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Effect of seed rate and plant growth regulators on productivity and quality of Wheat (*Triticum aestivum* L.) under early sowing in North Western Plains Zone

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Abstract
The present field experiment was conducted at Agricultural Research Farm of Raja Balwant Singh College, Bichpuri Agra, during *Rabi* season of 2023-24 to evaluate the "Effect of seed rate and plant growth regulators on productivity and quality of wheat (*Triticum aestivum* L.) under early sowing in North Western Plains Zone". The Variables involved in this study were three seed rates *viz*., 100 kg ha^{-1} (SR_3), 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) in main plot, and five growth regulators *viz*., water spray (GR_1), Drum rolling (30 and 45 DAS) (GR_2), 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4) and two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) in sub plot. Thus, in all 15 treatment combinations were compared in a split plot design seed rate in main plots and growth regulators in sub plots with three replications. The soil of experimental field was sandy loam in texture with a pH 8.42. The soil was low in available nitrogen (181.45 Kg ha^{-1}), medium in available phosphorus (28.34 kg P_20_5 ha^{-1}) and potash (283.76 kg K_2O ha^{-1}). Studies were made during the investigation *viz*., Growth and development (germination counts at 15 DAS and crop stnad metre^{-1} row length, plant height (cm), dry matter accumulation (g), days to 75% spike emergence and days to maturity; yield attributes *viz*., number of spike, no. of grain spike^{-1}, weight of grains spike^{-1} (g) and test weight (g); per hectare studies *viz*., Biological, grain, straw yield (q ha^{-1}) and harvest index (%); qualitative studies *viz.,* N, P K content (%) and uptake (kg ha^{-1}); economics *viz.,* Gross returns, net returns (₹ ha^{-1}) and B: C ratio. Seed rate 100 kg ha^{-1} (SR_3) was found better growth characters; yield attributes and yield, comparison to all other seed rate, application of 100 ppm, 2, 3, 5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was found better growth characters; yield attributes and yield, comparison to all other plant growth regulators and maximum net returns (₹ 132918 ha^{-1}) and B: C ratio (3.43) of wheat crop, application of 100 kg ha^{-1} (SR_3) with 100 ppm, 2, 3, 5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), respectively.

Keywords: Seed rate, plant growth regulators, wheat, *Triticum aestivum*, early sowing

Introduction
Wheat (*Triticum aestivum* L.) belong to family *Poaceae* is one of the most important cereal crop of the world that has been considered as integral component of food security system of several nations of the world. India is fortunate to have both fertile land and a climate that is ideal for growing crops. As a result, wheat output is at the second-highest rate globally. The low average wheat yield in this nation is still caused by a number of reasons. One of these environmental influences is premature planting, which has a significant impact on wheat crop output. Due to the crop's comparatively shorter growing period, another significant factor is the dearth of improved varieties with quick maturity that are appropriate for late-planted conditions. Furthermore, under late-planted conditions, cultivars differ in terms of production and nutrient uptake. The area of crop adaptation to climate change that needs the most investigation right now is agricultural science. In terms of cultivated area and production rate, winter wheat (*Triticum aestivum* L.) is one of the most significant crops in the world and is crucial to meeting human cultures' food needs. For around fifty years, Iranian researchers have given saline stress, one of the environmental elements, careful consideration. Research on methods to increase agricultural plant production in saline

environments has gained more attention as a result of the salinization of soil and water resources. Salinity directly harms a plant's interior structure and results in the physiological dryness phenomena. Reducing the amount and quality of water is one of the problems restricting output in arid and semiarid areas. Food security is significantly impacted by water stress, another significant factor restricting agricultural product supply. Additionally, it impacts stomatal conductance, photosynthetic pigments, leaf water potential, and element absorption, particularly of nitrogen and phosphorus. Sowing technique, seeding rate, and the choice of suitable growth regulator are among the crop management parameters that have the most effects on wheat productivity. Farmers frequently use more seed than is advised, up to 160 kg ha^{-1}, instead of the required 120 kg ha^{-1}. Because of the rivalry between plants brought on by increased plant density for available resources, crop productivity is impacted. Using a farmer's field demonstration is a tried-and-true method of showcasing technology to boost farmer adoption.

One way to boost agricultural plants' productivity under various stress situations is to use plant growth regulators, or PGRs. The intensity, genotype, application time, concentration, and degree of stress all affect its yield. PGRs consist of cytokinins (CK), gibberellic acid (GA_3), and salicylic acid (SA). Inducing grain germination and promoting the synthesis of crucial hydrolyzing enzymes for leguminous grain germination are just two of GA3's many effects on plants. Effect of GA_3 on plant tolerance to salt stress: One of the most significant phytohormones, SA, promotes plants' resistance to a variety of water stressors and plays a critical and developing role in how plants react to salt stress. In addition to promoting cell division, removing apical dominance, stem differentiation, and postponing aging, cytokinins also lessen the negative impacts of non-living stressors.

