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Influence of plant growth regulators on growth and yield of wheat (*Triticum aestivum* L.) under late sown condition

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Abstract
The present investigation entitled "Influence of plant growth regulators on growth and yield of wheat (*Triticum aestivum* L.) Under late sown condition" has been taken to focus the involvement and potential role of plant growth regulator and was carried out in during 2019-20 and 2020-21 at Agronomy Research Farm of C.S.A. University of Agriculture and Technology, Kanpur (U.P.). The experiment was done during *Rabi* (2019-20 and 2020-21) using wheat variety K-9423 using randomized block design having eleven treatments and three replications having thirty-three plots different plant growth regulators are used at various growth stages for overall development of crop. The details of the following treatments used for two years of experimentation is as follows T1: Control, T2: IAA, 25 ppm T3: IAA, 50 ppm T4: Abscisic acid 10 ppm, T5: Abscisic acid 20 ppm, T6: TRIA 5 ppm, T7: TRIA 10 ppm, T8:B rassinosteroid 5 ppm, T9: Brassinosteroid 10 ppm, T10: Cytokinin 5 ppm, T11: Cytokinin 10 ppm. Foliar spraying at two stages - first at 30 DAS (Vegetative stage) and second at anthesis in uniform dose of all treatments. The maximum Grain Yield in wheat was observed in T3 (3965.00) and (4065.00) with application of IAA 50 PPM which was significantly superior over T11 (3815.00) and (3918.00) which was statistically at par with T2 (3705.00) and (3813.00), T10 (3595.00) and (3719.00), T9 (3475.00) and (3584.00) and T8 (3405.00) and (3480.00).

Keywords: Regulator, significantly, experimentation and cytokinin

Introduction
Wheat (*Triticum aestivum* L. em. Thell.) is the second most important staple food crop of the world after rice. Wheat is one of the top three cereal crops in terms of global production, along with maize and rice. Wheat, belonging to grass family Poaceae, constitutes a major portion of *Rabi* cereals because of its wide adaptation and role in human nutrition as well as in agriculture economy of the country. Wheat is consumed in a variety of ways, such as bread Chapati, Flour, Suji etc. India stands second both in area and production next to the China in the world.

The wheat crop being cultivated as winter and spring in the world, world's main winter wheat producing countries are USA, Russian Federation, Australia, Europe, etc., while spring wheat is grown in Asia and in some part of USA (FAO, 2020). Globally wheat occupies around 220 m ha area, holding the position of highest acreage among all crops with an annual production having around 764.4 million tons with the average productivity of 3.53 tons/ha during 2019-20 (USDA, 2020).

In India during 2020-2021 area under wheat 31.76 mha with the production 109.52 mtones. (Source: DES, MoA & FW). The major source of this increase in production is mainly attributed to expansion in area followed by marginal increase in productivity. Uttar Pradesh still holds the position of largest producer in the country accounting for about 28 million tonnes which is roughly 30% of the total production. Around 85 million tonnes (90%) of wheat has been produced from traditional wheat-growing regions such as Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Bihar and Rajasthan.

Wheat is a widely adapted crop. It is grown from temperate, irrigated to dry and high rain fall areas and from warm, humid to dry, cold environments.

Materials and Methods

In order to accomplish the objectives of the present study entitled "Effect of plant growth regulators on morpho-physiological parameters and yield of wheat (*Triticum aestivum* L.) under late sown condition" was carried out during *Rabi* seasons of 2018-19 and 2019-20.

The present investigation entitled "Effect of plant growth regulators on morpho- physiological parameters and yield of wheat (*Triticum aestivum* L.) Under late sown condition" has been taken to focus the involvement and potential role of plant growth regulator and was carried out in during 2019-20 and 2020-21 at Agronomy Research Farm of C.S.A. University of Agriculture and Technology, Kanpur (U.P.) have been discussed.

Growth Attributes

Plant Height

The maximum Plant height at 30 days in wheat was observed in T3 (19.31) and (19.45) with application of IAA 50 PPM which was significantly superior over T11 (19.20) and (19.40) which was statistically at par with T2 (19.15 and (19.32), T10 (19.05) and (19.15), T9 (18.90) and (19.05) and T8 (18.72) and (18.92).

