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I N D E X

Vol 49	No. 2	July 2025
Response of Explants on Micropropagation In Spine Gourd (<i>Momordica dioica</i> Roxb.) Priyanka Sardar, D. R. Rathod, P. R. Shingote, V. S. Kale, G. D. Chandankar, K. A. Uike and B. S. Mundhe		1
Assessment on Shoot Induction And Survival of Jamun Var. Konkan Bahadoli (<i>Syzygium cumini</i> L.) <i>In Vitro</i> Cultures Using Nodal Segment Monica Watekar, D. R. Rathod, P. R. Shingote, P. M. Chandan, G. D. Chandankar, B. M. Badge and B. S. Mundhe		8
Correlation Studies In Desi Cotton (<i>Gossypium arboreum</i> L) Genotypes Vaibhav V. Ujjainkar, T. H. Rathod and A. D. Warade		12
Effect of Land Configuration and Plant Growth Regulators on Drought Management As Climate Resilient Technologies in Cotton S. U. Kakade, N. V. Kayande, P. P. Patil, O. S. Rakhonde and S. H. Ingale		16
Adaptability and Productivity of Different <i>Kharif</i> and <i>Rabi</i> Grain Sorghum Cultivars under Summer Season Gopal V. Thakare, Charansing Ramsing Dingar, V. V. Kalpande, R. T. Bhowate and Y. R. Sable		27
Productivity Dynamics and Economics of Soybean Genotypes Under Modified Paired Row Planting Harsh Dixit, Sangeeta Sawadhakar, Varsha Tapare, Anita Chorey, Yogita Shelke and Juhee Sonule		34
Evaluation of Newer Insecticides Against Insect Pests of Sunflower P. N. Mane, S. J. Gahukar, Manjusha Gaikwad, B. K. Farkade, M. Y. Ladole and Sangita Fatak		38
Effective Management of Sucking Insect Pests in Sunflower P. N. Mane, S. J. Gahukar, Manjusha Gaikwad, B. K. Farkade, M. Y. Ladole and Sangita Fatak		49
Genetic Variability Analysis for Growth and Root Yield Attributes in Ashwagandha M. M. Wakode, N. K. Patke, A. G. Deshmukh and Y. R. Chauke		55
Evaluation of Tree-Borne Oils as Eco-Friendly Preservatives for Bamboo Poles V. M. Ilorkar, L. P. Uikey, P. D. Raut, Aarti P. Deshmukh and A. D. Bhosale		61
Short Notes		
Green Synthesis of Nano Zinc Oxide for Wheat Snehal Jawardikar, Mohammad Sajid, B. A. Sonune, Mangesh Moharil and H. B. Goramnagar		68

Response of Explants on Micropropagation In Spine Gourd (*Momordica dioica* Roxb.)

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ABSTRACT

Present investigation was conducted with the objective to study response of different explants source on *in vitro* propagation in Spine gourd (*Momordica dioica* Roxb.) var. Arka Bharat at Biotechnology Centre, Dr PDKV, Akola during year 2023-24 and 2024-25. The mother explants source were obtained from mother orchard plantation that developed and maintained under the Head, Dept of Vegetable Science, Dr PDKV, Akola. The nodal explants of female having 3-4 months old were taken and treatment with 0.1% tween-20 for 20 mins, 1% carbendazim for 20 mins, 1% streptomycin for 20 mins and 0.1% HgCl₂ for 5 mins. 50 explants from mother vines excised at different aged 1, 2, 3 and 4th year old over different types of explants such as shoot tip and nodal segment were inoculated on artificially synthesized nutrient media and grown under *in vitro* conditions of plant tissue culture laboratory. It was found that Jan-Feb and shown maximum initiation rate 92.47% with lowest (20.88%) contamination percentage. In the present study, the effect of different explants age and types were undertaken with seven treatments in three replications using CRD. During the present investigations, it has noticed that the nodal segment shows significantly higher rate of survival, initial culture establishment, high rate of multiple shoots and shoot-let proliferation as compared to the shoot tips. Overall, across two years study, it was noticed that among all the treatment, treatment of MS + BAP (2.0 mg L⁻¹) + LGA (2.0 mg L⁻¹) gives better results as compare to the other treatments in spine gourd. For micropropagation of Spine gourd var. Arka Bharat tissue culture plantlets, following treatments was optimum for micropropagation of Spine gourd var. Arka Bharat, a nodal segment of 2 cm sterilized with 5% sodium hypochlorite 40 min + 0.2% Carbendazim + 1.25 mg L⁻¹ cefotaxime each for 60 min and explants inoculation on MS basic media (pH=5.8) supplemented each with 2mg L⁻¹ BAP + L-GA for its efficient shoot multiplication is recommended for its rapid clonal micropropagation.

Spine gourd (*Momordica dioica* Roxb.) (2n=28) is an important but underexploited rare vegetable crop. It is a dioecious, perennial, herbaceous climber having tuberous roots belonging to *cucurbitaceae* family, under the natural order cucurbitales. It is believed to be originated in the tropics of old world. Spine gourd is probably native of India, plants are distributed from Himalayas to Sri Lanka, up to an altitude of 1500m. Plants of Spine gourd are found naturally growing in hilly tract of Rajmahal, Hazaribagh and Rajgir of Jharkhand and Wet hills of Maharashtra, Assam and West Bengal. West Bengal and Karnataka are two major Indian States that grow Spine gourd commercially. Spine gourd is largely cultivated in Malda and Nadia districts of West Bengal. It is grown for its immature nutritious tender fruits. The plants undergoes dormant during winter season. It is a high demandable seasonal vegetable and medicinal plant. It is free from cholesterol and has adequate amount of

high energy (45.74 Kcal), water (84%), minerals and vitamins (Gopala *et al.*, 1994). Fruits are rich source of protein, calcium, phosphorus, iron and highest amount of carotene (162mg 100g⁻¹ edible portion) among cucurbits. Fruits are also a rich source of lectins, triterpinse of ursolic acid, momordic ursenol, vitamins, iodine, flavonoids and glycosides and is described as “Good supplement for nutrient”.

Spine gourd has high demand in market but still remain underutilized and underexploited mainly due to its vegetative mode of propagation and dioecious nature. Commercial multiplication using the tuberous roots and stem cuttings are critically limited due to inadequate availability of tuberous roots and late availability of stem cuttings in fruiting season. Tuberous roots have low multiplication rate and occupy the valuable cultivable land until next planting season. Male plants dominate natural populations and sex determination is possible only when

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the plants start flowering. Since fruits are the main edible portion of this species, which are harvested on female plants, it is desirable to have commercial fields with a large proportion of female plants. Due to its dioecious nature, poor natural pollination of female flowers results in lower yield. To compensate this problem plantation needs 5-10 % male plants as pollinizer and it is imperative for good fruit set. It is highly cross pollinated in nature and exhibit genetic variation for morphology and growth parameters. As the conventional methods of spine gourd propagation impose several limitations for large scale production of sex specific plants, an efficient clonal propagation is must. Improvement of plant species via biotechnological approach depends on plant tissue culture. Micropropagation helps to overcome above said problems in great extent and systematic improvement is boon for horticulture, pharmaceutical industry and Ayurveda. High multiplication ratio achieved rapid multiplication of disease and pest free elite plant within short span of time and space. An *in vitro* propagation system offers unlimited availability of planting material early in the planting season. It can be employed as an alternative means for genetic upgradation and its application largely depends on a reliable plant regeneration system.

MATERIAL AND METHODS

The mother explants source was obtained from Central Horticultural Experiment Station, Chettalli, Karnataka in the year 2022 as well as from the experimental field developed and maintained under the Head, Dept of Vegetable Science, Dr PDKV, Akola.

Media Used and Optimum Conditions

The nodal and shoot tip explants of female having 1, 2, 3 and 4th month old were taken and treatment with 0.1% tween-20 for 20 mins, 1% carbendazim for 20 mins, 1% streptomycin for 20 mins and 0.1% HgCl₂ for 5 mins. These were inoculated in the month of Jan-Feb and shown maximum initiation rate 92.47% with lowest (20.88%) contamination percentage. Overall, across two years study, it was noticed that among all the treatment, treatment of MS + BAP (2.0 mg L⁻¹) + LGA (2.0 mg L⁻¹) gives better results as compare to the other treatments in spine gourd.

RESULTS AND DISCUSSION

Response of different explants types of spine gourd for in vitro cultural initiation and their optimization: In an attempt to standardize explants for tissue culture of spine gourd, two types of explants were tried for in-vitro shoot regeneration and multiplication. The response observed from each explant is presented in Table 1.

Table 1. Response of different of explants types of Spine gourd *Momordica dioica* Roxb.) on in vitro condition

Explant	Callus	Shoot proliferation	Shoot multiplication
Shoot tip	+	—	—
Nodal segment	+	+	+

+ Positive response - Negative response.

Source of different explant and its preparation

Growing seasonal condition of mother plants:

The source of explants of spinegourd plant vine was very difficult and not easily available at given time. Hence, its availability is one of the limiting factor during critical stage of micropropagation along with its proper stage of nodal segment and shoot tips are only available at the specific season of the year i.e. during monsoon period. Depending on season and site where mother plants were to be established in the field, very crucial for successful culture establishments. Mother plant bearing lateral and healthy actively growing branches, about 2-3 mm in diameter, seem to be the most suitable source of nodal segment and stem cutting. Normally the young and actively growing new branch of male and female vines develops during onset of monsoon. Therefore, an attempt was made to compare and contrast the season during explants collection from selected and identified mother vines during the rainy and off-time season.

During rainy season growth of plant, all the four ages (years) of mother plant source viz., 1st year, 2nd years, 3rd year and 4th years aged mother vines were used to study the of effect of mother plant age on *in vitro* culture initiation, multiplication and establishment of spinegourd. Spine gourd shows fast growing upon sprouting under favorable for overall growth. Hence, onset of monsoon

was found to be best period for its inoculation as the results of effect of plant age were given in Table 2 and graphically depicted in Fig. 1 and steps wise images were depicted in Plate 1.

As per the data presented in Table 2, it reveals that, the T_1 having 1 year age of plant vine shows highest initiation rate in MS + BAP 3 mg l⁻¹ was 41.67% followed by the other combination of MS + BAP 2 mg l⁻¹ was 40%. Similarly, T_1 gives higher rate of shoot multiplication after 2 week of explants inoculation in MS + BAP 3 mg l⁻¹ was 44.44% and same trends also observed after 3rd week in same treatment with 25.33% followed by its MS + BAP 2 mg l⁻¹ was 43.33% and 22.67% after 2nd and 3rd week duration.

Similar trends of the results were noticed in case of all other treatments T_2 and T_4 except T_3 ; where treatment T_2 (2nd year old vines) mother plant age affecting highest initiation and multiplication rate in MS media with BAP 3 mg l⁻¹ (52.20%, 55.56% and 30.67%) followed by the MS with BAP 2 mg l⁻¹ (46.67; 51.11 and 29.33%) after 1st, 2nd and 3rd week of its inoculation, respectively and treatment T_4 (4th years old) mother plant age affecting highest initiation and multiplication rate in MS media with BAP 3 mg l⁻¹ (52.20% 55.56% and 30.67%) followed by the MS with BAP 2 mg l⁻¹ (46.67%, 51.11% and 29.33%) after 1st, 2nd and 3rd week of its inoculation, respectively. Among all the treatment combinations, T_2 (2nd year age of mother plant) shows highest response for initial culture establishment and further multiplication than the other three treatments, which followed by T_1 (1st year), T_3 (3rd years) and T_4 (4th year) age of mother plant source for explants excised from female mother vines in spinegourd.

When two treatment combinations of basal MS media with varying concentration of BAP follows non uniform patters in respect of age of the explants source. In all treatment namely (T_1), (T_2) and (T_4) except (T_3) the combination of basal MS + 3 mg l⁻¹ BAP shows greater initiation and multiplication success rate of 41.67, 52.50, 38.33 % against its basal media with BAP 2 mg l⁻¹ 40.00%, 46.67%, 36.67% for of explants after 1st week periods of its inoculation respectively. The similar trend was observed in (T_2) and (T_4) except (T_3) where lower concentration of BAP gives better results.

Whereas, treatment (T_3) with 15-18 years of mother plant age exhibits highest initiation and multiplication rate in MS media with lower dose of BAP 2 mg l⁻¹ (40.83%, 55.56% and 30.67%) as compare to the MS with BAP 3 mg l⁻¹ (46.67%, 51.11% and 29.33%) after 1st, 2nd and 3rd week of its inoculation respectively. In brief, age of mother plant for explants source should be 3 to 6 years old with MS basal media and BAP 3 mg l⁻¹ was found most suitable combination for getting maximum success rate of culture initiation and its multiplication during establishment stage of *in vitro* culture survival and establishment of spinegourd.

The finding of these observations was at par with earlier results reported by Negi and Saxena (2011) where age of mother plant gives highest survival rate of culture initiation from 2-4th years old of spinegourd vines when taken of shoot tips and its culture in MS medium supplemented with 1 mg l⁻¹ 6-Benzylaminopurine (BA) and 1mg l⁻¹. Similarly, Islam and Rahman (2005) shown nodal explants of *M. dioica* shows best results. Choudhary *et al.* (2017) reported that, necrotic tendency of the culture regenerates enhanced with the physiological age of the donor plant. Oprins *et al.* (2004) who reported that, when using adult spinegourd vines however major issue were endogenous contamination, seasonal influence and instability of multiplication rate and many problems with rooting, but nodal segment collected during onset of rainy season were major factor and effective in initial culture establishment.

During the present study thinner branches were more vulnerable to the sterilization procedure, while in thicker branches necrosis and browning occurs at a higher rate. The uniformed size branches bearing 2-3 mm in diameter shows good response, hence these criteria were followed during collection of explants source. The age of the mother plant does not affect greatly during establishment of shoot tip culture at certain level, but efforts put for getting younger and actively growing nodal segment before to start explants inoculation.

Effect of explant position on *in vitro* shoot multiplication and establishment of spine gourd

Effect of explant position of explants source from mother plant of female vines of spine gourd was tested

Table 2. Effect of mother plant age on *in vitro* shoot multiplication and culture establishment of spine gourd female plants of Arka bharat.

Treats.	Treatment/ Age of explants	Media composition (MS + BAP)	Initiation rate after 1 week of inoculation (%)	Multiplication rate after 2 week of inoculation (%)	Multiplication rate after 3 week of inoculation (%)
T ₁	1 st year old	MS+2mg l ⁻¹	40.00	43.33	22.67
		MS+3mg l ⁻¹	41.67	44.44	25.33
T ₂	2 nd year old	MS+2mg l ⁻¹	46.67	51.11	29.33
		MS+3mg l ⁻¹	52.50	55.56	30.67
T ₃	3 rd year old	MS+2mg l ⁻¹	40.83	45.56	26.67
		MS+3mg l ⁻¹	40.00	43.33	21.33
T ₄	4 th year old	MS+2mg l ⁻¹	36.67	37.78	18.67
		MS+3mg l ⁻¹	38.33	38.89	20.00
	SE (m)±		1.10	1.52	1.49
	CD @ 1%		3.30	4.56	4.47

Table 3. Effect of node position on *in vitro* shoot multiplication and establishment of Spine gourd var. Arka Bharat

Treats.	Details of treatment	Media composition (MS + BAP)	Initiation rate after 1 st week of inoculation (%)	Multiplication rate after 2 nd week of inoculation (%)	Multiplication rate after 3 rd week of inoculation (%)
T ₁	Basal	MS+2mg/l	36.67	37.78	18.67
		MS+3mg/l	40.83	41.11	24.00
T ₂	Middle	MS+2mg/l	45.00	48.89	29.33
		MS+3mg/l	51.67	55.56	37.33
T ₃	Tip	MS+2mg/l	27.50	30.00	14.67
		MS+3mg/l	24.17	25.56	10.67
	SE (m) ±	1.08	1.01	1.54	
	CD @ 1%	4.65	4.38	6.65	

Table 4. Effect of surface sterilization agent on *in vitro* shoots multiplication and establishment of explants in spine gourd female vine

Treats.	Details of treatment	Time period (min.)	Bud breaks frequency (%)	Rate of multiplication after 2 week (%)	Rate of multiplication after 3 week (%)
T ₁	Tween-20	5	44.17	47.78	25.33
		10	39.17	42.22	17.33
T ₂	HgCl ₂ (0.1%)	5	35.83	38.89	18.67
		10	47.50	52.22	21.33
	SE (m) ±	1.02	1.11	1.33	-
	CD @ 1%	-	0.18	0.18	0.18

Response of Explants on Micropropagation In Spine Gourd (*Momordica dioica* Roxb.)

on MS media fortified with BAP 2mg l⁻¹ and 3 mg l⁻¹, where the 3% sucrose and 0.8% agar was used in various combinations based on previous research best work publications. This observation was carried out during rainy season of plant growth, in which the nodal part excised from the selected mother plant having age 2 years old. The nodal part excised from the basal, middle portion and apex (tip) position from the lateral branch of main secondary branches of mother plant vines. The observations were recorded from its first day after inoculation till 30th days after inoculation. The results of effect of nodal position excised from mother plant was given in Table 3 and graphically depicted in Fig.2

The data presented in Table 3, it was very clear that, the treatment (T₁) basal nodes from the lateral branches of secondary branches mother plant of age 2 years old, shows the rate of initiation after 1st week was 40.83% @ MS + BAP 3 mg l⁻¹ followed by the @ MS + BAP 2 mg l⁻¹ was 36.67%. The rate of multiplication after 2nd week was increased up to 41.11% @ MS + BAP 3 mg/l and lowest @ MS + BAP 2 mg l⁻¹ were 37.78%. The rate of multiplication after 3rd week @ MS + BAP 3 mg l⁻¹ was 24.00 % and @ MS + BAP 2 mg l⁻¹ were 18.67 %. The rate of initiation in 1st week of middle node position (T₂) was highest @ MS + BAP 3 mg l⁻¹ was 51.67% and lowest @ MS + BAP 2 mg l⁻¹ were 45.00 %. While the rate of multiplication after 2nd week was increased up to 55.56% @ MS + BAP 3 mg l⁻¹ and @ MS + BAP 2

mg l⁻¹ were 48.89%. While the rate of shoot multiplication after 3rd week of its inoculation was lower up to 37.33% at @ MS+ BAP 3 mg l⁻¹ and @ MS + BAP 2 mg l⁻¹ were 29.33%.

Effect of sterilization on explant preparation:

The data presented in table 4 showed that, tween-20 detergent (T₁) for 5 min. duration shows bud breaking frequency 44.17% and lowest 39.17 % with 10 min. The rate of multiplication after 2 week was increased at 5 min. duration up to 47.78 %; while at 10 min. it was also increased 42.22%. The rate of shoot multiplication after 3 weeks was shown reducing trend in both treatments with 25.33% at 5 min., which followed at 10 min. by 17.33%. The 0.1% HgCl₂ treatment (T₂) @ 5 min. the bud breaking frequency was 35.83% was found lowest, while 10 min. duration was shown 47.50%. The rate of multiplication after 2 week was found highest at 10 and 5 min. with 52.22 % and 38.89 % respectively. The maximum rate of multiplication after 3 week of culture inoculation was shown with 21.33 % at 10 min. time period, which was followed by 18.67% at 5 min. among all the treatments. The treatment (T₁) the detergent Tween-20 @ 5 min were performed better than the time span of 10 min., while treatment (T₂) at the rate of 0.1% HgCl₂ for 10 min. duration performed significantly better than 5 min. period sterilization as graphically shown in Fig. 3.

In shoot tip position (T₃) the highest rate of initiation was noticed after 1 week at @ MS + BAP 2

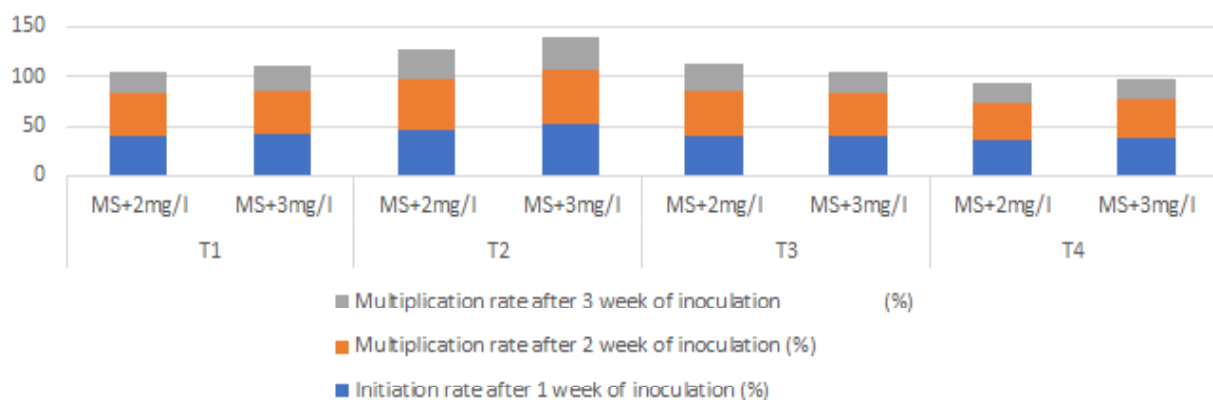


Fig. 1. Effect of mother plant age on in vitro shoot multiplication and culture establishment of spinegourd female plants of Arka bhara.

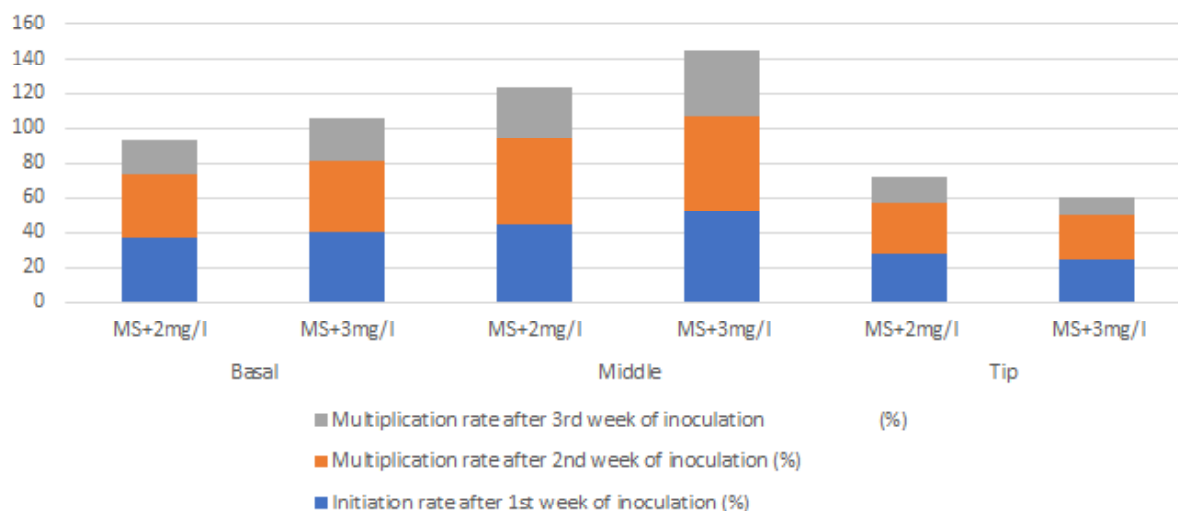


Fig. 2 Effect of explant position on *in vitro* shoot multiplication and establishment of Spinegourd var. Arka Bharat

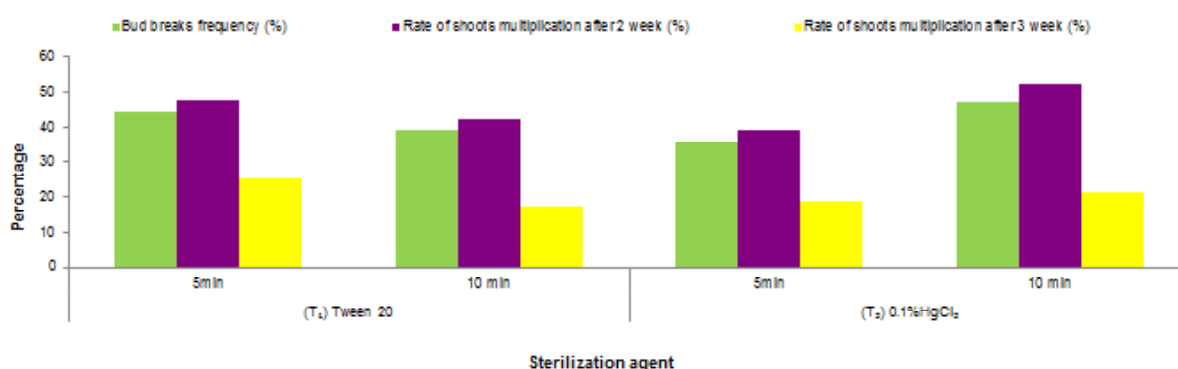


Fig. 3 Effect of sterilization agents HgCl₂ and Tween 20 on explant survival and establishment in vitro

mg l⁻¹ was 27.50% and lowest @ MS + BAP 3 mg l⁻¹ was 24.17%. The rate of multiplication after 2 week was increased up to 30.00% @ MS + BAP 2 mg l⁻¹ and 25.56 % @ MS + BAP 3 mg l⁻¹ shows lowest. The rate of multiplication after 3 week @ MS + BAP 2 mg l⁻¹ was 14.67%, while it was lowest 10.67 % @ MS + BAP 3 mg l⁻¹. Among all treatments (T₂) middle nodal position of mother vine plants shows significantly better results followed by the basal position (T₁) than (T₃) tip position. These results were correlated with the earlier results reported by Saxena and Bhojwani (1993), Haberlandt *et al.*, (1902) and Rathod *et. al.*, (2025). They reported that the mid culm node of secondary branches as the best explant for axillary shoot initiation Verma *et al.*, (2014).

