four inferences shows the .000 level of significance and $R^2$ value also fits the equation. India has a potential to produce the oil at a large scale. To conclude, Oilseeds are one of the basic necessities of human and industrial life as the edible oils are derived from the oilseeds. Traditionally, Indian cooking method is oil based particularly sesame, groundnut and sunflower. Enhancing production of oilseeds and extraction of oils are essential as it reduces imports from foreign countries. Appropriate latest technologies, minimum support prices, disseminating knowledge about the utilization of technical units, educate the farmers, proper irrigation management on drought prone areas, quality of seeds, also improves the oilseed production.

## REFERENCES

Chand R and Raju 2009. Instability in Indian Agriculture during different phases of technology and policy. *Indian Journal of Agricultural Economics*, **64**(2): 283-288.

Chauhan J S, Choudhury P R and Singh K H 2021. Production, varietal improvement programme and seed availability of annual oilseeds in India: Current scenario and future prospects. *Journal of Oilseeds Research*, **38**(1): 1-18.

Gandhimathy B 2020. Growth and Instability of Rice Production in India. Social Vision, 7(2):519.

Gandhimathy B 2021. Growth and Instability of coconut cultivation in India, *EPRA International Journal of Agriculture and Rural Economic Research*, **9**(8): 2321.

Joshi D and Singh H P 2015. An Empirical Analysis of Growth and Instability in Major Spices in India. *International Journal of Agricultural Science*, **7**(2):440-442.

Mishra P 2013. Instability and Forecasting Using ARIMA model in Area, Production and Productivity of Onion in India. *Journal of Crop and Weed*, **9**(2): 96-101.

Shabana A 2018. Growth and Instability analysis in Indian Agriculture. https//www. Research gate. Net/publication/ 329208143.

Singh and Asokan 2000. Competitiveness of Indian oilseeds under WTO. *Artha Vijnana*, **42**(3):240-249.

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

***Abstract***

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Rao C R 1968. *Advances in Statistical Methods in Biometrical Research*, pp.40-45, John Wiley & Sons, New York.

Kanwar J S and Raychaudhuri S P 1971. *Review of Soil Research in India*, pp 30-36. Indian Society of Soil Science, New Delhi.

Mukherjee J N 1953. The need for delineating the basic soil and climatic regions of importance to the plant industry. *Journal of the Indian Society of Soil Science*, **1** : 1-6.

Khan S K, Mohanty S K and Chalam A B, 1986. Integrated management of organic manure and fertilizer nitrogen for rice. *Journal of the Indian Society of Soil Science*, **34** : 505-509.

Bijay-Singh and Yadvinder-Singh 1997. Green manuring and biological N fixation: North Indian perspective. In: Kanwar J S and Katyal J C (Ed.) *Plant Nutrient Needs, Supply, Efficiency and Policy Issues 2000-2025*. National Academy of Agricultural Sciences, New Delhi, India, pp.29-44.

Singh S, Pahuja S S and Malik R K 1992. Herbicidal control of water hyacinth and its effect on chemical composition of water *(in) Proceedings of Annual Weed Science Conference*, held during 3-4 March 1992 by the Indian Society of Weed Science, at Chaurdhary Charan Singh Haryana Agricultural University, Hisar, 127p.

AICRP on Soybean 1992. *Proceedings of 23rd Annual Workshop of All-India Co-ordinated Research Project on Soybean*, held during 7-9 May 1992 at University of Agricultural Sciences, Bangalore, Karnataka, National Research Centre for Soybean, Indore, pp.48.

Devakumar C. 1986. Identification of nitrification retarding principles in neem (*Azadirachta indic*a A.Juss.) seeds. Ph D Thesis, Indian Agricultural Research Institute, New Delhi.

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

**Short Communication**

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

**Tables**

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

The data in tables should be corrected to minimum place of decimal so as to make it more meaningful. Do not use full stop with CD, SEm $\pm$, NS (not C.D., S.E.m $\pm$, N.S.). Do not put cross-rules inside the table. Tables should be numbered consecutively and their approximate positions indicated in the margin of the manuscript. Tables should not be inserted in the body of the text. Type each table on a separate sheet. Do not use capital letters for the tabular headings, do not underline the words and do not use a full-stop at the end of the heading. All the tables should be tagged with the main body of the text i.e. after references.

**Figures**

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

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

**Expression of Plant Nutrients on Elemental Basis**

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

**SI Units and Symbols**

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

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

***Names and Symbols of SI Units***

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

***Primary Units***

| | | | |
|---|---|---|---|
| length | l | time | t |
| metre | m | second | s |
| mass | m | electric current | I |
| kilogram | kg | ampere | A |

***Secondary Units***

| | | | | | |
|---|---|---|---|---|---|
| plane angle | radian | rad | Solid angle | steradian | sr |

***Unit Symbols***

| | | | |
|---|---|---|---|
| centimetre | cm | microgram | µg |
| cubic centimetre | $cm^3$ | micron | µm |
| cubic metre | $m^3$ | micronmol | µmol |
| day | d | milligram | mg |
| decisiemens | dS | millilitre | mL |
| degree-Celsium | °C [=(F-32)x0.556] | minute | min |

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

***Some applications along with symbols***

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