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Effect of growth regulators on productivity of late sown wheat (*Triticum aestivum* L.) in Chhattisgarh

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Abstract
An investigation entitled "Effect of growth regulators on productivity of late sown wheat (*Triticum aestivum* L.) in Chhattisgarh" was carried out during rabi season 2025-26 at the Instructional Cum Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C.G.). The treatments consisted of ten different growth regulator treatments *viz*., T_1 - Foliar application of GA_3 @ 10 ppm at tillering, T_2 - Foliar application of GA_3 @ 20 ppm at tillering, T_3 - Foliar application of GA_3 @ 40 ppm at tillering, T_4 - Foliar application of GA_3 @ 80 ppm at tillering, T_5 - Foliar application of GA_3 @ 160 ppm at tillering, T_6 - Foliar application of ABA @ 50 ppm at anthesis, T_7 - Foliar application of ABA @ 100 ppm at anthesis, T_8 - Foliar application of ABA @ 150 ppm at anthesis, T_9 - Foliar application of ABA @ 200 ppm at anthesis and T_{10} - Control. Observations on growth parameters *viz*., plant population, plant height, number of tillers, plant dry matter accumulation, crop growth rate and relative growth rate at different stages of crop growth, along with phenological parameters including crown root initiation, flag leaf stage, booting, heading and anthesis, were recorded. Growing degree days and photothermal units required for attaining different phenological stages were also calculated. Yield and yield-attributing parameters including ear length, number of ears m^{-2}, number of grains ear^{-1}, test weight, grain yield, straw yield and harvest index, along with economic parameters such as cost of cultivation, gross return, net return and benefit cost ratio, were recorded and subjected to statistical analysis. The results indicated that growth and phenological parameters of late-sown wheat were significantly influenced by the application of growth regulators. The highest plant height, number of tillers and plant dry matter accumulation at different stages of crop growth were generally recorded under T_5 - foliar application of GA_3 @ 160 ppm at tillering, followed by T_4 - GA_3 @ 80 ppm. Treatment T_5 also promoted comparatively earlier attainment of flag leaf, booting, heading and anthesis stages and required lower growing degree days and photothermal units for advancement through successive phenological stages. The control treatment T_{10} generally recorded comparatively lower growth and delayed attainment of reproductive stages. Yield and yield-attributing parameters were also considerably influenced by the application of growth regulators. Treatment T_5 - foliar application of GA_3 @ 160 ppm at tillering recorded the maximum ear length (9.74 cm), number of ears (314.07 m^{-2}), number of grains ear^{-1} (35.34), test weight (44.30 g), grain yield (38.78 q ha^{-1}), straw yield (42.49 q ha^{-1}) and harvest index (47.66%). The highest gross return (₹ 98,301 ha^{-1}) was also obtained under T_5. However, the highest net return (₹ 63,051 ha^{-1}) and B:C ratio (1.90) were recorded under T_3 - foliar application of GA_3 @ 40 ppm at tillering. The lowest growth, yield and economic performance was generally recorded under T_{10} - Control, which recorded the lowest gross return (₹ 69,251 ha^{-1}), net return (₹ 38,193 ha^{-1}) and B:C ratio (1.23).

Keywords: Wheat, panicle, photothermal units, tillers, Growing degree days and anthesis

Introduction
Wheat (*Triticum aestivum* L.), belonging to the family Poaceae, is the most important staple food crop globally and serves as a cornerstone of India's food security. It is grown in nearly all parts of the world, with major producers including China, India, the United States, Russia, France and Australia. As a key cereal crop of the rabi season, wheat plays a vital role in the food security of many countries. Its wide cultivation, adaptability, and high yield potential have earned it the title "king of cereals" and it holds a dominant position in international grain trade. Wheat is predominantly cultivated as a spring type belonging to the species *Triticum aestivum* L. (bread wheat). Compared to other cereals, wheat is nutritionally superior and possesses a rich nutrient composition. It contains about 12.1% protein, 1.8%