These results indicated that the variation of shoot emergence may be due to size, age or other associated conditions of explants Hoque *et al.*, (2000).

CONCLUSION

For micropropagation of Spinegourd var. Arka Bharat tissue culture plantlets, and its acclimatization following treatments are recommended : For micropropagation of Spinegourd var. Akra Bharat, a nodal segment of 2 cm sterilized with 5% sodium hypochlorite 40 min + 0.2% Carbendazim + 1.25 mg L⁻¹ cefotaxime each for 60 min and explants inoculation on MS basic media (pH=5.8) supplemented each with 2mg L⁻¹ BAP + L-GA for its efficient shoot multiplication and MS + 1

mg L⁻¹ NAA for high root induction, followed by hardening for 45 days with sand/cocopeat: soil:vermicompost/FYM (1:2:1) proportion is recommended. The important implication of present work is to contribute for establishment of efficient in- vitro protocol, that was composed of MS media and hormonal combination with basal MS + BAP (2.0 mg L⁻¹) + LGA (2.0 mg L⁻¹). The proposed protocol will be effectively used for nodal segment used as explants source. Further the proposed treatment combination will be helpful for obtaining initial culture establishment, good survival and shoot multiplication rate in spine gourd.

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Assessment on Shoot Induction And Survival of Jamun Var. Konkan Bahadoli (*Syzygium cumini* L.) In Vitro Cultures Using Nodal Segment

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ABSTRACT

The present study was aimed to Assessment on shoot induction and survival of Jamun var. Konkan Bahadoli (*Syzygium cumini* L.) in vitro cultures using nodal segment of mature plants. The shoot induction, culture survival (%) and shoot length (cm) was studied on different variants of the basal nutrient MS medium, with or without charcoal in combination of different concentration of NAA and BAP. The shoot induction in the pre-formed meristem is the initial development was found maximum in treatment combination of MS + 2.5 µM BAP+1.00 µM NAA+ 1% charcoal) was 2.78, while minimum noted in its control) was 0.1 shoots per culture. Shoot induction was maximum due to higher concentration of BAP, suggesting it plays pivotal role in said hypothesis that cytokinins play a crucial role in the alleviation of bud dormancy within meristematic explants. Whereas, cultural survival (%) was recorded highest 82% in treatment (MS + 2.5 µM BAP+1.00 µM NAA+ 1 % charcoal, whereas minimum survivability 75 % was noted in its control. The highest survival of induced shoot on the explant was observed at higher concentration of Auxin (NAA) and Cytokinin (BAP), suggesting both hormone increases the survivability of the induced shoot. Maximum Length of shoot induced was 1.5 cm. recorded in same treatment Therefore the present study highlights the role of growth hormone in combination of MS media for in vitro study of Jamun (*Syzygium cumini* L.) Var. Kokan Bahadoli and its successful micropropagation using nodal segment from mature tree.

Jamun (*Syzygium cumini* L.) having chromosome number $2n = 40$, is a common seasonal berry fruit ripen during June–July i.e. monsoon season. The fruit is commonly known as Jamun (Hindi), Java Plum, Malabar plum, black plum, Jambul or Indian black berry. It belongs to Myrtaceae family, which is highly adapted to diverse environmental conditions and widely distributed in India up to an altitude of 1600 m. It is well-known for its nutritional and therapeutic attributes. It is tall in nature, evergreen widely distributed forest tree of India, Sri Lanka, Malaysia and Australia generally cultivated for its edible fruits. It has been successfully introduced to many Tropical countries like West Indies, East and West Africa and some Sub tropical regions due to its commercial importance. as fodder for animals, food for silkworm in India. The bark of *S. cumini* is stated to be astringent, digestive Chaudhary and Mukhopadhyay (2012).

Micropropagation is an advanced vegetative propagation technique for producing a large number of genetically uniform and pathogen-free transplants in a limited time and space Ghosh *et al.*, (2017). In this context

it is necessary to standardize a suitable protocol for clonal micropropagation of this species. Each plant species propagated through in vitro techniques has different requirements of plant growth regulators and their concentrations. Depending on the auxin/cytokinin ratios of the induction medium, either shoots or roots can be regenerated (Murashige and Skoog, 1962) The propagation of a majority of woody plants through vegetative propagation is very difficult to maintain it's true to type identity due to high level of heterozygosity. Besides this, *S. cumini* suffer few drawbacks that is very low level of seed viability coupled with poor germination of seeds in its natural habitat. The seed germinates only when it is fresh but after 2 weeks at room temperature the seed is not viable. Hence, the use of in-vitro grown seedlings as explants for micropropagation proves beneficial to control the tissue culture related problems namely browning of the culture media due to phenolics compounds present in woody plant species as reported by earlier works (Saini and Jaiwal 2002.)

Need of the study: Jamun suffers from very low seed viability and poor germination in its natural habitat

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(Dent, 1948). Thus, propagation through stem cuttings is an alternative, but not feasible for obtaining large quantity of planting materials within a short time interval. In this context it is necessary to standardize a suitable protocol for rapid, clonal propagation of elite genotypes of this species (Remashree *et al.*, 2007). Although tissue culture of herbaceous angiosperms has been extensively studied Choudhari *et al.*, (2013), but it has not received much attention in case of perennial trees like jamun due to inherent problems like phenolic exudation, explant browning etc. Micropropagation method could assist in rapid and mass production of clonal stock of newly released cultivars.

Micropropagation is an advanced vegetative propagation technique for producing a large number of genetically uniform and pathogen-free transplants in a limited time and space. In this context it is necessary to standardize a suitable protocol for clonal micropropagation of this species. Each plant species propagated through in vitro techniques has different requirements of plant growth regulators and their concentrations. Depending on the auxin/cytokinin ratios of the induction medium, either shoots or roots can be regenerated (Murashige and Skoog, 1962).

MATERIAL AND METHODS

The present study was conducted at Plant Tissue Culture laboratory, Centre of Excellence in Plant Biotechnology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Dist. Akola (M.S.) during year 2024-25. The explants (nodal segment) were collected from the campus in sterilized polythene bags and were brought in the laboratory for further processes. The explants were

washed with sterilized water to remove the extra dust particles. Explants were then subjected with 1% Tween-20 detergent for 5 minutes, followed by 1% Bavistin (systemic fungicide) for 25 minutes and 1% Streptocycline antibiotic for 25 minutes on orbital shaker followed by repeated washing with sterilized water thrice after each sterilization treatment. The explants were further treated with 0.1% HgCl_2 solution under laminar air flow for 5-7 mins followed by washing with distilled water. Five treatments of MS media with different concentration of BAP and NAA with or without Charcoal were designed. It includes:

T₁ - MS control media,

T₂ - MS + 1.00 μM BAP +1.00 μM NAA,

T₃ - MS + 1.5 μM BAP + 1.00 μM NAA+ 1% charcoal

T₄ - MS + 2.00 μM BAP + 1.00 μM NAA and

T₅ - MS + 2.5 μM BAP+1.00 μM NAA+ 1% charcoal

Thirty bottles of each treatment were prepared; two explants in each bottle were inoculated into the sterile environment of the Laminar Air Flow machine. Shoot induction and Survival (%) were noted after two weeks of date of inoculation, while Shoot length (cm) was recorded in after four weeks of date of inoculation.

RESULTS AND DISCUSSION

The number of shoot induction, Survival (%) and Shoot length (cm) were recorded in Table 1. exhibited random variation in different treatment.

Shoot induction in the pre-formed meristem is the initial development; it was recorded maximum in T₅ (MS + 2.5 μM BAP+1.00 μM NAA+ 1% charcoal) was

Table1: Effect of different treatments of MS media on Shoot induction, survival (%) and length of shoot in Jamun Var. Konkan Bahadoli (*Syzygium cumini* L.)

Treatments	Concentrations: MS + BAP + NAA (mg L ⁻¹)	No. of shoot induction	Survival (%)	Length of shoot (cm.)
T ₁	MS control media	0.1	75.00	0.2
T ₂	MS + 1.00 μM BAP +1.00 μM NAA	2.03	81.00	1.2
T ₃	MS + 1.5 μM BAP + 1.00 μM NAA+ 1% charcoal	1.5	78.00	1.3
T ₄	MS + 2.00 μM BAP + 1.00 μM NAA	2.4	75.00	0.4
T ₅	MS + 2.5 μM BAP+1.00 μM NAA+ 1% charcoal	2.78	82.00	1.5



Mother Plant



Nodal Explant



Short shoot length



Long shoot length

Fig. 2 : Shoot length

2.78, while minimum noted in T_1 (Control) was 0.1. Shoot induction in T_2 , T_3 and T_4 was 2.03, 1.5 and 2.4 respectively.

Shoot induction was maximum in T_5 where concentration of BAP is maximum, suggesting it plays pivotal role in shoot induction. According to Naaz *et al.*, (2014) facilitation of shoot development in the presence of benzylaminopurine (BAP) substantiated the hypothesis that cytokinins play a crucial role in the alleviation of bud dormancy within meristematic explants. The similar finding was also reported earlier by Kumar *et al.*, (2019), Prabhuling *et al.*, (2017).

Survival (%) was recorded highest 82% in T_5 (MS + 2.5 μ M BAP+1.00 μ M NAA+ 1% charcoal), whereas minimum survivability 75 % was noted in T_1 (Control) and T_4 (MS + 2.00 μ M BAP + 1.00 μ M NAA); whereas in T_2 and T_3 it was 81% and 78%.

Highest survival of induced shoot on the explant was observed at higher concentration of Auxin (NAA) and Cytokinin (BAP), suggesting both hormone increases the survivability of the induced shoot. Role of Auxin and Cytokinin in shoot induction was also emphasized by Naaz *et al.*, (2014), Raju and Divya (2020), Sirsat *et al.*, (2019).

Maximum Length of shoot induced was 1.5 cm. recorded in T₅ (MS + 2.5 µM BAP+1.00 µM NAA+ 1% charcoal), while shortest length 0.2 cm. was noted in T₁ Control. Shoot length in T₂, T₃ and T₄ was 1.2, 1.3 0.4 cm. and this result was in accordance with earlier work by Purohit *et al.*, (2000), Sivasubramaniam and Selvarani (2012), Swami *et al.*, (2012).

After successful survival of the shoot, its length exhibits the growth potential of the explant. The length of shoot was shortest in the control devoid of NAA and BAP; whereas it maximized at higher concentration of NAA and BAP. Similar observation were recorded in WPM media by Sirsat *et al.*, (2019) and also these finding was in accordance with earlier report of Kamboj *et al.* (2023) and Remashree *et al.*, (2007).

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Correlation Studies In Desi Cotton (*Gossypium arboreum* L) Genotypes

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ABSTRACT

Desi cotton (*Gossypium arboreum* L.) is an important diploid cotton species cultivated predominantly under rainfed conditions owing to its adaptability to drought, tolerance to biotic and abiotic stresses, and stable productivity. The present investigation was conducted to evaluate the performance of ten desi cotton genotypes and to determine the association among yield and its component traits through correlation analysis for identifying efficient selection criteria in cotton improvement programs. The genotypes were evaluated for eleven quantitative characters, namely plant height, days to 50 per cent flowering, days to 50 per cent boll bursting, number of monopodia, number of sympodia, number of bolls plant⁻¹, boll weight, seed index, lint index, seed cotton yield and lint yield.

The mean performance analysis revealed considerable variability among the genotypes for all the traits studied. Among the evaluated genotypes, AKA 7 recorded the highest seed cotton yield (835 kg ha⁻¹) and lint yield (312 kg ha⁻¹), followed by AKA 8 and PA 796, indicating their superiority for yield improvement. PAIG 77 was the earliest flowering and earliest maturing genotype, while PA 741 recorded the maximum plant height. The observed variability suggested the existence of sufficient genetic diversity for effective selection and utilization in breeding programs. Correlation analysis revealed that seed cotton yield exhibited a strong positive association with number of bolls per plant ($r = 0.950$) and lint yield ($r = 0.977$), indicating that these are the most important yield-contributing traits. Moderate positive correlations were observed with lint index ($r = 0.516$), days to 50 per cent boll bursting ($r = 0.498$), days to 50 per cent flowering ($r = 0.493$), number of sympodia ($r = 0.481$) and boll weight ($r = 0.382$), whereas plant height showed a moderate negative association ($r = -0.551$) with seed cotton yield. Overall, the study identified number of bolls per plant, number of sympodia, boll weight, and lint index as key selection criteria for improving seed cotton yield. The superior performance of AKA 7, AKA 8, and PA 796 suggests their potential as promising parents for developing high-yielding, early-maturing, and climate-resilient desi cotton cultivars.

The *Gossypium arboreum* L., commonly known as *desi* or Asiatic cotton, is a cytologically diploid species possessing $2n = 2x = 26$ chromosomes with the A genome (A₂). It is one of the four cultivated cotton species and is

native to the Indian subcontinent. In contrast, the cultivated upland and Egyptian cottons (*G. hirsutum* and *G. barbadense*) are allotetraploid species with $2n = 4x = 52$ (AD genome). The diploid nature of *G. arboreum*, together with its rich reservoir of genes for resistance to biotic and abiotic stresses, makes it an important genetic resource for cotton breeding and crop improvement program. Desi cotton (*Gossypium arboreum* L.) is an important cultivated cotton species valued for its adaptability to rainfed and marginal environments, tolerance to drought, resistance to several insect pests and diseases, and stable performance under diverse agro-climatic conditions. *Gossypium arboreum* L., commonly known as *desi* or Asiatic cotton, is a cytologically diploid species possessing $2n = 2x = 26$ chromosomes with the A genome (A₂). It is one of the four cultivated cotton species and is native to the Indian subcontinent. In contrast, the cultivated upland and Egyptian cottons (*G. hirsutum* and *G. barbadense*) are allotetraploid species with $2n = 4x = 52$ (AD genome). The diploid nature of *G. arboreum*, together with its rich reservoir of genes for resistance to biotic and abiotic stresses, makes it an important genetic resource for cotton breeding and crop improvement program. The assessment of genotype performance is a fundamental step in cotton improvement program as it helps identify superior genotypes possessing desirable agronomic, yield, and fiber quality traits. Evaluation of characters such as plant height, flowering and maturity duration, number of monopodia, number of sympodia, number of bolls per plant, boll weight, seed index, lint index, seed cotton yield and lint yield provides

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information on the extent of genetic variability available for effective selection. Since seed cotton yield is a complex quantitative trait influenced by several component characters and environmental factors, simultaneous evaluation of these traits is essential for developing high-yielding and climate-resilient cultivars (Singh and Chaudhary, 1985; Falconer and Mackay, 1996).

Correlation analysis is an important biometrical technique that measures the degree and direction of association among quantitative traits and helps identify characters that contribute directly or indirectly to seed cotton yield. Knowledge of trait associations enables breeders to formulate efficient selection strategies by emphasizing characters that exhibit strong positive relationships with yield while avoiding undesirable associations. In desi cotton, characters such as number of bolls per plant, number of sympodia, boll weight, and lint index are generally considered major yield determinants and are frequently used as selection criteria in breeding program. Therefore, the combined assessment of genotype performance and correlation among yield components provides valuable information for identifying superior genotypes and improving the efficiency of cotton breeding aimed at enhancing productivity and fiber quality (Panse and Sukhatme, 1985; Johnson and Wichern, 2019; Burton and Devane, 1953).

MATERIAL AND METHODS

An experiment was conducted in randomized block design with three replications at cotton research unit, Dr. PDKV, Akola during the year 2023. Ten elite genotypes of desi cotton (*Gossypium arboreum* L.) from major cotton growing areas of country were evaluated for eleven morphological traits viz., plant height (cm), days to 50% flowering, days to 50% boll bursting, no. of monopodia, no. of sympodia, no. of bolls per plant, boll weight (g), seed index (g), lint index (g), seed cotton yield (kg ha⁻¹) and lint yield (kg ha⁻¹) along with their inter relationship through correlation coefficients.

RESULTS AND DISCUSSION

The ten elite diploid cotton genotypes were evaluated for eleven important quantitative traits and mean performance is given in Table 1, depicting that the mean

plant height of the ten cotton genotypes was 114.1 cm, with values ranging from 106 cm (AKA 7) to 122 cm (PA 741). Among the genotypes, PA 741 (122 cm) exhibited the tallest plants, followed by PA 778 (120 cm) and AKA 8 and PAIG 77 (118 cm). In contrast, AKA 7 (106 cm), PAIG 326 and PA 796 (110 cm), and PA 793, PAIG 373, and PA 760 (112 cm) recorded comparatively shorter plant stature. Moderate plant height is considered desirable in cotton as it provides better lodging resistance and facilitates crop management. The observed variation indicates the presence of sufficient genetic diversity for plant architecture among the evaluated genotypes.

The average number of days to 50% flowering was 66.7 days, with the genotypes flowering between 64 and 69 days. PAIG 77 was the earliest flowering genotype (64 days), followed by PAIG 326, PA 778, PAIG 373, and PA 796 (66 days). AKA 8 and AKA 7 (67 days) and PA 741 and PA 760 (68 days) showed intermediate flowering, whereas PA 793 (69 days) was the latest flowering genotype. Early flowering is an important breeding objective as it helps the crop escape late-season moisture stress and insect infestation while allowing timely harvesting. The mean duration to 50% boll bursting was 118.9 days, ranging from 116 days (PAIG 77) to 121 days (PA 741 and PA 793). PAIG 326 and PA 778 (117 days) also matured relatively early, while PAIG 373, PA 796 and PA 760 (119 days) showed intermediate maturity. AKA 8 and AKA 7 (120 days) exhibited slightly delayed boll bursting. The relatively narrow variation indicates that the genotypes belonged to a medium maturity group, with PAIG 77 being the earliest maturing genotype.

The average number of monopodia was 2.1 plant⁻¹, with values ranging from 2 to 3. Most of the genotypes recorded two monopodia, whereas PA 796 was the only genotype that produced three monopodia. Lower monopodial branching is generally considered desirable because it favors the development of fruiting branches and efficient partitioning of assimilates toward boll production. The low variability observed suggests that this trait remained relatively stable among the genotypes. The mean number of sympodia was 21.9 plant⁻¹, varying from 18 (PAIG 77) to 25 (PAIG 326 and PA 796). PAIG 326 and PA 796 recorded the highest number of sympodia, followed by PA 793 and AKA 7 (23) and PA 741, AKA 8,

and PAIG 373 (22). PA 760 (20) and PA 778 (19) produced comparatively fewer fruiting branches. Since sympodia are the principal fruiting branches in cotton, genotypes with more sympodia are expected to possess greater yield potential.

The average number of bolls per plant was 24.7, with a range of 21 to 27 bolls. The highest number of bolls was recorded by AKA 8 and AKA 7 (27 bolls), followed by PA 796 (26 bolls) and PA 793, PA 778, and PA 760 (25 bolls). PA 741 and PAIG 326 (24 bolls) and PAIG 373 (23 bolls) showed moderate performance, while PAIG 77 (21 bolls) recorded the lowest number of bolls. Since boll number is one of the major yield-contributing characters, the superior performance of AKA 7 and AKA 8 is reflected in their higher seed cotton yield. The mean boll weight was 2.68 g, ranging from 2.5 g (PAIG 326) to 2.8 g (PA 793, PAIG 373, and AKA 7). PA 741, AKA 8, and PA 796 (2.7 g) also recorded relatively higher boll weights, whereas PAIG 77, PA 778, and PA 760 (2.6 g) showed intermediate values. Although the variation was narrow, genotypes with higher boll weight contribute positively toward increasing seed cotton yield.

The average seed index was 5.99 g, with values ranging from 5.5 g (PAIG 373) to 6.2 g, recorded by PA 741, PAIG 77, AKA 8, AKA 7, and PA 760. PA 778 (6.1 g) and PA 793 (6.0 g) also exhibited relatively higher seed index, whereas PAIG 326 (5.8 g) and PA 796 (5.7 g) recorded comparatively lower values. The limited variation indicates stable seed size among the evaluated genotypes. The mean lint index was 3.31 g, varying from 3.0 g (PAIG 373) to 3.7 g (AKA 7). AKA 8 (3.6 g) and PA 760 (3.5 g) also recorded higher lint index values, while PA 741 and PAIG 77 (3.3 g), PAIG 326, PA 778, and PA 796 (3.2 g) and PA 793 (3.1 g) exhibited moderate performance. Higher lint index indicates greater lint production per unit seed weight and is considered desirable for improving fiber yield.

The average seed cotton yield was 727.8 kg ha⁻¹, ranging from 595 kg ha⁻¹ (PAIG 77) to 835 kg ha⁻¹ (AKA 7). AKA 7 was the highest yielding genotype, followed by AKA 8 (798 kg ha⁻¹), PA 796 (763 kg ha⁻¹), PA 793 (760 kg ha⁻¹), PA 760 (748 kg ha⁻¹), PA 778 (723 kg ha⁻¹) and PAIG 326 (712 kg ha⁻¹). PAIG 373 (687 kg ha⁻¹) and PA 741 (657 kg ha⁻¹) showed comparatively

lower yield, while PAIG 77 recorded the lowest yield. The superior performance of AKA 7 can be attributed to its higher number of sympodia, greater boll number, higher boll weight, and higher lint index. The mean lint yield was 258.7 kg ha⁻¹, with values ranging from 207 kg ha⁻¹ (PAIG 77) to 312 kg ha⁻¹ (AKA 7). AKA 7 recorded the highest lint yield, followed by AKA 8 (293 kg ha⁻¹), PA 796 (273 kg ha⁻¹), PA 760 (272 kg ha⁻¹), PA 793 (259 kg ha⁻¹), PAIG 326 (253 kg ha⁻¹), and PA 778 (248 kg ha⁻¹). PAIG 373 (241 kg ha⁻¹), PA 741 (229 kg ha⁻¹) and PAIG 77 (207 kg ha⁻¹) produced comparatively lower lint yields. The higher lint yield observed in AKA 7 and AKA 8 reflects their superior seed cotton yield and lint index, making them promising genotypes for cotton improvement programs. The mean performance of the ten cotton genotypes revealed considerable variability for agronomic and yield-related traits. AKA 7 emerged as the best-performing genotype, exhibiting the highest seed cotton yield, lint yield, lint index, and a high number of bolls plant⁻¹, while AKA 8 and PA 796 also demonstrated superior yield performance. PAIG 77 was the earliest flowering and earliest maturing genotype, making it a valuable source of earliness despite its comparatively lower yield. PA 741 was the tallest genotype, whereas PAIG 326 and PA 796 produced the highest number of sympodial branches. The observed variability among genotypes indicates ample genetic diversity, which can be effectively exploited in cotton breeding programs aimed at developing high-yielding, early-maturing, and superior fiber-quality cultivars. (Dewey and Lu, 1959 and Falconer and Mackay, 1996)

The correlation coefficients were calculated for understanding the mutual relationship among the characters studied in the present investigation (Table 2). The results exhibited that considerable variation in the magnitude and direction of association between traits, indicating the complex nature of yield determination in cotton. Seed cotton yield exhibited a very strong positive correlation with number of bolls per plant ($r = 0.950$) and lint yield ($r = 0.977$), suggesting that these characters are the major contributors to yield improvement. The high association between seed cotton yield and boll number indicates that selection for increased boll production would be highly effective in enhancing productivity.

Similarly, the almost perfect positive correlation between seed cotton yield and lint yield is expected because lint yield is directly dependent on seed cotton production. Among the yield-contributing traits, lint index ($r = 0.516$), days to 50% boll bursting ($r = 0.498$), days to 50% flowering ($r = 0.493$), number of sympodia ($r = 0.481$), and boll weight ($r = 0.382$) exhibited positive correlations with seed cotton yield. These relationships indicate that genotypes possessing more sympodial branches, larger boll weight, and higher lint index tend to produce higher seed cotton yield. Although the correlations were moderate, these traits may serve as useful indirect selection criteria for yield improvement in cotton breeding programs.

Plant height showed a moderately negative correlation with seed cotton yield ($r = -0.551$) and lint yield ($r = -0.583$), suggesting that taller plants were generally associated with lower productivity in the present set of genotypes. This indicates that excessive vegetative growth may reduce the allocation of assimilates towards reproductive structures. On the other hand, seed index ($r = 0.071$) and number of monopodia ($r = 0.178$) exhibited only weak positive correlations with seed cotton yield, indicating that these traits had relatively little influence on yield performance under the present experimental conditions. A strong positive association was observed between days to 50% flowering and days to 50% boll bursting ($r = 0.847$), indicating that genotypes flowering later also tended to mature later. Days to 50% boll bursting also exhibited a strong positive correlation with boll weight ($r = 0.734$), suggesting that relatively late-maturing genotypes produced heavier bolls. Seed index was positively associated with lint index ($r = 0.718$), indicating that genotypes with larger seed size generally possessed greater lint weight per seed. In addition, number of bolls per plant showed positive associations with days to 50% flowering ($r = 0.518$), days to 50% boll bursting ($r = 0.552$), and lint index ($r = 0.552$), demonstrating the importance of these traits in determining boll production and ultimately seed cotton yield (Ahuja *et al.*, 2006 and Nandini *et al.*, 2020).

Negative associations were also observed among several traits. Plant height was negatively correlated with number of sympodia ($r = -0.584$), number of bolls

plant⁻¹ ($r = -0.328$), and boll weight ($r = -0.226$), indicating that taller plants tended to produce fewer fruiting branches and bolls. Likewise, seed index exhibited negative correlations with number of sympodia ($r = -0.520$) and number of monopodia ($r = -0.426$), suggesting an inverse relationship between seed size and branching habit in the evaluated genotypes (Ramesh *et al.*, 2017, Jangid *et al.*, 2022, Aishwarya *et al.*, 2024 and Ujjainkar *et al.*, 2023).