The maximum Plant height at 60 days in wheat was observed in T3 (60.45) and (61.75) with application of IAA 50 PPM which was significantly superior over T11 (59.60) and (60.31) which was statistically at par with T2 (58.35) and (59.65), T10 (57.85) and (58.30), T9 (56.60) and (57.80) and T8 (55.75) and (56.91).

The maximum Plant height at 90 days in wheat was observed in T3 (88.51) and (89.66) with application of IAA 50 PPM which was significantly superior over T11 (87.80) and (88.28) which was statistically at par with T2 (86.65) and (87.55), T10 (86.10) and (87.15), T9 (85.56) and (86.71) and T8 (85.11) and (86.44).

The maximum Plant height at harvest in wheat was observed in T3 (90.64) and (91.10) with application of IAA 50 PPM which was significantly superior over T11 (89.51) and (89.80) which was statistically at par with T2 (88.41) and (89.72), T10 (88.35) and (88.98), T9 (87.70) and (87.91) and T8 (87.25) and (87.38). Plant height is mainly controlled by the genetic makeup of a genotype, but it is also affected by environmental conditions thus it varies from variety to variety. However, up to some extent it is also governed by dates of sowing. He Zhong Hu and Rajaram (1993) [21] observed that plant height, seeds per spike, biomass are more thermo sensitive than spike number per square meter and test weight of wheat. Behera (1994) revealed that the plant height is significantly affected by dates of sowing. The maximum plant height was obtained by sowing wheat on 17 November (98.0 cm) which was significantly higher than that sown on 2 November (93.0 cm) and 11 December (90.4 cm). This may be attributed to maximum period available for vegetative growth of the crop, resulting in tallest plant. Lathwal and Thakral (1999) [22] recorded the decreasing trend in plant height with the delay in dates of sowing. The maximum height of the crop was recorded on November, 5 which was significantly higher than that of December, 5 and remaining at par with November, 15 and 25 sown crops. Sarkar and Torofder (1992) [12] also reported similar effects on plant height under rainfed conditions.

Number of tillers per plant

The maximum number of tillers per plant at 30 days in wheat was observed in T3 (2.99) and (3.11) with application of IAA 50 PPM which was significantly superior over T11 (2.88) and (2.89) which was statistically at par with T2 (2.80) and (2.86), T10 (2.66) and (2.71), T9 (2.60) and (2.66) and T8 (2.61) and (2.64).

The maximum number of tillers per plant at 60 days in wheat was observed in T3 (6.22) and (6.32) with application of IAA 50 PPM which was significantly superior over T11 (5.66) and (5.80) which was statistically at par with T2 (5.66) and (5.70), T10 (5.60) and (5.64), T9 (5.40) and (5.44) and T8 (5.11) and (5.20). Least number of tillers per plant was Observed under T5 (4.22) and (4.33) during both the years of investigation.

The maximum number of tillers per plant at 90 days in wheat was observed in T3 (6.99) and (7.11) with application of IAA 50 PPM which was significantly superior over T11 (6.89) and (7.00) which was statistically at par with T2 (6.33) and (6.40), T10 (6.35) and (6.39), T9 (6.05) and (6.10) and T8 (5.90) and (5.98).

The maximum number of tillers per plant at harvest days in wheat was observed in T3 (7.77) and (7.89) with application of IAA 50 PPM which was significantly superior over T11 (7.44) and (7.56) which was statistically at par with T2 (7.22) and (7.33), T10 (6.44) and (6.56),

