

INFLUENCE OF DIFFERENT PLANT GROWTH REGULATORS ON GROWTH AND YIELD PERFORMANCE OF SESAME (*SESAMUM INDICUM* L.)

A K Vishwakarma¹, Nainee Dehariya^{*2}, Rajani Bisen^{**1}, Surabhi Jain^{***1}, K N Gupta¹, Namrata Jain², Roshni Sahu¹, Vijay Katara¹, Priya Chourasiya², Subrata Sharma², Shanti Bhushan³, Sanjay Kumar⁴, Ekhlake Ahmad⁵, Varsha Rani⁶, Milon Jyoti Konwar⁷ and Gyanendra Tiwari²

¹PC Unit (Sesame and Niger), ICAR, JNKVV, Jabalpur

²Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh (482004), India

³VKS College of Agriculture, Dumraon-802136 (BAU, Sabour)

⁴Irrigation Research Station, Araria-854311 (BAU, Sabour)

⁵ & ⁶Birsa Agricultural University, Kanke, Ranchi, Jharkhand

⁷Assam Agricultural University, Jorhat, Assam

*Corresponding author- Nainee Dehariya, naineemehra2213@gmail.com

**Corresponding author- Rajani Bisen, rajanibisen@jnkvv.org

***Corresponding author- Surbhi Jain, sur_812004@yahoo.com

ABSTRACT

Sesame is an important oilseed crop cultivated in India since ages during kharif season. Due to congenial environment and availability of moisture excessive vegetative growth is observed, which resulted in poor capsule formation and low seed yield due to poor source to sink partitioning of photosynthates. A field experiment was conducted to evaluate the influence of foliar application of plant growth regulators tested against control with no plant growth regulator application on crop growth, seed and oil yield of sesame (*Sesamum indicum* L.). The experiment was laid out in a randomized block design (RBD) with three replications and eleven treatments comprising a control, salicylic acid, paclobutrazol, mepiquat chloride, chlormequat chloride and potassium chloride (KCl), applied either as a single spray at 60 days after sowing (DAS) or as split sprays at 45 and 60 DAS. Each foliar treatment was applied at a spray volume of 300 L ha⁻¹. The treatments included salicylic acid at 200 ppm at 60 DAS and 100 ppm at 45 and 60 DAS; paclobutrazol, mepiquat chloride and chlormequat chloride at 200 ppm at 60 DAS and 100 ppm at 45 and 60 DAS; and KCl at 2% at 60 DAS and at 45 and 60 DAS. Observations were recorded on plant growth attributes, physiological parameters, yield attributes and seed yield. The results showed non-significant differences for plant population m² and it varied from 20.00 to 22.67 plants m², maximum plant height at maturity 115.11 cm in treatment T₁₁. While maximum number of branches per plant (4.44), maximum LAI (3.18), number of capsules plant⁻¹ (68.33), seeds capsule⁻¹ (68.83), capsule length (28.52 mm) and capsule girth (8.73 mm) was recorded in treatment T₈. Treatment T₂ (1837.03 kg ha⁻¹) recorded maximum straw yield while the harvest index varied between 23.99 in T₁ to 32.44% in treatment T₈. Among the treatments, chlormequat chloride @ 200 ppm applied at 60 DAS (T₈) showed the most consistent superior performance by producing maximum number of capsules plant⁻¹, seeds capsule⁻¹, capsule length and capsule girth with the greater number of branches and leaf area index, together. These improvements in reproductive attributes were reflected in the highest seed yield of 692.03 kg ha⁻¹, along with higher seed test weight and harvest index.

KEYWORDS: Sesame, plant growth regulators, salicylic acid, paclobutrazol, mepiquat chloride, chlormequat chloride, potassium, seed yield.