CONCLUSION

The mean performance of the ten cotton genotypes revealed considerable variability for agronomic and yield-related traits. AKA 7 emerged as the best-performing genotype, exhibiting the highest seed cotton yield, lint yield, lint index, and a high number of bolls per plant, while AKA 8 and PA 796 also demonstrated superior yield performance. PAIG 77 was the earliest flowering and earliest maturing genotype, making it a valuable source of earliness despite its comparatively lower yield. PA 741 was the tallest genotype, whereas PAIG 326 and PA 796 produced the highest number of sympodial branches. The observed variability among genotypes indicates ample genetic diversity, which can be effectively exploited in cotton breeding program aimed at developing high-yielding, early-maturing, and superior fiber-quality cultivars

Overall, the correlation analysis demonstrated that number of bolls per plant, lint index, boll weight, and number of sympodia are the most important yield-contributing characters and should receive greater emphasis during selection for higher seed cotton yield. Conversely, plant height showed an undesirable negative association with yield, while seed index and number of monopodia had only a limited contribution to productivity. Therefore, simultaneous selection for higher boll number, greater sympodial branching, improved boll weight, and enhanced lint index is likely to be an effective breeding strategy for developing high-yielding cotton genotypes.

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Effect of Land Configuration and Plant Growth Regulators on Drought Management As Climate Resilient Technologies in Cotton

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ABSTRACT

A field experiment was conducted during three consecutive years i.e. during 2022-23, 2023-24 and 2024-25 at Cotton Research Unit Research field, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. The experiment was laid out in split plot design with nine treatment combination replicated thrice. The cotton genotypes was straight hirsutum genotype AKH-9-05 (Suvarna Shubhra). The pooled data of three years revealed that plant height, number of sympodia, number of bolls picked plant⁻¹, length of sympodial branches were significantly influenced by land configuration treatments except bolls weight. Highest plant height (116.86 cm), number of sympodia (24.81), sympodial length (31.10 cm) and number of bolls plant⁻¹ (31.46) were observed in land configuration treatment of broad bed furrow and was found significantly superior over planting on ridges and furrow and over control i.e. farmers practice without any land configuration treatment. The pooled seed cotton yield was significantly highest (2346 kg ha⁻¹) with land configuration treatment of broad bed furrow which was significantly superior over ridges and furrow treatment (2074 kg ha⁻¹) and over control (1815 kg ha⁻¹). The SCY was significantly highest (2195 kg ha⁻¹) with drought management practice of Salicylic acid spraying @ 100 ppm as a single spray on cotton in drought situation. However, there were non-significant differences in Glycine Betanine @100 ppm spraying and Salicylic acid @100 ppm as a single spray which were found at par with each other. The lowest yield of 1919 kg ha⁻¹ was recorded in farmers practice. Combination of broad bed furrow and salicylic acid spraying recorded SCY of 2547 kg ha⁻¹ which was found superior over other combination of ridges and furrow and other chemicals. Significantly maximum pooled GMR (Rs. 158141 ha⁻¹) was registered in land configuration practice of broad bed and furrow followed by GMR of Rs. 139671 ha⁻¹ in ridges and furrow land configuration method. However, among the PGR spray, maximum GMR was registered in spraying of Salicylic acid @ 100 ppm single spray (Rs. 147938 ha⁻¹). B:C ratio was found maximum in broad bed furrow system (2.63) and among the use of PGR spray maximum B:C ratio (2.54) was registered in spraying of Salicylic acid @100 ppm as a single spray. It is concluded from the three years experiment that, land configuration of broad bed furrows and foliar application of salicylic acid @ 100 ppm as single spray was found most effective for enhancing the growth, yield attributes and seed cotton yield in drought situation as compared to farmer's practice

Cotton (*Gossypium hirsutum* L.) is an important commercial fiber crop belonging to *Malvaceae* family grown under diverse conditions around the World. It is called as a 'White gold' and as 'King of fiber crops. Cotton production in India during 2023-2024 was 361 lakh bales of 170 kg from 130 lakh hectares with productivity of 449 kg lint ha⁻¹. Maharashtra comes under central zone contributing with production of 75.73 lakh bales with the productivity of 305 kg ha⁻¹ occupying an area of 42.22 lakh hectares in 2023-24. Cotton is one of the most important cash crops of Vidarbha but average yield per hectare is quite low (368 kg ha⁻¹).

Cotton is grown mainly as a rainfed crop in Maharashtra and during the crop growth period, crop experienced long dry spell which ultimately reduce the

seed cotton yield. Under the situation of long dry spell during the critical growth stages of cotton, land configuration techniques such as broad bed furrow and ridges and furrows can play a vital role to overcome the situation of moisture deficit. Broad-bed and furrow (BBF) system is an improved in-situ soil and water conservation and drainage technology for the Vertisols. This system is useful for clayey soils with low infiltration capacity as soil profile gets saturated and waterlogged with the progression of rainy season. Ridging the soil is recommended as it helps to drain the plant in wet conditions and to conserve water in dry conditions. Land configuration also facilitates uniform germination as well as good growth and development of cotton crop. Adoption of appropriate land configuration and planting techniques

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help in better crop establishment, intercultural operations, reduce runoff, soil and nutrient loss, conserve water, efficient utilization of resources and result in higher productivity and profitability which helps farmer for better cotton production. Patode *et al.* (2021) recorded 18.6% more cotton equivalent yield in BBF sowing as compared to flatbed sowing in cotton.

Likewise, some Plant growth regulators (PGR) played a major role in drought situation that regulate the growth and differentiation of plant cells, tissues, and organs. The PGRs like glycine Betaine and salicylic acid have effective capacity to work on drought condition in cotton. Glycine betaine improves growth and survival of plants counteracting metabolic dysfunctions caused by stress. Salicylic Acid application improves photosynthetic performance and biochemical responses to mitigate saline stress in cotton. Plant growth regulators substance when added in small amount modify the growth of the plant usually by inhibiting part of the natural growth regulations. Exogenous application of glycine betaine and salicylic acid will help to ameliorate the detrimental effect of drought. Plant growth regulators have the potential to promote crop earliness, square and boll retention, higher nutrient uptake, and keeping vegetative and reproductive growth in harmony to improve lint yield and quality. PGRs can reduce water and nutrient requirements, decrease labor and reduce plant spacing. PGRs also help produce a more consistent crop, which increases sell-through. Ornamental growers are under increasing pressure to deliver plants with optimum size, shape and quality at competitive prices. The response of cotton with land configuration and PGRs is most researchable topic. Hence, to exploit the full potential of plant growth regulators and land configurations effect on drought condition, an attempt has made to study the effect in cotton with the objectives to find out the effect of land configuration and plant growth regulator on growth, yield and economics of cotton

MATERIAL AND METHODS

A field experiment was conducted during three consecutive years i.e. during 2022-23, 2023-24 and 2024-25 at Cotton Research Unit Research field, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra with an objective to find out the effect of land configuration

methods and plant growth regulators on growth, yield and economics of cotton. The experiment was laid out in split plot design with nine treatment combination replicated thrice. In land configuration, the cotton was sown on broad bed furrow (A1), ridges and furrow (A2) and compared with farmers practice i.e. sowing on flat bed i.e. A3. Among the drought management, two plant growth regulators viz. glycine betaine (D1) and salicylic acid (D2) @100 ppm as single spray was tried as foliar spray during the dry spell in cotton at 70% water depletion stage in cotton and farmers practice i.e. no spray of PGR (D3). The cotton genotypes of straight hirsutum genotype AKH-9-05 (Suvarna Shubhra) was sown on 24.06.2022, 10.07.2023 and 13.07.2024 by dibbling as per the recommended spacing of 90×30 cm.

The topography of the field was fairly uniform and levelled. The soil was medium black cotton belonging to Vertisols, clayey in texture, low in available nitrogen (242 kg ha⁻¹), medium in available phosphorus (16.60 kg ha⁻¹) and high in potassium (382 kg ha⁻¹). The seedling emerged out completely within 5 to 7 days after sowing and the optimum plant population was maintained by gap filling and subsequently by thinning keeping one plant per hill. Application of glycine betaine, salicylic acid @ 100 ppm in single spray was applied at 70% water depletion stage. During the *kharif* season of 2022, 2023 and 2024, the total rainfall received at Akola center was 929 mm (57 rainy days), 694.5 mm (33 rainy days) and 955.1 mm (44 rainy days) respectively during 2022-23, 2023-24 and 2024-25. The biometric observations were recorded on these plants periodically at 30 days interval till maturity of crops. Cost of cultivation, gross returns and benefit cost ratio for each treatment were calculated by taking into consideration of total costs incurred and returns obtained. Data on various growth and yield attributing characters of cotton were statistically analyzed as per the standard procedure.

RESULTS AND DISCUSSION

A) Growth parameters, Yield attributes and SCY

a) Effect of Land Configuration

The pooled data presented in Table 1 and Table 2 in respect of Growth and yield parameters viz. plant height, number of monopodia, number of sympodia,

Table 1: Growth characters of cotton as influenced by land Configuration and drought management practices (Pooled of Three Years)

Treatments	Plant Height (cm)	No. of Monopodia at harvest	No of Sympodia plant ⁻¹	Sympodial Length Plant ⁻¹ (cm)	No. of Bolls picked plant ⁻¹			Pooled
					2022-23	2023-24	2024-25	
I. Land Configuration (Main Plot)								
A1: Broad Bed Furrow	116.86	1.49	24.81	31.10	28.53	31.65	34.21	31.46
A2: Ridges & Furrow	106.77	1.38	21.69	25.95	24.39	27.26	26.86	26.17
A3: Control-Farmers Practice	97.21	1.24	17.96	21.41	19.69	21.54	22.41	21.21
S.E. m ±	1.74	0.06	0.33	0.56	1.06	1.02	1.18	1.01
CD at 5%	6.84	-	1.29	2.19	4.18	4.02	4.62	3.98
II. Drought Management (Sub Plot)								
D1: Glycine Betaine@100 ppm single spray	107.94	1.38	21.69	26.30	24.51	27.29	27.97	26.59
D2: Salicylic acid @ 100 ppm single spray	111.00	1.44	23.12	27.90	26.23	28.76	31.54	28.85
D3: Control	101.90	1.29	19.66	24.25	21.87	24.40	23.98	23.41
S.E. m ±	1.48	0.08	0.48	0.64	0.75	0.68	1.03	0.79
CD at 5%	4.55	NS	1.47	1.96	2.31	2.09	3.17	2.43
Interaction (A x D)								
S.E. m ±	2.56	0.13	0.83	1.10	1.30	1.17	1.78	1.36
CD at 5%	-	-	-	-	-	-	5.50	4.20

Table 2.No. of Bolls picked per plant as influenced by land Configuration and drought management practices (two-way table)

Treatments	A1	A2	A3	Mean (Drought)	Anova	SE m	CD (5%)
D1	29.85	27.71	22.20	26.59	Land Configuration (A)	1.01	3.98
D2	37.30	28.05	21.19	28.85	Drought management(D)	0.79	2.43
D3	27.25	22.75	20.24	23.41	A x D	1.36	4.20
Mean (Land Configuration)	31.46	26.17	21.21				

sympodial length, number of bolls per plant, seed cotton yield per plant and seed cotton yield per hectare were significantly influenced due to different land configuration methods except monopodial branches. Significantly highest pooled plant height, number of sympodia, number of bolls per plant, length of sympodial branches were significantly influenced by land configuration treatments except monopodial branches and boll weight. Highest pooled plant height (116.86 cm), number of sympodia (24.81), sympodial length (31.10 cm), number of bolls per plant (31.46) and seed cotton yield per plant (75.89 g) were observed in land configuration treatment of broad bed furrow (A1) and was found significantly superior over planting on ridges and furrow (A2) and over control (A3) i.e. farmers practice on flat sowing without any land configuration treatment. However, ridges and furrow land configuration method were found significantly superior over farmer's practice. All this growth attributes observed in land configurations (broad bed furrow and ridges and furrow) over control was observed due to better moisture available and optimum soil condition. Similar result were also earlier reported by *Deshmukh et al.* (2016) and by *Sathiya et al.* (2020). *Asewar et al.* (2017) also observed maximum plant height and more number of sympodial branches in land configuration methods as compared to flat sowing.

The data given in Table 1 and 3 revealed that all the significant yield attributes viz., number of bolls picked per plant, seed cotton yield per plant (g) and boll weight (g) of cotton resulted in higher seed cotton yield in broad bed furrow than other treatments. The land configuration method significantly influenced the number of picked bolls plant⁻¹. Number of picked bolls per plant were found significantly higher in broad bed furrow (34.21) over ridges and furrow (26.86) and control (22.41). The difference in number of bolls plant⁻¹ among treatments was direct consequence of difference in sympodial branches plant⁻¹. Similar results observed by *Paslawar et al.* (2022). The land configurations significantly influenced the pooled seed cotton yield per plant. Pooled seed cotton yield per plant was found significantly higher in land configuration of broad bed furrow (75.89) over ridges and furrow (68.88) and control (57.63). Higher seed cotton yield per plant in these treatments might be due to maximum number of bolls and boll weight. Broad

bed furrow and ridges and furrow produced higher seed cotton yield per plant over control due to better soil moisture and nutrient availability which was also reported earlier by *Lakpale et al.* (2012).

The individual year wise seed cotton yield data (2022-23, 2023-24 and 2024-25) and pooled data of three years is presented in Table 3. During the individual years of 2022-23, 2023-24 and 2024-25, the seed cotton yield was significantly highest i.e. 2130 kg ha⁻¹, 2365 kg ha⁻¹ and 2542 kg ha⁻¹ respectively in land configuration treatment of broad bed furrow which was significantly superior over ridges and furrow treatment (i.e. 1917 kg ha⁻¹, 2097 kg ha⁻¹ and 2207 kg ha⁻¹). The maximum yield in broad bed furrow might be due to moisture conservation which helped in later stages of cotton growth and development and it drains out the excess moisture from the furrow in the situation of excess and continuous rainfall during the three years of study. The pooled seed cotton yield of 2346 kg ha⁻¹ was also registered in broad bed furrow as compared to SCY of 2074 kg ha⁻¹ in ridges and furrow method of land configuration. Treatment of land configuration (A1) registered 22.63% more seed cotton yield as compared to farmer's practice. Similar results were observed by *Gabhane et al.* (2017) and *Ghogare et al.* (2020) in *kharif* season and reported significantly higher seed cotton yield in land configuration treatments over flat bed. Land configurations like broad bed furrow and ridges and furrow produced higher seed cotton yield due to higher number of sympodial branches, number of bolls picked per plant and seed cotton yield per plant over control.

b) Effect of Drought Management Practices (PGR Sprays)

The pooled data of three years (Table 1 & 3) indicated that, there was significant response to spraying of PGR chemicals during drought situation. Plant height, sympodial branches, sympodial length, seed cotton yield per plant and seed cotton yield per hectare were significantly influenced by use of different PGR sprayed during drought situation. The spraying of glycine betanine@100 ppm as a single spray (D1), Salicylic acid@100 ppm as a single spray at 70% water depletion stage in cotton. Monopodial branches and boll weight did not affect significantly due to spraying of chemicals.

Table 3: Yield attributes and Seed Cotton Yield ((Kg ha⁻¹) of cotton as influenced by land Configuration and drought management practices (Pooled of Three Years)

Treatments	Seed Cotton Yield plant ¹ (g)			Pooled Boll Weight(g)	SCY(Kg ha ⁻¹)			Pooled	
	2022-23	2023-24	2024-25		2022-23	2023-24	2024-25		
I. Land Configuration (Main Plot)									
A ₁ : Broad Bed Furrow	70.85	73.33	83.48	75.89	4.61	2130	2365	2542	2346
A ₂ : Ridges & Furrow	64.56	66.49	75.60	68.88	4.55	1917	2097	2207	2074
A ₃ : Control-Farmers Practice	52.26	55.99	64.64	57.63	4.49	1763	1766	1917	1815
S.E. m ±	1.13	1.36	1.50	1.42	0.04	38	41	68	36
CD at 5%	4.12	5.34	5.90	5.26	-	147	160	266	139
II. Drought Management (Sub Plot)									
D ₁ : Glycine Betaine@100 ppm single spray	62.85	66.90	75.47	68.41	4.57	1955	2145	2263	2121
D ₂ : Salicylic acid @ 100 ppm single spray	67.25	68.41	78.81	71.49	4.59	2020	2186	2379	2195
D ₃ : Control	57.30	60.50	69.45	62.42	4.49	1836	1898	2022	1919
S.E. (m) ±	1.09	1.34	1.04	1.19	0.05	34	32	49	26
CD at 5%	3.94	4.13	3.22	3.98	NS	106	100	150	80
Interaction (AxD)									
S.E. (m) ±	2.16	2.32	1.81	2.12	0.08	59.40	55.98	109	54.90
CD at 5%	-	-	-	-	-	-	172.50	334	169

Table 4: Seed Cotton Yield (SCY) kg/ha as influenced by land Configuration and drought management practices (two-way table)\

Treatments	A1	A2	A3	Mean (Drought)	Anova	S.E. m ±	CD (5%)
D1	2326	2107	1930	2121	Land Configuration	36	139
D2	2547	2116	1922	2195	Drought management	26	80
D3	2164	1998	1593	1919	A X D	54.90	169
Mean (Land Conf.)	2346	2074	1815				

Significantly higher plant height (111.00 cm), number of sympodia (23.12), number of bolls per plant (28.85), seed cotton yield per plant (71.49 g) was recorded in Salicylic acid spraying @ 100 ppm as a single spray on cotton in drought situation as compared to other treatments of PGR and farmer's practice. All these growth parameters were found lowest in D3 i.e. control. Application of salicylic acid and glycine betaine and enhanced photosynthesis, improved stomatal conductance, and maintained higher RWC. Similar result was observed by *El-Beltagi et al.* (2017). Mahmood *et al.* (2011) and Jagdish *et al.* (2015) also reported significant differences on growth parameters due to spraying of chemicals like salicylic acid and glycine betaine in cotton crop.

Drought management practices significantly influenced the number of bolls picked per plant. Salicylic acid @100 ppm as a single spray (D2) recorded significantly more pooled number of bolls picked per plant (28.85) than glycine betaine @ 100 ppm as a single spray (D1) with 26.59 number of bolls per plant than control (23.41). However salicylic acid @100 ppm as a single spray and glycine betaine @ 100 ppm as a single spray values were at par with each other but significantly superior over control (D3). It might be due to plant growth regulators application, which improved better water uptake and better photosynthesis as similarly observed by Shehata *et al.* (2000). Treatment differences in respect of seed cotton yield plant^{-1} due to drought management practices were observed to be significant. Salicylic acid @100 ppm as a single spray (D2) recorded significantly higher weight of seed cotton per plant as compared to the glycine betaine @100 ppm (D1) and control (D3). Salicylic acid @100 ppm as a single spray recorded 71.49 g seed cotton yield plant^{-1} which was found comparable with 68.41 g of seed cotton yield plant^{-1} but was found significantly superior over control (62.42 g). Salicylic acid and glycine betaine treatments improved vital plant components and preventing ion loss through ion leakage by controlling cell permeability.

The pooled SCY was significantly highest (2195 kg ha^{-1}) with drought management practice of Salicylic acid spraying @ 100 ppm as a single spray on cotton in drought situation. However, there were non-significant differences in D1 (Glycine Betaine @100 ppm spraying)

with SCY of 2121 kg ha^{-1} and D2 (Salicylic acid @100 ppm as a single spray) which were found at par with each other. The lowest pooled SCY 1919 kg ha^{-1} was recorded in farmers practice (D3). Salicylic acid treatment produced higher seed cotton yield over all other drought management practice due to improved plant abiotic stress tolerance via salicylic acid-mediated control of major plant metabolic processes similarly reported by Aldesuquy *et al.* (2023). Plant growth regulators helped to withstand against adverse condition and produce high number of sympodial branches, number of bolls per plant and seed cotton yield plant^{-1} which ultimately resulted in higher seed cotton yield in the treatments of PGR spray. These results are in conformity with the results observed by Shehata *et al.* (2000). Mahdi *et al.* (2020) results revealed that foliar spraying with salicylic acid enhances water deficit tolerance in cotton plants by improving physiological attributes, nutrients and tissue water status by increase membrane stability index (MSI) and relative water content (RWC), and decrease electrolyte leakage (EL)

c) Interaction

All the interaction effect of Land configuration X Drought management practices with regards to all growth parameters were found non-significant except number of bolls plant^{-1} in pooled data of three years. Highest pooled number of bolls (37.30) were recorded in treatment combination of A1D2 (Broad Bed Furrow and Salicylic acid spraying @ 100 ppm as a single spray).

The interaction effect of Land configuration X Drought management practices in respect of seed cotton yield during the year 2023-24, 2024-25 and in pooled mean was found significant. Combination of broad bed furrow and salicylic acid spraying was found superior over other combination of ridges and furrow and other chemicals in respect of seed cotton yield in pooled of three years. This combination recorded seed cotton yield of 2547 Kgha^{-1} significantly superior than other treatment combination.

B) Cost of cultivation, GMR, NMR and B:C ratio

Cost of cultivation was significantly influenced by different land configuration and drought management practices. Among the land configuration, highest cost of cultivation (Rs.60128 h^{-1}) was observed in broad bed

**Table 5 : Economics (GMR, NMR, B:C ratio) as influenced by land Configuration and drought management practices
(Pooled of Three Years)**

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furrow due to labour cost involved in preparation of broad bed furrows and more cost of picking due to more yield in this treatment., however it was found less in control i.e. farmers practice (Rs.55508 ha⁻¹). Maximum cost of cultivation was registered in D1 i.e glycine Betanine @100 ppm as a single spray due to more cost of this chemical. GMR and NMR was also influenced significantly by land configuration and drought management practices in cotton.

Significantly maximum pooled GMR (Rs.158141ha⁻¹) was registered in land configuration method of broad bed furrows (A1) followed by ridges & furrows (A2) with GMR of Rs.139671 ha⁻¹. Maximum GMR (Rs.147938 ha⁻¹) was also recorded in treatment of Salicylic acid @ 100 ppm as a single spray and lowest GMR (Rs.129039 ha⁻¹) in case of control i.e. farmer's practice. Similar trend was also observed in case of NMR. Pooled B:C ratio was found maximum (2.63) in BBF land configuration (A1) than A2 (2.37) i.e. Ridges and furrows and A3(2.20) i.e farmer's practice. Among the use of PGR for drought management Salicylic acid @ 100 ppm as a single spray showed maximum B:C ratio (2.54) and lowest B:C ratio in treatment of farmer's practice. (2.26). The interaction of land configuration & drought management practices was found non-significant. Similar results in respect of cost of cultivation, GMR, NMR and B:C ratio was also reported earlier by Jagdish *et al.* (2011) and Kumari *et al.* (2018) and Patode *et al.*(2021). Similar improvement in economics parameter results was also observed by Singh *et al.* (2023).

CONCLUSION

On the basis of three years data, it could be concluded that the growth, yield attributes and seed cotton yield were significantly highest in land Configuration method of broad bed furrow as compared to ridges & furrow and farmer's practice and in salicylic acid spraying @100 ppm as a single spray. Therefore, the sowing of cotton on broad bed and furrow method and single spray of Salicylic Acid @ 100 ppm during long dry spell of rainfall (at 70% water depletion stage) is recommended for higher seed cotton yield and monetary returns in cotton under rainfed condition.

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Adaptability and Productivity of Different *Kharif* and *Rabi* Grain Sorghum Cultivars under Summer Season

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ABSTRACT

Field experiment entitled “Evaluation of different *Kharif* and *rabi* grain sorghum cultivars in summer season” was conducted at the farm of Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra during *summer* 2025-26 on clay loam soil. The experiment was laid out in randomized block design with eighteen treatment and replicated thrice. The treatment consisted eighteen *Kharif* and *rabi* grain sorghum cultivars viz, CSH-9, CSH-30, CSH-35, SPH-1635, SPV-1595, BG-296, CSV-20, CSV-34, CSV-45, PDKV-Kalyani, PDKV-Kranti, Phule Suchitra, Phule Vasudha, Phule Revati, Parbhani Moti, Parbhani super Moti, M-35-1 and Vittal. The summer sorghum experiment was conduct to study the effect of different grain sorghum cultivars on growth character, yield attributes, quality and economics. The result revealed that among different grain sorghum cultivars PDKV Kalyani recorded significantly highest plant height and cultivar CSH-9 recorded significantly highest number of functional leaves. The dry matter accumulation (g) Plant⁻¹ was significantly highest in cultivar PDKV Kalyani. The grain yield (3489 Kg ha⁻¹) was recorded significantly highest with cultivar BG-29. The fodder yield (7255 Kg ha⁻¹) and biological yield (10454 Kg ha⁻¹) were found significantly highest with sorghum cultivar PDKV Kalyani and Phule Suchitra, respectively. Among of the all-other treatments cultivar BG-296 recorded significantly highest gross returns (114154 Rs ha⁻¹), net returns (75654 Rs ha⁻¹) and B: C (2.97).

Sorghum is India's third-most significant cereal crop, next to rice and wheat. The main sorghum growing states in India are Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Uttar Pradesh, Rajasthan and Gujarat. In that, Maharashtra ranks first in sorghum production and area, but in case of productivity Andra Pradesh ranks first while Maharashtra ranks third in productivity. India has a largest share in (32.30%) world's sorghum area and ranks fifth in production. Globally, sorghum is the fifth most important crop after rice, wheat, maize and barley, whereas in India it is the fourth largest crop. About 19.5 % of the world's population and 27 % of India's population takes sorghum as their primary food (Lamessa *et al.* 2016). In Vidarbha, sorghum area under *Kharif* and *rabi* sorghum has reducing trend. It has tremendous down fall in area during the year 1990, 1995, thereafter area was constant till 2005. It has area has reduced down during the year 2010. The Poor acceptance of *Kharif* sorghum grain as a food because of Grain mold in *Kharif* sorghum has largely nullified its importance under erratic rainfall condition in Vidarbha region. Shifting of more and more favorable production area from *Kharif* and *Rabi* sorghum to high valued crops,

where sustainable productivity increase would be more difficult. in recent years in Maharashtra and specially Vidarbha cultivation of sorghum under summer season significantly increases. During 2018-2019 summer cultivated area around 2500-3000 ha only, but last three-to-five-year area under sorghum cultivation is more than 1.95 lakh ha. Sorghum cultivated in *Rabi* and *Summer* Season is distinguished by outstanding grain quality, utilized for human and animal for food, feed and fodder consumption and as a result fetches high price.