lipids, 1.8% ash, 2.0% reducing sugars, 6.7% pentosans, 59.2% starch and nearly 70% total carbohydrates, providing approximately 314 calories per 100 g of edible portion. Wheat is also a valuable source of essential minerals and vitamins, supplying calcium (37 mg/100 g), iron (4.1 mg/100 g), thiamine (0.45 mg/100 g), riboflavin (0.13 mg/100 g) and nicotinic acid (5.4 mg/100 g) (Blake *et al*., 2007). In India, wheat is typically cultivated during the winter (Rabi) season following the harvest of summer crops. Late-sown wheat in northern regions often experiences very low temperatures up to the booting stage, followed by higher temperatures during the later stages of crop growth. Wheat genotypes differ in their temperature requirements, but in general, the optimum temperature range for growth and development lies between 18 and 24 °C. The ideal temperature varies with growth stages: 20-25 °C for germination, 16-20 °C for tillering and 20-23 °C for grain formation and development. According to previous studies, the most favourable temperature range for both vegetative and reproductive growth of wheat is 18-22 °C (Hadole *et al*., 2002). As per 2024 estimates, wheat in India occupies an area of about 318.3 lakh hectares, with a total production of 1132.92 lakh tonnes and an average productivity of 3559 kg ha^{-1}. In Chhattisgarh, wheat cultivation during the same period covered 1.34 lakh hectares, resulting in a production of 1.81 lakh tonnes and a productivity of 1350 kg ha^{-1} (Anonymous, 2024) [1].

In late-sown wheat, the shortened growing season adversely affects all major growth stages, including tillering, flowering and grain filling. A reduction in the optimum growth duration due to increased temperature accelerates leaf senescence, resulting in a decline in photosynthetic activity that is insufficient to sustain normal plant growth. Ramnath *et al.* (2024) [16] reported that for every day's delay in wheat sowing beyond 20th November, grain yield decreases at a rate of about 36 kg ha^{-1} day^{-1}. To meet the rising demand for food grains driven by rapid population growth, greater emphasis is needed on yield-enhancing agronomic practices, such as the application of plant growth regulators. Although plant growth regulators have long been used in agriculture, their overall impact has been limited and their application is generally confined to specific objectives, particularly improvement in crop quality and yield (Lamlom *et al.,* 2025) [10]. The low production and productivity of wheat can be attributed to several factors, including the tall growth habit of traditional varieties, which makes them prone to lodging under fertile soil conditions. Other constraints include poor tillering ability, low sink capacity, greater susceptibility to diseases and high sensitivity to thermo- and photo-periodic variations, leading to poor adaptability. In addition, the longer crop duration of such varieties increases their exposure to climatic fluctuations as well as insect pest and disease incidence. To address these limitations, several improved short-duration and high-tillering wheat varieties have been developed and released by the Rabi cereals section of this university, among which Mamta (K-607) is a notable example. Yield reductions associated with shortened growth periods can be partially offset by cultivating short-duration varieties, which are generally low yielding. Another effective strategy is the exogenous application of plant growth regulators (PGRs), which play a role in enhancing plant growth and development under both normal and stress conditions.

Plant growth regulators (PGRs) are known to affect a wide range of physiological processes in plants, including photosynthesis and stomatal conductance. Under different growth conditions, PGRs can alter plant growth and development in multiple ways, thereby influencing crop yield. The significance of biologically active substances in plant systems is well established. Plant growth regulators are naturally occurring compounds that exert profound effects on plant growth and development even at very low concentrations. They are known to regulate various processes such as growth, flowering and assimilate translocation. Several studies have also reported that plant hormones play a crucial role in regulating the partitioning and translocation of photo assimilates during the grain-filling stage (Iqbal and Ashraf, 2005). Foliar application of plant growth regulators, both natural and synthetic, has been found effective in improving crop growth under various abiotic stress conditions. In recent years, significant advances have been achieved through the use of new and efficient plant growth regulators that can manipulate plant development and enhance both yield and quality. Several studies on wheat have established that plant hormones such as auxins, gibberellins and cytokinins can improve traits related to stem strength, particularly stem diameter and stem wall thickness, following PGR application. However, excessive use of PGRs may reduce plant biomass, which can negatively affect grain yield due to a decreased photosynthetic area and lower availability of stored reserves for re-translocation during the grain-filling stage (Singh *et al.,* 2022). Moreover, the yield response of wheat to PGR application is also influenced by other crop management practices, including irrigation, nitrogen availability and timely sowing.