T9 (6.34) and (6.45) and T8 (6.00) and (6.11). Kumar and Sharma (2003) [16] reported that sowing time significantly affects the number of tillers per meter row length. The crop sown on 30th November (105.0) produced significantly higher number of tillers per meter row length than the crop sown on 16 December (94.1) and 31 December (94.1); Later dates of sowing did not differ significantly. Negi *et al*. (2003) [17] reported that sowing dates significantly affects the effective tillers. Significantly higher number of effective tillers m^{-2} was recorded in crop sown on 28 November (245.6) than the crop sown on 28 October (186.8). Dhaka *et al*. (2006) [18] found in pooled analysis of two years of study, that the numbers of tillers per plant were reduced by4.8 per cent when wheat was sown on 25 December (3.9 tillers/plant) instead of 20 November (4.1 tillers/plant), but this difference was not statistically significant. Shah *et al*. (2006) [29] carried out a field experiment at Peshawar (Pakistan) and reported that sowing on 1st November resulted in higher seedling emergence (179.29 seedling per meter square). Shahzad *et al*. (2007) [19] from Pakistan reported that the crop sown on December 15 produced significantly a greater number of fertile tillers (m^{-2}) (499.77) than the crop sown on November, 15 (475.33) and 30 (462.88). Singh *et al*. (2011) [20] found that crop sown on 15th October produced higher grain yield as compared to crop sown on 25th October, 4th and 14th November. The increase in yield was due to increase in effective tillers and 1000-grain weight of early sown crop. Hussain and Leitch (2007) [4] studied that early application of PGRs has resulted in increased tiller population compared with later applications.

Number of leaves per plant

The maximum number of leaves per plant at 30 days in wheat was observed in T3 (7.11) and (7.25) with application of IAA 50 PPM which was significantly superior over T11 (6.88) and (6.91) which was statistically at par with T2 (6.77) and (6.76),

T10 (6.61) and (6.69), T9 (6.55) and (6.60) and T8 (6.49) and (6.54).

The maximum number of leaves per plant at 60 days in wheat was observed in T3 (23.50) and (23.80) with application of IAA 50 PPM which was significantly superior over T11 (23.10) and (23.18) which was statistically at par with T2 (22.65) and (22.87), T10 (22.45) and (22.73), T9 (22.33) and (22.67) and T8 (22.05) and (22.41).

The maximum number of leaves per plant at 90 days in wheat was observed in T3 (24.51) and (24.94) with application of IAA 50 PPM which was significantly superior over T11 (24.11) and (24.40) which was statistically at par with T2 (23.00) and (23.98), T10 (23.51) and (23.90), T9 (22.96) and (23.33) and T8 (22.70) and (22.91). Patil and Subbanna (1988) conducted field experiment at UAS, Bangalore reported that triacontanol sprayed in varying concentrations significantly increased the number of leaves per plant, leaf area, plant spread, fresh weight of untrimmed lettuce heads wherein triacontanol at 4 ppm twice recorded the highest number of leaves per plant (22.5), leaf area (3698.8 cm^2), plant spread (1112.2 cm^2) and fresh weight of untrimmed heads (341 g) while the least values were obtained in control treatment.

Yield attributing traits

Number of grains per Spike

The maximum Number of grains per Spike in wheat was observed in T3 (44.97) and (48.15) with application of IAA 50 PPM which was significantly superior over T11 (43.16) and (46.35) which was statistically at par with T2 (41.87) and (43.90), T10 (41.40) and (43.50), T9 (41.05) and (43.15) and T8 (40.85) and (42.88). González *et al*. (2003) found close positive relationship between the grains number per spike and the final grain yield. Sharma-Natu *et al*. (2006) [26] found reduction in the optimum growth period caused by a rise in temperature leads to leaf senescence resulting in a photosynthetic rate. As a result, it affects two important yield parameters, i.e., the number of grains per spike and grain weight

Grain weight per Spike

The maximum Grain weight per Spike in wheat was observed in T3 (2.55) and (2.95) with application of IAA 50 PPM which was significantly superior over T11 (2.40) and (2.80) which was statistically at par with T2 (2.39) and (2.78), T10 (2.35) and (2.72), T9 (2.33) and (2.65) and T8 (2.32) and (2.61). Sharma-Natu *et al*. (2006) [26] found reduction in the optimum growth period caused by a rise in temperature leads to leaf senescence resulting in a photosynthetic rate. As a result, it affects two important yield parameters, i.e., the number of grains per spike and grain weight.

Straw Yield

The maximum Straw Yield in wheat was observed in T3 (63.74) and (64.12) with application of IAA 50 PPM which was significantly superior over T11 (61.55) and (62.07) which was statistically at par with T2 (60.63) and (62.32), T10 (58.98) and (59.06), T9 (57.16) and (57.26) and T8 (56.27) and (57.45). Gherroucha *et al*. (2011) [28] Reported that the application of IAA significantly increased straw yield, 1000-grain weight, number of grains/ spike and spike grain yield with foliar spraying of growth regulator (IAA) showed significant effect on plant.