Sowing time is the most important non-monetary input. Sowing at proper time improves the yield by offering suitable environment to crop at all growth stages. Until now effect of sowing date summer season on performance of these improved varieties and hybrids in Vidarbha region work has not evaluated. Sowing time directly affects the duration of crops during growing season; cultivars of different maturity groups will correspondingly be affected. The purpose of current study is identifying the suitable *rabi* / *kharif* cultivars available for summer sorghum cultivation. Summer cultivated sorghum has better food, feed, fodder quality and quantity. Therefore, felt to identify the effect of different *Kharif* /

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Rabi cultivars of sorghum for summer cultivation. Considering different views in mind, the thought is given for the determine summer cultivation of sorghum in the Vidarbha region.

MATERIAL AND METHODS

The present field trial was conducted at the Central research station, Sorghum research unit, Dr. PDKV, Akola during summer season 2025, which is located at 23°43' N latitude and 77°64' E longitude with an altitude of 281m above the mean sea level. The soil was clay loam in texture, medium in organic carbon and low in available nitrogen, phosphorous, zinc, iron and marginally high in available potassium. The soil was slightly alkaline (pH 7.9). The Experiment was laid out in Randomized Block Design, with Eighteen treatments which are replicated thrice. The experiment consisted different eighteen *Kharif* and *Rabi* grain sorghum cultivars viz. CSH-9, CSH-30, CSH-35, SPH-1635, SPV-1595, BG-296, CSV-20, CSV-34, CSV-45, PDKV-Kalyani, PDKV-Kranti, Phule Suchitra, Phule Vasudha, Phule Revati, Parbhani Moti, Parbhani super Moti, M-35-1 and Vittal. The nutrients sources were Urea, SSP, MOP to fulfill the requirement of nitrogen, phosphorous and potassium. The nitrogen applied as split dose half as basal dose remaining as top dressing. The date of sowing of sorghum was on 09th January, 2024 with the seed rate of 8-10 kg ha⁻¹. The treatment having spacing 45 cm × 15 cm. and plot size was 4.50 m x 5.10 m. For recording the crop observations, five plants were selected and tagged from every net plot of all the treatments of each replication. On every alternate day, phenology was observed. Data collected viz. plant height, no. of leaves per plant, dry matter, stem diameter, Leaf area, leaf area index (LAI), SPAD value, days to 50% flowering and physiological maturity were visually recorded and five randomly selected plants from each treatment were used for recording various yield attributes viz, 1000 seed weight (g), grain number per panicle, grain weight per panicle (g), grain yield (kg ha⁻¹), fodder yield (kg ha⁻¹), biological yield (kg ha⁻¹). The crop was harvested manually with the help of sickle when seed almost matured and stover had turned yellow. The sun-dried bundles were threshed and winnowed and seed so obtained were weighed and data on seed and stover yields were recorded Saini *et al.* (2018).

statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant Height (cm)

Plant height was significantly influenced by different grain sorghum cultivars shown in table.1. Among the cultivars PDKV-Kalyani (217cm) recorded the highest plant height, followed by PKV-Kranti (212 cm) and Phule Vasudha (204 cm). The cultivar PDKV-Kalyani found superior to the all-other remaining cultivars. The lowest plant height of sorghum grain cultivar was recorded by CSV-34 (140 cm). The increase plant height in this cultivar may also associated prolonged vegetative growth duration and efficient translocation of assimilates to growing tissues. Sorghum cultivar possessing greater stem elongation and higher leaf area generally exhibit superior biomass production. These finding in conformity with those of Mishra *et al.* (2017), Singh and Chavhan (2017) and Godre *et al.* (2024).

Number of Functional Leaves

The number of functional leaves differed significantly among the different eighteen kharif and rabi grain sorghum cultivars. The highest number of functional leaves was recorded with Phule Revati (7.60), which was statistically at par with CSH-9 (7.54), Vittal (7.38), PKV Kranti (7.34) and BG-296 (7.33). The lowest number of functional leaves was observed in Parbhani Moti (6.17). Functional leaves serve as primary source of assimilates production and therefore directly influence grain filling and biomass accumulation, the high number of functional leaves observed in superior cultivar may be due to better genetic expression, higher chlorophyll content and enhanced nutrient uptake efficiency. Similar observation was to be reported by Kumar *et al.* (2017), Nalini Naidu *et al.* (2018) and Mishra *et al.* (2017).

Leaf Area (dm²) and Leaf Area Index

Significantly higher leaf area and leaf area index was recorded by cultivars PKV-Kranti (57.39 and 8.50) followed by Parbhani Moti (56.58 and 8.34). The minimum leaf area value was recorded by cultivar CSH-9 (47.13 and 6.98). This increase in leaf area from panicle

initiation to flowering indicates active vegetative growth and canopy development. Among all cultivars, PKV-Kranti and Parbhani Moti consistently recorded higher leaf area and LAI at flowering stage, indicating vigorous growth and superior canopy development. The observed variation among cultivars reflects differences in genetic makeup and adaptability to environmental conditions. Similar findings were reported by Nalini Naidu *et al.* (2018.) and Mahalle *et al.* (2022)

Dry Matter Accumulation (g)

The significantly higher dry matter accumulation value was recorded with sorghum cultivar PDKV Kalyani (181.34 g). The sorghum cultivar PKV-Kranti (179.48 g), M-35-1(178.68 g) and Phule Revati (174.85 g) were found to be at par with PDKV Kalyani. The lowest dry matter accumulation per plant was recorded by sorghum cultivar Vittal (151.43 g) (Table 1). The higher dry matter production indicates greater photosynthetic efficiency and superior conversion of intercepted radiation into biomass. The result corroborates finding reported by Ramachandra *et al.* (2011), Chongtham *et al.* (2018), Godre *et al.* (2024) and Venkatesh *et al.* (2024).

Stem Diameter (cm)

The significant variation observed in stem diameter among grain sorghum cultivars. The maximum stem diameter was recorded in BG-296 (6.36 cm), which was found statistically at par with sorghum cultivar PKV Kranti (6.28 cm). The minimum stem diameter was recorded in CSH-35 (4.67 cm). A slight stabilization or marginal decline at harvest may be due to moisture loss and physiological maturity. The superior performance of BG-296 and PKV Kranti indicates their better vegetative growth potential and dry matter accumulation capacity. The cultivars possessing thicker stems generally exhibit greater structural strength, improved nutrient translocation, accumulates more carbohydrate, enhanced lodging resistance and fodder yield. and similar finding has been reported by Chongtham *et al.* (2018).

SPAD (Chlorophyll Content)

The SPAD value was recorded at flowering significantly differed in chlorophyll content among different grain sorghum cultivars. The highest SPAD value

was recorded with Cultivar CSV-20 (57.97), which was significantly superior over all other genotypes. The next higher values were observed in cultivars CSH-9 (54.40), CSH-30 (54.40) and CSH-35 (55.14), which were also comparatively higher but differed significantly from the maximum. Lower SPAD values were observed with cultivars SPH-1635 (47.00), SPV-1595 (47.58) and CSV-34 (47.68). The differences among treatments were found to be statistically significant indicating real variation in chlorophyll content among sorghum grain cultivars. The higher values of SPAD may be attributed to enhances light interception, photosynthetic activity and better root growth, resulting in higher water and nutrient uptake which resulted in increased chlorophyll content in leaves. The finding in agreement with Hari Kumar *et al.* (2024).

Days to 50% Flowering

Days to 50% flowering varied significantly among cultivars. The comparatively minimum days to 50% flowering were recorded with cultivar CSH-35 (66 days) followed by cultivar CSH-30 (67 days), CSH-9 (68 days), SPH-1635 (68 days) and BG-296 (67 days), indicating early flowering behaviors of these cultivars. The maximum days to 50% flowering were observed by cultivars CSV-45 (75 days), PDKV-Kalyani (73 days) and Phule Vasudha (73 days). The observed variation in flowering behavior among sorghum cultivars indicates genetic diversity for maturity duration. Early flowering cultivars may be advantageous under drought-prone conditions due to their shorter growth cycle.

Days to Physiological Maturity

Significant differences were observed in physiological maturity among grain sorghum cultivars. The cultivar CSH-30 matured earliest (113 days) and closely followed by cultivars CSV-34 (117 days), CSV-45(117 days) Phule Suchitra (117 days), Parbhani Moti (117 days) and Vittal (117 days). whereas PKV Kranti required the longest duration (121 days) to attain physiological maturity. Differences in maturity duration are mainly attributed to genotypic characteristics regulating growth and reproductive development. Longer maturity duration often permits greater photosynthate accumulation and biomass production, whereas early maturity enables crop escape from terminal drought stress.

Table:1- Effect of different grain sorghum cultivars on growth and yield attributes of summer sorghum 1000 grain weight (g)

Treatments	No. of functional leaves	Plant height (cm)	Leaf area plant ⁻¹ (dm ²)	Leaf area index	Dry matter (g)	Stem diameter (cm)	SPAD Value	Days to 50% flowering	Days to physiological maturity	1000 seed weight (g)	No. of grains panicle ⁻¹	Grain weight panicle ⁻¹
CSH-9	7.54	147	47.13	6.98	159.33	5.70	54.40	68	118	29.60	889	26.76
CSH-30	6.45	148	48.63	7.20	158.59	5.02	54.40	67	113	30.70	607	18.88
CSH-35	6.59	147	48.92	7.25	154.33	4.67	55.14	66	118	31.50	501	16.24
CSH1635	6.53	156	49.53	7.34	157.76	5.19	47.00	68	118	30.50	499	15.53
SPV-1595	6.55	164	48.56	7.19	164.90	4.72	47.58	72	119	28.00	680	19.03
BG-296	7.33	174	49.04	7.27	161.09	6.36	50.13	67	118	28.30	932	26.84
CSV-20	6.33	169	48.68	7.21	168.31	5.02	57.97	73	119	28.70	694	19.29
CSV-34	6.89	140	49.71	7.36	167.36	5.22	47.68	70	116	30.70	528	15.83
CSV-45	6.51	175	49.10	7.27	168.71	4.87	51.04	75	117	29.50	617	18.19
PKV Kalyani	6.96	217	55.67	8.25	181.34	5.23	49.10	73	119	28.50	587	16.97
PKV Kranti	7.34	212	57.39	8.50	179.48	6.28	50.38	70	121	28.90	875	25.80
Phule Suchitra	7.11	200	56.34	8.35	172.88	5.06	47.21	69	117	28.70	729	20.25
Phule Vasudha	6.77	204	55.77	8.26	171.61	5.14	48.41	73	118	29.20	672	20.42
Phule Revati	7.60	193	56.29	8.32	174.85	5.67	48.29	71	120	30.40	848	25.78
Parbhani Moti	6.17	201	56.58	8.34	169.00	4.78	48.61	68	117	27.00	684	18.55
Par. Super Moti	6.54	163	55.76	8.33	172.86	5.19	49.10	69	119	28.30	525	15.63
M-35-1	7.09	168	55.98	8.26	178.68	5.20	48.09	69	119	26.30	510	13.58
Vittal	7.38	148	48.57	8.29	151.43	5.64	49.91	71	117	27.60	810	22.75
SE(m)±	0.11	1.80	2.19	0.32	2.45	0.08	0.65	1.18	0.83	0.43	39.2	1.06
CD at 5%	0.33	5.17	8.73	1.28	7.05	0.23	1.86	3.39	2.39	1.37	119	3.22
GM7.87	175	51.96	7.70	167.36	5.28	49.80	69.78	118.02	29.00	677	20.00	

The 1000-seed weight differed significantly among grain sorghum cultivars. The highest test weight was recorded with cultivar CSH-35 (31.5 g), followed by sorghum cultivar CSH-30 and CSV-34 (30.7 g). The lowest test weight was observed in cultivar M-35-1 (26.3 g). The variation in test weight among cultivars reflects differences in grain filling efficiency and assimilate partitioning. Higher seed weight indicates its superior grain development potential and similar observation was reported by Mishra *et al.* (2017), and Venkatesh *et al.* (2024).

Number of Grain Panicle⁻¹

The number of grains per panicle differed significantly among grain sorghum cultivars. Significantly the greater number of grains per panicle was recorded in grain sorghum cultivar BG-296 (932), which was statistically found at par with CSH-9 (889) PKV Kranti (875) and Phule Revati (848). The lowest number of grains per panicle was observed in cultivar SPH-1635 (499). The greater no of grains per panicle is an important yield contributing character directly influence final yield. These finding give support to statement by Rakshit *et al.* (2021) and Hari Kumar *et al.* (2024).

Grains Weight (g) Panicle⁻¹

Grain weight per panicle varied significantly among different grain sorghum cultivars. The significantly highest grain weight par panicle was recorded by cultivar BG-296 (26.84 g). The cultivar CSH-9 (26.76 g), PKV-Kranti (25.80 g) and Phule Revati (25.78 g), were found to be at par with cultivar BG-296. The comparatively minimum number of grain weight par panicle was recorded with cultivar M-35-1 (13.58 g). The increased in grain weight may be attributed to efficient grain filling and greater assimilates supply during reproductive growth. The result is in conformity with Kumar *et al.* (2017) and Nalini Naidu *et al.* (2024).

Post Harvest Studies

Grain Yield (Kg ha⁻¹)

Grain yield among the different eighteen evaluated grain sorghum cultivars differed significantly showed in table 1. Sorghum cultivar BG - 296 (3489 kg ha⁻¹) recorded significantly superior grain yield and

followed by cultivar CSH-9 (3422 kg ha⁻¹), PKV Kranti (3354 kg ha⁻¹) and Phule Revati (3322 kg ha⁻¹). The significantly lowest grain yield was recorded by cultivar M-35-1 (1765 kg ha⁻¹). The increased yield might be due to increased number of grains per panicle, grain weight per panicle which resulted in higher panicle weight. These results are in conformity with findings of Mishra *et al.* (2017), Rao *et al.* (2017), Ghuraiya *et al.* (2021), Hariprasanna *et al.* (2023) and Kumar *et al.* (2022).

Fodder yield (Kg ha⁻¹)

Significant differences were recorded in fodder yield among different grain sorghum cultivars. The highest dry fodder yield was recorded by cultivar PDKV Kalyani (7255 kg ha⁻¹), and found at par with cultivar SPV-1595 (7245 kg ha⁻¹). The cultivars PKV Kranti (7100 kg ha⁻¹) and CSV-45 (7050 kg ha⁻¹) closely followed to the high performing cultivars PDKV-Kalyani and SPV-1595. The significantly the lowest dry fodder yield was recorded with cultivar CSV-34 (4530 kg ha⁻¹). Similar observations were reported by Mahalle *et al.* (2022), who found significant differences in fodder production among sorghum genotypes owing to genetic variability in biomass accumulation.

Biological Yield (Kg ha⁻¹)

Biological yield varied significantly among grain sorghum cultivars. The significantly highest biological yield was recorded with cultivar PKV-Kranti (10,454 kg ha⁻¹). PKV Kranti reported significantly superior biological yield over all other cultivars. The cultivars SPV-1595 (9719 kg ha⁻¹) and Phule Revati (9477 kg ha⁻¹) closely followed to the high performing cultivars PKV-Kranti. The lowest biological yield was recorded by cultivar CSV-34 (6429 kg ha⁻¹).

GMR, NMR and B:C Ratio

The table-2 illustrates the economic analysis of different treatments of grain sorghum cultivars. Among the all eighteen grain sorghum cultivars, BG 296 exhibited highest economic efficiency with the highest GMR, NMR and B:C ratio, (114,154 Rs ha⁻¹, 75654 Rs ha⁻¹ and 2.97) respectively. Indicating profitability of treatment among cultivars. The sorghum cultivars like PKV-Kranti (113,478 Rs. ha⁻¹, 74978 Rs ha⁻¹ and 2.95) and CSH-9

Table : 2 Effect of different grain sorghum cultivars on Grain, Fodder, biological yield and economics.

Treatments	Grain yield (Kg ha ⁻¹)	Fodder yield (Kg ha ⁻¹)	Biological yield (Kg ha ⁻¹)	GMR (Rs ha ⁻¹)	NMR (Rs ha ⁻¹)	B:C Ratio
CSH-9	3422	4750	8172	110791	72291	2.88
CSH-30	2455	5400	7855	83468	44968	2.17
CSH-35	2111	5720	7831	73926	35426	1.92
SPH1635	2019	5800	7819	71362	32862	1.85
SPV-1595	2474	7245	9719	87720	49220	2.28
BG-296	3489	5440	8929	114154	75654	2.97
CSV-20	2411	6210	8621	83786	45286	2.18
CSV-34	1899	4530	6429	65270	26770	1.70
CSV-45	2365	7050	9415	84104	45604	2.18
PDKV Kalyani	2036	7255	9291	74776	36276	1.94
PKV Kranti	3354	7100	10454	113478	74978	2.95
Phule Suchitra	2633	4570	7203	87077	48577	2.26
Phule Vasudha	2654	5520	8174	89598	51098	2.33
Phule Revati	3222	6255	9477	107881	69381	2.80
Parbhani Moti	2411	4822	7233	81010	42510	2.10
Par. Super Moti	1954	5066	7020	67970	29470	1.77
M-35-1	1765	6230	7995	64704	26204	1.68
Vittal	2958	5033	7991	97623	59123	2.54
SE(M)±	1.073	26.61	3.54	3520	3520	-
CD at 5%	3.25	80.90	10.77	10150	10150	-
GM	2535	5778	8313	86594	48094	

(110,791 Rs. ha⁻¹, 72291 Rs ha⁻¹ and 2.88) were found at par with sorghum cultivars BG 296, also exhibited high economic efficiency and achieved favorable returns ratio highlighting the potential of other cultivars. The lowest GMR, NMR and B; C ratio was observed with cultivar M-35-1 (64704 Rs ha, 26204 Rs ha⁻¹ and 1.68), respectively.

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Productivity Dynamics and Economics of Soybean Genotypes Under Modified Paired Row Planting

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ABSTRACT

The field experiment titled “Response of different soybean (*Glycine max*) genotypes to modified paired-row planting” was carried out in a split-plot design with three replications and twelve treatment combinations consisting of four genotypes viz., Suvam soya (G_1), PDKV amba (G_2), MAUS-162 (G_3) and MAUS-158 (G_4) in main plot and three spacings 45×5 cm (S_1), $30\text{-}60 \times 5$ cm (S_2), $45\text{-}90 \times 5$ cm (S_3) in sub plot during the *Kharif* season of 2025 at the Farm Section of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, to evaluate the performance of new soybean genotypes under modified paired-row spacing. The results of the experiment revealed that among the genotypes, PDKV amba (G_2) found significantly superior in yield attributing characteristics and recorded highest number of pods plant⁻¹ (48.82), seed and straw yield (1821 and 2090 kg ha⁻¹, respectively) and found to be significantly superior over the other genotypes. Among the row spacings, paired-row spacing ($30\text{-}60 \times 5$ cm) produced significantly higher yield attributes and seed, straw yield and HI (44.98) over the single row planting. And also, higher GMR and B:C were observed in S_2 paired row planting i.e 1,01,927 Rs. ha⁻¹ and 2.01 respectively.

Soybean (*Glycine max* (L.) Merrill) has become one of the most important leguminous oilseed crops in the world. It is the second-largest source of edible oil after palm oil. It is known as the “golden bean” (Khader, 2019) and “miracle crop” (Chauhan *et al.* 1988) because it has a very high nutritional value, with about 20% oil, 35 to 40% protein, and 25 to 30% carbohydrates, as well as important polyunsaturated fatty acids, micronutrients, and isoflavones (Bueno *et al.* 2018). Soybean is important for the environment in addition with being useful for food and industry, such as animal feed, biofuels, and protein concentrates and other industries. It fixes 65 to 115 kg of atmospheric nitrogen per hectare per year through a symbiotic relationship with *Rhizobium japonicum* (Alexander, 1977). The crop leaves behind 25 to 30 kg of nitrogen per hectare after meeting its own growth needs. The residues it adds to the soil organic matter make it an essential part of sustainable cropping systems.

In India, the majority of the soybean crop in India is grown in *Kharif* season, with rainfed conditions. In 2024-25, the total area under soybean cultivation increased to 126.90 lakh hectares. A significant contribution is made by the Vidarbha region, which accounts for 19.21 lakh hectares, while the crop is grown on 50.72 lakh hectares in Maharashtra, where it has an

average productivity of 1170.13 kg ha⁻¹ (Anonymous, 2025). National productivity continues to be hindered by fluctuating agrometeorological conditions and suboptimal agronomic management, despite the fact that these expansions and continuous government incentives have been applied. To meet the demands of the future agricultural and industrial sectors, it is essential to increase the yield per hectare through strategic agronomic innovations. This will ensure that a growing population will have access to food security.

New soybean genotypes come with distinct physical traits and nutrient needs, using a single standard planting strategy rarely works across the board. Modern techniques like modified paired-row planting have proven useful for capturing more sunlight and cutting down weed competition, but there is still a significant gap in our understanding of how to use it properly with higher resource use efficiency. Getting this dynamic right is incredibly important because row spacing and field geometry are major, low-cost drivers of crop success. When row spacing is poorly managed, plants end up fiercely competing for moisture, soil nutrients, and sunlight. This intense competition triggers stress that can completely neglect the benefits of a specialized layout, especially when the environment is already dry or

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challenging. By fine-tuning spatial configurations to match specific plant varieties, we can dial back that inter-plant competition and ensure each crop actually reaches its maximum genetic yield. Ultimately, closing this knowledge gap is the best way to give farmers practical, region-specific advice that improves their harvests and supports long-term sustainable farming.

MATERIAL AND METHODS

The field experiment was conducted at the Organic Research Field, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Kharif* season of 2025. The experiment was laid out in a split-plot design with three replications, comprising twelve treatment combinations consisting of four genotypes (G_1 - Suvarn soya, G_2 - PDKV amba, G_3 - MAUS-162, G_4 - MAUS-158) and three row spacings (S_1 : 45×5 cm, S_2 : $30\text{-}60 \times 5$ cm, S_3 : $45\text{-}90 \times 5$ cm). The experimental soil was clayey and slightly alkaline in nature, characterized by an initial status of low available nitrogen (198 kg ha^{-1}), moderate available phosphorus (20.24 kg ha^{-1}), and high available potassium (328 kg ha^{-1}). The rainfall during the crop growing season was 1068.4 mm , spread over 45 rainy days mm.

The crop was sown on 2nd July 2025. Thinning and gap filling was done on time and other necessary practices like spraying, weeding, hoeing was carried out timely in the field to maintain the healthy plant stand in the field. Five random plants were selected from experimental plot to measure out different types of growth parameters observations in the experiments and five randomly selected plants were uprooted for recording the dry matter weight of plants. The obtained data was the analysed by analysis of variance Gomez and Gomez (1984).

RESULTS AND DISCUSSION

1. Effect on Yield

Genotypes

Significant variations were observed among genotypes across all growth and yield attributes. Genotype PDKV Amba (G_2) consistently outclassed all other genotypes, recording the maximum number of pods plant⁻¹ (48.82), yield plant⁻¹ (6.93 g), seed yield (1821 kg ha^{-1}), and harvest index (44.98 %). Suvarn Soya (G_1) ranked second across these traits, while MAUS-162 (G_3)

produced the lowest values. The superior seed yield of G_2 is directly credited to its enhanced yield-reproducing components (pods plant⁻¹ and individual plant yield), which served as the primary drivers of final grain productivity. These genetic variations are in close agreement with Ramgiry *et al.* (2014) and Singh *et al.* (2019).

Regarding straw yield, PDKV Amba (G_2) produced the highest biomass (2090 kg ha^{-1}), but was statistically at par with Suvarn Soya (G_1 ; 2019 kg ha^{-1}). Genotypes MAUS-162 (G_3) and MAUS-158 (G_4) produced significantly lower straw yields but were mutually at par with each other. For harvest index, G_2 exhibited significant superiority, highlighting its high capacity for efficient dry matter partitioning from source to sink. G_1 and G_4 were statistically at par, while G_3 recorded the lowest partitioning efficiency, conforming with trends reported by Waghmare *et al.* (2019).

Row spacings

Row spacing exerted a highly significant influence on both individual plant attributes and total per-hectare yield. Interestingly, the wide paired row spacing $45\text{-}90 \times 5 \text{ cm}$ (S_3) registered the maximum number of pods plant⁻¹ (45.73) and yield plant⁻¹ (6.60 g), followed by S_2 , while the normal spacing $45 \times 5 \text{ cm}$ (S_1) recorded the lowest. This enhancement in individual plant performance under wider rows (S_3) is due to minimized spatial competition, allowing greater resource availability per plant.

However, this individual superiority did not translate to area-scale yields due to lower plant density per unit area. Consequently, the paired row spacing $30\text{-}60 \times 5 \text{ cm}$ (S_2) produced the highest total seed yield (1829 kg ha^{-1}) and straw yield (2166 kg ha^{-1}), establishing distinct statistical superiority over S_1 (1640 and 2024 kg ha^{-1} , respectively), while S_3 fell to the lowest position (1339 and 1796 kg ha^{-1} , respectively). This demonstrates that S_2 provides an optimal spatial configuration that balances adequate plant populations with efficient canopy geometry, corroborating Kelly *et al.* (2023) and Singh *et al.* (2023).

