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Effect of plant growth regulators on growth and physiological parameters of wheat (*Triticum aestivum* L.) under late sown condition

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Abstract
The present study entitled "Effect of plant growth regulators on growth and physiological parameters 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 T_1: Control, T_2: IAA, 25 ppm T_3: IAA, 50 ppm T_4: Abscisic acid 10 ppm, T_5: Abscisic acid 20 ppm, T_6: TRIA 5 ppm, T_7: TRIA 10 ppm, T_8: Brassinosteroid 5 ppm, T_9: Brassinosteroid 10 ppm, T_{10}: 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 Relative water content (RWC) (%) at heading stage in wheat was noted in T_3 with application of IAA 50 ppm which was significantly superior over T11 and was statistically at par with T_2 IAA 25 ppm and T_{10} Cytokinin 5 ppm. Minimum Relative water content (RWC) (%) at heading stage was observed under T_5 Abscisic acid 20 ppm during both the years of investigation. The maximum Protein content in grain (%) in wheat was found in T3 with application of IAA 50 ppm which was significantly superior over T11 and was statistically at par with T_2 IAA 25 ppm and T_{10} Cytokinin 5ppm. Least Protein content in grain (%) was observed under T5 Abscisic acid 20 ppm during both the years of investigation.

Keywords: RWC, IAA, Triticum aestivum L., physiological parameters, treatments

Introduction
Late sowing of wheat is a major problem in the rice-wheat (Hobbs and Gupta, 2002) [58] and cotton-wheat (Khan *et al*., 2010) [48] areas of Asia. Regmi *et al.* (2002) [52] also reported a yield decline in wheat when it was sown after the third week of November. A major reason for late sowing is the late harvest of the preceding crops. The inputs applied to the wheat crop were not efficiently utilized and resulted in reduced yield under late sowing (Hobbs and Gupta, 2002) [58]. In late sown wheat, all the growth stages, such as tillering, flowering and grain filling are adversely affected by the shortened growing period. The reduction in the optimum growth period caused by a rise in temperature leads to leaf senescence resulting in a photosynthetic rate that is too low to meet plant C economy (Hensel, *et al*. 1993; Sharma-Natu, *et al.* 2006) [61, 59]. As a result, it affects two important yield parameters, i.e., the number of grains per spike and grain weight (Ugarte, *et al.* 2007) [60]. Each day delay in sowing of wheat after 20th November onward in decreases grain yield at the rate of 36 kg ha^{-1} day^{-1} (Hussain, *et al.* 1998) [63]. To meet the increased demand for food grain of rapidly growing population, there are many yields boosting agronomic techniques like application of certain plant growth regulators which needs due attention. Although plant growth regulators have been used in agriculture for as long as crop cultivation their impact up to now has been relatively little detected and their application is limited to some specific objectives for example quality and quantity improvement (Pandey *et al*. 2011) [62].

Plant growth regulators (PGRs) are known to influence a wide array of physiological processes like photosynthesis (Jia and Lu 2003) [53] and stomata conductance (Mori *et al.*, 2006) [56]. PGRs are reported to modify growth and development in various ways under different growth conditions (Pan *et al.*, 2013) [65] and influence the crop yield (Yan *et al*. 2011) [55].