It is projected that India would produce a record 1105.54 lakh tonnes of wheat in 2022-2023. It surpasses the average wheat production of 1057.31 lakh tonnes by 48.23 lakh tonnes and the previous year's production of 1077.42 lakh tonnes by 28.12 lakh tonnes (Ministry of Agriculture & Farmers Welfare, P.I.B., 2022-23). There have been reports of 341.57 lakh hectares of wheat crop coverage in 2023-2024 as opposed to 339.20 lakh hectares (2022-23) at the same period previous year. Thus, within the same period, 2.37 lakh hectares more area was covered than the previous year (Ministry of Agriculture & Farmers Welfare, 2023-24). Of India's total wheat output and area, Madhya Pradesh contributed 16.08% & 86.30 lakh ha, Punjab produced 15.65% & 35.18 lakh ha, and Uttar Pradesh contributed 32.42% & 97.46 lakh ha (Ministry of Agriculture & Farmers Welfare, 2022-23). The Indian Council of Agricultural Research predicts that by 2050, the nation's wheat consumption will amount to 140 million tonnes. Since the amount of land planted to wheat is not anticipated to increase, the majority of this output need will need to be met by raising productivity. Therefore, in view of the above consideration the present investigation was conducted to study the effect of seed rate on growth, yield and quality of wheat, to study the effect of PGRs on growth, yield and quality of wheat, to study the effect of PGRs on growth, yield and quality of wheat.

Methodology

The present field experiment entitled "Effect of seed rate and plant growth regulators on productivity and quality of wheat (*Triticum aestivum* L.) under early sowing in North Western Plains Zone" was conducted during *Rabi* season of 2023-24 at Agricultural Research Farm, R.B.S. College, Bichpuri, Agra. The wheat crop was grown experimentally in the *Rabi* season at the Agricultural Research Farm, Raja Balwant Singh College, Bichpuri, Agra, which is situated at an elevation of 163.4 meters above mean sea level at 27.20^0 North and 77.90^0 East. The research farm is located in the south-western semi-arid region of Uttar Pradesh, approximately 11 kilometers west of Agra city on the Agra-Bharatpur Road. The Gangetic alluvial soil in the experimental field had good drainage and a calcareous layer that was 1.5 to 2.0 meters deep. Shortly before sowing, a composite soil sample was taken from a depth of 0 to 30 cm. It was then put through a series of mechanical and chemical tests to ascertain the fertility status and other physico-chemical properties of the soil in the experimental area. To fulfill the requirement of objectives of the investigation field experiment was conducted during *Rabi* season of 2023-24. A "*Split plot design*" with three seed rate (main plot) and five foliar application of growth regulators and mechanical drum rolling (sub plot) replicated three times was adopted. Other details about treatments are given below:

S. No.	Treatments	Notations
A.	**Main plots: Seed rate (Kg ha^{-1})**	
1.	60	SR_1
2.	80	SR_2
3.	100	SR_3
B.	**Sub plots: Varieties of Barley**	
1.	Control (water spray)	GR_1
2.	Drum rolling (30 and 45 DAS)	GR_2
3.	100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR_3
4.	100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR_4
5.	Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR_5

Result and Discussion

The results & discussion of various study carried out the course of investigation entitled "Effect of seed rate and plant growth regulators on productivity and quality of wheat (*Triticum aestivum* L.) under early sowing in North Western Plains Zone" on the growth and development, yield and yield attributes and quality of barley crop are presented in this chapter and expressed by the helps of suitable tables. The potential yield of a crop is greatly influenced by agronomic practices, fertility conditions, environmental factors, and other management strategies applied both prior to and during experiments. It is believed that growth regulators and seed rates are essential components in optimizing plant population. During the presentation of the experiment's results, it was observed that the various treatments had a significant impact on wheat yield and quality. Upon reviewing the material contained therein, some significant discoveries were made, which are discussed here together with our own observations and the work of other specialists.

Growth and development

Germination count at 15 DAS and no. of shoots metre^{-1} row length

Effect of seed rate

The data presented in Table-1 indicate that seed rate exert significant effect on germination count. Germination count was significantly higher with 100 kg ha^{-1} (SR_3) by 3.07 and 15.03 percent over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1), respectively. 80 kg ha^{-1} (SR_2) also increased germination count appreciably than 60 kg ha^{-1} (SR_1) and the difference was 11.60 percent. Number of shoots metre^{-1} row length was significantly affected due to seed rate at various stages of crop growth. The maximum number of shoots metre^{-1} row length was recorded with 100 kg ha^{-1} (SR_3) at all the stages of crop growth and it was significantly higher over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) seed rate. 80 kg ha^{-1} (SR_2) also had significantly higher number of shoots metre^{-1} row length than 60 kg ha^{-1} (SR_1) seed rate at all the stages of crop growth. At harvest, the magnitude of increase in number of shoots metre^{-1} row length with 100 kg ha^{-1} (SR_3) was to the tune of 10.29 and 17.90 percent, over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) seed rate, respectively. Similar results were also reported by Singh *et al.*, (2020) [17], Singh *et al.*, (2021), Sarkar *et al.*, (2022) [15], Singh and Verma (2023), and Kumar *et al.*, (2024) [6].

Table 1: Germination count at 15 DAS and number of shoots metre^{-1} row length at successive stages of crop growth as influenced by seed rate and growth regulators

Treatments		Germination Count	No. of shoots metre^{-1} row length				
		15 DAS	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
A. Main plot: Seed rate (kg ha^{-1}) - 03							
60	SR_1	48.70	76.30	84.57	92.75	86.75	76.50
80	SR_2	54.35	81.95	91.77	100.15	93.45	81.78
100	SR_3	56.02	84.95	94.22	109.70	101.20	90.20
SE(m) ±		0.28	0.73	0.38	0.43	0.46	0.46
C.D. (p=0.05)		1.11	2.88	1.50	1.70	1.82	1.82
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05							
Control (water spray)	GR_1	51.72	79.84	88.30	99.67	92.34	81.17
Drum rolling (30 and 45 DAS)	GR_2	52.54	60.47	88.46	99.58	92.40	81.25
100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR_3	54.92	82.76	93.59	102.71	96.01	85.47
100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR_4	54.30	82.72	92.09	101.92	94.67	84.34
Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR_5	53.17	80.84	88.42	100.55	93.51	82.55
SE(m) ±		0.31	0.32	0.41	0.42	0.53	0.30
C.D. (p=0.05)		0.92	0.96	1.21	1.29	1.26	0.91