The harvest index was also significantly maximized under S_2 (43.56 percent), whereas S_1 (42.10

%) and S_3 (41.05 %) remained statistically at par with each other. This indicates that the 30-60 x 5 cm paired row arrangement optimizes microclimate interception, enhancing post-flowering dry matter allocation toward the grains, which aligns with Verma *et al.* (2020).

2. Effect on Economics

Genotypes

Data presented in the table reveal that the cost of cultivation did not vary significantly among the genotypes, indicating uniform expenditure across all varieties. However, gross monetary returns, net monetary returns, and the benefit-to-cost ratio (B:C ratio) were significantly influenced by the genotypes. Genotype PDKV Amba (G_2) recorded the highest gross monetary returns (101927 Rs. ha⁻¹) and net monetary returns (51388 Rs. ha⁻¹), proving distinctly superior to all other varieties. This was followed by Suvarn Soya (G_1), which secured gross returns of 90825 Rs. ha⁻¹ and net returns of 39775 Rs. ha⁻¹. Conversely, MAUS-162 (G_3) recorded the lowest gross and net monetary returns. The economic efficiency,

expressed as the B:C ratio, followed a similar trend. Genotype PDKV Amba (G_2) registered the highest B:C ratio (2.01), which was significantly superior to the remaining genotypes, followed by Suvarn Soya (G_1) with a ratio of 1.78. The lowest B:C ratio was noted in MAUS-162 (G_3) with 1.61. The higher economic profitability of PDKV Amba (G_2) is directly attributed to its superior seed and straw yield performance, which maximized overall returns against a statistically static production cost.

Row spacings

Row spacing variations exerted a highly significant impact on all evaluated economic parameters. The cost of cultivation differed statistically among the regimes, with the paired row spacing of 30-60 x 5 cm (S_2) incurring the maximum expenditure (51656 Rs. ha⁻¹), followed closely by the normal spacing of 45 x 5 cm (S_1) at 51372 Rs. ha⁻¹. The wide paired row spacing of 45-90 x 5 cm (S_3) recorded the lowest cost of cultivation (49521 Rs. ha⁻¹).

Despite its slightly higher production cost, the

Table 1. Yield components of soybean as influenced by different treatments

Treatment	No. of pods plant ⁻¹	Yield Plant ⁻¹ (g)	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)
Genotypes (G)					
G_1 - Suvarn Soya	43.64	6.38	1616	2019	42.26
G_2 - PDKV Amba	48.82	6.93	1821	2090	44.98
G_3 - MAUS-162	38.49	5.98	1467	1979	39.83
G_4 - MAUS-158	42.18	6.08	1505	1893	41.88
SE(m) ±	1.05	0.11	40.90	34.65	0.91
CD at 5%	3.62	0.38	141.52	119.89	3.14
Row Spacings (S)					
S_1 (45 × 5 cm)	40.28	6.00	1640	2024	42.10
S_2 (30-60 × 5 cm)	43.83	6.43	1829	2166	43.56
S_3 (45-90 × 5 cm)	45.73	6.60	1339	1796	41.05
SE(m) ±	0.90	0.08	27.49	17.01	0.58
CD at 5%	2.71	0.23	82.41	51.00	1.73
Interaction (G × S)					
SE(m) ±	1.81	0.15	54.97	34.02	1.16
CD at 5%	-	-	-	-	-
GM	43.28	6.34	1602	1995	42.24

paired row spacing of 30–60 x 5 cm (S_2) generated the highest gross monetary returns (102526 Rs. ha⁻¹) and net monetary returns (50870 Rs. ha⁻¹), outperforming S_1 and S_3 by a wide margin. The normal row spacing (S_1) gave intermediate returns, while the wide paired row configuration (S_3) produced the lowest gross (75523 Rs. ha⁻¹) and net (26002 Rs. ha⁻¹) monetary returns.

In terms of profitability, the maximum B:C ratio was recorded under S_2 (1.98), demonstrating significant superiority over S_1 (1.79) and S_3 (1.53). This confirms that the 30–60 x 5 cm paired row geometry optimizes resource utilization and increases per-hectare grain and biomass yields sufficiently to override its minor increase in input costs, making it the most economically viable configuration.

CONCLUSION

Based on the experimental findings, it is concluded that selecting the genotype PDKV Amba (G_2) and adopting the paired row spacing of 30–60 x 5 cm (S_2) is the most effective approach to maximize soybean productivity and profitability.

While wider row spacing (45–90 x 5 cm) enhances individual plant attributes like pods per plant due to reduced competition, it fails to optimize area-scale production. The 30–60 x 5 cm paired row geometry strikes the ideal balance by maintaining an optimal plant population, maximizing seed yield (1829 kg ha⁻¹), and capturing the highest net monetary returns (50870 Rs. ha⁻¹) with a superior B:C ratio of 1.98.

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Evaluation of Newer Insecticides Against Insect Pests of Sunflower

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ABSTRACT

The present investigation, entitled “Evaluation of Newer Insecticides against Major Insect Pests of Sunflower”, was undertaken with objectives to study the efficacy of newer insecticides against sucking pests and defoliators of the sunflower crop, effect of insecticides on natural enemies and honey bees. The experiment was conducted in the Research Field of Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *kharif* 2022. The different Newer insecticides were used, Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg and Imidacloprid 48 FS @ 8 ml/kg were found equally effective for the control of thrips, leafhoppers and whiteflies. At 30 days after germination, it was observed that, necrosis per cent was lowest in insecticidal treatment as compare to untreated plot. Foliar spray of Diafenthiuron 50 WP @ 600 g ha⁻¹ (T₆) recorded minimum population of thrips, leafhoppers and whiteflies i.e., 0.57 nymphs 6L⁻¹ plant⁻¹, 1.00 nymphs 6L⁻¹ plant⁻¹ and 0.33 adults 6L⁻¹ plant⁻¹. Foliar spray of Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) recorded a maximum, i.e., 91.15 per cent, reduction in larval population of *Spodoptera litura* at 30 days after spraying. Foliar spray of Emamectin benzoate 5%+ Lufenuran 40% WG @ 60 g/ha (T₂) recorded a maximum, i.e., 92.41 per cent reduction in larval population of *H. armigera* at 30 days after spraying, Numerically more number of ladybird beetles plant⁻¹ was recorded in untreated plot as compared to treated plots. It was noticed that, honey bees visited more to untreated plots as compared to treated plots. The highest grain yield was recorded in seed treatment with Imidacloprid 48 FS @ 8 ml kg⁻¹; foliar spray of Emamectin benzoate 5% + Lufenuran 40% WG @ 60g (1196 kg ha⁻¹) Seed treatment with Imidacloprid 48 FS @ 8 ml kg⁻¹; foliar spray of Emamectin benzoate 5% + Lufenuran 40% WG @ 60g (T₂) treatment found cost effective, recorded the highest ICBR of 1:5.04 as compare to other treatment.

Sunflower is an important oilseed crop in the world, as it ranks third in the area after soybean and groundnut. Sunflower oil is a rich source of linoleic acid (64 per cent), which helps reduce cholesterol deposition in the coronary arteries of the heart and is thus good for heart patients. The oil is used for culinary purposes, in the manufacture of paints, soaps, cosmetics and for the preparation of margarine. Sunflower contains 32 to 44 per cent oil, 18 to 22 per cent carbohydrates, 20 to 24 per cent vitamins and 4 to 6 per cent salts (Jadhav *et al.* 2020). The crop is now grown in India over an area of 1.48 million hectares, with a production of 185 thousand metric tonnes. The state with the highest production is Karnataka i.e., 3.04 lakh tonnes from an area of 7.94 lakh hectares, followed by Andhra Pradesh, Maharashtra, Bihar, Orissa and Tamil Nadu, are major sunflower-producing states of India.

Currently, a variety of newer insecticides belonging to different classes are available for pest control. The development strategy for creating new pesticides has

been as development of pesticides that, are effective at an extremely low dosage; development of pesticides that, are readily degradable and less residual in the environment and development of selective toxic agrochemicals. The first strategy resulted in a remarkable decrease in the active ingredient required for the control of pest insects, fungi, mites, nematodes and weeds and eventually brought about a reduction in the load of pesticides on the environment. The second strategy realized the remarkable lowering of pesticide residue levels in crops and the environment. The third strategy, to seek a compound that, is effective in targeting only organisms such as insects, fungi, mites, nematodes, and weeds but not toxic to non-target organisms such as humans and beneficial organisms, was a tool for finding safer and more environmentally friendly pesticides. These development strategies have become increasingly prominent. The effects of pesticides on the natural enemies of pests are well documented. So today, it is increasingly desirable to intervene with insecticidal compounds that can act in harmony with predators and

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parasitoids, or at least reduce the effects against natural enemies and honey bees and it is possible with the use of novel insecticides. Hence, an attempt has been made to study the evaluation of newer insecticides having a unique mode of action against major insect pests of sunflowers, their effect on natural enemies and the activity of honey bees on sunflowers.

MATERIAL AND METHODS

The experiment was conducted in the Research Field of Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *kharif* 2022. The different Newer insecticides were used, where Thiamethoxam 30 FS @ 10 ml/kg, Imidacloprid 48 FS @ 8 ml kg⁻¹ were applied as seed treatments, Diafenthiuron 50 WP @ 600 g ha⁻¹ and Dimethoate 30 EC @ 800 ml ha⁻¹ were applied as foliar sprays for the control of sucking pests. Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹, Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml/ha, Flubendiamide 19.92% + thiacloprid 480 SC @ 200 ml/ha were applied as foliar sprays for control of both sucking and lepidopteran pests, whereas Emamectin benzoate 5% + Lufenuron 40% WG @ 60g, Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml ha⁻¹, Emamectin benzoate 1.9 EC @ 425 ml ha⁻¹, Lufenuron 5.4 EC @ 500 ml ha⁻¹, Profenofos 50 EC @ 1000 ml/ha and Cypermethrin 10% EC @ 500 ml ha⁻¹ were applied as foliar sprays for control of only lepidopteran pests and one treatment was maintained as an untreated control. The observations were recorded on nymphal counts of thrips, whiteflies, leafhoppers and larval populations of *Spodoptera litura* and *Helicoverpa armigera*, as well as adult counts of natural enemies from ten tagged plants from each plot, which were randomly selected. The population of honey bees was recorded on five randomly selected flower heads from tagged plants in each plot for 5 minutes at flowering. The results obtained from the present investigation are summarized here.

RESULTS AND DISCUSSION

Assessing seed treatment effect against sucking pests

Data given in table 1 revealed that, seed treatment (ST) with Thiamethoxam 30 FS @ 10 ml kg⁻¹ and seed treatment with Imidacloprid 48 FS @ 8 ml kg⁻¹ showed a significant difference over the plots without seed

treatment. Among the seed-treated plots, non-significant difference was observed.

Assessing foliar spray effect against sucking pests.

Thrips at 20 DAS

Foliar spray of Diafenthiuron 50 WP @ 600 g ha⁻¹ (T₆) recorded minimum, i.e., 1.17 nymphs 6L⁻¹ plant⁻¹ at 20 days after spraying, followed by Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹ (T₁) (1.30 nymphs 6L⁻¹ plant⁻¹), Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) (1.37 nymphs 6L⁻¹ plant⁻¹) and these treatments were at par with Diafenthiuron 50 WP @ 600 g ha⁻¹ (T₆). Next effective treatment was Flubendiamide 19.92% + thiacloprid 19.92 per cent 480 SC @ 200 ml ha⁻¹ (T₄) (1.97 nymphs 6 L⁻¹ plant⁻¹), which was at par with Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹ (T₁) (Table 2).

Leafhoppers at 20 DAS

The observation recorded at 20 days after spraying given in table 7 and fig. 7 revealed that, foliar spray of Diafenthiuron 50 WP @ 600 g ha⁻¹ (T₆) recorded a minimum, i.e., 1.53 nymphs 6L⁻¹ plant⁻¹, followed by Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹ (T₁) (1.83 nymphs 6L⁻¹ plant⁻¹), Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) (2.07 nymphs 6L⁻¹ plant⁻¹) and Flubendiamide 19.92% + thiacloprid 19.92% 480 SC @ 200 ml ha⁻¹ (T₄) (2.23 nymphs 6L⁻¹ plant⁻¹), these treatments were at par with Diafenthiuron 50 WP @ 600 g ha⁻¹ (T₆), followed by Dimethoate 30 EC @ 800 ml ha⁻¹ (T₈) (3.00 nymphs 6L⁻¹ plant⁻¹) (Table 2).

Whiteflies at 20 DAS

The observation recorded at 20 days after spraying revealed that, the foliar spray of Diafenthiuron 50 WP @ 600 g ha⁻¹ (T₆) recorded a minimum, i.e., 0.67 adults 6L⁻¹ plant⁻¹, followed by Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹ (T₁) (0.77 adults 6L⁻¹ plant⁻¹) and Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) (0.97 adults 6L⁻¹ plant⁻¹) and these treatments were at par with Diafenthiuron 50 WP @ 600 g ha⁻¹ (T₆). Next was Flubendiamide 19.92% + Thiacloprid 19.92% 480 SC @ 200 ml ha⁻¹ (T₄) (1.27 adults 6L⁻¹ plant⁻¹), which was at par with Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) and Dimethoate 30 EC @ 800 ml ha⁻¹ (T₈) (1.53 adults 6L⁻¹ plant⁻¹) (Table 2).

Table 1. Effect of seed treatment against sucking pests and Necrosis

Treatment	Thrips (Nymphs/6L/ Plant)			Leafhoppers (Nymphs/ 6L/Plant)			Whiteflies (Adults/ 6L/Plant)			Necrosis infected plants		
	At 15	At 30	DAS	At 15	At 30	DAS	At 15	At 30	DAS	At 30	At 30	DAS
	DAS	DAS	DAS	DAS	DAS	DAS	DAS	DAS	DAS	DAS	DAS	DAS
T ₁	1.87 (1.34)*	2.33 (1.52)*		2.53 (1.59)*	2.67 (1.63)*		1.73 (1.31)*	2.70 (1.63)*		1.23 (1.11)*		
T ₂	2.03 (1.42)	2.93 (1.70)		2.80 (1.67)	3.47 (1.86)		1.90 (1.37)	3.50 (1.87)		1.07 (1.03)		
T ₃	1.73 (1.31)	2.83 (1.68)		2.80 (1.67)	2.60 (1.59)		1.93 (1.22)	2.63 (1.60)		1.13 (1.04)		
T ₄	2.00 (1.39)	2.43 (1.52)		2.30 (1.52)	2.87 (1.69)		1.50 (1.38)	2.60 (1.61)		1.30 (1.12)		
T ₅	2.30 (1.51)	2.80 (1.67)		2.87 (1.67)	3.47 (1.86)		2.00 (1.41)	3.50 (1.87)		1.33 (1.15)		
T ₆	2.40 (1.54)	2.57 (1.60)		2.93 (1.70)	3.03 (1.74)		1.80 (1.33)	2.97 (1.72)		0.90 (0.94)		
T ₇	2.17 (1.46)	3.10 (1.76)		2.97 (1.72)	3.60 (1.90)		1.67 (1.29)	2.63 (1.62)		1.07 (1.03)		
T ₈	3.63 (1.91)	3.87 (1.96)		4.23 (2.06)	4.73 (2.17)		3.57 (1.88)	4.47 (2.11)		1.33 (1.15)		
T ₉	2.50 (1.58)	3.07 (1.75)		2.83 (1.68)	3.60 (1.89)		1.93 (1.39)	3.20 (1.78)		1.30 (1.14)		
T ₁₀	4.37 (2.09)	5.23 (2.29)		5.67 (2.37)	6.80 (2.60)		5.00 (2.23)	6.00 (2.45)		2.17 (1.47)		
SE (m) ±	0.10	0.10		0.10	0.11		0.10	0.10		0.07		
CD at 5 %	0.31	0.31		0.31	0.32		0.27	0.27		0.21		
CV (%)	11.61	10.26		10.16	9.70		8.55	8.65		11.04		

* Figures given in the parenthesis are square root transformed values

Table 2. Effect of foliar spray against Sucking pests

Treatment	Thrips (Nymphs/ 6L/Plant)	Leafhoppers (Nymphs/ 6L/Plant)	Whiteflies (Adults/6L /Plant)
	20 DAS	20 DAS	20 DAS
T1 Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Cyantraniliprole 10.26 OD @ 600 ml/ha	1.30 (1.13)*	1.83 (1.35)*	0.77 (0.85)*
T2 Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Emamectin benzoate 5 % + Lufenuran 40 % WG @ 60g.	3.17 (1.78)	3.17 (1.77)	2.50 (1.58)
T3 Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Chlorantraniliprole 9.3 % + L-cyhalothrin 4.6 % ZC @ 120 ml/ha	1.37 (1.17)	2.07 (1.42)	0.97 (0.96)
T4 Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Flubendiamide 19.92 % + thiacloprid 480 SC @ 200 ml/ha	1.97 (1.40)	2.23 (1.48)	1.27 (1.12)
T5 Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml/ha	3.50 (1.87)	3.27 (1.81)	2.57 (1.60)
T6 Seed treatment with Thiamethoxam 30 FS @ 10ml/kg; foliar spray of Diafenthuron 50 WP @ 600 g/ha for sucking pests and Emamectin benzoate 1.9 EC @ 425 ml/ha	1.17 (1.08)	1.53 (1.24)	0.67 (0.80)
T7 Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Lufenuron 5.4 EC @ 500 ml/ha.	3.70 (1.92)	3.17 (1.77)	2.70 (1.64)
T8 Foliar spray of Dimethoate 30 EC @ 800 ml/ha for sucking pests, foliar spray of Profenofos 50 EC @ 1000 ml/ha.	2.93 (1.71)	3.00 (1.73)	1.53 (1.24)
T9 Seed Treatment with imidacloprid 48 FS @ 8ml/kg; foliar spray of Cypermethrin 10% EC @ 500ml/ha.	3.73 (1.93)	3.90 (1.97)	3.70 (1.91)
T10 Untreated control	6.03 (2.46)	6.37 (2.52)	5.47 (2.34)
SE (m) ±	0.11	0.10	0.08
CD at 5 %	0.31	0.29	0.25
CV (%)	11.16	9.87	10.28

* Figures given in the parenthesis are square root transformed values

Assessing foliar spray effect against lepidopteran pests

Effect of foliar spray of insecticides against *Spodoptera litura*

At 10 DAS

Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml/ha (T_3) recorded highest .i.e., 71.67 per cent reduction in larval population at 10 days after spraying. Followed by Emamectin benzoate 5% + Lufenuran 40% WG @ 60 g ha⁻¹ (T_2) (66.03%), Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml ha⁻¹ (T_5) (59.76%),

Flubendiamide 19.92% + thiacloprid 19.92% 480 SC @ 200 ml ha⁻¹ (T_4) (58.33%) and Lufenuron 5.4 EC @ 500 ml ha⁻¹ (T_7) (58.33%), which were at par with the superior one, Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T_3). The next effective treatments were Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹ (T_1) (55.69%), Emamectin benzoate 1.9 EC @ 425 ml ha⁻¹ (T_6) (55.00%), Profenofos 50 EC @ 1000 ml ha⁻¹ (T_8) (53.00%), Cypermethrin 10% EC @ 500 ml ha (T_9) (52.93%), which were at par with Emamectin benzoate 5%+ Lufenuran 40% WG @ 60 g ha⁻¹ (T_2) (Table 3).

Table 3. Effect of treatment against *Spodoptera litura*

Treatments	<i>S.litura</i> (Larvae plant ⁻¹)	<i>S.litura</i> (Per cent larval reduction)	
		BS	10 DAS 20 DAS
T ₁ Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Cyantraniliprole 10.26 OD @ 600 ml/ha	2.20 (1.47)*	55.69 (48.28)**	75.13 (60.35)**
T ₂ Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Emamectin benzoate 5 % + Lufenuran 40 % WG @ 60g.	2.43 (1.56)	66.03 (54.40)	7.33 (61.64)
T ₃ Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Chlorantraniliprole 9.3 % + L-cyhalothrin 4.6 % ZC @ 120 ml/ha	2.47 (1.57)	71.67 (57.86)	82.78 (65.90)
T ₄ Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Flubendiamide 19.92 % + thiacloprid 480 SC @ 200 ml/ha	2.10 (1.45)	58.33 (49.89)	76.11 (60.90)
T ₅ Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml/ha	2.33 (1.53)	59.76 (50.72)	76.30 (60.91)
T ₆ Seed treatment with Thiamethoxam 30 FS @ 10ml/kg; foliar spray of Diafenthiuron 50 WP @ 600 g/ha for sucking pests and Emamectin benzoate 1.9 EC @ 425 ml/ha	2.03 (1.41)	55.00 (47.89)	74.00 (60.11)
T ₇ Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Lufenuron 5.4 EC @ 500 ml/ha.	2.13 (1.46)	58.33 (49.89)	75.47 (60.67)
T ₈ Foliar spray of Dimethoate 30 EC @ 800 ml/ha for sucking pests, foliar spray of Profenofos 50 EC @ 1000 ml/ha.	2.23 (1.49)	53.00 (46.75)	73.08 (58.91)
T ₉ Seed Treatment with imidacloprid 48 FS @ 8ml/kg; foliar spray of Cypermethrin 10% EC @ 500ml/ha.	2.33 (1.52)	52.93 (46.69)	70.29 (57.03)
T ₁₀ Untreated control	3.43 (1.85)	23.61 (28.85)	30.45 (33.43)
SE (m) ± -	2.87	3.40	
CD at 5 % -	8.51	10.11	
CV (%) -	10.31	10.17	

*Figures given in the parenthesis are square root transformed values

**Figures given in the parenthesis are arc sin transformed values

At 20 DAS

Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) recorded the maximum, i.e., 82.78 per cent, reduction in larval population at 20 days after spraying, followed by Emamectin benzoate 5%+ Lufenuran 40% WG @ 60 g ha⁻¹ (T₂) (77.33%), Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml ha⁻¹ (T₅) (76.30%), Flubendiamide 19.92% + thiacloprid 19.92% 480 SC @ 200 ml ha⁻¹ (T₄) (76.11%), Lufenuron 5.4 EC @ 500 ml ha⁻¹ (T₇) (75.47%), Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹ (T₁) (75.13%), Emamectin benzoate 1.9 EC @ 425 ml ha⁻¹ (T₆) (74.00%), Profenofos 50 EC @ 1000 ml ha⁻¹

(T₈) (73.08%), Cypermethrin 10% EC @ 500 ml ha⁻¹ (T₉) (70.29%) which were at par with Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) (Table 3).

Effect of foliar spray of insecticides against head borer (*Helicoverpa armigera*)**At 10 DAS**

Emamectin benzoate 5%+ Lufenuran 40% WG @ 60 g ha⁻¹ (T₂) recorded the highest i.e., 76.42 per cent reduction in larval population at 10 days after spraying, followed by foliar spray of Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹ (T₁) (67.15%), Novaluran 5.25 + Indoxacarb

Table 4. Effect of treatment against head borer (*Helicoverpa armigera*)

Treatment	Head borer (Larvae/plant)	Head borer (Per cent larval reduction)	
		BS	10DAS 20DAS
T ₁ Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Cyantraniliprole 10.26 OD @ 600 ml/ha	1.67 (1.29)*	67.15 (55.09)**	84.74 (67.26)**
T ₂ Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Emamectin benzoate 5 % + Lufenuran 40 % WG @ 60g.	1.27 (1.12)	76.42 (60.95)	86.36 (68.38)
T ₃ Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Chlorantraniliprole 9.3 % + L-cyhalothrin 4.6 % ZC @ 120 ml/ha	1.30 (1.14)	64.96 (53.72)	78.57 (62.81)
T ₄ Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Flubendiamide 19.92 % + thiacloprid 480 SC @ 200 ml/ha	1.50 (1.22)	65.74 (54.31)	80.88 (64.17)
T ₅ Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml/ha	1.93 (1.39)	66.58 (54.84)	81.82 (65.04)
T ₆ Seed treatment with Thiamethoxam 30 FS @ 10ml/kg; foliar spray of Diafenthiuron 50 WP @ 600 g/ha for sucking pests and Emamectin benzoate 1.9 EC @ 425 ml/ha	1.77 (1.32)	64.34 (53.34)	78.25 (62.24)
T ₇ Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Lufenuron 5.4 EC @ 500 ml/ha.	2.00 (1.40)	65.35 (54.06)	80.04 (63.71)
T ₈ Foliar spray of Dimethoate 30 EC @ 800 ml/ha for sucking pests, foliar spray of Profenofos 50 EC @ 1000 ml/ha.	1.43 (1.20)	63.94 (53.51)	77.22 (62.29)
T ₉ Seed Treatment with imidacloprid 48 FS @ 8ml/kg; foliar spray of Cypermethrin 10% EC @ 500ml/ha.	2.67 (1.63)	63.11 (52.69)	74.44 (60.16)
T ₁₀ Untreated control	3.17 (1.78)	18.93 (25.75)	40.38 (39.41)
SE (m) ±		3.1	3.32
CD at 5 %		9.22	9.87
CV (%)		10.37	9.35

* Figures given in the parenthesis are square root transformed values

**Figures given in the parenthesis are arc sin transformed values

4.5 SC @ 850 ml ha⁻¹ (T₅) (66.58%), Flubendiamide 19.92% + thiacloprid 19.92% 480 SC @ 200 ml ha⁻¹ (T₄) (65.74%), Foliar spray of Lufenuron 5.4 EC @ 500 ml ha⁻¹ (T₇) (65.35%), Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) (64.96%), Profenofos 50 EC @ 1000 ml ha⁻¹ (T₈) (63.94%), Emamectin benzoate 1.9 EC @ 425 ml ha⁻¹ (T₆) (64.34%), Cypermethrin 10% EC @ 500 ml ha⁻¹ (T₉) (63.11%) (Table 4).