The phytohormone abscisic acid (ABA) plays a crucial role in enabling plants to adapt to a range of environmental stresses, including cold, heat, drought, and salinity. Abscisic acid is widely recognized for its function in stress regulation, particularly under drought, low-temperature and saline conditions. In wheat crops, ABA is especially important as it regulates stomata closure, thereby minimizing water loss and improving drought tolerance. It also induces seed dormancy, which prevents premature germination under unfavourable environmental conditions and ensures proper crop establishment. Furthermore, abscisic acid enhances the ability of mustard plants to withstand cold stress, making it vital for sustaining growth and productivity in challenging environments. Through these diverse functions, ABA strengthens the resilience and adaptability of mustard, ultimately contributing to improved crop performance. Its multifaceted roles emphasize its significance not only in stress responses but also in normal plant growth and developmental processes. A better understanding of ABA-mediated mechanisms can offer valuable insights for developing agricultural practices aimed at enhancing crop resilience to environmental stresses (Singh *et al*., 2024). A transient increase in abscisic acid (ABA) levels under water-stress conditions can activate a range of downstream stress responses, including the induction and expression of numerous drought-responsive genes and protective proteins. These responses collectively enhance the drought tolerance capacity of plants, enabling them to better withstand water-limited conditions (Tripathi *et al*., 2003) [21]. Gibberellins are first isolated from Gibberella fuzikuroi fungus. Subsequently gibberellins were also found in plant tissue. There are 50 different forms of gibberellins designated as GA_1, GA_2, GA_3, GA_7, etc. Gibberellins generally increase cell division and cell elongation. The gibberellins commonly available GA_3 and is known as gibberellic acid. They promote cell elongation and increase in size of leaf, flower and fruit. Dormancy is broken by gibberellic acid. Gibberellins play an essential role in many aspects of plant growth and development such as seed germination. The morphological and yield contributing characteristics of soybean could be modified by GA_3 at all development stages (Yadav *et al*., 2021) [22].

Materials and methods

A field experiment entitled "Effect of growth regulators on productivity of late sown wheat (*Triticum aestivum* L.) in Chhattisgarh" was conducted at the Agricultural Research Farm of Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C.G.) during 2025-26. The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments consisted of ten different growth regulator treatments *viz*., T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering, T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering, T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering, T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering, T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering, T_6 - Foliar application of abscisic acid (ABA) @ 50 ppm at anthesis, T_7 - Foliar application of abscisic acid (ABA) @ 100 ppm at anthesis, T_8 - Foliar application of abscisic acid (ABA) @ 150 ppm at anthesis, T_9 - Foliar application of abscisic acid (ABA) @ 200 ppm at anthesis and T_{10} - Control. Observations on growth parameters such as plant population (m^{-1} row length), plant height (cm), number of tillers (m^{-2}), plant dry matter accumulation (g $plant^{-1}$), crop growth rate (g $plant^{-1}$ day^{-1}) and relative growth rate (g g^{-1} day^{-1}) were recorded at different stages of crop growth. Phenological parameters including crown root initiation, flag leaf stage, booting, heading and anthesis were also recorded. Growing degree days (°C) and photothermal units (°C day hrs) required to attain different phenological stages were calculated. Yield and yield-attributing parameters *viz*., ear length (cm), number of ears (m^{-1}), number of grains ear^{-1}, test weight (g), grain yield (q ha^{-1}), straw yield (q ha^{-1}) and harvest index (%) were recorded. Economic parameters such as cost of cultivation (₹ ha^{-1}), gross return (₹ ha^{-1}), net return (₹ ha^{-1}) and benefit: cost ratio was also calculated. The data obtained from the experiment were statistically analyzed to determine the significance of treatment effects.