The importance of biologically active substances in plants is well documented. Plant growth regulators are natural compounds that have shown far reaching effects on the growth and development of plants even at low concentration (Arshad and Franken Berger, 1998) [57]. Plant growth regulators are known to affect growth, flowering and assimilate translocation in plants (Hayat *et al*., 2007 [24] Studies have shown that plant hormones could regulate the partitioning and translocation of photo assimilates during grain filling (Ahmadi and Baker, 1999) [34]. Both 3-indoleacetic acid (IAA) and cytokinins have been shown to play an important role in the transportation of assimilates to wheat spikes (Darussalam *et al*., 1998 and Lejeune *et al*., 1998) [45, 46]. As well, cytokinins are required for cell division during the early phase of grain filling (Yang *et al*., 2000) [33]. Plant growth regulators impress production of plant hormones and are thus able to modify plant growth and development, this being a regulatory rather than a nutritional role. They are generally only applied at low rates without showing phytotoxic effects (Rademacher and Brahm, 2010) [3]. Foliar application of plant growth regulators, both natural and synthetic, has proven worthwhile for improving crop growth against a variety of abiotic stresses. Remarkable accomplishments of plant growth regulators, such as manipulating plant developments, enhancing yield and quality have been actualized in recent years using new emerging and efficient plant growth regulators. It has long been ascertained that plant hormones including auxins, gibberellins, cytokinin and ethylene etc., in some studies with wheat, characteristics associated with stem strength have increased with application of PGRs, in particular stem diameter stem wall thickness (Tripathi *et al*., 2003) [64]. Given the potential influence on yield components from productive tillers to grains/spike and then grain weight, timing of the PGR should also progressively affect these yield components. Disparity in the chemical nature and mode of action of PGRs result in variation in response to application. Uptake sites vary; while most PGRs are mostly absorbed through leaves and stems (Kim *et al*., 2010) [10]. Reduction in plant biomass due to higher PGRs may also have negative consequences for grain yield through reduced photosynthetic area and lower levels of stored reserves for re-translocation at grain filling time of wheat (Espindula *et al*., 2009) [47]. Other crop management inputs such as irrigation, nitrogen status and earlier time of sowing have also influence in greater yield response to PGR treatment.

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 morph 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.).

Results and Discussion

Number of tillers per plant

The data pertaining to number of tillers per plant presented in the (Table-4.2) revealed that the maximum number of tillers per plant at 30 days in wheat was observed in T_3 (2.99) and (3.11) with application of IAA 50 ppm which was significantly superior over T_{11} (2.88), (2.89) which was statistically at par with T_2 (2.80), (2.86), T_{10} (2.66), (2.71), T_9 (2.60), (2.66), T_8 (2.61), (2.64). Least number of tillers per plant was Observed under T_5 (2.36) and (2.41) during both the years of investigation.

The maximum number of tillers per plant at 60 days in wheat was observed in T_3 (6.22), (6.32) with application of IAA 50 ppm which was significantly superior over T_{11} (5.66) and (5.80) which was statistically at par with T_2 (5.66), (5.70), T_{10} (5.60), (5.64), T_9 (5.40), (5.44), T_8 (5.11), (5.20). Least number of tillers per plant was Observed under T_5 (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 T_3 (6.99), (7.11) with application of IAA 50 ppm which was significantly superior over T_{11} (6.89), (7.00) which was statistically at par with T_2 (6.33), (6.40), T_{10} (6.35), (6.39), T_9 (6.05), (6.10), T_8 (5.90), (5.98). Least number of tillers per plant was Observed under T_5 (5.38) and (5.43) during both the years of investigation.

The maximum number of tillers per plant at harvest days in wheat was observed in T_3 (7.77) and (7.89) with application of IAA 50 ppm which was significantly superior over T_{11} (7.44), (7.56) which was statistically at par with T_2 (7.22) and (7.33), T_{10} (6.44), (6.56), T_9 (6.34), (6.45), T_8 (6.00), (6.11). Least number of tillers per plant was Observed under T_5 (5.51) and (5.55) during both the years of investigation. Kumar and Sharma (2003) [32] 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) [35] 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) [38] found in pooled analysis of two years of study, that the numbers of tillers per plant were reduced by 4.8% 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) [37] 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) [39] 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) [40] 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) [49] studied that early application of PGRs has resulted in increased tiller population compared with later applications.

Number of leaves per plant

The data pertaining to number of leaves per plant presented in the (Table-4.3) revealed that the maximum number of leaves per plant at 30 days in wheat was observed in T_3 (7.11) and

(7.25) with application of IAA 50 ppm which was significantly superior over T_{11} (6.88), (6.91) which was statistically at par with T_2 (6.77) and (6.76), T_{10} (6.61) and (6.69), T_9 (6.55), (6.60), T_8 (6.49) and (6.54). Least number of leaves per plant was Observed under T_5 (6.10) and (6.22) during both the years of investigation.