INTRODUCTION:

Sesame (*Sesamum indicum* L.) is an important oilseed crop cultivated in India since ages popularly known as the “Queen of Oilseeds” and often called as the “poor man’s ghee”. It is generally cultivated during the *Kharif* season, which contributes nearly 75% of the total production. Sesame seeds are highly nutritious, containing high amount of fat, protein, minerals, vitamins, and dietary fiber. Sesame contains about 21.9% protein and fat, considered an excellent energy source. Sesame seeds also contain carbohydrates, sugars, starch, fiber, and ash. The oil content in sesame varies from 40-50% depending on the cultivar. Notably, oleic and linoleic acids consist about 80% of the fatty acids which providing several health benefits (Were et al. 2006). In addition, sesame seeds are good and rich sources of essential minerals including calcium, magnesium, copper, iron, manganese, phosphorus, potassium, zinc, and sodium and also provide important vitamins especially selenium, β-carotene vitamin E, vitamin B1, vitamin B2, vitamin B3, vitamin B5, vitamin B6, and vitamin B9 (Wei et al. 2022). Sesame cultivation in India is widely concentrated in West Bengal, Madhya Pradesh, Gujarat, Uttar Pradesh, Andhra Pradesh, Rajasthan, and Telangana, which collectively account for 85% of the total production in the country. Sesame occupies an area of 15.31 lakh hectares, with a total production of 8.47 lakh tonnes and an average productivity of 553 kg ha⁻¹ in India. Due to congenial environment and availability of moisture during kharif season excessive vegetative growth is observed, which resulted in poor capsule formation and low seed yield due to poor source to sink partitioning of

photosynthates. Plant hormones are organic compounds produced naturally inside plants that maintain growth and development even at very low concentrations. These hormones influence key physiological processes such as cell elongation, differentiation, cell division, flowering, and fruit development. However, the synthesis and balance of plant hormones are affected by both abiotic and biotic factors, which may limit the plant growth and productivity. PGRs are considered as a new class of agrochemicals that can improve plant architecture, optimize source-sink relationship, and facilitate the translocation of photo-assimilates by promoting greater retention of flowers, improve pod and seed development, and ultimately enhance seed yield and productivity through their exogenous application to boost crop productivity. Keeping in view the above facts, the present investigations was undertaken to determine whether modification of plant growth through growth retardants, stress-mitigating compounds and potassium nutrition could improve the yield and productivity of sesame and to identify an environmentally acceptable and practically affordable PGR for sesame.

MATERIAL AND METHODS:

The field experiment was conducted during the *Kharif* season of 2025 at the Research Farm of the ICAR All India Coordinated Research Project (Sesame and Niger) Unit, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV). The experimental site had a fairly uniform topography and was characterized by the occurrence of localized weeds commonly prevalent in the area. Geographically, Jabalpur is located at 23° 90' N latitude and 79° 58' E longitude and at an altitude nearly of 411.78 m above mean sea level as per the classification of the National Agricultural Research Project (NARP), New Delhi, Jabalpur comes under the “Kymore Plateau and Satpura Hills” agro-climatic zone. The average annual rainfall of Jabalpur region is approximately 1350 mm, primarily received during mid-June to the end of September. The soil of the experimental area was sandy clay loam texture with proper drainage, gentle slope. The soil reaction was slightly alkaline, with an optimum pH of 7.3, low in organic carbon content, moderate in available nitrogen, phosphorus and potassium, with optimum electrical conductivity. The experiment was laid out in a randomized block design (RBD) with three replications and eleven treatments comprising a Control (T₁), Salicylic acid @ 200 ppm at 60 DAS @ 300 L ha⁻¹(T₂), Salicylic acid @ 100 ppm at 45 & 60 DAS @ 300 L ha⁻¹ (T₃), Paclobutrazol @ 200 ppm at 60 DAS @ 300 L ha⁻¹(T₄), Paclobutrazol @ 100 ppm at 45 & 60 DAS @ 300 L ha⁻¹(T₅), Mepiquat chloride @ 200 ppm at 60 DAS @ 300 L ha⁻¹(T₆), Mepiquat chloride @ 100 ppm at 45 & 60 DAS @ 300 L ha⁻¹(T₇), Chlormequat chloride @ 200 ppm at 60 DAS @ 300 L ha⁻¹(T₈), Chlormequat chloride @ 100 ppm at 45 & 60 DAS @ 300 L ha⁻¹(T₉), KCL @ 2% at 60 DAS @ 300 L ha⁻¹(T₁₀) and KCL @ 2% at 45 & 60 DAS @ 300 L ha⁻¹(T₁₁). Observations were recorded on plant growth attributes; yield attributes seed and oil yield.