Results and Discussions

Growth Parameters

Growth parameters of late-sown wheat *viz*., plant population at 30 DAS, plant height at 30, 60, 90 DAS and at harvest, number of tillers at 30, 60, 90 DAS and at harvest, plant dry matter accumulation at 30, 60, 90 DAS and at harvest, crop growth rate and relative growth rate showed varying responses to different growth regulator treatments. The results revealed that T_5 - foliar application of GA_3 @ 160 ppm at tillering was most effective in promoting vegetative growth, as it recorded the highest plant height, number of tillers and plant dry matter accumulation at most of the growth stages. This was followed by T_4 - foliar application of GA_3 @ 80 ppm at tillering and T_3 - foliar application of GA_3 @ 40 ppm at tillering. The growth-promoting effect of GA_3 may be attributed to enhanced cell division, cell elongation, tiller development, leaf expansion and photosynthetic activity. In contrast, the T_{10} - Control generally recorded comparatively lower values of growth parameters. Thus, foliar application of GA_3, particularly at 160 ppm, proved more effective than ABA treatments in improving the vegetative growth of late-sown wheat.

Phenological parameters

Phenological parameters of late-sown wheat *viz*., days to crown root initiation (CRI), flag leaf stage, booting, heading and anthesis, growing degree days (GDD) and photothermal units (PTU) were influenced by different growth regulator treatments. The results indicated that T_5 - foliar application of GA_3 @ 160 ppm at tillering generally promoted earlier attainment of flag leaf, booting, heading and anthesis stages and required comparatively lower GDD and PTU for advancement through successive phenological stages. This was followed by T_4 - GA_3 @ 80 ppm and T_3 - GA_3 @ 40 ppm at tillering. The T_{10} - Control recorded comparatively delayed attainment of reproductive stages and required higher GDD and PTU, particularly from flag leaf stage onwards.

Yield and yield attributing parameters

Yield and yield-attributing parameters of late-sown wheat *viz*., ear length, number of ears m^{-2}, number of grains ear^{-1}, test weight, grain yield, straw yield and harvest index showed considerable variation among the different growth regulator treatments. The results revealed that T_5 - foliar application of GA_3 @ 160 ppm at tillering recorded the highest ear length (9.74 cm), number of ears (314.07 m^{-2}), number of grains ear^{-1} (35.34), test weight (44.30 g), grain yield (38.78 q ha^{-1}), straw yield (42.49 q ha^{-1}) and harvest index (47.66%). This was followed by T_4 - GA_3 @ 80 ppm and T_3 - GA_3 @ 40 ppm at tillering. The lowest values of most yield and yield-attributing parameters were recorded under T_{10} - Control. The improvement in yield under GA_3 application may be attributed to enhanced vegetative growth, greater tiller production, increased ear development, better grain formation and improved translocation of photosynthates towards developing grains.

Economical parameters

Economic parameters of late-sown wheat showed considerable variation among the different growth regulator treatments due to differences in input costs and yield response. The highest gross return (₹ 98,301 ha^{-1}) was recorded under T_5 - foliar application of GA_3 @ 160 ppm at tillering, whereas the highest net return (₹ 63,051 ha^{-1}) and benefit: cost ratio (1.90) were obtained under T_3 - foliar application of GA_3 @ 40 ppm at tillering. The lowest gross return (₹ 69,251 ha^{-1}), net return (₹ 38,193 ha^{-1}) and B:C ratio (1.23) were recorded under T_{10} - Control. Although T_5 produced the highest gross return, the higher cost of cultivation reduced its net return and B:C ratio. Therefore, T_3 - foliar application of GA_3 @ 40 ppm at tillering proved to be the most economically efficient treatment for late-sown wheat, providing the best balance between productivity, input cost and profitability.