The maximum number of leaves per plant at 60 days in wheat was observed in T_3 (23.50) and (23.80) with application of IAA 50 ppm which was significantly superior over T_{11} (23.10) and (23.18) which was statistically at par with T_2 (22.65), (22.87), T_{10} (22.45), (22.73), T_9 (22.33), (22.67), T_8 (22.05) and (22.41). Least number of leaves per plant was Observed under T_5 (20.11) and (20.38) during both the years of investigation.

The maximum number of leaves per plant at 90 days in wheat was observed in T_3 (24.51) and (24.94) with application of IAA 50 ppm which was significantly superior over T_{11} (24.11) and (24.40) which was statistically at par with T_2 (23.00), (23.98), T_{10} (23.51), (23.90), T_9 (22.96), (23.33), T_8 (22.70) and (22.91). Least number of leaves per plant was Observed under T_5 (5.38) and (5.43) during both the years of investigation. Patil and Subbanna (1988) [51] 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.

Leaf area per plant

The data pertaining to leaf area per plant presented in the (Table-4.4) revealed that the maximum leaf area per plant at 30 days in wheat was observed in T_3 (50.50) and (50.72) with application of IAA 50 Ppm which was significantly superior over T_{11} (50.20) and (50.35) which was statistically at par with T_2 (50.05), (50.27), T_{10} (49.98), (50.20), T_9 (49.91), (50.05), T_8 (49.76), (49.91). Least leaf area per plant was Observed under T_5 (49.43) and (49.74) during both the years of investigation.

The maximum leaf area per plant at 60 days in wheat was observed in T_3 (513.65) and (514.31) with application of IAA 50 ppm which was significantly superior over T_{11} (496.85) and (497.74) which was statistically at par with T_2 (502.82) and (503.92), T_{10} (488.90), (489.78), T_9 (486.02), (488.01), T_8 (482.27) and (483.37). Least leaf area per plant was Observed under T_5 (465.91) and (466.57) during both the years of investigation.

The maximum leaf area per plant at 90 days in wheat was observed in T_3 (748.14) and (750.10) with application of IAA 50 PPM which was significantly superior over T_{11} (742.00) and (742.30) which was statistically at par with T_2 (732.22), (745.10), T_{10} (738.20), (738.60), T_9 (736.70), (737.20), T_8 (732.80) and (733.30). Least leaf area per plant was Observed under T_5 (725.10) and (726.50) during both the years of investigation. Meyer and Green (1980) found that the amount of photosynthate available for biomass production is related to the current leaf area and the photosynthetic rate of the crop in consideration.

Days to Heading

The data pertaining to days to heading presented in the (Table-4.4) revealed that the maximum days to heading in wheat was observed in T_3 (77.11) and (78.34) with application of IAA 50 ppm which was significantly superior over T_{11} (71.66) and (72.92) which was statistically at par with T_2 (77.33), (77.67), T_{10} (73.33), (74.81), T_9 (72.66), (75.38) and T_8 (72.16) and (72.46). Least days to heading was Observed under T_5 (76.33) and (76.55) during both the years of investigation. Meena (2009) [50] observed that number of days taken to physiological maturity and days to heading was significantly affected by sowing dates. The November 14 sown crop took significantly higher number of days to attain maturity and heading as compared to December 4 and December 24 sown crops.

Days to Maturity

The data pertaining to days to maturity presented in the (Table-4.4) revealed that the maximum days to maturity in wheat was observed in T_3 (126.00) and (127.00) with application of IAA 50 ppm which was significantly superior over T_{11} (119.00) and (119.15) which was statistically at par with T_2 (125.00), (126.15), T_{10} (120.00), (120.30), T_9 (120.60), (121.00), T_8 (121.33) and (121.66). Least days to maturity was Observed under T_5 (121.33) and (121.66) during both the years of investigation. Meena (2009) [50] observed that number of days taken to physiological maturity and days to heading was significantly affected by sowing dates. The November 14 sown crop took significantly higher number of days to attain maturity and heading as compared to December 4 and December 24 sown crops.