RESULTS & DISCUSSION

Growth parameters

The results showed non-significant differences for plant population m². The plant population varied from 20.00 to 22.67 plants m². Treatment T₃ and T₈ (22.67 plants m²) recorded the maximum plant population followed by T₁, T₆ and T₁₁ (21.67 plants m²), while minimum plant population was recorded in treatment T₅ and T₇ (20.00 plants m²). The results indicated that the effect of different plant growth regulator treatments on plant height at maturity was non-significant and varied from 112.89 cm to 115.11 cm, among all treatments T₁₁ (115.11 cm) recorded the highest plant height while the lowest plant height observed under treatment T₆ (112.89 cm). Similarly, Tung et al. (2020) found that the reduction in plant height under mepiquat chloride was due to its anti-gibberellin activity, which restricted cell elongation by inhibiting the conversion of geranylgeranyl diphosphate to ent-kaurene. Significant variations existed for number of branches @ maturity and the maximum number of branches (4.44) were recorded under treatment T₈. These findings are in agreement with the present study of Pirasteh-Anosheh et al. (2021), Bajya et al. (2023), Desta and Amare (2021) Kale et al. (2021), Kumar et al. (2014), and Parmar et al. (2022) that chlormequat chloride, mepiquat chloride and paclobutrazol, respectively, reduced stem elongation and improved plant architecture and promoted branching. Different plant growth regulator treatments observed significant effect on leaf area index (LAI) at 60 DAS. The mean value was 2.95, ranging 2.68 to 3.18. Among all treatments T₈ (3.18) recorded maximum LAI and was found at par with T₆ (3.13) and T₄ (3.10), meanwhile minimum LAI was recorded in treatment T₅ (2.68) which remained at par with T₇ (2.84) and T₁₁ (2.80). Similarly, Nuraini et al. (2018) reported that paclobutrazol application reduced leaf area index while enhancing chlorophyll content and promoting a more compact and efficient canopy structure.

Treatments	Plant population per m²	Plant height (cm)	Number of branches	Leaf Area Index (60 DAS)
T1	21.67	115.00	3.22	2.90
T2	21.33	114.56	3.89	2.95
T3	22.67	113.11	4.11	2.94
T4	21.33	114.22	3.89	3.10

T5	20.00	113.11	4.11	2.68
T6	21.67	112.89	4.22	3.13
T7	20.00	113.56	3.78	2.84
T8	22.67	114.00	4.44	3.18
T9	21.33	113.33	4.00	2.88
T10	21.33	114.89	3.78	2.98
T11	21.67	115.11	3.89	2.80
SEM	2.22	4.52	0.20	0.06
CD at 5%	NS	NS	0.59	0.18