Effect of growth regulators

Table-1 under reference reveals that the germination count at 15 DAS and number of shoots metre^{-1} row length at various stages of crop growth were significantly affected due to growth regulators. Maximum germination count (54.92) was noted with application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) which was significantly higher than application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively. GR_3 found at par with GR_4 and the magnitude of increase in germination count with application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 1.20, 3.29 and 4.52 percent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively. Lowest germination count (51.72) was noted with application of water spray (GR_1). The number of shoots metre^{-1}length was found to be highest with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), magnitude of increase in number of plants metre^{-1} with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 1.33, 3.53 and 5.19 percent, over application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), at harvest respectively. Lowest number of shoots metre^{-1} length (81.17) was noted with application of water spray (GR_1) at harvest. Similar results were also reported by Singh *et al.*, (2020) [17], Biradar *et al.*, *(*2021) [2], Auskalniene *et al.*, (2022) [1], Rajala (2023) [12] and Raut *et al.*, (2024) [14].

Plant height (cm)

Effect of seed rate

Significant variations in seed rate were observed throughout the entire crop growing cycle. At every stage of plant growth, there was a constant rise in plant height in response to a decrease in seed rate. The maximum plant height of

4.85, 23.07, 45.49, 88.85 and 89.50 cm was recorded with 100 kg ha^{-1} (SR_3) at 30, 60, 90, 120 DAS and at harvest followed by 80 kg ha^{-1} (SR_2) (4.35, 21.18, 44.00, 87.14 and 87.37 cm, and 60 kg ha^{-1} (SR_1) respectively, the magnitude of increase in plant height with 100 kg ha^{-1} (SR_3) was to the tune of 2.43 and 4.37 percent, over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) row at harvest. Lowest plant height (4.12, 19.92, 42.31, 86.07 and 86.50 cm) was noted with application of 60 kg ha^{-1} (SR_1) at 30, 60, 90, 120 DAS and at harvest. These results are in agreement with the findings of Singh and Verma (2023), and Kumar *et al.*, (2024) [6].

Effect of growth regulators

The advancement of the crop growing period and an increase in growth regulator with the application of 100 ppm, 2, 3, 5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) resulted in a considerable rise in plant height. In order to reach the maximum plant height of 4.58 cm at 30 DAS, 25.77 cm at 60 DAS, 45.13 cm at 90 DAS, 88.75 cm at 120 DAS, including harvest stage (90.27 cm), the maximum plant height was corded with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3). GR_3 found at par with GR_4 at 120 DAS and the magnitude of increase in plant height with application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 1.29, 3.16 and 4.43 percent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), at harvest respectively. The minimum plant height was application of water spray (GR_1) (4.33, 19.78, 40.17, 84.51 and 84.69 cm, at 30, 60, 90, 120 DAS and at harvest, respectively). Throughout the whole growth stage, there were substantial differences in plant height with varying growth regulator. Similar findings were recorded by Singh *et al.*, (2021), Sarkar *et al.*, (2022) [15].

Table 2: Plant height (cm) at successive stages of crop growth as influenced by seed rate and growth regulators

Treatments		Plant height (cm)				
		30 DAS	60 DAS	90 DAS	120 DAS	At harvest
A. Main plot: Seed rate (kg ha^{-1}) - 03						
60	SR_1	4.12	19.92	42.31	86.07	86.50
80	SR_2	4.35	21.18	44.00	87.14	87.37
100	SR_3	4.85	23.07	45.49	88.85	89.50
SE(m) ±		0.10	0.11	0.15	0.34	0.16
C.D. (p=0.05)		0.39	0.44	0.61	1.12	0.63
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05						
Control (water spray)	GR_1	4.33	19.78	40.17	84.51	84.69
Drum rolling (30 and 45 DAS)	GR_2	4.45	20.04	41.19	84.98	86.44
100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR_3	4.58	25.77	45.13	88.75	90.27
100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR_4	4.54	23.46	44.62	88.56	89.12
Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR_5	4.52	21.17	42.24	86.06	87.50
SE(m) ±		0.08	0.07	0.19	0.35	0.42
C.D. (p=0.05)		NS	0.17	0.45	0.83	0.99

Dry matter accumulation (g)

Effect of seed rate

The data presented in Table-3 indicate that seed rate exert significant effect on dry matter accumulation (g). Dry matter accumulation (g) was significantly higher with 100 kg ha^{-1} (SR_3) by 2.27 and 6.52 percent over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) at harvest, respectively. 80 kg ha^{-1} (SR_2) also increased dry matter accumulation (g) appreciably than 60 kg ha^{-1} (SR_1) and the difference was 4.15 percent. Dry matter accumulation (g) was significantly affected due to seed rate at various stages of crop growth. The maximum dry matter accumulation (g) was recorded with 100 kg ha^{-1} (SR_3) at all the stages of crop growth and it was significantly higher over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) seed rate. 80 kg ha^{-1} (SR_2) also had significantly higher dry matter accumulation (g) than 60 kg ha^{-1} (SR_1) seed rate at all the stages of crop growth. Lowest dry matter accumulation (g) was noted with application of 60 kg ha^{-1} (SR_3) at 30, 60, 90, 120 DAS and at harvest. Similar results were also reported by Singh *et al.*, (2020), Singh *et al.*, (2021), Sarkar *et al.*, (2022) [15], Singh and Verma (2023) and Kumar *et al.*, (2024) [6].