At 20 DAS

Data given in table 4 revealed that, Emamectin benzoate 5%+ Lufenuran 40% WG @ 60 g ha⁻¹ (T₂) recorded the maximum, i.e., 86.36 per cent reduction in larval population at 20 days after spraying, followed by foliar spray of Cyantraniliprole 10.26 OD @ 600 ml ha⁻¹ (T₁) (84.74%), Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml ha⁻¹ (T₅) (81.82%), Flubendiamide 19.92% + thiacloprid 19.92% 480 SC @ 200 ml ha⁻¹ (T₄) (80.88%),

Foliar spray of Lufenuron 5.4 EC @ 500 ml ha⁻¹ (T₇) (80.04%), Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ (T₃) (78.57%), Emeactin benzoate 1.9 EC @ 425 ml ha⁻¹ (T₆) (78.25%), Profenofos 50 EC @ 1000 ml ha⁻¹ (T₈) (77.22%), Cypermethrin 10% EC @ 500 ml ha⁻¹ (T₉) (74.44%) which were at par with Emeactin benzoate 5%+ Lufenuran 40% WG @ 60 g ha⁻¹ (T₂).

Effects of Insecticides on population of Ladybird beetles

At Star Bud Stage of Crop

Non- significant differences were observed among the treatments at 20 days after spraying. The population of ladybird beetles was observed in the range of 0.27 to 0.53 plant⁻¹. However, a numerically higher number of ladybird beetles, i.e., 0.90 plant⁻¹, was recorded in the untreated plot. There was a significant difference between the treated and untreated plots (Table 5).

At Flowering Stage of Crop

The population of ladybird beetles was not found uniform over the plots, whereas the population of ladybird beetles in untreated plot was observed more than the treated plots (Table 5).

Effect of insecticides on foraging of honey bees

The population of honey bees was not uniform across the experimental plots. However, based on the data given in Table 13 and Figure 13, we noticed that, honey bees visited more to untreated plots as compared to treated plots (Table 5).

Grain Yield (kg ha⁻¹) and Incremental Cost-Benefit Ratio (ICBR)

The data presented in Table 6 revealed that, the grain yield of sunflower obtained from all the plots, including the untreated control, ranged from 940 to 1196.58 kg ha⁻¹. The highest grain yield was recorded in seed treatment with Imidacloprid 48 FS @ 8 ml kg⁻¹; foliar spray of Emeactin benzoate 5% + Lufenuran 40% WG @ 60g (1196.58 kg ha⁻¹) and found economical having ICBR of 1:5.04

The present findings are in close conformity with the findings of Ingale *et al.* 2019^b who suggested that, imidacloprid 0.003 per cent was the most effective

treatment in reducing the population of leafhoppers, followed by thiamethoxam 0.005 per cent in sunflower. Ingale *et al.* 2019^a found that, imidacloprid (0.003 %) was the most effective treatment in reducing the population of whiteflies in sunflower crop. Zhang *et al.* (2010) suggested that, the thiamethoxam and imidacloprid seed treatments against whiteflies of cotton caused whitefly adult mortality, reduced oviposition and increased mortality of nymphs at 10, 20, 30 and 40 days after germination. El-Naggar and Zidan (2013) found that, the seed treatment with imidacloprid 70 WS (7 g kg⁻¹ seed) and thiamethoxam 70 WS (2 g kg⁻¹ seed) protected cotton seedlings from thrips for at least 6 weeks after sowing. Hossain *et al.* (2013) reported that, the seed treatment with imidacloprid (5.5 g kg⁻¹ seed) significantly reduced the population of aphids, whiteflies and thrips in cotton crop. Ding *et al.* (2018) revealed that, among the tested neonicotinoid seed treatments, thiamethoxam (1.0 and 2.0 g active ingredient (AI) kg⁻¹ of seeds), clothianidin (1.0 and 2.0 g AI kg⁻¹ of seeds) and imidacloprid (2.0 g AI kg⁻¹ of seeds) showed the highest control efficacy against corn thrips throughout the corn growing season. Through observation, it is concluded that, both insecticides as a seed treatment provide protection to crop from sucking pests up to 25 days after germination.

The foliar spray of Diafenthiuron 50 WP @ 600 g ha⁻¹ was most effective for controlling the population of thrips, leafhoppers and whiteflies at 10, 20, 30 and 45 days after spraying. The lowest nymphal population of thrips and leafhoppers recorded was 0.57, 1.00 and that of whiteflies, adult population recorded was 0.33 plant⁻¹ respectively, at 45 days after spraying. These findings obtained support from Huded *et al.* (2019), who evaluated & reported that, diafenthiuron 50% WP @ 1 g l⁻¹ was found to be the best and most effective against whiteflies in sunflower. Asi *et al.* (2008) evaluated the efficacy of different insecticides against whitefly, leafhopper and thrips on cotton and found that, diafenthiuron 500 SC (polo) were highly effective. Bharpoda *et al.* (2014) reported that, among the different insecticides, diafenthiuron 50 WP @ 0.05% recorded the lowest thrip count, in cotton. Stanley *et al.* (2010) revealed that, diafenthiuron 50 WP alone has recorded a 52.77 per cent reduction. Kalyan *et al.* (2017) found that, maximum reduction in the leafhopper population and population of

Table 5. Effect of treatments against Ladybird beetle and Honey bees

Treatments	Ladybird beetle (Adult plant ⁻¹)		Honey bee count
	At Star Bud Stage	At Flowering Stage	At Flowering
T1 Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Cyantraniliprole 10.26 OD @ 600 ml/ha	0.33 (0.57)*	0.03 (0.73)*	0.00 (0.71)*
T2 Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Eamectin benzoate 5 % + Lufenuran 40 % WG @ 60g.	0.43 (0.66)	0.13 (0.80)	0.07 (0.75)
T3 Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Chlorantraniliprole 9.3 % + L-cyhalothrin 4.6 % ZC @ 120 ml/ha	0.37 (0.60)	0.07 (0.75)	0.13 (0.80)
T4 Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Flubendiamide 19.92 % + thiacloprid 480 SC @ 200 ml/ha	0.27 (0.50)	0.00 (0.71)	0.00 (0.71)
T5 Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml/ha	0.53 (0.73)	0.07 (0.75)	0.20 (0.84)
T6 Seed treatment with Thiamethoxam 30 FS @ 10ml/kg; foliar spray of Diafenthiuron 50 WP @ 600 g/ha for sucking pests and Eamectin benzoate 1.9 EC @ 425 ml/ha	0.30 (0.54)	0.00 (0.71)	0.13 (0.79)
T7 Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Lufenuron 5.4 EC @ 500 ml/ha.	0.30 (0.54)	0.00 (0.71)	0.07 (0.75)
T8 Foliar spray of Dimethoate 30 EC @ 800 ml/ha for sucking pests, foliar spray of Profenofos 50 EC @ 1000 ml/ha.	0.37 (0.60)	0.00 (0.71)	0.00 (0.71)
T9 Seed Treatment with imidacloprid 48 FS @ 8ml/kg; foliar spray of Cypermethrin 10% EC @ 500ml/ha.	0.40 (0.63)	0.00 (0.71)	0.13 (0.80)
T10 Untreated control	0.90(0.95)	0.37(0.92)	0.23(0.86)
SE (m) ±	0.06	0.03	0.06
CD at 5 %	0.19	0.10	0.20
CV (%)	17.32	7.96	18.38

* Figures in the parenthesis indicate "X+0.5 square root transformed values

whiteflies was recorded in diafenthiuron 50 WP @ 300g a.i. ha⁻¹ at 3rd, 5th and 7th days after the first spray.

The foliar spray of Chlorantraniliprole 9.3% + L-cyhalothrin 4.6% ZC @ 120 ml ha⁻¹ was found most effective for the control of the larval population of *Spodoptera litura*. The highest larval reduction of *Spodoptera litura* was obtained at 45 days after spraying. This result found close conformity with the findings of Floret and Regupathy (2018), who assessed the bio-

efficacy of Ampligo 150 ZC (chlorantraniliprole 9.3% + lambdacyhalothrin 4.6%) against leaf-eating caterpillars in tomato and found that, chlorantraniliprole 9.3% w/w + lambdacyhalothrin 4.6% w/w 150 was the most effective.

The foliar spray of Eamectin benzoate 5%+ Lufenuran 40% WG @ 60 g ha⁻¹ was most effective for the control of the larval population of *Helicoverpa armigera*. The highest larval reduction of *Helicoverpa armigera* was obtained 45 days after spraying. This result

Table 6. Influence of Insecticides on Grain yield and Cost Economics of Sunflower during *Kharif* 2022

Treatment Details		Yield (kg/ ha)	Cost of treatments	Yield increased over control	Increment of Benefit	ICBR
T ₁	Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Cyantraniliprole 10.26 OD @ 600 ml/ha	1111.11	13287	171	10282	1:0.77
T ₂	Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Emamectin benzoate 5 % + Lufenuron 40 % WG @ 60g.	1196.58	3060	256	15423	1:5.04
T ₃	Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Chlorantraniliprole 9.3 % + L-cyhalothrin 4.6 % ZC @ 120 ml/ha	1168.09	4438	228	13709	1:3.09
T ₄	Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Flubendiamide 19.92 % + thiacloprid 480 SC @ 200 ml/ha	1139.6	5277	199	11996	1:2.27
T ₅	Seed treatment with Imidacloprid 48 FS @ 8 ml/kg; foliar spray of Novaluran 5.25 + Indoxacarb 4.5 SC @ 850 ml/ha	1082.62	2320	142	8568	1:3.69
T ₆	Seed treatment with Thiamethoxam 30 FS @ 10ml/kg; foliar spray of Diafenthuron 50 WP @ 600 g/ha for sucking pests and Emamectin benzoate 1.9 EC @ 425 ml/ha	1111.11	5120	171	10282	1:2.01
T ₇	Seed treatment with Thiamethoxam 30 FS @ 10 ml/kg; foliar spray of Lufenuron 5.4 EC @ 500 ml/ha.	1054.13	7059	114	6855	1:0.97
T ₈	Foliar spray of Dimethoate 30 EC @ 800 ml/ha for sucking pests, foliar spray of Profenofos 50 EC @ 1000 ml/ha.	997.15	3326	57	3427	1:1.03
T ₉	Seed Treatment with imidacloprid 48 FS @ 8ml/kg; foliar spray of Cypermethrin 10% EC @ 500ml/ha.	1105.00	3044	165	9915	1:3.26
T ₁₀	Untreated control	940	0	0	0	0.00

found close conformity with the findings of Prakash *et al.* (2020), who reported that, emamectin benzoate 5%+ lufenuron 40% WG at 60 and 70 g ha⁻¹ recorded the lowest populations of *Helicoverpa armigera* after 7 days of spraying. Pod damage due to the larvae of *Helicoverpa armigera* and *Maruca vitrata* was significantly lower in the treatment emamectin benzoate 5% + lufenuron 40% WG at 70 g/ha, followed by lufenuron 5.4% EC. The test product was found to be safe for natural enemies. Further, emamectin benzoate 5% + lufenuron 40% WG at 70 and 140 g/ha did not show any phytotoxic effects on pigeonpea. Jadhav *et al.* (2021) revealed that, emamectin benzoate 5% + lufenuron 40% WG (0.82 larvae/meter row length) was most superior to reducing the *Helicoverpa armigera* population in chickpeas.

The lady bird beetle adult population was found to be significantly lower in insecticide-treated plots as compared to untreated control plots at the star bud and flowering stages. These findings obtained support from Gontijo *et al.* (2014), who assessed the effects of chlorantraniliprole and thiamethoxam on *Chrysoperla carnea* when employed as sunflower seed treatments. Both chlorantraniliprole and thiamethoxam adversely impacted *Chrysoperla carnea* adults when they fed on the extrafloral nectar of seedlings grown from treated seed. Both insecticides reduced adult survival and fecundity, especially thiamethoxam, and offspring of chlorantraniliprole-exposed adults had lower survival than those of controls. Mane *et. al.* (2025) reported that, Seed treatment with Imidacloprid 48% FS @ 5 ml kg⁻¹ seed, spraying of cypermethrin 10 % EC @ 1.5ml lit⁻¹ at starbud and flowering stage is most effective. Sabry *et al.* (2014) evaluated, the residual effects of insecticides against some natural enemies such as *Chrysoperla carnea*, *Coccinella septempunctata* and trichogramma wasps and found that, the per cent of mortality with the highest concentrations. Thiamethoxam and chlorantraniliprole were most toxic to the second instar larvae of *Coccinella septempunctata*.

The synchronization of the stages of the insects at which they are predominant for the particular stage of the crop and the use of insecticides with specific modes of action are required for the proper management of

insects. This strategy helps to achieve insect pest management successfully.

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Effective Management of Sucking Insect Pests in Sunflower

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ABSTRACT

Field experiment was conducted at Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krushi Vidhyapeeth, Akola in Rabi during 2023-24 with an objective to screen out the effective management of sucking insect pests affecting sunflower. Imidacloprid 48% FS @ 5 ml kg⁻¹ seed and Thiamethoxam 30FS @ 3 ml/kg seed were evaluated as seed treatment, while Foliar spray of pyriproxyfen 10EC @ 500ml/ha, pyriproxyfen 5 EC + diafenthiuron 25 SE, Thiamethoxam 12.6% + L-cyhalothrin 9.5% ZC, diafenthiuron 47% + bifenthrin 9.4 SC, Foliar spray of thiacloprid 21.7SC @ 500ml/ha, dinotefuran 20SG @ 150g ha⁻¹, diafenthiuron 50WP @ 600 g ha⁻¹, Dimethoate 30EC @ 800 ml ha⁻¹ and profenofos 50EC @ 1000ml ha⁻¹ were tried as foliar spray, at vegetative stage of the crop. Seed treatment with Thiamethoxam 30FS @ 10 ml kg⁻¹ and Seed treatment with Imidacloprid 48FS @ 8 ml kg⁻¹ shows significant difference over the plots without seed treatment. Foliar spray of pyriproxyfen 10 EC @ 500 ml ha⁻¹ recorded minimum population of leaf hoppers, whiteflies and thrips i.e 0.9 nymphs 6L⁻¹ plant⁻¹, 0.8 adults 6L⁻¹ plant⁻¹ and 0.7 nymphs 6L⁻¹ plant⁻¹, respectively and also recorded maximum i.e 92.9, 93.6 and 95.8 per cent reduction in population of leafhoppers, whiteflies and thrips respectively. Coccinellids was reported slightly more untreated control treatment over chemical treatments. Higher seed yield 1553 kg ha⁻¹ was recorded due to Foliar spray of Pyriproxyfen 5 EC + Diafenthiuron 25 SE @ 1000 ml ha⁻¹ and Seed treatment with Thiamethoxam 30FS @ 10 ml kg⁻¹; Dinotefuran 20SG @ 150g/ha. Foliar spray of Diafenthiuron 47 % + bifenthrin 9.4 SC @ 625 ml ha⁻¹ having ICBR 12.35 found economical.

Sunflower (*Helianthus annuus* L.) is an important oilseed crop in India popularly known as “Surajmukhi.” It is a major source of vegetable oil in the World and is used for a variety of cooking purposes. The oil is also used for manufacturing hydrogenated oil. Sunflower is also a source of lecithin and tocopherols. It is used as nutritious meal for birds and animals. It is also used in the preparation of cosmetics and pharmaceuticals. Though sunflower is an important oilseeds crop, but there is a wide gap between the productivity and its yield potential. Insect pests are one of the major constraints in reducing yield. The production of sunflower crop is seriously affected by the insect pests, attacking at different stages like seedling, star bud, flowering, grain filling and maturing stage. Among the insect pests, sucking pests attack the crop in the early growth period and suck the sap resulting in reduced vigour. The average annual yield losses due to sucking pests and other have been estimated at about 20 – 25 per cent. The major insect pests which drew the attention of both farmers and scientists are sucking pests like leafhopper (*Amrasca biguttula biguttula* Ishida) and Thrips (*Thrips palmi*), Infestation by sucking insect pests is becoming a major concern in obtaining the

expected yield from sunflower crops because its incidence starts at the seedling stage and prevails throughout the entire plant life. Both nymphs and adults of the leafhopper desap the plant and show symptoms like stunted growth, burning of leaf margins, cupped and crinkled leaves. In severe cases, characteristic “hopper burn” symptoms are noticed. Several species of thrips are associated with the crop, which does not cause direct damage but enormous losses indirectly as vectors of viral diseases, especially the sunflower necrosis virus (Chander Rao, 2002). As crop producers are able to have the support of natural enemies as predators or parasitoids for insect pest management, it is clearly important not to destroy these natural enemies. The effects of pesticides on the natural enemies of pests are well documented. So today, it is increasingly desirable to intervene with insecticidal compounds that can act in harmony with predators and parasitoids, or at least reduce the effects against natural enemies. Hence, an attempt an attempt has been made to study the efficacy of insecticides against major insect pests of sunflowers through seed treatment and foliar application of an insecticides at critical stage of crop.

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MATERIAL AND METHODS

Field experiment was conducted at Oilseeds Research Unit, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *rabi* season of 2023-24. Sunflower hybrid KBSH 44 was used for sowing and followed the recommended package of practices except plant protection. Sunflower was cultivated using a randomised block design with a plot size of 4.5 x 4.2 sq.m. and a spacing of 60 x 30 cm between rows and plants. This was done in accordance with the package of practices advised by Dr.PDKV, Akola. The treatments comprised the seed treatment with Imidacloprid 48% FS @ 5 ml kg⁻¹ seed & Thiamethoxam 30% FS @ 3 ml kg⁻¹ seed and foliar application of insecticides viz Pyriproxyfen 10EC @ 500 ml ha⁻¹, Pyriproxyfen 5 EC + Diafenthiuron 25 SE @ 1000 ml ha⁻¹, Thiamethoxam 12.6% + L-cyhalothrin 9.5% ZC @ 125 ml ha⁻¹, Diafenthiuron 47% + bifenthrin 9.4 SC @ 625 ml ha⁻¹, Thiacloprid 21.7SC @ 500 ml ha⁻¹, Dinotefuran 20SG @ 150 g ha⁻¹, Diafenthiuron 50WP @ 600 g ha⁻¹ Dimethoate 30EC @ 800 ml ha⁻¹, Profenofos 50EC @ 1000 ml ha⁻¹ at seedling stage of the crop. Observation on *Thrips palmi* (Nymphs/ 6L Plant⁻¹), leafhopper (*Amrasca biguttula biguttula* Ishida) was recorded at 30 days after germination and at 10 days after foliar spray. The population of Coccinellids (adults plant⁻¹) was recorded at starbud stage of crop. Yield was recorded from net plot and calculated the incremental cost benefit ratio. The data was subjected to suitable statistical analysis by using appropriate analytical methods (R software and OP STAT) and on the basis of critical difference results were compared.

RESULTS AND DISCUSSION

Data given in Table 1 revealed that, seed treatment (ST) with Thiamethoxam 30FS @ 10 ml kg⁻¹ and Seed treatment with Imidacloprid 48FS @ 8 ml kg⁻¹ shows significant difference over the plots without seed treatment. Among the seed treated plots non significant difference was observed in between the treatments and leafhoppers, whiteflies & thrips. At 25 days after germination, population of leafhoppers was observed in the range of 1.9 to 2.3 nymphs 6L⁻¹ plant⁻¹ in seed treated treatments which were at par with each other and significantly superior over foliar spray of dimethoate 30 EC @ 800 ml ha⁻¹ and untreated control. Whiteflies was

recorded in the range of 2.4 to 3.8 adults 6L⁻¹ plant⁻¹ in seed treated plots and foliar spray of dimethoate 30 EC @ 800 ml ha⁻¹. The population of thrips was 1.4 to 1.6 nymphs 6L⁻¹ plant⁻¹ at 15 days after germination in seed treated plots, which were at par and significantly superior over foliar spray of dimethoate 30 EC @ 800 ml ha⁻¹ and untreated control. Foliar spray of pyriproxyfen 10 EC @ 500 ml ha⁻¹ recorded minimum population of leafhoppers, whiteflies and thrips i.e 0.9 nymphs 6L⁻¹ plant⁻¹, 0.8 adults 6L⁻¹ plant⁻¹ and 0.7 nymphs 6L⁻¹ plant⁻¹, respectively and also recorded maximum i.e 92.9, 93.6 and 95.8 per cent reduction in population of leafhoppers, whiteflies and thrips respectively (Table 2). Highest i.e 0.73 adults of Coccinellids was reported from untreated control treatment, while in chemical treatment Coccinellids was recorded in the range of 0.43 to 0.60 adults plant⁻¹ (Table 2).

Higher seed yield 1553 kg ha⁻¹ was recorded due to Foliar spray of Pyriproxyfen 5 EC + Diafenthiuron 25 SE @ 1000 ml ha⁻¹ and Seed treatment with Thiamethoxam 30FS @ 10 ml kg⁻¹; Dinotefuran 20SG @ 150 g ha⁻¹ followed by Foliar spray of Diafenthiuron 47 % + bifenthrin 9.4 SC @ 625 ml ha⁻¹ (1425), which was 41.2, 41.2 and 29.5 per cent increased yield untreated control treatment. Insecticidal treatments show significant difference over untreated control. Among the insecticidal treatment non significant difference was observed. Foliar spray of Diafenthiuron 47 % + bifenthrin 9.4 SC] @ 625 ml ha⁻¹ having ICBR 12.35 found economical, followed by spraying of Dimethoate 30EC @ 800 ml ha⁻¹, profenofos 50 EC @ 1000 ml ha⁻¹ having ICBR 9.75. (Table 3.)

These findings corroborated those of Ingale *et al.* (2019), El-Naggar and Zidan (2013) and Ding *et al.* (2018) with seed treatment of imidacloprid and thiamethoxam, revealed in reducing the population of leafhoppers and thrips. Imidacloprid is a systemic insecticide which acts on the central nervous system of insect's works by interfering with the transmission of stimuli in the insect nervous system. Specifically, it causes a blockage of the nicotinic neuronal pathway. By blocking nicotinic acetylcholine receptors, imidacloprid prevents acetylcholine from transmitting impulses between nerves, resulting in the insect's paralysis and

Table1: Effect of seed treatment with insecticides against sucking pests

Treatments	Leafhoppers	Whiteflies	Thrips
	Nymphs/6 leaves/Plant	Adults/6 leaves/Plant	Nymphs/6 leaves/Plant
T1 Seed treatment with Thiamethoxam 30FS @10ml/kg; Foliar spray of Pyriproxyfen 10EC @ 500ml/ha	1.9 (1.3)	2.4 (1.5)	1.6 (1.3)
T2 Seed treatment with Imidacloprid 48FS @ 8ml/kg; Foliar spray of [Pyriproxyfen 5 EC + Diafenthiuron 25 SE] @ 1000 ml/ha	1.9 (1.3)	2.5 (1.6)	1.4 (1.2)
T3 Seed treatment with imidacloprid 48FS @ 8ml/kg; Foliar spray of [Thiamethoxam 12.6% + L- cyhalothrin 9.5% ZC] @ 125 ml/ha	2.3 (1.5)	2.7 (1.6)	1.9 (1.3)
T4 Seed treatment with Thiamethoxam 30FS @10ml/kg; Foliar spray of [Diafenthiuron 47% + bifenthrin 9.4 SC] @ 625 ml/ha	1.9 (1.4)	3.5 (1.9)	1.7 (1.3)
T5 Seed treatment with imidacloprid 48FS @ 8ml/kg; Foliar spray of Thiachlorid 21.7SC @ 500ml/ha	1.9 (1.3)	3.3 (1.8)	1.7 (1.3)
T6 Seed treatment with Thiamethoxam 30FS @10ml/kg; Dinotefuran 20SG @ 150g/ha	2.0 (1.4)	3.5 (1.8)	1.7 (1.3)
T7 Seed treatment with Thiamethoxam 30FS @10ml/kg; Foliar spray of Diafenthiuron 50WP @ 600g/ha	2.0 (1.4)	3.8 (1.9)	1.6 (1.3)
T8 Dimethoate 30EC @ 800 ml/ha, Profenofos 50EC @ 1000ml/ha (check)	3.1 (1.8)	3.7 (1.9)	2.2 (1.5)
T9 Untreated control	10.9(3.3)	10.5(3.2)	5.3(2.3)
SE (m) ±	0.07	0.14	0.08
CD at5 %	0.22	0.43	0.24
CV (%)	7.76	12.74	9.89

PBT : Population before treatment MPAT : Mean population after treatment PROC : Per cent reduction over control

eventual death. Thiamethoxam is a broad-spectrum, systemic insecticide, which means it is absorbed quickly by plants and transported to all of its parts, including through direct contact, including through its stomach after feeding, or through direct contact, including through direct contact, including through its tracheal system. The compound gets in the way of information transfer between nerve cells by interfering with nicotinic acetylcholine receptors in the central nervous system and eventually paralyzing the muscles of the insects. In this way, both insecticides provide protection to crop from sucking pests. Through observation, it is concluded that, both insecticides as a seed treatment provide protection to crop from sucking pests up to 30 days after germination.