Yield Attributes & yield

Significant differences were found for number of capsules per plant at maturity. The overall average recorded as 62.92 capsules plant⁻¹, while the range varied from 56.11 to 68.33 capsules plant⁻¹. Treatment T₈ (68.33 capsules plant⁻¹) recorded maximum number of capsules and T₇ (67.33 capsules plant⁻¹) and T₃ (66.89 capsules plant⁻¹) varied non-significantly from it. Meanwhile minimum number of capsules was recorded in treatment T₁ (56.11 capsules plant⁻¹) which was remained at par with T₅ (57.11 capsules plant⁻¹). The results are consistent with Hanchinamath (2005), Rathod et al. (2021), Sharma et al. (2022), Sharma et al. (2020), Tuli et al. (2022) findings, who reported the highest number of pods plant⁻¹ with chlormequat chloride, while mepiquat chloride remained statistically at par. The results exhibited significant differences for number of seeds per capsule. The overall average recorded 61.94 seeds capsule⁻¹ while the range varied from 55.67 to 68.83 seeds capsule⁻¹. Treatment T₈ (68.83 seeds capsule⁻¹) recorded maximum number of seeds per capsule and was found at par with T₅ (64.67 seeds capsule⁻¹), T₂ (64.00 seeds capsule⁻¹), T₁₁ (64.17 seeds capsule⁻¹) and T₉ (63.33 seeds capsule⁻¹), while minimum seeds per capsule was recorded in treatment T₁ (55.67 seeds capsule⁻¹) which was remained at par with T₇ (61.67 seeds capsule⁻¹), T₁₁ (59.33 seeds capsule⁻¹) T₃ and T₄ (57.38 seeds capsule⁻¹), which agreement with Hanchinamath (2005) and Ahmed et al. (2022), who reported that chlormequat chloride and paclobutrazol improved major yield-attributing traits, including capsules plant⁻¹ and seeds capsule⁻¹. Similarly, Alim et al. (2020) reported an increase in seeds capsule⁻¹ with salicylic acid application in sesame. The results showed significant differences for capsule length (mm). The overall average recorded as 26.77 mm, while the range varied from 25.38 to 28.52 mm. Among all treatment, T₈ (28.52 mm) recorded maximum capsule length and varied non-significantly from T₉ (27.56 mm), T₇ (27.21 mm), T₄ (27.09 mm) and T₁₀ (26.89 mm) meanwhile minimum capsule length was recorded in treatment T₁ (25.38 mm) which was at par with T₁₀ (26.89), T₁₁, T₆ (26.73), T₃ (26.63), T₂ (25.89) and T₅ (25.84). Significant differences were found for capsule girth in diameter (mm). The mean value was 8.48 mm, while the range varied from 8.32 to 8.73 mm. Treatment T₈ (8.73 mm) recorded maximum capsule girth and varied non-significantly from T₉ (8.64 mm) and T₁₀ (8.56 mm), meanwhile minimum capsule girth was recorded in treatment T₁ (8.32 mm) which was remained at par with T₁₁ (8.50 mm), T₃, T₆ (8.42 mm), T₄ (8.40 mm) and T₅ (8.37 mm). The improvement in capsule length and girth may be attributed to enhanced source-sink interaction and assimilate partitioning. Hadiya et al. (2021), Mehmood et al. (2021), Tung et al. (2020) Gorlapalli et al. (2022), Indoria et al. (2024) and Kale et al. (2020).

reported similar effects with chlormequat chloride, paclobutrazol and mepiquat chloride, respectively.

Table 2: Influence of different doses of PGR treatments on Yield Attributes				
Treatments	Number of capsule plant ⁻¹	Number of seed capsule ⁻¹	Capsule length (mm)	Capsule girth (mm)
T1	56.11	55.67	25.38	8.32
T2	61.89	64.00	25.89	8.38
T3	66.89	57.83	26.63	8.42
T4	62.56	57.83	27.09	8.40
T5	57.11	64.67	25.84	8.37
T6	60.44	58.00	26.73	8.42
T7	67.33	61.67	27.21	8.54
T8	68.33	68.83	28.52	8.73
T9	63.33	63.33	27.56	8.64
T10	59.33	59.33	26.89	8.56
T11	58.78	64.17	26.73	8.50