Dry matter accumulation

The data pertaining to dry matter accumulation presented in the (Table-4.5) revealed that the maximum dry matter accumulation at 30 days in wheat was observed in T_3 (2.41) and (2.43) with application of IAA 50 ppm which was significantly superior over T_{11} (2.41) and (2.42) which was statistically at par with T_2 (2.40), (2.41), T_{10} (2.40), (2.41),T_9 (2.38), (2.39), T_8 (2.36), (2.37). Least dry matter accumulation was Observed under T_5 (2.39) and (2.41) during both the years of investigation.

The maximum dry matter accumulation at 60 days in wheat was observed in T_3 (10.79) and (10.88) with application of IAA 50 ppm which was significantly superior over T_{11} (10.58), (10.76) which was statistically at par with T_2 (10.44) and (10.53), T_{10} (10.32), (10.40), T_9 (9.91) and (9.99) and T_8 (9.79) and (9.87). Least dry matter accumulation was Observed under T_5 (10.23) and (10.35) during both the years of investigation.

The maximum dry matter accumulation at 90 days in wheat was observed in T_3 (21.32) and (21.55) with application of IAA 50 ppm which was significantly superior over T_{11} (20.90) and (21.30) which was statistically at par with T_2 (20.62) and (20.84), T_{10} (20.37) and(20.57), T_9 (19.42) and (19.71) and T_8 (19.17) and (19.36). Least dry matter accumulation was Observed under T_5 (20.17) and (20.40) during both the years of investigation.

The maximum dry matter accumulation at harvest in wheat was observed in T_3 (29.10) and (29.45) with application of IAA 50 ppm which was significantly superior over T_{11} (28.50) and (29.10) which was statistically at par with T_2 (27.76), (28.12), T_{10} (27.32), (27.35), T_9 (25.90), (26.35), T_8 (25.55) and (25.86). Least dry matter accumulation was Observed under T_5 (26.97) and (27.36) during both the years of investigation SC and Luan S (2012) reported that application of ABA enhanced GB accumulation, RWC and dry matter production in maize plants.

Leaf Area Index (LAI)

The data pertaining to leaf area index presented in the (Table-4.6) revealed that the maximum leaf area index at 30 days in wheat was observed in T_3 (0.26) and (0.28) with application of IAA 50 ppm which was significantly superior over T_{11} 0.25) and (0.27) which was statistically at par with T_2 (0.25) and (0.26), T_{10} (0.25) and (0.26), T_9 (0.25) and (0.26) and T_8 (0.25) and (0.26). Least leaf area index was Observed under T_5 (0.24) and (0.25) during both the years of investigation.

The maximum leaf area index at 60 days in wheat was observed in T_3 (2.38) and (2.40) with application of IAA 50 ppm which was significantly superior over T_{11} (2.33) and (2.35) which was statistically at par with T_2 (2.30) and (2.32), T_{10} (2.26) and (2.28), T_9 (2.25) and (2.27) and T_8 (2.23) and (2.25). Least leaf area index was Observed under T_5 (2.05) and (2.13) during both the years of investigation.

The maximum leaf area index at 90 days in wheat was observed in T_3 (3.46) and (3.48) with application of IAA 50 ppm which was significantly superior over T_{11} (3.39) and (3.42) which was statistically at par with T_2 (3.33) and (3.36), T_{10} (3.27) and (3.30), T_9 (3.26) and (3.29) and T_8 (3.24) and (2.28). Least leaf area index was Observed under T_5 (3.11) and (3.17) during both the years of investigation.

The maximum leaf area index at harvest in wheat was observed in T_3 (7.89) and (7.11) with application of IAA 50 ppm which was significantly superior over T_{11} (7.56) and (6.88) which was statistically at par with T_2 (7.33) and (6.77), T_{10} (6.56) and (6.61), T_9 (6.45) and (6.55) and T_8 (6.11) and (6.49). Least leaf area index was Observed under T_5 (5.55) and (6.10) during both the years of investigation. Aldesuquy (2000) reported that the significance of leaf area increments in higher grain production have been discussed and emphasized from time to time where the higher leaf area index was found to be positively correlated with higher grain yield. In the discussions, it can be said that higher leaf area implies more because the sink source relationship increases with increase in photosynthates and hence is reflected to grains hence more grain yield recorded.