Effect of growth regulators

Table-3 under reference reveals that the dry matter accumulation (g) at 30, 60, 90, 120 DAS and at harvest of crop growth were significantly affected due to growth regulators. Maximum dry matter accumulation (g) was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively.

Table 3: Dry matter accumulation (g) in plant of 25 cm row length at successive stages of crop growth as influenced by seed rate and growth regulators

Treatments		Dry matter accumulation (g)				
		30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**At harvest**
A. Main plot: Seed rate (kg ha^{-1}) - 03						
60	SR_1	6.46	14.13	51.32	122.35	127.14
80	SR_2	7.00	15.58	51.95	126.34	132.42
100	SR_3	7.72	16.45	54.02	127.98	135.43
SE(m) ±		0.13	0.22	0.55	0.42	0.67
C.D. (p=0.05)		0.52	0.69	1.51	1.52	2.64
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05						
Control (water spray)	GR_1	6.19	12.77	48.98	119.93	128.84
Drum rolling (30 and 45 DAS)	GR_2	6.67	14.09	50.08	121.55	130.59
100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR_3	7.89	16.29	56.72	128.79	134.89
100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR_4	7.23	15.61	53.20	126.24	132.26
Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR_5	6.77	14.44	51.72	123.08	131.10
SE(m) ±		0.17	0.25	1.12	1.05	0.72
C.D. (p=0.05)		0.40	0.59	3.04	2.56	2.12

GR_3 found at par with GR_4 at 120 DAS and the magnitude of increase in dry matter accumulation (g) with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 1.98, 2.89 and 3.29 percent, over application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4) and two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) at harvest, respectively. Lowest dry matter accumulation (g) was noted with the application of water spray (GR_1). Similar findings were recorded by Singh *et al.*, (2021), Sarkar *et al.*, (2022) [15].

Yield attributes

Stand count m^{-2}

Effect of seed rate

The data presented in Table-4 indicate that seed rate exert significant effect on stand count m^{-2}. The maximum stand count m^{-2} was recorded with 100 kg ha^{-1} (SR_3) and it was significantly higher over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) seed rate. 80 kg ha^{-1} (SR_2) also had significantly higher stand count m^{-2} than 60 kg ha^{-1} (SR_1) seed rate at harvest. Stand count m^{-2} were significantly higher with 100 kg ha^{-1} (SR_3) by 1.30 and 6.65 percent over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) at harvest, respectively. 80 kg ha^{-1} (SR_2) also increased stand count m^{-2} appreciably than 60 kg ha^{-1} (SR_1) and the difference was 5.27 percent. Lowest stand count m^{-2} (239.37) were noted with the application of 60 kg ha^{-1} (SR_1). Similar findings were recorded by Rajala (2023) [12] and Raut *et al.*, (2024) [14].

Effect of growth regulators

Table-4 under reference reveals that the stand count m^{-2} at harvest was significantly affected due to growth regulators. Maximum stand count m^{-2} was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively, the magnitude of increase in stand count m^{-2} with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 1.65, 2.79 and 3.51 percent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively. Lowest stand count m^{-2} (241.93) were noted with the application of water spray (GR_1).

No. of spikes m^{-2}

Effect of seed rate

The maximum number of spikes m^{-2} was recorded with 100 kg ha^{-1} (SR_3) and it was significantly higher over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) seed rate. 80 kg ha^{-1} (SR_2) also had significantly higher number of spikes m^{-2} than 60 kg ha^{-1} (SR_1) seed rate at harvest. Number of spikes m^{-2} was significantly higher with 100 kg ha^{-1} (SR_3) by 0.82 and 4.40 percent over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) at harvest, respectively. 80 kg ha^{-1} (SR_2) also increased number of spikes m^{-2} appreciably than 60 kg ha^{-1} (SR_1) and the difference was 3.54 percent. Lowest number of spikes m^{-2} (228.75) was noted with the application of 60 kg ha^{-1} (SR_1).

Effect of growth regulators

Maximum number of spikes m^{-2} was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively, the magnitude of increase in number of spikes m^{-2} with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 0.65, 1.66 and 1.99 percent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively. Lowest number of spikes m^{-2} (233.02) was noted with the application of water spray (GR_1). Similar findings were recorded by Ram *et al.,* (2012) [13] and Khokhar *et al.,* (2013) [5].

No. of grains spike^{-1}

Effect of seed rate

The maximum number of grains spike^{-1} was recorded with 100 kg ha^{-1} (SR_3) and it was significantly higher over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) seed rate. 80 kg ha^{-1} (SR_2) also had significantly higher number of grains spike^{-1} than 60 kg ha^{-1} (SR_1) seed rate at harvest. Number of grains spike^{-1} was significantly higher with 100 kg ha^{-1} (SR_3) by 6.85 and 17.56 percent over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) at harvest, respectively. 80 kg ha^{-1} (SR_2) also increased number of grains spike^{-1} appreciably than 60 kg ha^{-1} (SR_1) and the difference was 10.01 percent. Lowest number of grains spike^{-1} (46.91) were noted with the application of 60 kg ha^{-1} (SR_1).

Effect of growth regulators

Number of grains spike^{-1} at harvest was significantly affected due to growth regulators. Maximum number of grains spike^{-1} was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively, the magnitude of increase in number of grains spike^{-1} with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 4.27, 8.27 and 12.82 percent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively. Lowest number of grains spike^{-1} (48.04) was noted with the application of water spray (GR_1). Similar findings were recorded by Meena and Verma (2015) [8] and Marasini *et al.*, (2016) [7].