SEM	0.90	2.25	0.57	0.06
CD at 5%	2.65	6.63	1.67	0.18

The results showed significant differences for seed yield (kg ha^{-1}). The mean value was $611.60 \text{ kg ha}^{-1}$, while the range varied from 511.86 to $692.03 \text{ kg ha}^{-1}$. Treatment T_8 ($692.03 \text{ kg ha}^{-1}$) recorded maximum seed yield which is at par with T_2 ($677.86 \text{ kg ha}^{-1}$), T_9 ($654.44 \text{ kg ha}^{-1}$) and T_6 ($637.49 \text{ kg ha}^{-1}$) meanwhile minimum seed yield was recorded in treatment T_1 ($511.86 \text{ kg ha}^{-1}$) which varied non-significantly from T_{10} ($556.01 \text{ kg ha}^{-1}$) these findings corroborate the observations of Pirasteh-Anosheh et al. (2021) and Lone et al. (2010), who reported enhanced crop productivity with chlormequat chloride. Also, Kuchlan and Kuchlan (2023) demonstrated the beneficial effect of salicylic acid on seed yield and physiological performance. The results showed non-significant differences for straw yield (kg ha^{-1}). The mean value was $1541.98 \text{ kg ha}^{-1}$, and the range varied between 1347.38 to $1837.03 \text{ kg ha}^{-1}$. Treatment T_2 ($1837.03 \text{ kg ha}^{-1}$) recorded maximum straw yield followed by T_9 ($1721.75 \text{ kg ha}^{-1}$) and T_5 ($1670.20 \text{ kg ha}^{-1}$), meanwhile minimum straw yield was recorded in treatment T_4 ($1347.38 \text{ kg ha}^{-1}$). The results exhibited non-significant differences for biological yield (kg ha^{-1}). The mean value was $2153.95 \text{ kg ha}^{-1}$, while the range varied from 1928.40 to $2514.34 \text{ kg ha}^{-1}$. Treatment T_2 ($2514.34 \text{ kg ha}^{-1}$) recorded maximum biological yield followed by T_9 ($2376.19 \text{ kg ha}^{-1}$) and T_5 ($2285.92 \text{ kg ha}^{-1}$), meanwhile minimum biological yield was recorded in treatment T_4 ($1928.40 \text{ kg ha}^{-1}$). The results exhibited significant differences for seed test weight (gm). Likewise, Laishram et al. (2023) reported significantly enhanced stover and biomass production in response to salicylic acid application. The mean value was 3.96 gm , while a range between 3.77 to 4.03 gm . Treatment T_4 , T_8 and T_{10} (4.03 gm) recorded maximum test weight and was found at par with T_2 (3.90 gm), T_3 (3.97 gm), T_5 (3.97 gm), T_6 (3.97 gm), T_7 (3.97 gm), T_9 (4.00 gm) and T_{11} (3.97 gm), meanwhile minimum test weight was recorded in treatment T_1 (3.77 gm) and T_2 (3.90) varied non-significantly from it. The improvement in 1000-seed weight may be attributed to enhanced assimilate partitioning and seed filling under PGR application. Hadiya et al. (2021), Athari and Talebi (2019), Bajya et al. (2023), Brajendra et al. (2012) and Caon et al. (2017), reported similar increases with chlormequat chloride, salicylic acid and mepiquat chloride, respectively. The results showed non-significant differences for harvest index. The mean value was 29.07% , while a range between 23.99 to 32.44% . Treatment T_8 (32.44%) recorded maximum harvest index followed by T_4 (32.28%) and T_6 (32.21%), meanwhile minimum harvest index was recorded in treatment T_1 (23.99%). The similar findings corroborate Lone et al. (2010), who reported that chlormequat chloride improved harvest index. Likewise, Barman et al. (2015) observed enhanced harvest index with paclobutrazol application.

Table 3: Influence of different doses of PGR treatments on test weight, seed yield, straw yield, biological yield, and Harvest index (HI)					
Treatments	Test weight (gm)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (HI) (%)
T1	3.77	511.86	1620.00	2131.86	23.99
T2	3.90	677.31	1837.03	2514.34	27.65
T3	3.97	621.30	1459.94	2081.24	30.81
T4	4.03	581.01	1347.38	1928.40	32.28
T5	3.97	615.72	1670.20	2285.92	28.50
T6	3.97	637.50	1450.70	2088.19	32.21
T7	3.97	601.38	1407.47	2008.85	30.18
T8	4.03	692.03	1457.01	2149.05	32.44
T9	4.00	654.44	1721.75	2376.19	27.88
T10	4.03	556.01	1443.51	1999.53	27.81
T11	3.97	579.02	1540.83	2119.85	27.87
SEM	0.05	22.19	218.87	250.15	3.00
CD at 5%	0.14	65.45	NS	NS	NS

CONCLUSION

Plant growth regulators (PGRs) have considerable potential for regulating growth and seed yield in sesame (*Sesamum indicum* L.), particularly under conditions where proficient vegetative development and reproductive growth are important for improving productivity. Among the treatments, chlormequat chloride @ 200 ppm applied at 60 DAS (T_8) showed the most consistent superior performance by producing maximum number of capsules plant^{-1} , seeds capsule^{-1} , capsule length and capsule girth with the greater number of branches and leaf area index, together. These improvements in reproductive attributes were reflected in the highest seed yield of $692.03 \text{ kg ha}^{-1}$, along with higher seed test weight and harvest index. The greater productivity under plant growth regulator application may be associated with improved regulation of plant architecture, enhanced canopy development and more efficient partitioning of assimilates towards reproductive sinks. The response of sesame to PGR application, however, may vary with the type of growth regulator, concentration, time of application and prevailing environmental conditions. Therefore, chlormequat chloride @ 200 ppm at 60 DAS can be considered a promising treatment for improving yield performance of sesame under the conditions of the present investigation. Further

studies involving different agro-climatic conditions, seasons, genotypes and application schedules are required to validate the consistency of PGR responses and to develop location-specific recommendations for efficient and sustainable sesame production.