Physiological Parameters

Relative Growth Rate (RGR)

The data pertaining to relative growth rate presented in the (Table-4.7) revealed that the maximum relative growth rate at 30 days in wheat was observed in T_3 (49.96) and (51.80) with application of IAA 50 ppm which was significantly superior over T_{11} (49.31) and (49.46) which was statistically at par with T_2 (49.00), (49.15), T_{10} (48.62), (48.71), T_9(47.54) and (47.67) and T_8 (47.42) and (47.55). Least relative growth rate was Observed under T_5 (48.47) and (48.57) during both the years of investigation.

The maximum relative growth rate at 60 days in wheat was observed in T_3 (22.70) and (22.78) with application of IAA 50 PPM which was significantly superior over T_{11} (22.69) and (22.76) which was statistically at par with T_2 (22.68) and (22.75), T_{10} (22.66) and (22.73),T_9 (22.42) and (22.48) and T_8 (22.40) and (22.46). Least relative growth rate was Observed under T_5 (22.62) and (22.71) during both the years of investigation.

The maximum relative growth rate at 90 days in wheat was observed in T_3 (10.37) and (10.44) with application of IAA 50 ppm which was significantly superior over T_{11} (10.34) and (10.40) which was statistically at par with T_2 (9.91) and (10.01), T_{10} (9.80) and (9.98), T_9 (9.58) and (9.67) and T_8 (9.57) and (9.64). Least relative growth rate was Observed under T_5 (9.68) and (9.78) during both the years of investigation. Wahid *et al*. (2007) [37] observed in pearl millet that net assimilation rate, plants relative growth rate as well as shoot dry mass get considerably reduced due to elevated temperatures. Elevated temperature hastens phenological development in wheat and influence grain growth and yield. Increase in atmospheric temperature can disturb plant productivity since duration and rate of grain filling together are controlled by change in temperature. Enhancement in rate of grain development and shortening of grain filling period has been observed in several crops

Canopy Temperature depression (CTD) Pre and post anthesis

The maximum Canopy Temperature depression (CTD) Pre anthesis in wheat was observed in T_3 (5.05) and (5.16) with application of IAA 50 ppm which was significantly superior over T_{11} (4.76) and (4.81) which was statistically at par with T_2 (4.61) and (4.68), T_{10} (4.55) and (4.63), T_9 (4.33) and (4.40) and T_8 (4.24) and (4.32). Least Canopy Temperature depression (CTD) Pre anthesis was Observed under T_5 (4.05) and (4.11) during both the years of investigation.

The maximum Canopy Temperature depression (CTD) Post anthesis in wheat was observed in T_3 (6.75) and (6.83) with application of IAA 50 ppm which was significantly superior over T_{11} (6.15) and (6.22) which was statistically at par with T_2 (5.93), (6.01), T_{10} (5.76), (5.82), T_9 (5.62), (5.70), T_8 (5.51) and (5.64). Least Canopy Temperature depression (CTD) was Observed under T_5 (5.11) and (5.19) during both the years of investigation. Sharma *et al*. (2003) [32] reported that canopy temperature depression (CTD 0C), relative water content (%) and water potential decreased significantly with increases water deficit in soil.

Chlorophyll Intensity (SPAD) (%) Pre and post anthesis

The maximum Chlorophyll Intensity (SPAD) (%) Pre anthesis in wheat was observed in T_3 (44.25) and (44.78) with application of IAA 50 ppm which was significantly superior over T_{11} (44.10) and (44.66) which was statistically at par with T_2 (43.80) and (43.92), T_{10} (43.71) and (43.79), T_9 (43.55) and (43.60) and T_8 (43.30) and (43.56). Least Chlorophyll Intensity (SPAD) (%) Pre anthesis was Observed under T_5 (42.11) and (42.40) during both the years of investigation.