These findings obtained support from Swami *et*

al. 2018, who reported that, Pyriproxyfen 10% EC @ 1250 ml ha⁻¹ followed by Imidacloprid 17.8% SL 50 g a.i. @ 250 ml/ha found the most effective to reduce the thrips, Thrips tabaci and jassids, *Amrasca biguttula biguttula* (Ishida) population in chilli crop. Lee *et al.*, (2002) found that, chitin synthesis inhibitors (pyriproxyfen and novaluron) were very effective against immature stages of *B. tabaci* and were relatively low effective against the adults of *B. tabaci* and *A. gossypii*. Vijay Kumar *et al.* (2019) concluded that, pyriproxyfen 10 EC and spiromesifen 22.9SC have good nymphicidal action while flonicamid 50WP and diafenthiuron 50WP have adulticidal action. The insecticide molecule Flonicamid 50 % WG @ 150 g/ha was found best for managing the major sucking pest viz. Aphids, jassids, whitefly and thrips

Table 2. Effect of foliar spray of insectic ides against sucking pests

Treatments	Foliar Spray									Coccinellids
	Leafhoppers			Whiteflies			Thrips			
	Nymphs/6 leaves/Plant			Adults/6 leaves/Plant			Nymphs/6 leaves/plant			
	PBT	MPAT	PROC	PBT	MPAT	PROC	PBT	MPAT	PROC	
T1	Seed treatment with Thiamethoxam 30FS @10ml/kg; Foliar spray of Pyriproxyfen 10EC @ 500ml/ha									0.53 (0.73)
T2	Seed treatment with Imidacloprid 48FS @ 8ml/kg; Foliar spray of [Pyriproxyfen 5 EC + Diafenthion 25 SE] @ 1000 ml/ha									0.47 (0.68)
T3	Seed treatment with imidacloprid 48FS @ 8ml/kg; Foliar spray of [Thiamethoxam 12.6% + L- cyhalothrin 9.5% ZC] @ 125 ml/ha									0.50 (0.70)
T4	Seed treatment with Thiamethoxam 30FS @ 10ml/kg; Foliar spray of [Diafenthion 47% + bifenthrin 9.4 SC] @ 625 ml/ha									0.53 (0.73)
T5	Seed treatment with imidacloprid 48FS @ 8ml/kg; Foliar spray of Thiacloprid 21.7SC @ 500ml/ha									0.60 (0.77)
T6	Seed treatment with Thiamethoxam 30FS @ 10ml/kg; Dinotefuran 20SG @ 150g/ha									0.43 (0.65)
T7	Seed treatment with Thiamethoxam 30FS @ 10ml/kg; Foliar spray of Diafenthion 50WP @ 600g/ha									0.53 (0.73)
T8	Dimethoate 30EC @ 800 ml/ha, Profenofos 50EC @ 1000ml/ha (check)									0.47 (0.68)
T9	Untreated control									0.73 (0.85)
SE (m)+										0.05
CD at5 %										0.14
CV (%)										11.75

PBT: Population before treatment MPAT: Mean population after treatment PROC : Per cent reduction over control

Table 3. Seed yield and IBC ratio

Treatments		Seed yield (Kg ha ⁻¹)	IOC %	IBC ratio
T1	Seed treatment with Thiamethoxam 30FS @10ml/kg; Foliar spray of Pyriproxyfen 10EC @ 500ml/ha	1339	21.7	7.39
T2	Seed treatment with Imidacloprid 48FS @ 8ml/kg; Foliar spray of [Pyriproxyfen 5 EC + Diafenthiuron 25 SE] @ 1000 ml/ha	1553	41.2	7.25
T3	Seed treatment with imidacloprid 48FS @ 8ml/kg; Foliar spray of [Thiamethoxam 12.6% + L- cyhalothrin 9.5% ZC] @ 125 ml/ha	1325	20.5	7.80
T4	Seed treatment with Thiamethoxam 30FS @10ml/kg; Foliar spray of [Diafenthiuron 47% + bifenthrin 9.4 SC] @ 625 ml/ha	1425	29.5	12.35
T5	Seed treatment with imidacloprid 48FS @ 8ml/kg; Foliar spray of Thiachlorpid 21.7SC @ 500ml/ha	1325	20.5	4.42
T6	Seed treatment with Thiamethoxam 30FS @10ml/kg; Dinotefuran 20SG @ 150g/ha	1553	41.2	6.17
T7	Seed treatment with Thiamethoxam 30FS @10ml/kg; Foliar spray of Diafenthiuron 50WP @ 600g/ha	1319	19.9	3.92
T8	Dimethoate 30EC @ 800 ml/ha, Profenofos 50EC @ 1000 ml/ha (check)	1345	22.3	9.75
T9	Untreated control	1100	0.0	0.00
	SE (m)+	130.7		
	CD at5 %	392.1		
	CV (%)	16.89		

IOC: yield increase over control

of Bt-cotton crop followed by Thiamethoxam 25% WG @ 200 g ha⁻¹, Diafenthiuron 50% WP @ 600 g ha⁻¹ and Fipronil 5% SC @1000 ml ha⁻¹ were also found effective against the major sucking pests of Bt-cotton crop. (Baraskar and Paradkar, 2020). In case of whitefly, maximum mortality was recorded from the treatment Diafenthiuron 30% + Pyriproxyfen 8% SE @ 1200 ml ha⁻¹ followed by the treatment Diafenthiuron 30% + Pyriproxyfen 8% SE @ 1000 ml ha⁻¹ (Suvash, 2023). Diafenthiuron 30% + Pyriproxyfen 8% SE at 1000 ml ha⁻¹ could be used for the management of whiteflies without any phytotoxic effect on plants (Hugar *et al.*, 2020). The best treatment in reducing the pest population was Pyriproxyfen 5% + Diafenthiuron 25% SE @ 1000ml/ha with per cent reduction of 63.03, 76.90, 73.47 and 75.25, 77.80, 74.48 at 5, 10 & 15 days after first and second spray, respectively. The next effective treatment was Pyriproxyfen 5% +Diafenthiuron 25% SE @ 750 ml ha⁻¹ followed by Diafenthiuron 50% WP, Pyriproxyfen

5% + Diafenthiuron 25% SE @ 500 ml ha⁻¹, Pyriproxyfen 10% EC and Fenpropathrin 30% EC (Dangi *et al.*, 2018). On the basis of efficacy, diafenthiuron 25% + pyriproxyfen 5% SE (1000 and 1250 ml ha⁻¹) found relatively more effective against sucking insect pests viz., aphids, leafhoppers, whiteflies and thrips. These two doses of diafenthiuron 25% + pyriproxyfen 5% SE also reflected on cotton seed yield. (Thumar *et al.*, 2018). Bharpoda *et al.* (2014) reported that, among the different insecticides, diafenthiuron 50 WP @ 0.05% recorded the lowest thrip count, in cotton. Stanley *et al.* (2010) revealed that, diafenthiuron 50 WP alone has recorded a 52.77 per cent reduction. Diafenthiuron is photochemically or metabolically transformed into a highly reactive metabolite, Diafenthiuron carbodiimide, which covalently and irreversibly binds to microsomal glucose-6-phosphate translocase, a part of the adenosine triphosphatase (ATPase) complex. The binding, inhibits the function of the ATPase complex due to the modification of a single

sulphydral amino⁻¹ phosphate group of the glucose-6-phosphate translocase. Therefore, substrates such as inorganic phosphate, carbamoyl phosphate, and pyrophosphate cross the microsomal membrane freely without the catalytic function of the translocase; ATP production is inhibited. Diafenthiuron carbodiimide also affects mitochondrial porins, but due to the fact that, the function of these mitochondrial porins is not fully known yet, the effects of the carbodiimide on these porins are also not understood. In summary, diafenthiuron inhibits the process of mitochondrial respiration by binding to various mitochondrial components and in this way, it provides protection to crop from sucking pests.

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Genetic Variability Analysis for Growth and Root Yield Attributes in Ashwagandha

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ABSTRACT

Ashwagandha (*Withania somnifera* (L.) Dunal) is an important medicinal crop, and its genetic improvement depends on the availability of sufficient genetic variability. The present study evaluated 16 ashwagandha germplasm lines during *rabi* 2024 at Nagarjun Medicinal Plant Garden, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, using a Randomized Block Design with three replications to estimate genetic variability, heritability and genetic advance for six growth and yield traits. Analysis of variance revealed significant differences among genotypes for all the characters, indicating substantial genetic variability. PCV values were slightly higher than the corresponding GCV values, suggesting limited environmental influence on trait expression. Dry root yield plot⁻¹ recorded the highest PCV (22.11%), GCV (19.33%), heritability (76.44%) and genetic advance as percent of mean (34.82%), followed by dry root weight plant⁻¹ (GAM 20.13%). Plant height and root length also exhibited high heritability coupled with moderate to high genetic advance, indicating predominance of additive gene action. Among the germplasm, AKA 08 recorded the highest dry root yield per plot (48.2), followed by AKA 02 (42.7) and AKA 04 (42.5). The results indicate that dry root yield plot⁻¹, dry root weight plant⁻¹, plant height and root length are effective selection criteria for developing high-yielding ashwagandha varieties.

Ashwagandha (*Withania somnifera* (L.) Dunal), popularly known as Indian ginseng or winter cherry, is one of the most important medicinal plants belonging to the family Solanaceae (Mir *et. al.*, 2013). The genus *Withania* distributed in tropical and subtropical regions, of which *W. somnifera* is the most economically important species cultivated for its medicinal roots and leaves (Ranjithkumar *et.al.*, 2023). The crop is indigenous to India and distributed throughout the drier and Subtropical parts of India, especially in Madhya Pradesh, Uttar Pradesh, Punjab, and the North-Western parts of India like, Gujarat, Maharashtra and Rajasthan. India is the largest producer, consumer and exporter of ashwagandha, accounting for a major share of the global demand for its roots and herbal products (Srivastava *et. al.* 2017). Ashwagandha has gained considerable importance owing to its wide spectrum of pharmacological properties. The roots, leaves and berries contain biologically active compounds, particularly withanolides, withaferin A, sitoindosides and alkaloids, which exhibit adaptogenic, anti-inflammatory, antioxidant, immunomodulatory, anticancer, antimicrobial, neuroprotective and anti-stress activities. The increasing global preference for herbal medicines, nutraceuticals and plant-based pharmaceuticals has substantially enhanced the commercial value of

ashwagandha. Consequently, there is a growing demand for high-yielding varieties possessing superior root yield, higher dry matter production and enhanced withanolide content (Khare, 2007 and Gupta & Rana, 2007).

Despite its medicinal and economic importance, the productivity of ashwagandha remains relatively low due to the cultivation of heterogeneous local landraces, limited availability of improved cultivars and inadequate exploitation of the existing genetic diversity. Genetic improvement in ashwagandha primarily aims at increasing dry root yield, improving root quality through enhanced withanolide content, developing early-maturing genotypes and improving tolerance to biotic and abiotic stresses. The success of any crop improvement programme depends largely on the availability of sufficient genetic variability and a clear understanding of the inheritance of economically important traits (Venugopal *et. al.*, 2021).

Assessment of genetic variability provides the foundation for effective plant breeding by identifying the magnitude of heritable variation present in the germplasm. Parameters such as phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance help breeders distinguish between genetic and environmental components of

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variation and predict the response to selection leaves (K Ranjithkumar *et. al.* 2023). High heritability coupled with high genetic advance generally indicates the predominance of additive gene action and suggests that direct phenotypic selection would be effective. Conversely, low heritability or low genetic advance may indicate greater environmental influence or the predominance of non-additive gene action, requiring alternative breeding strategies (Chauhan *et. al.* 2020).

Evaluation of diverse germplasm lines for morphological and yield-contributing traits is therefore an essential prerequisite for identifying superior parental lines and developing improved cultivars. Information generated from variability studies also facilitates germplasm conservation, characterization and utilization in breeding programmes aimed at enhancing genetic gain. Therefore, the present investigation entitled “Genetic Variability Analysis in Ashwagandha (*Withania somnifera* (L.) Dunal)” was undertaken to assess the extent of genetic variability among selected germplasm lines and to estimate genetic parameters including phenotypic and genotypic coefficients of variation, heritability and genetic advance for important growth and yield attributes. The findings are expected to provide valuable information for the selection of superior genotypes and formulation of effective breeding strategies for the genetic improvement of ashwagandha.

MATERIAL AND METHODS

The total sixteen germplasm lines available at Nagarjun Medicinal Plant Garden, Dr. PDKV, Akola were evaluated during *rabi* season of 2024. The trial was conducted in RBD with sixteen genotypes and three replications. The sowing was done in the plot size of 3 x 1.5 m with 30 x 5 cm row to row and plant to plant spacing. All the recommended package of practices were adopted to raise the healthy crop. The observations were recorded on 5 randomly selected plants on five characters and the Dry yield per plot on net plot basis. The analysis of variance was worked out separately for each character as per method suggested by Fisher (1954) and using standard statistical procedure given by Panse and Sukhatme (1954). Genotypic coefficient of variation (GCV) and Phenotypic coefficient of variation (PCV) were calculated as per the standard formula suggested by Burton (1952).

GCV was calculated using the following formula as suggested by Burton (1952).

$$GCV = \frac{\sqrt{V_g}}{\bar{X}} \times 100$$

Where,

V_g = Genotypic variance

$\bar{X}$ = Population mean

PCV was calculated using the following formula as suggested by Burton (1952).

$$PCV = \frac{\sqrt{V_p}}{\bar{X}} \times 100$$

where,

V_p = Phenotypic variance

$\bar{X}$ = Population mean

Heritability in Broad Sense () was computed using the following formula stated by Hanson *et. al.* (1956).

$$h_{BS}^2 (\%) = \frac{V_g}{V_p} \times 100$$

Where,

V_g = Genotypic variance

V_p = Phenotypic variance

h_{BS} = Broad-sense heritability

Genetic Advance (GA) was calculated using flowing formula.

$$GA = K \sqrt{V_p} \times \frac{V_g}{V_p}$$

(Equivalent standard expression: $GA = K \times \sigma_p \times h^2$)

Where,

V_g = Genotypic variance

V_p = Phenotypic variance

K = Selection differential at 5 per cent selection intensity, i.e., 2.06

Genetic Gain

The percent expected genetic advance over the population mean was computed using the formula given by Johnson *et. al.* (1955).

$$GG = \frac{GA}{\bar{X}} \times 100$$

Where,

$\bar{X}$ = Population mean

GA = Genetic advance

GG = Genetic gain (Genetic advance as percent of mean)

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) presented in table 1 revealed considerable variation among the evaluated ashwagandha germplasm lines for all the studied characters. For each trait, the treatment mean square was substantially higher than the corresponding error mean square, indicating the presence of appreciable genetic variability among the genotypes. Plant height recorded the highest treatment mean square (180.94), followed by dry root yield plot⁻¹ (133.75), demonstrating wide genetic variation for these economically important traits. Likewise, root length (12.10), root diameter (1.81), number of primary branches (1.25) and dry root weight plant⁻¹ (0.35) also exhibited treatment mean squares considerably greater than their respective error mean squares, confirming significant genetic differences among the germplasms.

The relatively low error mean squares for all the characters indicate good experimental precision and reliable observations. The marked differences between treatment and error mean squares suggest that the observed variation was predominantly genetic with comparatively less environmental influence. These findings confirm the availability of sufficient genetic variability in the experimental material, providing a strong basis for effective selection and further genetic improvement of root yield and its contributing traits in ashwagandha.

The data present in table 2 showed that, the highest plant height (91.4 cm) was recorded in AKA 04, followed by AKA 13 (82.5 cm) and AKA 03/AKA 06 (81.5 cm), while the minimum plant height (58.3 cm) was observed in AKA 09. The maximum number of primary

branches was observed in AKA 03 (8.9), followed by AKA 01 and AKA 02 (7.8) and AKA 05 and AKA 06 (7.3). The minimum (6.1) was recorded in AKA 07. The highest dry root weight (2.9 g) was recorded in AKA 03 and AKA 08, followed by AKA 11 and JA 20 (2.8 g) and AKA 04 and AKA 07 (2.7 g). The lowest value (1.9 g) was observed in AKA 10.

The genotype AKA 02 recorded the longest roots (24.3 cm), followed by AKA 08 (23.5 cm) and AKA 10 (22.1 cm), whereas the shortest roots (17.3 cm) were observed in AKA 05. The maximum root diameter (13.8 mm) was recorded in AKA 06 and AKA 08, followed by AKA 02 (13.6 mm) and AKA 07 (13.4 mm). The minimum diameter (11.4 mm) was recorded in AKA 05. The highest dry root yield per plot was obtained from AKA 08 (48.2), followed by AKA 02 (42.7) and AKA 04 (42.5), while the lowest yield (25.4) was recorded in AKA 06.

The estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad-sense heritability (h^2), genetic advance (GA) and genetic advance as percent of mean (GAM) provide valuable information regarding the nature of variability and the effectiveness of selection in the evaluated ashwagandha germplasm (Table 3 & Fig. 3). Overall, the PCV values were slightly higher than the corresponding GCV values for all the characters, indicating limited environmental influence on trait expression and the predominance of genetic factors. The narrow differences between PCV and GCV suggest that phenotypic selection based on these traits would be effective. Among the traits, dry root yield per plot exhibited the highest PCV (22.11%), GCV (19.33%), heritability (76.44%) and

Table 1: RBD-Analysis of Variance-(ANOVA) of 16 germplasm lines of ashwagandha

SN	Characters	Mean Sum of Squares		
		Replication (DF=2)	Treatments (DF=7)	Error (DF=14)
1	Plant Height (cm)	41.81	180.94*	17.70
2	Number of Primary branches	0.61	1.25*	0.19
3	Dry root weight per plant (g)	0.01	0.35*	0.06
4	Root Length (cm)	4.21	12.10*	1.33
5	Root diameter (mm)	0.20	1.81*	0.24
6	Dry root yield per plot	29.81	133.75*	12.46

* Indicates significant level at 5%

Table 2: Mean performance of 16 germplasm lines of ashwagandha for different characters

SN	Genotype	Plant Height (cm)	Number of Primary branches	Dry root weight plant ⁻¹ (g)	Root Length (cm)	Root diameter (mm)	Dry root yield plot ⁻¹
1	AKA 01	79.4	7.8	2.5	18.9	12.8	28.0
2	AKA 02	77.5	7.8	2.6	24.3	13.6	42.7
3	AKA 03	81.5	8.9	2.9	19.7	11.6	37.2
4	AKA 04	91.4	7.2	2.7	21.9	13.0	42.5
5	AKA 05	77.9	7.3	2.4	17.3	11.4	29.2
6	AKA 06	81.5	7.3	2.0	19.9	13.8	25.4
7	AKA 07	80.9	6.1	2.7	19.0	13.4	33.9
8	AKA 08	76.5	6.9	2.9	23.5	13.8	48.2
9	AKA 09	58.3	6.6	2.0	18.5	12.3	34.1
10	AKA 10	65.6	7.0	1.9	22.1	13.3	26.7
11	AKA 11	80.2	6.7	2.8	18.8	13.2	34.2
12	AKA 12	69.0	6.7	2.2	19.3	11.6	28.6
13	AKA 13	82.5	7.1	2.3	20.1	13.0	27.4
14	Red Berris	76.0	7.2	2.5	17.7	12.9	29.5
15	JA 134	69.7	6.8	2.1	19.4	12.6	27.5
16	JA 20	76.4	6.6	2.8	18.7	11.9	31.0

genetic advance as percent of mean (34.82%), indicating ample genetic variability and the predominance of additive gene action, making it the most promising trait for direct selection. Similarly, dry root weight plant⁻¹ showed relatively high variability (PCV 16.31%, GCV 12.63%) with moderate heritability (59.91%) and high GAM (20.13%), suggesting good scope for improvement through selection.

Plant height ($h^2 = 75.45\%$, GAM = 17.25%) and root length ($h^2 = 72.99\%$, GAM = 16.72%) also exhibited

high heritability coupled with moderate to high genetic advance, indicating that these traits are predominantly governed by additive gene effects and can be effectively improved through simple phenotypic selection. In contrast, number of primary branches ($h^2 = 65.20\%$, GAM = 13.87%) and root diameter ($h^2 = 68.67\%$, GAM = 9.67%) recorded comparatively lower genetic advance despite moderate heritability, suggesting relatively lower additive genetic variance and consequently slower response to direct selection. Overall, the combination of

Table 3: Estimates of variability, heritability and genetic advance as percent of mean for 6 characters in 16 germplasm lines of ashwagandha

SN	Character	PCV (%)	GCV (%)	h^2 bs (%)	Genetic Advance	GA as percent of mean
1	Plant Height (cm)	11.10	9.64	75.45	13.20	17.25
2	Number of Primary branches	10.33	8.34	65.20	0.99	13.87
3	Dry root weight per plant (g)	16.31	12.63	59.91	0.49	20.13
4	Root Length (cm)	11.12	9.50	72.99	3.34	16.72
5	Root diameter (mm)	6.84	5.67	68.67	1.23	9.67
6	Dry root yield per plot	22.11	19.33	76.44	11.45	34.82

Genetic Variability Analysis for Growth and Root Yield Attributes in Ashwagandha

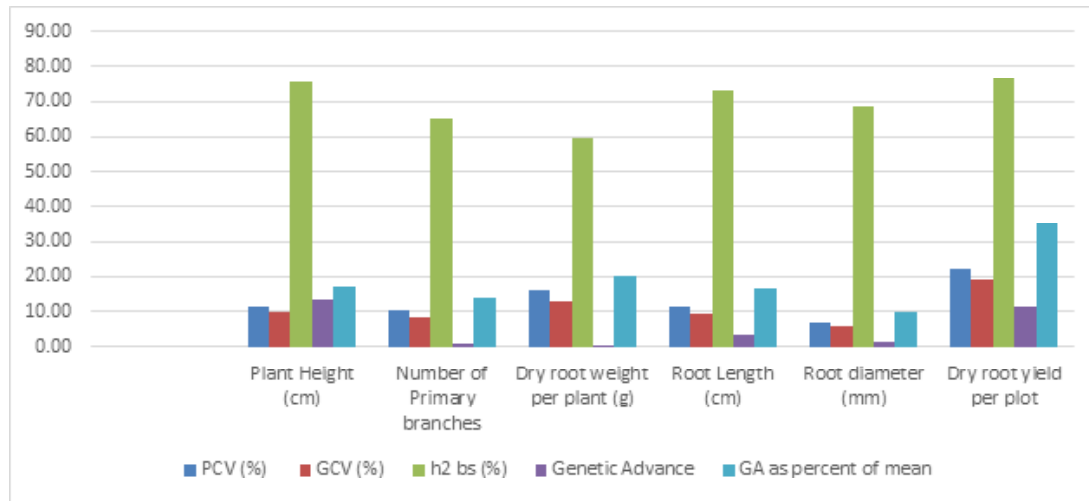


Fig 1: Estimates of Variability, Heritability and GAM of 6 characters in ashwagandha

high heritability and high genetic advance for dry root yield plot⁻¹, dry root weight plant⁻¹, plant height and root length indicates that these characters should be prioritized in breeding programmes aimed at improving root yield in ashwagandha. The findings are in conformity with the findings of Kumar *et al.*, (2007), Sangwan *et al.*, (2013), Joshi *et al.*, (2014), Chauhan *et al.* 2020.

From a breeding perspective, dry root yield per plot emerged as the most promising trait owing to its high genetic variability, high heritability and high genetic advance as per cent of mean, indicating that improvement through direct selection would be highly rewarding. Dry root weight plant⁻¹, plant height and root length also possess considerable breeding value because of their moderate to high variability, high heritability and relatively high genetic advance, suggesting predominance of additive gene action. These traits can therefore be effectively utilized as selection criteria in developing superior high-yielding ashwagandha varieties. In contrast, root diameter and number of primary branches exhibited comparatively lower expected genetic gain, indicating that selection for these characters alone may be less effective and may require evaluation over multiple environments or incorporation into hybridization programmes.

The present study demonstrates the existence of sufficient genetic variability among the 16 ashwagandha germplasm lines. The combination of high heritability and high genetic advance for dry root yield plot⁻¹, plant height,

root length and dry root weight plant⁻¹ suggests that these traits are predominantly controlled by additive gene action and can be effectively improved through direct phenotypic selection. Consequently, these characters should receive priority while selecting superior parents and advancing breeding populations aimed at improving root yield in ashwagandha.

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Evaluation of Tree-Borne Oils as Eco-Friendly Preservatives for Bamboo Poles

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ABSTRACT

This study investigated the preservative efficacy of three tree-borne oils (mahua, neem and karanj) applied after a 160 °C thermal pretreatment on three commercial bamboo species (*Bambusa balcooa*, *Dendrocalamus strictus* and *Dendrocalamus stocksii*). The treated specimens were evaluated for their interactive properties, including water absorption, resistance to the fungal decay and aesthetic response under simulated dark-moist and sunny-dry environmental conditions. The thermo-oil modifications significantly enhanced moisture resistance, with mahua oil reducing water absorption to 12.15%, compared to 56.61% in the untreated controls. Neem oil provided the most superior defense against fungal degradation, yielding the lowest mass loss. Furthermore, aesthetic evaluations by an expert panel indicated that mahua oil treatment, particularly on *B. balcooa*, produced the highest visual appeal under both environmental conditions. These results demonstrate that tree-borne oils are highly effective, biodegradable alternatives to synthetic chemicals for extending the service life and marketability of bamboo products.

Bamboo, a fast-growing member of the family Poaceae, is widely distributed worldwide. Recognized as one of the most versatile non-wood forest resources, it attains maturity within 3–5 years, regenerates naturally without replanting and yields high biomass per unit area, making it a sustainable alternative to timber (Liese 1980). Despite its global relevance, the limited natural durability of bamboo restricts its broader utilization. In the absence of preservation, bamboo culms are highly vulnerable to fungal decay, insect infestation and environmental weathering, leading to rapid deterioration and shortened service life (Liese and Köhl, 2015).

Chemical preservatives such as CCB, creosote and LOSPs are commonly applied to enhance bamboo durability; however, their effectiveness is limited by poor penetration into bamboo tissues and concerns regarding environmental and health risks, including soil and water contamination (Khatun *et al.*, 2025). Inadequate preservation has been associated with significant post-harvest losses, as untreated bamboo under humid conditions may rapidly lose structural integrity due to termite attack, limiting its suitability for durable applications (Perminder *et al.*, 2016).

Tree- and plant-derived natural oils represent a sustainable alternative for bamboo preservation. Rich in bioactive compounds such as alkaloids, flavonoids, terpenoids and fatty acids, these oils exhibit antimicrobial, insecticidal

and antioxidant properties. Being biodegradable and renewable, they offer a safer and environmentally compatible option compared to conventional chemical preservatives.