Test weight (g)

Effect of seed rate

The data presented in Table-4 indicate that seed rate exert significant effect on test weight (g). The maximum weight of grains spike^{-1} (g) test weight (g) was recorded with 100 kg ha^{-1} (SR_3) and it was significantly higher over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1) seed rate. 80 kg ha^{-1} (SR_2) also had significantly higher test weight (g) than 60 kg ha^{-1} (SR_1) seed rate at harvest. Test weight (g) was significantly higher with 100 kg ha^{-1} (SR_3) by 1.12 and 12.00 percent over 80 kg ha^{-1} (SR_2) and 60 kg ha^{-1} (SR_1), 100 kg ha^{-1} (SR_3) was found at par with 80 kg ha^{-1} (SR_2) at harvest, respectively. 80 kg ha^{-1} (SR_2) also increased test weight (g) appreciably than 60 kg ha^{-1} (SR_1) and the difference was 10.76 percent. Lowest test weight (37.73 g) were noted with the application of 60 kg ha^{-1} (SR_1). Similar findings were recorded by Rajala (2023) [12] and Raut *et al.,* (2024) [14].

Effect of growth regulators

Maximum test weight (g) was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively, the magnitude of increase in test weight (g) with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 9.99, 13.80 and 15.77 percent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively. Lowest test weight (38.22 g) was noted with the application of water spray (GR_1). Similar findings were recorded by Ram *et al.,* (2012) [13] and Khokhar *et al.,* (2013) [5].

Table-4: Yield attributes of wheat as influenced by seed rate and growth regulators

Treatments	Stand count m^{-2}	No. of spikes m^{-2}	Length of Spike (cm)	No. of Spikelet's spike^{-1}	No. of Fertile Spikelet's spike^{-1}	No. of grains spike^{-1}	Weight of Grains spike^{-1} (g)	Test weight (g)
A. Main plot: Seed rate (kg ha^{-1}) - 03								
SR_1	239.37	228.75	7.15	49.41	43.88	46.91	2.33	37.73
SR_2	252.00	236.87	8.49	59.72	56.96	51.61	2.61	41.79
SR_3	255.30	238.83	8.78	60.54	59.52	55.15	2.99	42.26
SE(m) ±	0.43	0.38	0.15	0.43	0.60	0.51	0.06	0.30
C.D. (p=0.05)	1.69	1.50	0.58	1.68	2.36	1.66	0.22	1.18
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05								
GR_1	241.93	233.02	7.22	47.79	45.52	48.04	2.65	38.22
GR_2	249.77	235.96	8.09	52.55	50.20	49.29	2.72	39.37
GR_3	258.56	240.66	9.79	65.37	61.36	55.61	3.38	45.58
GR_4	254.35	239.09	9.09	61.77	57.99	53.33	3.06	41.44
GR_5	251.53	236.73	8.66	57.02	54.11	51.36	2.75	40.05
SE(m) ±	0.67	0.60	0.21	1.20	1.33	0.65	0.10	0.31
C.D. (p=0.05)	1.60	1.43	0.62	2.86	3.17	1.55	0.24	1.02

Yield studies (q ha^{-1})

Biological yield (q ha^{-1})

Effect of seed rate

The perusal of biological yield (q ha^{-1}) data in Table-5 revealed that the highest biological yield (q ha^{-1}) was recorded with 100 kg ha^{-1} (SR$_3$) (120.75 q ha^{-1}), followed by 80 kg ha^{-1} (SR$_3$) (116.09 q ha^{-1}) and 60 kg ha^{-1} (SR$_3$) (111.85 q ha^{-1}), the magnitude of increase in of biological yield (q ha^{-1}) with 100 kg ha^{-1} (SR$_3$) was to the tune of 4.01 and 7.95 percent, over 80 kg ha^{-1} (SR$_3$) and 60 kg ha^{-1} (SR$_3$). Lowest biological yield (111.85 q ha^{-1}) were noted with the application of 60 kg ha^{-1} (SR$_1$). Similar results were also reported by Sulieman (2010), Kanika *et al.*, (2011) [4] and Ram *et al.*, (2012) [13].

Effect of growth regulators

When we intensely scrutinize the treatments with different growth regulators we conclude that biological yield of wheat significantly increased with decrease in growth regulators. Table-5 under reference reveals that the biological yield (q ha^{-1}) at harvest was significantly affected due to growth regulators. Maximum biological yield (q ha^{-1}) was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR$_3$), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR$_4$), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR$_5$) and Drum rolling (30 and 45 DAS) (GR$_2$), respectively, the magnitude of increase in biological yield (q ha^{-1}) with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR$_3$) was to the tune of 8.16, 11.61 and 14.16 percent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR$_4$), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR$_5$) and Drum rolling (30 and 45 DAS) (GR$_2$), respectively. Lowest biological yield (107.85 q ha^{-1}) was noted with the application of water spray (GR$_1$). Similar results were also reported by Utpal *et al.*, (2018) [19], Singh *et al.*, (2019), Gupta (2020) [3], Qin *et al.*, (2020) [11], Singh *et al.*, (2020) [17], Biradar *et al.*, (2021) [2], Auskalniene *et al.*, (2022) [1], Rajala (2023) [12] and Raut *et al.*, (2024) [14].