Table 1: Effect of growth regulators on plant height of late sown wheat (*Triticum aestivum* L.)

Treatment details	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	29.92	64.73	85.29	83.62
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	30.56	65.85	88.32	86.59
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	31.72	70.73	93.86	92.02
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	31.97	71.55	95.03	93.17
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	32.29	72.63	96.57	94.68
T_6 - Foliar application of abscisic acid @ 50 ppm at anthesis.	29.29	57.63	76.29	74.68
T_7 - Foliar application of abscisic acid @ 100 ppm at anthesis.	29.45	58.18	77.07	75.45
T_8 - Foliar application of abscisic acid @ 150 ppm at anthesis.	29.82	59.40	78.82	77.16
T_9 - Foliar application of abscisic acid @ 200 ppm at anthesis.	29.59	58.63	77.72	76.08
T_{10} - Control.	28.65	57.18	76.51	74.05
SEm (±)	1.52	1.47	2.00	1.97
CD (5%)	NS	4.37	5.95	5.86

Table 2: Effect of growth regulators on number of tillers of late sown wheat (*Triticum aestivum* L.)

Treatment details	Number of tillers (m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	184.65	273.46	291.81	290.45
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	185.61	276.77	294.97	293.61
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	185.21	288.81	312.95	311.59
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	186.09	293.34	318.17	316.81
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	188.37	295.90	321.93	320.57
T_6 - Foliar application of abscisic acid @ 50 ppm at anthesis.	182.81	260.70	276.80	274.24
T_7 - Foliar application of abscisic acid @ 100 ppm at anthesis.	182.86	261.13	277.15	275.59
T_8 - Foliar application of abscisic acid @ 150 ppm at anthesis.	184.62	262.61	278.04	276.42
T_9 - Foliar application of abscisic acid @ 200 ppm at anthesis.	184.07	261.55	277.59	276.03
T_{10} - Control.	182.85	260.30	275.08	272.52
SEm (±)	2.80	3.63	4.61	4.54
CD (5%)	NS	10.78	13.72	13.50

Table 3: Effect of growth regulators on plant dry matter accumulation of late sown wheat (*Triticum aestivum* L.)

Treatment details	Plant dry matter accumulation (g $plant^{-1}$)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	0.82	6.12	15.23	19.40
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	0.84	6.32	15.71	20.03
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	0.88	7.45	18.45	23.58
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	0.93	7.63	18.88	24.14
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	0.98	7.73	19.13	24.46
T_6 - Foliar application of abscisic acid @ 50 ppm at anthesis.	0.74	5.34	12.34	16.95
T_7 - Foliar application of abscisic acid @ 100 ppm at anthesis.	0.79	5.75	13.34	18.25
T_8 - Foliar application of abscisic acid @ 150 ppm at anthesis.	0.80	5.91	13.72	18.74
T_9 - Foliar application of abscisic acid @ 200 ppm at anthesis.	0.79	5.78	13.41	18.33
T_{10} - Control.	0.72	5.12	11.81	15.25
SEm (±)	0.08	0.32	1.02	1.33
CD (5%)	NS	0.96	3.04	3.97

Table 4: Effect of growth regulators on CRI, flag leaf stage and days to booting of late sown wheat (*Triticum aestivum* L.)

Treatment details	Days to CRI stage	Days to Flag leaf stage	Days to booting
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	20.33	59.97	69.19
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	20.66	58.88	67.12
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	20.88	57.73	67.88
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	20.33	57.47	66.66
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	20.33	55.61	65.58
T_6 - Foliar application of abscisic acid @ 50 ppm at anthesis.	20.16	61.78	70.85
T_7 - Foliar application of abscisic acid @ 100 ppm at anthesis.	20.06	61.65	70.68
T_8 - Foliar application of abscisic acid @ 150 ppm at anthesis.	20.08	61.45	70.35
T_9 - Foliar application of abscisic acid @ 200 ppm at anthesis.	20.77	61.73	70.54
T_{10} - Control.	20.66	61.92	70.88

Table 5: Effect of growth regulators on days to heading and anthesis of late sown wheat (*Triticum aestivum* L.)