REFERENCES:

1. Ahmed J, Qadir G, Ansar M, Wattoo FM, Javed T, Ali B, Marc RA and Rahimi M. 2022. Shattering and yield expression of sesame (*Sesamum indicum* L.) genotypes influenced by paclobutrazol concentration under rainfed conditions of Pothwar. BMC Plant Biology 23: 137.
2. Alim MA, Swain D, Prusty M and Ray M. 2020. Enhancing growth and yield in sesame through nipping, growth regulators, and foliar nutrition. International Journal of Chemical Studies 8(5): 1543-1547.
3. Athari SN, Talebi R. 2014. Effect of exogenous foliar salicylic acid application on sesame (*Sesamum indicum* L.) morphological characters, seed yield and oil content under different irrigation regimes. International Journal of Biosciences, 5(9): 70-74.
4. Bajya M, Sharma P and Dhaliwal SN. 2023. Assessment of mepiquat chloride in hastening the maturity of groundnut. Biological Forum - An International Journal 15(8): 270-277.
5. Barman M, Gunri SK, Puste AM and Paul S. 2015. Effect of paclobutrazol on growth and yield of kharif groundnut (*Arachis hypogaea* L.). International Journal of Bio-resource and Stress Management 6(4): 511-515.
6. Brajendra, Patiram, & Singh, L. S. (2012). Soil test-based fertilizer recommendation and verification for maize grown in mid hills of Meghalaya. Asian Journal of Soil Science, 7(1), 1–5.
7. Caon, L., Vargas, R., & Brajendra. (Eds.). (2017). Threats to soils: Global trends and perspectives (Global Land Outlook Working Paper). Food and Agriculture Organization of the United Nations, Intergovernmental Technical Panel on Soils.
8. Desta B, Amare G. 2021. Paclobutrazol as a plant growth regulator. Chemical and Biological Technologies in Agriculture 8(1): 1-15.
9. Gorlapalli, A., Kallakuri, S., Sreekanth, P. D., Patil, R., Bandumula, N., & Ondrasek, G. (2022). Characterization and prediction of water stress using time series and artificial intelligence models. Sustainability, 14(11), Article 6690. <https://doi.org/10.3390/su14116690>
10. Hanchinamath PV (2005) Effect of plant growth regulators, organics and nutrients on growth physiology and yield in clusterbean (*Cyamopsis tetragonoloba* Taub). M. Sc. thesis, University of Agricultural Sciences, Dharwad, Karnataka, India.
11. Indoria, A K, Munna Lal, K Srinivas, K L Sharma, K Sammi R, S Kundu, G Pratibha, V K Singh, Brajendra Parmar, S Suvana, G P Pandurang, M Prabhakar, Manisha and K V Rao (2024) Effect of Eighteen Years of Continuous Crop Residue Application on Crop Yields, Soil P Fractions, and Crop P Uptake in Conservation Tillage Under Semi-Arid Tropical Rainfed Conditions. Agri Res & Tech: Open Access J. 28(5): 556426. DOI: 10.19080/ARTOAJ.2024.28.556426
12. Kale, R. R., Anila, M., Mahadeva Swamy, H. K., Bhadana, V. P., Durga Rani, C. V., Senguttuvel, P., Subrahmanyam, D., Hajira, S. K., Rekha, G., Ayyappadass, M., Laxmiprasanna, B., Punniakotti, E., Kousik, M. B. V. N., Kulkarni, S., Dilip, T., Sinha, P., Harika, G., Pranathi, K., Chaitra, K., ... Sundaram, R. M. (2020). Morphological and molecular screening of rice germplasm lines for low soil P tolerance. Journal of Plant Biochemistry and Biotechnology, 30, 282–292. <https://doi.org/10.1007/s13562-020-00586-5>
13. Kale, R. R., Durga Rani, C. V., Anila, M., Mahadeva Swamy, H. K., Bhadana, V. P., Senguttuvel, P., Subrahmanyam, D., AyyappaDass, M., Swapnil, K., Anantha, M. S., Punniakotti, E., Laxmi Prasanna, B., Rekha, G., Sinha, P., Kousik, M. B. V. N., Dilip, T., Hajira, S. K., Brajendra, P., Mangrauthia, S. K., ... Sundaram, R. M. (2021). Novel major QTLs associated with low soil phosphorus tolerance identified from the Indian rice landrace, Wazuhophek. PLoS ONE, 16 (7), Article e0254526. <https://doi.org/10.1371/journal.pone.0254526>
14. Kuchlan P and Kuchlan MK. (2023). Effect of salicylic acid on plant physiological and yield traits of soybean. Legume Research, 46(1): 56-61.
15. Kumar, G., Kurothe, R. S., Brajendra, Vishwakarma, A. K., Rao, B. K., & Pande, V. C. (2014). Effect of farmyard manure and fertilizer application on crop yield, runoff and soil erosion and soil organic carbon under rainfed pearl millet (*Pennisetum glaucum*). Indian Journal of Agricultural Sciences, 84 (7), 816–823.
16. Laishram B, Singh TB, Devi OR, Khumukcham PS and Ngairangba H. 2023. Yield and economics of lentil influenced by salicylic acid. Environment and Ecology 41(3A): 1591-1596.
17. Nuraini A, Sumadi, Mubarak S and Hamdani JS. 2018. Effects of application time and concentration of paclobutrazol on the growth and yield of potato seed of G2 cultivar Medians at medium altitude. Journal of Agronomy 17: 169-173.
18. Parmar B., Vishwakarma A.K., Gupta V., Jha P., Biswas A.K., Hati K.M., Malgaya G., Patra A.K. (2023). Effect of crop residue retention and nutrient application rates on soil health dynamics: A study on Vertisols of central India. Indian Journal of Soil Conservation, 51(1), 11–17.
19. Parmar, B., Vishwakarma, A., Padbhushan, R., Kumar, A., Kumar, R., & Kumari, R. (2022). Hedge and alder-based agroforestry systems: Potential interventions to carbon sequestration and better crop productivity in Indian Sub-Himalayas. Frontiers in Environmental Science, 10, Article 858948. <https://doi.org/10.3389/fenvs.2022.858948>