Grain yield (q ha^{-1})

Effect of seed rate

Table-5 revealed that the highest grain yield (q ha^{-1}) was recorded with 100 kg ha^{-1} (SR$_3$) (52.36 q ha^{-1}), followed by 80 kg ha^{-1} (SR$_3$) (48.47 q ha^{-1}) and 60 kg ha^{-1} (SR$_3$) (43.65 q ha^{-1}), the magnitude of increase in of grain yield (q ha^{-1}) with 100 kg ha^{-1} (SR$_3$) was to the tune of 8.02 and 19.95 percent, over 80 kg ha^{-1} (SR$_3$) and 60 kg ha^{-1} (SR$_3$). Lowest grain yield (43.65 q ha^{-1}) were noted with the application of 60 kg ha^{-1} (SR$_1$). Similar results were also reported by Sulieman (2010), Kanika *et al.*, (2011) [4] and Ram *et al.*, (2012) [13].

Effect of growth regulators

Table-5 under reference reveals that the grain yield (q ha^{-1}) at harvest was significantly affected due to growth regulators. Maximum grain yield (q ha^{-1}) was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR$_3$), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR$_4$), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR$_5$) and Drum rolling (30 and 45 DAS) (GR$_2$), respectively, the magnitude of increase in grain yield (q ha^{-1}) with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR$_3$) was to the tune of 10.42, 15.82 and 20.10 percent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR$_4$), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR$_5$) and Drum rolling (30 and 45 DAS) (GR$_2$), respectively. Lowest grain yield (43.85 q ha^{-1}) was noted with the application of water spray (GR$_1$). Similar results were also reported by Utpal *et al.*, (2018) [19], Singh *et al.*, (2019), Singh *et al.*, (2020) [17], Biradar *et al.*, (2021) [2], Auskalniene *et al.*, (2022) [1], Rajala (2023) [12] and Raut *et al.*, (2024) [14].

Straw yield (q ha^{-1})

Effect of seed rate

Highest straw yield (q ha^{-1}) was recorded with 100 kg ha^{-1} (SR$_3$) (68.39 q ha^{-1}), followed by 80 kg ha^{-1} (SR$_3$) (67.62 q ha^{-1}) and 60 kg ha^{-1} (SR$_3$), the magnitude of increase in of straw yield (q ha^{-1}) with 100 kg ha^{-1} (SR$_3$) was to the tune of 1.13 and 0.27 percent, over 80 kg ha^{-1} (SR$_3$) and 60 kg ha^{-1} (SR$_3$). Lowest grain yield (67.62 q ha^{-1}) were noted with the application of 80 kg ha^{-1} (SR$_1$). Similar results were also reported by Sulieman (2010), Kanika *et al.*, (2011) [4] and Ram *et al.*, (2012) [13].

Table 5: Biological, Grain, Straw yield (q ha^{-1}) and harvest index (%) of wheat as influenced by various treatments

Treatments		Yield (q ha^{-1})			
		Biological yield (q ha^{-1})	**Grain yield (q ha^{-1})**	**Straw yield (q ha^{-1})**	**Harvest index (%)**
A. Main plot: Seed rate (kg ha^{-1}) - 03					
60	SR$_1$	111.85	43.65	68.20	39.02
80	SR$_2$	116.09	48.47	67.62	41.75
100	SR$_3$	120.75	52.36	68.39	43.36
SEm ±		0.43	0.56	0.27	0.14
C.D. (p=0.05)		1.69	2.22	1.08	0.55
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05					
Control (water spray)	GR$_1$	107.85	43.85	64.00	40.65
Drum rolling (30 and 45 DAS)	GR$_2$	112.15	46.31	65.84	41.29

100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR_3	128.04	55.62	72.42	43.43
100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR_4	118.38	50.37	68.01	42.54
Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR_5	114.72	48.02	66.70	41.85
SE(m) ±		1.07	1.03	0.73	0.34
C.D. (p=0.05)		2.56	2.45	1.73	1.03

Effect of growth regulators

Maximum straw yield (q ha^{-1}) was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively, the magnitude of increase in straw yield (q ha^{-1}) with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 6.48, 8.57 and 9.99 per cent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively. Lowest straw yield (64.00 q ha^{-1}) was noted with the application of water spray (GR_1). Similar results were also reported by Utpal *et al.*, (2018) [19], Singh *et al.*, (2019), Gupta (2020) [3], Qin *et al.*, (2020) [11], Singh *et al*., (2020) [17], Biradar *et al.*, *(*2021) [2] and Auskalniene *et al.*, (2022) [1].

Harvest index (%)

Effect of seed rate

Highest harvest index (%) was recorded with 100 kg ha^{-1} (SR_3) (43.36%), followed by 80 kg ha^{-1} (SR_3) (41.75%) and 60 kg ha^{-1} (SR_3) (39.02%), the magnitude of increase in of harvest index (%) with 100 kg ha^{-1} (SR_3) was to the tune of 1.61 and 4.34 per cent, over 80 kg ha^{-1} (SR_3) and 60 kg ha^{-1} (SR_3). Similar results were also reported by Sulieman (2010), Kanika *et al.*, (2011) [4] and Ram *et al.*, (2012) [13].

Effect of growth regulators

Table-5 under reference reveals that the harvest index (%) at harvest was significantly affected due to growth regulators. Maximum harvest index (%) was noted with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3), which was significantly higher than the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively, the magnitude of increase in harvest index (%) with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) was to the tune of 0.89, 1.58 and 2.14 per cent, over the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2), respectively. Lowest harvest index (40.65%) was noted with the application of water spray (GR_1). Similar results were also reported by Utpal *et al.*, (2018) [19], Singh *et al.*, (2019), Gupta (2020) [3], Qin *et al.*, (2020) [11], Singh *et al*., (2020) [17], Biradar *et al.*, *(*2021) [2] and Auskalniene *et al.*, (2022) [1].