Treatment details	Days to heading	Days to anthesis
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	79.23	88.26
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	78.94	87.03
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	76.65	86.77
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	76.45	86.85
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	75.14	85.66
T_6 - Foliar application of abscisic acid @ 50 ppm at anthesis.	81.76	90.74
T_7 - Foliar application of abscisic acid @ 100 ppm at anthesis.	81.65	90.62
T_8 - Foliar application of abscisic acid @ 150 ppm at anthesis.	81.28	90.34
T_9 - Foliar application of abscisic acid @ 200 ppm at anthesis.	81.46	90.48
T_{10} - Control.	81.92	90.86

Table 6: Effect of growth regulators on Growing degree days of late sown wheat (*Triticum aestivum* L.)

Treatments details	Growing degree days (°C)				
	CRI Stage	Flag leaf stage	Booting stage	Heading stage	Anthesis stage
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	276.3	900.9	1074.6	1261.5	1418
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	276.3	884.5	1041.1	1241.9	1377.5
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	276.3	868.5	1041.1	1201.1	1397.9
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	276.3	868.5	1024.5	1201.1	1377.5
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	276.3	853.1	1024.5	1182	1356.6
T_6 - Foliar application of abscisic acid (ABA) @ 50 ppm at anthesis.	276.3	936.2	1094	1299.3	1437.1
T_7 - Foliar application of abscisic acid (ABA) @ 100 ppm at anthesis.	276.3	936.2	1094	1299.3	1418
T_8 - Foliar application of abscisic acid (ABA) @ 150 ppm at anthesis.	276.3	936.2	1094	1299.3	1437.1
T_9 - Foliar application of abscisic acid (ABA) @ 200 ppm at anthesis.	276.3	936.2	1094	1299.3	1456
T_{10} - Control.	276.3	936.2	1094	1299.3	1475.1

Table 7: Effect of growth regulators on Photo thermal unit of late sown wheat (*Triticum aestivum* L.)

Treatments details	Photo thermal units (°C day hrs)				
	CRI Stage	Flag leaf stage	Booting stage	Heading stage	Anthesis stage
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	2438.77	7619.46	9189.71	10955.42	12180.42
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	2438.77	7463.66	8878.51	10779.02	11986.68
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	2438.77	7287.66	8878.51	10409.78	12176.4
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	2438.77	7287.66	8722.47	10409.78	11986.68
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	2438.77	7142.9	8722.47	10228.33	11825.75
T_6 - Foliar application of abscisic acid (ABA) @ 50 ppm at anthesis.	2438.77	8104.35	9344.91	11329.74	12344.68
T_7 - Foliar application of abscisic acid (ABA) @ 100 ppm at anthesis.	2438.77	8104.35	9344.91	11329.74	12180.42
T_8 - Foliar application of abscisic acid (ABA) @ 150 ppm at anthesis.	2438.77	8104.35	9344.91	11329.74	12344.68
T_9 - Foliar application of abscisic acid (ABA) @ 200 ppm at anthesis.	2438.77	8104.35	9344.91	11329.74	12458.08
T_{10} - Control.	2438.77	8104.35	9344.91	11329.74	12553.01

Table 8: Effect of growth regulators on ear length, number of ear, number of grains and test weight of late sown wheat (*Triticum aestivum* L.)