Neem oil, rich in azadirachtin, nimbin and quercetin, exhibits insecticidal, antifungal and growth-regulating properties. Treated bamboo shows reduced decay and termite-induced weight loss (Boateng and Owusu 2019, Perminder *et al.*, 2016, Erukwa and Ndang 2021). Karanj oil (*Pongamia pinnata*) contains fatty acids and antioxidants with demonstrated antibacterial and antifungal activity across temperature ranges (Baswa *et al.*, 2001). Mahua oil (*Madhuca longifolia*), rich in fatty acids, vitamins, flavonoids and saponins, exhibits antioxidant and antimicrobial properties (Das *et al.*, 2022, Dubey *et al.*, 2023, Sinha *et al.*, 2017).

Although neem, karanj and mahua oils possess documented pesticidal and antimicrobial properties, their comparative efficacy in bamboo preservation, particularly under controlled heat treatment, is insufficiently studied. Limited information is available on their effects across different bamboo species. Accordingly, the present study evaluates the preservative performance of three tree-borne oils on *Dendrocalamus stocksii*, *Dendrocalamus strictus* and *Bambusa balcooa* using post-harvest oil surface application following heat treatment.

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MATERIAL AND METHODS

The experiment was conducted during the year 2024–25 to evaluate the preservative efficacy of selected tree-borne oils on bamboo. Three bamboo species, namely *Bambusa balcooa*, *Dendrocalamus strictus* and *Dendrocalamus stocksii*, were used in the study. Mahua oil, neem oil and karanj oil served as the oil-based preservatives. The experiment was laid out in a Factorial Randomized Block Design (FRBD) comprising twelve treatments with three replications. The treatment details are as below.

TREATMENTS	BAMBOO SPECIES + OIL PRESERVATIVES
S ₁ T ₁	Control stocksii
S ₁ T ₂	<i>Dendrocalamus stocksii</i> + Karanj Oil
S ₁ T ₃	<i>Dendrocalamus stocksii</i> + Neem Oil
S ₁ T ₄	<i>Dendrocalamus stocksii</i> + Mahua Oil
S ₂ T ₁	Control strictus
S ₂ T ₂	<i>Dendrocalamus strictus</i> + Karanj Oil
S ₂ T ₃	<i>Dendrocalamus strictus</i> + Neem Oil
S ₂ T ₄	<i>Dendrocalamus strictus</i> + Mahua Oil
S ₃ T ₁	Control balcooa
S ₃ T ₂	<i>Bambusa balcooa</i> + Karanj Oil
S ₃ T ₃	<i>Bambusa balcooa</i> + Neem Oil
S ₃ T ₄	<i>Bambusa balcooa</i> + Mahua Oil

Preparation of Bamboo specimens

Bamboo selection and harvesting

Bamboo selection was conducted at the AICRP Agroforestry field, where well-developed, straight, defect-free poles aged 2.5–3 years were tagged and harvested. The poles were cleaned, sorted and air-dried for 3–4 days, after which basal and middle sections were cut at the node and shade-dried for two additional days to achieve uniform moisture content. To reduce experimental error, five randomly selected poles of similar age from each species (*Bambusa balcooa*, *Dendrocalamus stocksii* and *Dendrocalamus strictus*) were used.

Pretreatment of bamboo

Specimens of required dimensions were randomly selected from harvested bamboo poles, sorted by species and subjected to hot water treatment at 160 °C for 2 h (Hao *et al.*, 2021). After boiling, the specimens were immersed in normal water for sap removal, then cleaned and air-dried to remove surface moisture prior to oil application the following day.

Oil application

Bamboo specimens were uniformly coated with oil using a paintbrush to enhance absorption and then set aside for further testing, while control specimens received heat or oil treatment. The experimental design aimed to evaluate the effects of tree-borne oil preservatives on bamboo, selected to access durability, structural integrity and usability of the treated specimens.

Interactive Tests

Water Absorption Test

This test was carried out to assess the hygroscopic behavior of treated and untreated bamboo. Oven-dried specimens were weighed, submerged in water for 48 hours and reweighed to determine water uptake. The water absorption percentage was calculated as:

$$\text{Water Absorption (\%)} = [(\text{Wet Weight} - \text{Dry Weight}) / \text{Dry Weight}] \times 100$$

This test helped evaluate the effectiveness of oil treatments in reducing moisture intake.

Bamboo specimens (25 × 25 mm, full wall thickness) from the basal portion of (*D. stocksii*, *D. strictus* and *B. balcooa*) were sorted into control and treatment groups. After 24-hour air-drying, treatment samples were boiled at 160 °C for 2 hours (Hao *et al.*, 2019), cooled in water, air-dried 12 hours and coated with oil using a brush. Both control and treated specimens were oven-dried at 103 ± 2 °C for 30 minutes, weighed to 0.01 g accuracy, then immersed in water for 48 hours to measure wet weight and calculate water uptake (ASTM International 2010).

Fungal Decay Test

The fungal decay resistance of bamboo was examined by exposing specimens to natural decay fungus, *Trametes versicolor* in a controlled environment. Samples

were partially buried or placed in moist conditions conducive to fungal growth for 60 days. The percentage of mass loss was calculated using following equation (Wei *et al.*, 2013):

$$\text{Mass Loss (\%)} = [(\text{Initial dry Weight} - \text{Final Oven-dry Weight}) / \text{Initial dry Weight}] \times 100$$

This experiment provided insight into the preservative effect of the oils against biological deterioration.

Bamboo specimens (25 × 25 mm) from the basal culms of *D. stocksii*, *D. strictus* and *B. balcooa* were air-dried for 24 hours, sorted and labeled as control or treatment. Treatment samples were boiled at 160 °C for 2 hours (Hao *et al.*, 2021), cooled in water, air-dried 12 hours and coated the next day with karanj, neem, or mahua oil using a brush for maximum absorption.

Fungal Decay Exposure

Pre-sterilized petri plates (autoclaved at 150 psi for 1 hour) contained a sterilized soil medium to mimic natural fungal degradation. Both control and treated bamboo specimens were exposed to UV light to eliminate contaminants. Their initial dry weights were recorded before placement in the petri plates. To maintain moisture, 10 mL of distilled water was added to each plate, along with a fungal agar bead inoculated with *Trametes versicolor*. The experiment was conducted in a controlled incubation lab (Plant Pathology Department, College of Agriculture, Nagpur) to monitor fungal growth and contamination over 60 days.

Post-Exposure Analysis

On the 60th day, specimens were cleaned of soil and fungal mats, then oven-dried at 103°C until oven dry state (Liu 2023), to remove absorbed moisture. The final oven-dry weight was recorded and mass loss percentage was calculated using following formula (Wei *et al.*, 2013):

$$\text{Mass Loss (\%)} = (\text{Initial Dry Weight} - \text{Final Oven-Dry Weight}) / \text{Initial Dry Weight} \times 100$$

Aesthetic Evaluation

Aesthetic evaluation was performed to assess the visual appeal of treated bamboo using a structured Likert scale. A panel of three experts rated the specimens on color retention, surface texture, natural patterns and

overall aesthetic impact, with total scores analyzed to predict public perception and acceptability (Wu *et al.*, 2023).

Specimens were taken from the central, internode portions of bamboo poles to allow proper visual inspection. Split bamboo samples were boiled at 160 °C for 2 hours (Hao *et al.*, 2021) in an electric heater, then immediately quenched in room-temperature water to remove sap. After cleaning, the specimens were air-dried for 12 hours and oil was applied evenly the following day with a paintbrush to maximize absorption. Treated specimens were then prepared for evaluation.

The aesthetic study was conducted at the research fields of the All India Coordinated Research Project (AICRP) on Agroforestry, Nagpur, under two environmental conditions. The first simulated a dark, moist environment using a container with moist cocopeat, covered with perforated plastic and a dark polythene sheet, housed in a greenhouse to maintain consistent conditions. The second condition simulated sunny, dry exposure, with specimens hung on poles for continuous sunlight and airflow. Control and treated specimens were grouped and labeled to prevent mix-ups.

On the 60th day, the three experts evaluated the specimens using a questionnaire, scoring visual appearance, color retention, surface texture, natural patterns and overall aesthetic impact on a Likert scale. The experts included R1, a Senior Research Assistant at AICRP with 25+ years of experience; R2, a Scientist-B with nearly 28 years of bamboo training experience; and R3, a Senior Scientist with over 30 years of experience at AICRP. Scores and expert comments were analyzed to identify the superior specimens and evaluate interactions among species, treatment and environmental conditions.

RESULTS AND DISCUSSION

Water Absorption test (%)

The water absorption test assesses bamboo fiber durability, porosity and suitability for moisture-exposed applications by quantifying moisture uptake and hygroscopic behaviour. Lower absorption reflects improved dimensional stability, while higher absorption indicates greater porosity and susceptibility to swelling and degradation. Water absorption among species showed

minor variation, ranging from 21.79–25.45% (Table 1). *Bambusa balcooa* (S3) recorded the lowest mean absorption (21.79%), followed by *Dendrocalamus strictus* (S2, 25.37%), while *D. stocksii* (S1) showed the highest (25.45%). Preservative treatments had a highly significant independent effect, with mean absorption values ranging from 12.15–56.61%. The untreated control (T1) exhibited the highest absorption (56.61%). Among oil treatments, mahua oil (T4) was most effective in reducing absorption (12.15%), followed by karanj oil (T2, 13.59%) and neem oil (T3, 14.45%).

Table 1. Interaction effect of oil preservative treatment on the water absorption test of bamboo species

Bamboo species (Factor A)	Water Absorption Test (%)				
	Oil Preservatives Treatment (Factor B)				
	T ₁	T ₂	T ₃	T ₄	MEAN
S ₁ - <i>D. stocksii</i>	55.24	15.24	16.77	14.55	25.45
S ₂ - <i>D. strictus</i>	67.33	11.24	12.76	10.13	25.37
S ₃ - <i>B. balcooa</i>	47.25	14.29	13.83	11.78	21.79
MEAN	56.61	13.59	14.45	12.15	24.20
	A	B	A X B		
SE(m)	0.522	0.603	1.045		
SE(d)	0.739	0.853	1.478		
CD @ 5%	1.532	1.769	3.065		
CV	7.480				

A significant species × treatment interaction was observed, with absorption values ranging from 10.13–67.33%. The lowest absorption occurred in *D. strictus* treated with mahua oil (S2T4, 10.13%), while the highest was in untreated *D. strictus* (S2T1, 67.33%). Overall, oil heat treatment markedly reduced hygroscopicity compared to the control, following the order: T1 > T3 > T2 > T4. The superior performance of mahua oil suggests more effective pore sealing and hydrophobic modification, likely due to its fatty acid composition and stability at 160 °C. These findings align with earlier studies reporting reduced water absorption in oil- and heat-treated bamboo due to hemicellulose degradation, reduced microfibril accessibility and formation of hydrophobic barriers (Erakhrumen and Ogunsanwo 2010, Azadeh and Ghavami

2018, Tang *et al.*, 2019, Hao *et al.*, 2021). Overall, oil heat modification—particularly with mahua oil—significantly enhances water resistance of bamboo under the tested conditions.

Fungal Decay Test (%)

Table 2. Interaction effect of oil preservative treatment on the fungal decay test of bamboo species

Bamboo species (Factor A)	Fungal Decay Test (%)				
	Oil Preservatives Treatment (Factor B)				
	T ₁	T ₂	T ₃	T ₄	MEAN
S ₁ - <i>D. stocksii</i>	0.11	0.04	0.03	0.07	0.06
S ₂ - <i>D. strictus</i>	0.24	0.03	0.02	0.03	0.08
S ₃ - <i>B. balcooa</i>	0.22	0.03	0.03	0.07	0.09
MEAN	0.19	0.04	0.03	0.06	0.08
	A	B	A X B		
SE(m)	0.001855	0.002142	0.003711		
SE(d)	0.002624	0.00303	0.005248		
CD @ 5%	0.005442	0.006284	0.010884		
CV	8.196				

The fungal decay test evaluates the extent of fungal degradation in bamboo and the effectiveness of oil preservatives in enhancing decay resistance. Species showed only minor variation in decay ratings (0.06–0.09) (Table 2). *Dendrocalamus stocksii* (S1) exhibited the lowest mean decay (0.06), followed by *D. strictus* (S2, 0.08), while *Bambusa balcooa* (S3) showed the highest (0.09). Preservative treatments had a highly significant independent effect, with mean decay values ranging from 0.03 to 0.19. The untreated control (T1) recorded the highest decay (0.19). Among oil treatments, neem oil (T3) was most effective (0.03), followed by karanj oil (T2, 0.04) and mahua oil (T4, 0.06).

A significant species × treatment interaction was observed, with decay values ranging from 0.02 to 0.24. The lowest decay occurred in *D. strictus* treated with neem oil (S2T3, 0.02), while the highest was in untreated *D. strictus* (S2T1, 0.24). Overall, oil heat treatments substantially improved fungal resistance compared to the control, with neem oil providing the greatest protection.

These findings agree with earlier reports showing that oil heat treatment reduces fungal susceptibility by degrading starch and hemicellulose, increasing lignin proportion and forming hydrophobic barriers that limit moisture and nutrient availability (Cheng *et al.*, 2018, Tang *et al.*, 2019, Hao *et al.*, 2021, Piao *et al.*, 2022). The results confirm that oil type strongly influences decay resistance, with neem oil emerging as the most effective under the tested conditions.

Aesthetic evaluation test, dark-moist condition

Table 3. Interaction effect of oil preservative treatment on the aesthetics (dark-moist condition) of bamboo species

Bamboo Species (Factor A)	Aesthetic evaluation test (DARK MOIST)				
	Oil Preservatives Treatment (Factor B)				
	T ₁	T ₂	T ₃	T ₄	MEAN
S ₁ - <i>D. stocksii</i>	4.00	5.33	4.70	6.27	5.08
S ₂ - <i>D. strictus</i>	4.67	4.90	4.27	5.23	4.77
S ₃ - <i>B. balcooa</i>	6.50	5.23	5.73	11.77	7.31
MEAN	5.06	5.16	4.90	7.76	5.72
	A		B		A X B
SE(m)	0.127		0.147		0.255
SE(d)	0.180		0.208		0.361
CD @ 5%	0.375		0.433		0.750
CV	7.750				

The test assessed visual interactions between oils and bamboo using a Likert-scale evaluation by a three-member expert panel. Aesthetic scores varied among species from 4.77 to 7.31 (Table 3), with *Bambusa balcooa* (S3) recording the highest mean score (7.31), followed by *Dendrocalamus stocksii* (S1, 5.08) and *D. strictus* (S2, 4.77). Preservative treatments had a significant independent effect, with mean scores ranging from 4.90 to 7.76. Mahua oil (T4) produced the most preferred aesthetics (7.76), whereas neem oil (T3) yielded the lowest score (4.90). Karanj oil (T2, 5.16) and the control (T1, 5.06) showed intermediate and comparable responses.

A significant species × treatment interaction was

observed, with scores ranging from 4.00 to 11.77. The lowest scores (4.00) occurred in untreated *D. stocksii* and *D. strictus*, while the highest score (11.77) was recorded in *B. balcooa* treated with mahua oil (S3T4). Overall, treatment ranking followed T4 > T2 > T1 > T3. The superior visual appeal of mahua oil-treated *B. balcooa* is likely due to enhanced oil penetration, deeper and more stable coloration and smoother surface texture. These trends align with earlier studies showing that thermal modification intensifies bamboo color, improves surface smoothness and enhances grain contrast through lignin and hemicellulose modification, resulting in greater aesthetic preference (Zhang *et al.*, 2021, Hu *et al.*, 2022).

Aesthetic evaluation test, sunny-dry condition

Table 4. Interaction effect of oil preservative treatment on the aesthetics (sunny-dry condition) of bamboo species

Bamboo Species (Factor A)	Aesthetic evaluation test (SUNNY DRY)				
	Oil Preservatives Treatment (Factor B)				
	T ₁	T ₂	T ₃	T ₄	MEAN
S ₁ - <i>D. stocksii</i>	4.00	5.50	6.83	12.00	7.08
S ₂ - <i>D. strictus</i>	4.00	6.77	7.10	5.80	5.92
S ₃ - <i>B. balcooa</i>	6.00	11.97	8.00	13.23	9.80
MEAN	4.67	8.08	7.31	10.34	7.60
	A	B	A X B		
SE(m)	0.259		0.299		0.518
SE(d)	0.366		0.423		0.733
CD @ 5%	0.760		0.877		1.520
CV		11.812			

Aesthetic scores differed significantly among species, ranging from 5.92 to 9.80 (Table 4). *Dendrocalamus strictus* (S2) recorded the lowest mean score (5.92), followed by *D. stocksii* (S1, 7.08), while *Bambusa balcooa* (S3) achieved the highest rating (9.80). Preservative treatments also showed a significant independent effect, with mean scores between 4.67 and 10.34. The untreated control (T1) was least preferred (4.67). Among oil treatments, neem oil (T3) improved

aesthetics moderately (7.31), karanj oil (T2) performed better (8.08) and mahua oil (T4) produced the most preferred appearance (10.34).

A significant species $\times$ treatment interaction was evident, with scores ranging from 4.00 to 13.23. The lowest scores (4.00) occurred in untreated *D. stocksii* and *D. strictus* (S1T1, S2T1), whereas the highest score (13.23) was observed in *B. balcooa* treated with mahua oil (S3T4). Overall, oil heat-treated samples, particularly *B. balcooa* with mahua oil, showed markedly enhanced visual appeal under sunny-dry exposure. This improvement is attributed to oil penetration combined with thermal modification, which deepens color, enriches tone and accentuates natural grain patterns. These findings agree with (Tang *et al.*, 2019), who reported that tung oil heat treatment of bamboo at $\sim 180^\circ\text{C}$ significantly darkened color, increased redness and enhanced visual preference, confirming that oil heat modification strongly influences aesthetic perception.

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SHORT NOTE

Green Synthesis of Nano Zinc Oxide for Wheat

Nano fertilizers are synthesized or modified forms of traditional fertilizers, fertilizers bulk materials or extracted from different vegetative or reproductive parts of the plant by different physical, chemical, or biological methods with the help of nanotechnology used to improve soil fertility, productivity and quality of agriculture produce.

The main reason for high interest in nano fertilizers is mainly their penetration capacity, size and very high surface area which is usually differ from the same material found in bulk form. Nano fertilizers are not only ecofriendly but also reduce environment pollution.

Micronutrient deficiencies in plants may lead to reduced yields and, in severe cases, to plant death, also. Among the micronutrients, Zn deficiency is the most detrimental to crop growth and yield of all the cereal crops including wheat (Alloway, 2008; Marschner, 1995). The deficiency of Zn in Indian as well as world soils is very well documented constraint in crop production and since last couple of decades, it is considered to be the 4th most yield limiting nutrient after N, P and K, respectively in India (Sillanpaa, 1990; Katyal and Sharma, 1991; Singh, 2009; Shukla *et al.*, 2014).

Zinc activates enzymes that are responsible for the synthesis of certain proteins. It is used in the formation of chlorophyll and some carbohydrates, conversion of starches to sugars and its presence in plant tissue helps the plant to withstand cold temperatures. Zinc is essential in the formation of auxins, which help with growth regulation and stem elongation.

Nanoparticles have the huge potential of technology, thus the need of environmental friendly synthesis of nanoparticles, researchers are using green approach based synthesis using plants, microbial, and algae for the formation of various metal nanoparticles for various industrial and medical applications. Moreover, the nanoparticles were reported as an ideal photocatalyst because of cost effective, stability and highly photoactive activity. (Vidya *et al.*, 2017; Senthikumar *et al.*, 2013).

Green synthesis of ZnO NPs

To make extract powder, 5 mg of dried roots of wheat were grinded and dispersed in 100 ml distilled water. The suspension was autoclaved for 30 min at 100 °C to obtain aqueous solution of extract. To eliminate the solid part of extract, the suspension was filtered with the filter paper. 5 ml of plant extract was added in 95 ml of distilled water to make final concentration of plant extract (5%) and zinc nitrate mixture was added drop wise to it continuously stirring with final concentration of 1 mM. Following the preparation of mixture, NaOH added in suspension additionally in the reaction mixture, while heated at 70 °C for 1.5 h for the synthesis of ZnO nanoparticles. Zinc hydroxide precipitates were formed within 30 min by the complete reduction of zinc hydroxide. For collecting the precipitate, centrifugation was done at 8000 rpm for 15 min. In final, the synthesized ZnO NPs were suspended with distilled water to eliminate the impurities. Then, the nanoparticles were air dried at 60 °C in vacuum oven for overnight and the powder was collected (Lu *et al.*, 2018).

Characterization of ZnO NPs

The optical properties of ZnO NPs were obtained using UV–vis Spectrophotometer absorption spectra. The absorption spectrum reveals a characteristic absorption peak of ZnO NPs at wavelength of 360 nm, which confirmed that ZnO NPs were formed. The maximum absorption spectra of bulk ZnO usually occurs around 330–380 nm accordingly (Senthilkumar *et al.*, 2014).

Data presented in table 1 revealed that the prepared ZnO nanoparticles showed a particle size of 45.18–47.33 nm. The Poly-dispersity (PdI) Index scale in all the samples range from 0.224 to 0.250 indicates that it is the mid-range value and the particles remain in disperse form in all the samples. It can be considered as a good result because the particle size of synthesized ZnO nanoparticles is below than 100 nm (Hasnidawani *et al.*, 2016).

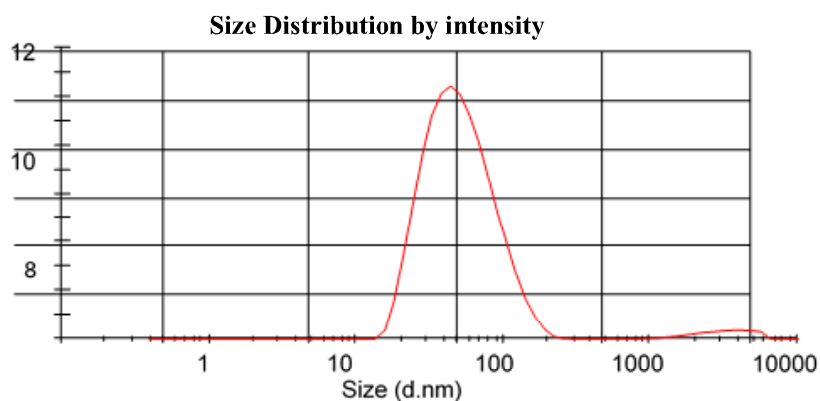
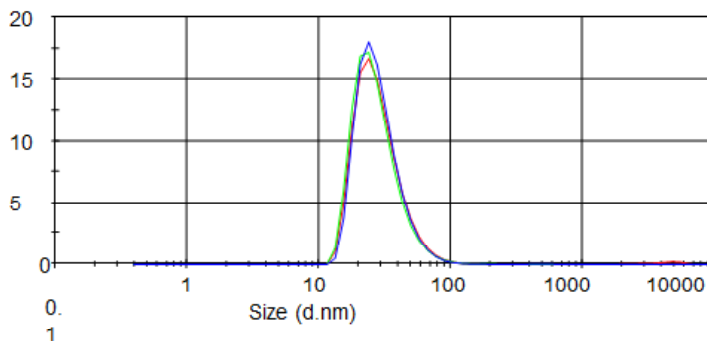
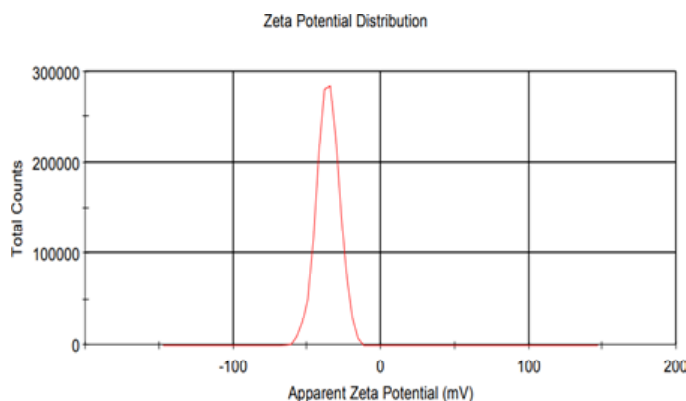
Zeta potential measurement specifies the electro kinetic potential of a colloidal system (Garcia *et al.*, 1997).

Table 1: Characterization of ZnO NPs for particle size (nm), PdI and Kcps

S.N.	Sample details	Particle size (nm)	PdI	Kcps
1	ZnO NPs (ST)	45.18±1.60	0.224±0.022	225.2±0.2
2	ZnO NPs (1 st spray)	46.8±1.50	0.249±0.024	225.2±0.8
3	ZnO NPs (2 nd spray)	47.33±1.25	0.250±0.016	225.4±0.4

Magnitude of the zeta potential is an indicator of repulsive forces between particles and therefore it can provide a good estimation of the suspension stability (Hunter, 1981). The larger zeta values represent lower degree of

aggregation that leads to higher degree of stability of nanoparticles and smaller z-averaged hydrodynamic diameter potential values represent lower degree of aggregation that leads to higher degree of stability of

**Fig 1. Particle size distribution of nano ZnO with seed treatment with 1000 ppm****Fig 2. Particle size distribution of nano ZnO at foliar spray****Fig 3. Zeta potential distribution**

nanoparticles and smaller z-averaged hydrodynamic diameter. At lower zeta values, the nanoparticles flocculate early and the stability in nano-suspension reduces. The common dividing line between unstable and stable suspensions is taken as +30 or -30 mV; particles having

zeta potentials beyond these limits are generally considered as stable (Zak *et al.*, 2011). The zeta potential value was found to be $(-27.2 \pm 7.6 \text{ mV})$, revealing the better stability of synthesized ZnO nanoparticles in aqueous suspension.

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