Economics

Gross returns (₹ ha^{-1})

Effect of seed rate

It is evident from Table-6 that the highest gross returns of the wheat crop were obtained from the application of 100 kg seed rate ha^{-1} (₹ 161756 ha^{-1}) followed by 80 kg seed rate ha^{-1} (₹ 152756 ha^{-1}) and 60 kg seed rate ha^{-1} (₹ 72786 ha^{-1}), whereas the lowest gross returns of (₹ 142679 ha^{-1}) was obtained from under 60 kg seed rate ha^{-1}. Similar results were also reported by Sulieman (2010), Kanika *et al.*, (2011) [4] and Ram *et al.*, (2012) [13].

Effect of growth regulators

Table-6 that the highest gross returns of the wheat crop were obtained from the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) (₹ 171668 ha^{-1}) followed by the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4) (₹ 157162 ha^{-1}), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) (₹ 151134 ha^{-1}) and Drum rolling (30 and 45 DAS) (GR_2) (₹ 146812 ha^{-1}), whereas the lowest gross returns of (₹ 140174 ha^{-1}) was obtained from under the application of water spray (GR_1). Similar results were also reported by Singh *et al.*, (2020) [17], Singh *et al.*, (2021), Sarkar *et al*., (2022) [15], Singh and Verma (2023).

Gross returns (₹ ha^{-1})

Effect of seed rate: Table-6 that the highest net returns of the wheat crop were obtained from the application of 100 kg seed rate ha^{-1} (₹ 122506 ha^{-1}) followed by 80 kg seed rate ha^{-1} (₹ 114256 ha^{-1}) and 60 kg seed rate ha^{-1} (₹ 105429 ha^{-1}), whereas the lowest net returns of (₹ 105429 ha^{-1}) was obtained from under 60 kg seed rate ha^{-1}. Similar results were also reported by Sulieman (2010), Kanika *et al.*, (2011) [4] and Ram *et al.*, (2012) [13].

Effect of growth regulators

Table-6 that the highest net returns of the wheat crop were obtained from the application of 100 ppm, 2,3,5-

triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) (₹ 132918 ha^{-1}) followed by the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4) (₹ 117812 ha^{-1}), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) (₹ 111574 ha^{-1}) and Drum rolling (30 and 45 DAS) (GR_2) (₹ 108562 ha^{-1}), whereas the lowest net returns of (₹ 102224 ha^{-1}) was obtained from under the application of water spray (GR_1). Similar results were also reported by Singh *et al.*, (2020), Singh *et al.*, (2021) [8], Sarkar *et al.*, (2022) [15], Singh and Verma (2023).

Table 6: Economics (₹ ha^{-1}) of wheat as influenced by various treatments

Treatments		Economics (₹ ha^{-1})			
		Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B: C ratio
A. Main plot: Seed rate (kg ha^{-1}) - 03					
60	SR_1	37250	142679	105429	2.82
80	SR_2	38500	152756	114256	2.96
100	SR_3	39250	161756	122506	3.12
SE(m) ±		-	2663	1382	0.04
C.D. (p=0.05)		-	6784	4134	0.11
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05					
Control (water spray)	GR_1	37950	140174	102224	2.69
Drum rolling (30 and 45 DAS)	GR_2	38250	146812	108562	2.83
100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR_3	38750	171668	132918	3.43
100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR_4	39350	157162	117812	2.99
Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR_5	39560	151134	111574	2.82
SE(m) ±		-	1153	1456	0.05
C.D. (p=0.05)		-	3458	4358	0.16

Qualitative studies

Nitrogen, phosphorus and potassium content (%) and uptake (kg ha^{-1})

Effect of seed rate & growth regulators

Different seed rate had significant effect on phosphorus content (%) and uptake (kg ha^{-1}). The highest phosphorus content (0.337% in grain & 0.046% in straw) and uptake (17.65 kg ha^{-1} by grain & 3.15 kg ha^{-1} by grain) was recorded with the application of 100 kg seed rate ha^{-1} followed by 80 kg seed rate ha^{-1}. Minimum phosphorus content (0.318% in grain & 0.031% in straw) and uptake (13.88 kg ha^{-1} by grain & 2.11 kg ha^{-1} by grain) was recorded with the application of 60 kg seed rate ha^{-1} of wheat crop. Different growth regulators had significant effect on phosphorus content (%) and uptake (kg ha^{-1}). The highest phosphorus content (0.341% in grain & 0.048% in straw) and uptake (18.35 kg ha^{-1} by grain & 3.20 kg ha^{-1} by grain) was recorded with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) followed by the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR_4), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR_5) and Drum rolling (30 and 45 DAS) (GR_2).