1000 Grains weight

The maximum 1000 grains weight in wheat was observed in T3 (41.28) and (42.15) with application of IAA 50 PPM which was significantly superior over T11 (39.25) and (42.08) which was statistically at par with T2 (39.15) and (42.01), T10 (39.05) and (41.95), T9 (39.00) and (41.92) and T8 (38.98) and (41.84). Zahir *et al*. (2000) [24] reported up to 50% increase in fresh biomass of soybean by the application of L-tryptophan (precursor of IAA). Significant increase in 1000-grain weight and protein quality of wheat has been reported in response to kinetin application.

Biological Yield

The maximum Biological Yield in wheat was observed in T3 (10339.00) and (10470.00) with application of IAA 50 PPM which was significantly superior over T11 (9970.00) and (10125.00) which was statistically at par with T2 (9768.00) and (10122.00), T10 (9493.00) and (9625.00), T9 (9191.00) and (9310.00) and T8(9032.00) and (9225.00). Arif *et al*. (2001) [23] documented that the application of IAA at the rate of 10-5 M increased grain yield and biological yield in wheat. Zahir *et al*., (2000) [24] reported up to 50% increase in fresh biomass of soybean by the application of L-tryptophan (precursor of IAA). Significant increase in 1000- grain weight and protein quality of wheat has been reported in response to kinetin application.

Grain Yield

The maximum Grain Yield in wheat was observed in T3 (3965.00) and (4065.00) with application of IAA 50 PPM which was significantly superior over T11 (3815.00) and (3918.00) which was statistically at par with T2 (3705.00) and (3813.00), T10 (3595.00) and (3719.00), T9 (3475.00) and (3584.00) and T8 (3405.00) and (3480.00). Ma *et al*. (1994) found that PGRs have potential to increase grain yield and may also alter grain protein levels of cereal crops especially wheat. Arif *et al*. (2001) [23] documented that the application of IAA at the rate of 10-5 M increased grain yield and biological yield in wheat.

Harvest Index

The maximum Harvest Index in wheat was observed in T3 (38.35) and (38.79) with application of IAA 50 PPM which was significantly superior over T11 (38.26) and (38.69) which was statistically at par with T2 (37.93) and (38.43), T10 (37.87) and (38.63), T9 (37.87) and (38.49) and T8 (37.70) and (37.72). Foulkes *et al*. (2010) [27] reported that increasing partitioning to spike growth at the expense of stem and other structural organs (rachis, glumes and palea) within the spike may provide an avenue for the improvement of the harvest index of wheat.

Table 1: Effect of plant growth regulators on Plant height at different growth stages in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Plant height 30 I Year	Plant height 30 II Year	Plant height 60 I Year	Plant height 60 II Year	Plant height 90 I Year	Plant height 90 II Year	Plant height at Harvest I Year	Plant height at Harvest II Year
T0: Control	17.65	17.90	53.85	54.05	82.88	83.15	83.66	84.25
T2: IAA 25 ppm	19.15	19.32	58.35	59.65	86.65	87.55	88.41	89.72
T3: IAA 50 ppm	19.31	19.45	60.45	61.75	88.51	89.66	90.64	91.10
T4: Abscisic acid 10 ppm	15.57	15.78	50.84	50.95	80.34	80.64	81.69	81.90
T5: Abscisic acid 20 ppm	15.31	15.50	50.41	50.71	80.05	80.31	81.40	81.51
T6: TRIA 5 ppm	18.35	18.50	55.15	56.05	84.48	85.05	86.13	87.00
T7: TRIA 10 ppm	18.65	18.75	55.40	56.35	84.90	85.35	86.54	86.83
T8: Brassinosteroid 5 ppm	18.72	18.92	55.75	56.91	85.11	86.44	87.25	87.38
T9: Brassinosteroid 10 ppm	18.90	19.05	56.60	57.80	85.56	86.71	87.70	87.91
T10: Cytokinin 5 ppm	19.05	19.15	57.85	58.30	86.10	87.15	88.35	88.98
T11: Cytokinin 10 ppm	19.20	19.40	59.60	60.31	87.80	88.28	89.51	89.80
S.Em±	0.486	0.403	1.488	1.235	1.715	2.325	1.778	2.313
CD at 5%	1.473	1.222	4.515	3.745	5.203	7.052	5.394	7.016