20. Parmar, B., Vishwakarma, A.K., Jha, P., Biswas, A.K., Meena, B.P., Das, A. and Rani, K., 2026. Residue and nutrient inputs optimization for sustainable soybean-wheat system under zero tillage in central Indian vertisol. *Journal of Soil Science and Plant Nutrition*, 26(1), pp.1517-1534.
21. Pirasteh-Anosheh H, Emam Y, Hashemi SE and Gaur A. 2021. Role of chlormequat chloride and salicylic acid in improving cereal crops production under saline conditions. In: *Agronomic Crops*. Woodhead Publishing.
22. Rathod, S., Saha, A., Patil, R., Ondrasek, G., Gireesh, C., Anantha, M. S., Rao, D. V. K. N., Bandumula, N., Senguttuvel, P., & Swarnaraj, A. K. (2021). Two-stage spatiotemporal time series modelling approach for rice yield prediction & advanced agroecosystem management. *Agronomy*, 11(12), Article 2502. <https://doi.org/10.3390/agronomy11122502>
23. Sahoo, S., Mukhopadhyay, P., Sinha, A. K., Bhattacharya, P. M., Rakesh, S., & Kumar, R. (2022). Yield, nitrogen-use efficiency, and distribution of nitrate nitrogen in the soil profile as influenced by irrigation and fertilizer nitrogen levels under zero-till wheat in the eastern Indo-Gangetic plains of India. *Frontiers in Environmental Science*, 10, Article 970017. <https://doi.org/10.3389/fenvs.2022.970017>
24. Sawant C.P., Singh K.P., Singh R.S., Lakaria B.L., Nandeha N., Patel A., Vishwakarma A.K. (2023). Irrigation and conservation agricultural practices improve crop yield, water productivity and energetics of chickpea (*Cicer arietinum* L.) in Vertisols of central India. *Irrigation and Drainage*, 72, 664–681. <https://doi.org/10.1002/ird.2817>
25. Sawant, C.P., Singh, K.P., Gupta, A., Meena, B.P., Fagodiya, R.K., Singh, A., Lakaria, B.L., Vishwakarma, A.K., Khadatkhar, A., Magar, A.P. and Chaudhary, V.P., 2026. Conservation Agricultural Practices Enhance Food-Water-Economics Nexus and Mitigate Greenhouse Gas Emissions in Maize (*Zea mays* L.)–Chickpea (*Cicer arietinum* L.) Cropping System in Central High Lands of India. *International Journal of Plant Production*, 20(1), p.1.
26. Sharma, K.L., A.K. Indoria, K. Srinivas, K. Sammi Reddy, G. Ravindra Charry, Munna Lal, Ch. Srinivasarao, D. Suma Chandrika, M. Osman, J.V.N.S. Prasad, S.S. Balloli, G. Pratibha, Brajendra Parmar, V.Girija Veni, Pushpanjali Pushpanjali, M. Vasavi, P. Haindavi & D. Lakshmi Aruna Gayatri (2020) Effect of Long-Term Use of Tillage, Crop Residue and N Application on Phosphorus Fractions in Soil under Sorghum (*Sorghum vulgare*) (L.)-castor System (*Ricinus Communis*) in Rainfed Alfisol Soils, *Communications in Soil Science and Plant Analysis*, 51:1, 1-13, DOI: 10.1080/00103624.2019.1689252