Treatment details	Ear length (cm)	Number of ear (m^{-2})	Number of grains ear^{-1}	Test weight (g)
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	7.21	285.95	31.51	40.60
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	7.83	287.11	31.68	41.18
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	8.94	305.09	33.56	42.25
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	9.55	310.31	34.05	42.29
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	9.74	314.07	35.34	44.30
T_6 - Foliar application of abscisic acid @ 50 ppm at anthesis.	7.31	267.74	29.77	38.09
T_7 - Foliar application of abscisic acid @ 100 ppm at anthesis.	7.35	269.09	30.09	38.21
T_8 - Foliar application of abscisic acid @ 150 ppm at anthesis.	7.61	271.92	31.03	39.39
T_9 - Foliar application of abscisic acid @ 200 ppm at anthesis.	7.48	270.53	30.37	40.56
T_{10} - Control.	6.29	253.02	27.63	37.59
SEm (±)	0.32	4.51	0.60	2.38
CD (5%)	0.96	13.40	1.81	NS

Table 9: Effect of growth regulators on grain yield, straw yield and harvest index of late sown wheat (*Triticum aestivum* L.)

Treatment details	Grain yield (q ha⁻¹)	Straw yield (q ha⁻¹)	Harvest index (%)
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	33.5	38.43	46.57
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	34.08	38.53	45.92
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	37.96	41.78	47.6
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	38.15	41.84	47.64
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	38.78	42.49	47.66
T_6 - Foliar application of abscisic acid @ 50 ppm at anthesis.	31.83	37.6	45.84
T_7 - Foliar application of abscisic acid @ 100 ppm at anthesis.	32.42	37.78	46.18
T_8 - Foliar application of abscisic acid @ 150 ppm at anthesis.	33.06	38.02	46.51
T_9 - Foliar application of abscisic acid @ 200 ppm at anthesis.	32.71	37.82	46.38
T_{10} - Control.	27.14	34.36	44.13
SEm (±)	1.23	1.33	-
CD (5%)	3.64	3.96	-

Table 10: Effect of growth regulators on economics of late sown wheat cultivation

Treatment details	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
T_1 - Foliar application of gibberellic acid (GA_3) @ 10 ppm at tillering.	32430.00	85081.00	52651.00	1.62
T_2 - Foliar application of gibberellic acid (GA_3) @ 20 ppm at tillering.	32680.00	86497.00	53817.00	1.65
T_3 - Foliar application of gibberellic acid (GA_3) @ 40 ppm at tillering.	33180.00	96231.00	63051.00	1.90
T_4 - Foliar application of gibberellic acid (GA_3) @ 80 ppm at tillering.	34180.00	96702.00	62522.00	1.83
T_5 - Foliar application of gibberellic acid (GA_3) @ 160 ppm at tillering.	36180.00	98301.00	62121.00	1.72
T_6 - Foliar application of abscisic acid @ 50 ppm at anthesis.	32980.00	80948.00	47968.00	1.45
T_7 - Foliar application of abscisic acid @ 100 ppm at anthesis.	33780.00	82397.00	48617.00	1.44
T_8 - Foliar application of abscisic acid @ 150 ppm at anthesis.	34580.00	83973.00	49393.00	1.43
T_9 - Foliar application of abscisic acid @ 200 ppm at anthesis.	35380.00	83104.00	47724.00	1.35
T_{10} - Control.	31058.00	69251.00	38193.00	1.23

Conclusion

The study concluded that foliar application of GA_3 @ 160 ppm at tillering (T_5) was the most effective treatment for improving the growth of wheat. Treatment T_5 recorded the highest plant height, number of tillers per plant and dry matter accumulation, and was found to be significantly superior over the other treatments. The study concluded that foliar application of GA_3 @ 160 ppm at tillering (T_5) was the most effective treatment for enhancing yield and yield attributes of wheat. Treatment T_5 recorded the highest number of grains per spike, test weight, grain yield and straw yield, indicating its superiority over the remaining treatments. The study concluded that foliar application of GA_3 @ 40 ppm at tillering (T_3) was the most economical treatment. Treatment T_3 recorded the highest net return and benefit: cost ratio, indicating that the application of GA_3 @ 40 ppm at tillering is economically beneficial for wheat cultivation.

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