Table 7: Nitrogen content (%) and uptake (kg ha^{-1}) of wheat as influenced by various treatments

Treatments		Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})	
		Grain	Straw	Grain	Straw
A. Main plot: Seed rate (kg ha^{-1}) - 03					
60	SR_1	2.21	0.40	96.47	27.28
80	SR_2	2.23	0.42	108.09	28.40
100	SR_3	2.32	0.47	121.48	32.14
SE(m) ±		0.010	0.004	0.98	0.75
C.D. (p=0.05)		0.028	0.010	2.89	2.21
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05					
Control (water spray)	GR_1	2.07	0.35	90.77	22.40
Drum rolling (30 and 45 DAS)	GR_2	2.15	0.37	99.57	24.36
100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR_3	2.29	0.46	127.37	33.31
100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR_4	2.25	0.42	113.33	28.56
Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR_5	2.20	0.40	105.64	26.68
SE(m) ±		0.011	0.003	1.02	0.87
C.D. (p=0.05)		0.032	0.009	3.05	2.62

Minimum phosphorus content (0.320% in grain & 0.032% in straw) and uptake (14.03 kg ha^{-1} by grain & 2.05 kg ha^{-1} by grain) was recorded with the application of water spray (GR$_1$) Similar results were also reported by Singh *et al*., (2020) [17], Singh *et al.*, (2021), Sarkar *et al*., (2022) [15], Singh and Verma (2023), and Kumar *et al*., (2024) [6]. Different seed rate had significant effect on potassium content (%) and uptake (kg ha^{-1}). The highest potassium content (0.80% in grain & 2.21% in straw) and uptake (41.89 kg ha^{-1} by grain & 151.14 kg ha^{-1} by grain) was recorded with the application of 100 kg seed rate ha^{-1} followed by 80 kg seed rate ha^{-1}. Minimum potassium content (0.71% in grain & 2.01% in straw) and uptake (30.99 kg ha^{-1} by grain & 137.08 kg ha^{-1} by grain) was recorded with the application of 60 kg seed rate ha^{-1} of wheat crop. Different growth regulators had significant effect on potassium content (%) and uptake (kg ha^{-1}). The highest potassium content (0.79% in grain & 2.39% in straw) and uptake (43.94 kg ha^{-1} by grain & 173.08 kg ha^{-1} by grain) was recorded with the application of 100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR$_3$) followed by the application of 100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage (GR$_4$), two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application) (GR$_5$) and Drum rolling (30 and 45 DAS) (GR$_2$). Minimum potassium content (0.64% in grain & 1.92% in straw) and uptake (28.06 kg ha^{-1} by grain & 122.88 kg ha^{-1} by grain) was recorded with the application of water spray (GR$_1$) Similar results were also reported by Singh and Verma (2023), and Kumar *et al.*, (2024) [6].

Table 8: Phosphorus content (%) and uptake (kg ha^{-1}) of wheat as influenced by various treatments

Treatments		Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})	
		Grain	Straw	Grain	Straw
A. Main plot: Seed rate (kg ha^{-1}) - 03					
60	SR$_1$	0.318	0.031	13.88	2.11
80	SR$_2$	0.325	0.037	15.75	2.50
100	SR$_3$	0.337	0.046	17.65	3.15
SE(m) ±		0.002	0.003	0.32	0.27
C.D. (p=0.05)		0.005	0.009	1.02	0.85
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05					
Control (water spray)	GR$_1$	0.320	0.032	14.03	2.05
Drum rolling (30 and 45 DAS)	GR$_2$	0.327	0.040	15.14	2.63
100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR$_3$	0.341	0.048	18.35	3.20
100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR$_4$	0.332	0.043	16.72	2.97
Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR$_5$	0.330	0.041	16.37	2.92
SE(m) ±		0.004	0.003	0.46	0.32
C.D. (p=0.05)		0.010	0.009	1.34	0.96

Table 9: Potassium content (%) and uptake (kg ha^{-1}) of wheat as influenced by various treatments

Treatments		Potassium content (%)		Potassium uptake (kg ha^{-1})	
		Grain	Straw	Grain	Straw
A. Main plot: Seed rate (kg ha^{-1}) - 03					
60	SR$_1$	0.71	2.01	30.99	137.08
80	SR$_2$	0.74	2.13	35.87	144.03
100	SR$_3$	0.80	2.21	41.89	151.14
SE(m) ±		0.004	0.005	0.62	0.65
C.D. (p=0.05)		0.011	0.015	1.85	1.89
B. Sub plot: Foliar application of growth regulators and mechanical drum rolling: 05					
Control (water spray)	GR$_1$	0.64	1.92	28.06	122.88
Drum rolling (30 and 45 DAS)	GR$_2$	0.68	2.12	31.49	139.58
100 ppm, 2,3,5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage	GR$_3$	0.79	2.39	43.94	173.08
100 ppm, 6-benzyl amino purine (Cytokinin derivative) at tiller initiation stage	GR$_4$	0.73	2.28	36.77	155.06
Two sprays as tank mix-Chlormequat chloride (Lihocin) @ 0.2% + tebuconazole (Folicur 430 SC) @ 0.1% of commercial product dose at first node and flag leaf (Tank mix application)	GR$_5$	0.70	2.24	33.61	149.41
SE(m) ±		0.007	0.006	0.59	0.51
C.D. (p=0.05)		0.021	0.018	1.73	1.52

Conclusion

Seed rate 100 kg ha^{-1} (SR$_3$) was found better growth characters; yield attributes and yield, comparison to all other seed rate. Application of 100 ppm, 2, 3, 5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR$_3$) was found better growth characters; yield attributes and yield, comparison to all other plant growth regulators. On the basis of maximum net returns (₹ 132918 ha^{-1}) and B: C ratio (3.43) of wheat crop, application of 100 kg ha^{-1} (SR_3) with 100 ppm, 2, 3, 5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage (GR_3) under early sowing in North Western Plains Zone.

Recommendation

On the basis of all growth characters, yield attributes, yield, maximum returns and B: C ratio (3.43) was obtained higher with application of 100 kg ha^{-1} with 100 ppm, 2, 3, 5-triiodobenzoic Acid (TIBA) (Auxin transport inhibitor) at tiller initiation stage should be recommended for farmers under early sowing in North Western Plains Zone.

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