27. Sharma, K.L., Munna Lal, K. Sammi Reddy, A.K. Indoria, Ch. Chandra Sekhar, K. Srinivas, M. Prabhakar, V. K. Singh, Brajendra & D. L. A. Gayatri (2022) Effect of Different Levels of Surface Application of Sorghum Residue under Minimum Tillage on Crop Yields and Sustainable Yield Index of Sorghum (*Sorghumbicolor* (L.) Moench) and Cowpea (*Vigna unguiculata* (L.) Walp) and Nutrient Status in Rainfed Alfisol Soils, *Communications in Soil Science and Plant Analysis*, 53:2, 268-280, DOI: 10.1080/00103624.2021.1993883
28. Srilatha, P., Yousuf, F., Methre, R., Vishnukiran, T., Agarwal, S., Poli, Y., Reddy, M. R., Vidyasagar, B., Shanker, C., Krishnaveni, D., Triveni, S., Brajendra, Praveen, S., Balachandran, S. M., Subrahmanyam, D., & Mangrauthia, S. K. (2019). Physical interaction of RTBV ORF I with D1 protein of *Oryza sativa* and Fe/Zn homeostasis play a key role in symptoms development during rice tungro disease to facilitate the insect mediated virus transmission. *Virology*, 526, 117–124. <https://doi.org/10.1016/j.virol.2018.10.013>
29. Tung SA, Huang Y, Hafeez A, Ali S, Liu A, Chattha MS, Ahmad S and Yang G. 2020. Morpho-physiological effects and molecular mode of action of mepiquat chloride application in cotton: A review. *Journal of Soil Science and Plant Nutrition* 20: 2073-2086.
30. Tuti, M. D., Rapolu, M. K., Sreedevi, B., Bandumula, N., Kuchi, S., & Bandeppa, S. (2022). Sustainable intensification of a rice-maize system through conservation agriculture to enhance system productivity in southern India. *Plants*, 11(9), Article 1229. <https://doi.org/10.3390/plants11091229>
31. Vishwakarma, A.K., Meena, B.P., Das, H., Jha, P., Biswas, A.K., Bharati, K., Hati, K.M., Chaudhary, R.S., Shirale, A.O., Lakaria, B.L. and Gurav, P.P., 2023. Impact of sequential herbicides application on crop productivity, weed and nutrient dynamics in soybean under conservation agriculture in Vertisols of Central India. *PloS one*, 18(1), p.e0279434.
32. Wei X, Liu K, Zhang Y, Feng Q, Wang L, Zhao Y and Zhang X. 2022. Morphological and genetic characteristics of sesame (*Sesamum indicum* L.). *Plants* 11(5): 620-632.
33. Were BA, Onkware AO, Gudu S, Welander M and Carlsson AS. 2006. Seed oil content and fatty acid composition in East African sesame (*Sesamum indicum* L.) accessions evaluated over 3 years. *Field Crops Research* 97(2-3): 254-260.