Table 2: Effect of plant growth regulators on Number of tillers plant^{-1} at different growth stages in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Number of tillers plant^{-1} 30 I year	Number of tillers plant^{-1} 30 II year	Number of tillers plant^{-1} 60 I year	Number of tillers plant^{-1} 60 II year	Number of tillers plant^{-1} 90 I year	Number of tillers plant^{-1} 90 II year	Number of tillers Plant at harvest I year	Number of tillers Plant at harvest II year
T0: Control	2.00	2.11	3.41	3.52	4.22	4.44	4.66	4.77
T2: IAA 25 ppm	2.80	2.86	5.66	5.70	6.33	6.40	7.22	7.33
T3: IAA 50 ppm	2.99	3.11	6.22	6.32	6.99	7.11	7.77	7.89
T4: Abscisic acid 10 ppm	2.41	2.47	4.44	4.50	5.65	5.72	5.44	5.51
T5: Abscisic acid 20 ppm	2.36	2.41	4.22	4.33	5.38	5.43	5.51	5.55
T6: TRIA 5 ppm	2.45	2.50	4.70	4.88	5.70	5.76	5.76	5.88
T7: TRIA 10 ppm	2.55	2.61	4.99	5.11	5.74	5.81	5.99	5.75
T8: Brassinosteroid 5 ppm	2.61	2.64	5.11	5.20	5.90	5.98	6.00	6.11
T9: Brassinosteroid 10 ppm	2.60	2.66	5.40	5.44	6.05	6.10	6.34	6.45
T10: Cytokinin 5 ppm	2.66	2.71	5.60	5.64	6.35	6.39	6.44	6.56
T11: Cytokinin 10 ppm	2.88	2.89	5.66	5.80	6.89	7.00	7.44	7.56
S.Em±	0.056	0.072	0.115	0.092	0.156	0.164	0.140	0.171
CD at 5%	0.170	0.219	0.349	0.279	0.472	0.496	0.425	0.520

Table 3: Effect of plant growth regulators on Number of leaves per plant at different growth stages in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Number of leaves per plant 30 I Year	Number of leaves per plant 30 II Year	Number of leaves per plant 60 I Year	Number of leaves per plant 60 II Year	Number of leaves per plant 90 I Year	Number of leaves per plant 90 II Year
T0: Control	5.91	6.11	12.17	19.37	20.15	20.40
T2: IAA 25 ppm	6.77	6.76	2.78	22.87	23.00	23.98
T3: IAA 50 ppm	7.11	7.25	13.35	23.80	24.51	24.94
T4: Abscisic acid 10 ppm	6.00	6.32	13.21	20.61	21.23	21.75
T5: Abscisic acid 20 ppm	6.10	6.22	13.03	20.38	21.10	21.33
T6: TRIA 5 ppm	6.31	6.36	13.45	21.57	22.33	22.66
T7: TRIA 10 ppm	6.37	6.41	12.54	21.79	22.55	22.88
T8:Brassinosteroid 5 ppm	6.49	6.54	13.62	22.41	22.70	22.91
T9:Brassinosteroid 10 ppm	6.55	6.60	13.74	22.67	22.96	23.33
T10: Cytokinin 5 ppm	6.61	6.69	13.77	22.73	23.51	23.90
T11: Cytokinin 10 ppm	6.88	6.91	13.91	23.18	24.11	24.40
S.Em±	0.140	0.130	0.156	0.434	0.605	0.491
CD at 5%	0.426	0.395	0.468	1.318	1.834	1.490

Table 4: Effect of plant growth regulators on Grain weight spike, Straw Yield and 1000 grains weight in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Grain weight per spike I Year	Grain weight per spike II Year	Straw Yield I Year	Straw Yield II Year	1000 grain Weight Year	1000 grain weight I Year
T0: Control	1.78	2.17	5434.00	5487.00	15.50	40.50
T2: IAA 25 ppm	2.39	2.78	6063.00	6232.00	17.71	42.01
T3: IAA 50 ppm	2.55	2.95	6374.00	6412.00	18.28	42.15
T4: Abscisic acid 10 ppm	2.24	2.46	5501.00	5565.00	16.78	41.50
T5: Abscisic acid 20 ppm	2.21	2.40	5493.00	5517.00	16.60	41.33
T6: TRIA 5 ppm	2.27	2.51	5501.00	5578.00	17.46	41.55
T7: TRIA 10 ppm	2.29	2.58	5622.00	5665.00	17.34	41.76
T8:Brassinosteroid 5 ppm	2.32	2.61	5627.00	5745.00	17.27	41.84
T9:Brassinosteroid 10 ppm	2.33	2.65	5716.00	5726.00	17.63	41.92
T10: Cytokinin 5 ppm	2.35	2.72	5898.00	5906.00	17.74	41.95
T11: Cytokinin 10 ppm	2.40	2.80	6155.00	6207.00	17.89	42.08
S.Em±	0.050	0.049	117.828	155.967	0.114	1.130
CD at 5%	0.151	0.150	357.430	473.125	0.345	3.427

Table 5: Effect of plant growth regulators on Main spike length and number of grain per spike in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Main spike length I Year	Main spike length II Year	No of grain spike I Year	No of grain spike II Year
T0: Control	8.32	8.35	36.50	38.55
T2: IAA 25 ppm	8.85	8.86	41.87	43.90
T3: IAA 50 ppm	9.10	9.12	44.97	48.15
T4: Abscisic acid 10 ppm	8.62	8.63	40.05	41.50
T5: Abscisic acid 20 ppm	8.60	8.62	39.90	40.90
T6: TRIA 5 ppm	8.64	8.66	40.25	41.70
T7: TRIA 10 ppm	8.67	8.68	40.80	42.50
T8: Brassinosteroid 5 ppm	8.68	8.70	40.85	42.88
T9: Brassinosteroid 10 ppm	8.70	8.73	41.05	43.15
T10: Cytokinin 5 ppm	8.73	8.75	41.40	43.50
T11: Cytokinin 10 ppm	8.99	9.05	43.16	46.35
S.Em±	0.178	0.233	0.872	1.159
CD at 5%	0.539	0.707	2.645	3.517

Table 6: Effect of plant growth regulators on Biological Yield, Grain Yield and Harvest Index (%) at Pre anthesis stage in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Biological Yield I Year	Biological Yield II Year	Grain yields I Year	grain yield II Year	Harvest Index I year	Harvest Index II year
T0: Control	8679.00	8822.00	3245.00	3335.00	37.39	37.80
T2: IAA 25 ppm	9768.00	10122.00	3705.00	3813.00	37.93	38.43
T3: IAA 50 ppm	10339.00	10470.00	3965.00	4065.00	38.35	38.79
T4: Abscisic acid 10 ppm	8806.00	8985.00	3305.00	3420.00	37.55	37.06
T5: Abscisic acid 20 ppm	8789.00	8945.00	3296.00	3428.00	37.50	38.32
T6: TRIA 5 ppm	8816.00	8996.00	3315.00	3418.00	37.60	37.99
T7: TRIA 10 ppm	9017.00	9165.00	3395.00	3500.00	37.65	38.18
T8: Brassinosteroid 5 ppm	9032.00	9225.00	3405.00	3480.00	37.70	37.72
T9: Brassinosteroid 10 ppm	9191.00	9310.00	3475.00	3584.00	37.81	38.49
T10: Cytokinin 5 ppm	9493.00	9625.00	3595.00	3719.00	37.87	38.63
T11: Cytokinin 10 ppm	9970.00	10125.00	3815.00	3918.00	38.26	38.69
S.Em±	248.421	204.022	94.054	77.996	0.767	1.047
CD at 5%	753.583	618.899	285.312	236.601	2.326	3.176

Conclusions

On the basis of results presented and discussed in preceding chapters concluded that maximum yield and productivity and build up in soil fertility might be achieved with the application of recommended doses of fertilizer along with IAA 50 PPM, IAA 25 ppm and Cytokinin 5ppm as a growth enhancer. Hence it may be recommended for enhancing productivity of wheat.

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