The maximum Chlorophyll Intensity (SPAD) (%) Post anthesis in wheat was observed in T_3 (42.55) and (42.66) with application of IAA 50 ppm which was significantly superior over T_{11} (42.13) and (42.22) which was statistically at par with T_2 (41.81) and (41.88), T_{10} (41.43) and (41.51), T_9 (41.31) and (41.38) and T_8 (41.05) and (41.13). Least Chlorophyll Intensity (SPAD) (%) Post anthesis was Observed under T_5 (40.21) and (40.27) during both the years of investigation. Patil *et al*. (2002) [41] conducted an experiment at Akola (Maharashtra) and investigated that the effect of five sowing dates (initial sowing was performed on 15th November, whereas, successive sowing was conducted at 15-day intervals) on wheat cultivars *viz*., AKW-1071, AKW-381, AKW-3294, NIAW34, HI-977, and HD-2501. It was observed that the sowing on 15th November resulted in the highest chlorophyll content. Singh *et al*. (2002)[42] reported that chlorophyll content was higher in 10th and 30th October sowing as compared to 20th November and 10th December). Fattah *et al*. (1998)[43] observed that foliar spray of 2 ppm and 4 ppm triacontanol significantly increased the plant height, leaf area index, dry weight per plant and chlorophyll content in leaves of niger as compared to control.

Relative Water Content (RWC) (%) Pre anthesis

The maximum Relative Water Content (RWC) (%) Pre anthesis in wheat was observed in T_3 (72.42) and (72.65) with application of IAA 50 PPM which was significantly superior over T_{11} (70.97) and (71.19) which was statistically at par with T_2 (70.07), (70.29), T_{10} (68.99), (69.21), T_9 (68.63), (68.84), T_8 (68.09) and (68.30). Least Relative Water Content (RWC) (%) Pre anthesis was Observed under T_5 (65.66) and (65.87) during both the years of investigation. Bano *et al*. (2012) demonstrated that exogenous application of ABA protected wheat from drought-induced oxidative damage by improving the antioxidant system and relative water content.

Protein Content (%) Pre anthesis

The maximum Protein Content (%) Pre anthesis in wheat was observed in T (11.45) and (11.48) with application of IAA 50 ppm which was significantly superior over T_{11} (11.40) and (11.43) which was statistically at par with T_2 (11.37) and (11.40), T_{10} (11.37) and (11.40), T_9 (11.34) and (11.37) and T_8 (11.33) and (11.36). Least Protein Content (%) Pre anthesis was Observed under T_5 (11.18) and (11.21) during both the years of investigation. Concluded that the foliar application of TRIA has been reported to enhance chlorophyll contents, total soluble sugars, protein, nucleic acids, photosynthetic rate and chlorophyll fluorescence in wheat. Hayat *et al*. (2007) [24] reported that activity of synthesis of protein in plants was enhanced greatly under stressful condition.

Main spike length

The maximum main spike length in wheat was observed in T_3 (9.10) and (9.12) with application of IAA 50 ppm which was significantly superior over T_{11} (8.99) and (9.05) which was statistically at par with T_2 (8.85) and (8.86), T_{10} (8.73) and (8.75), T_9 (8.70), (8.73), T_8 (8.68), (8.70). Least main spike length was Observed under T_5 (8.60) and (8.62) during both the years of investigation. Emam, and Cartwright, (1998) [44] reported that hormonal treatments stimulated significant increase in number of tillers, spike length, biomass and grain yield of the plants when composition was sprayed.

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

Treatments (T)	Number of tiller Plant 30 I year	Number of tiller Plant 30 II year	Number of tiller Plant 60 I year	Number of tiller Plant 60 II year	Number of tiller Plant 90 I year	Number of tiller Plant 90 II year	Number of tiller Plant at harvest I year	Number of tiller Plant at harvest II year
T_0 Control	2.00	2.11	3.41	3.52	4.22	4.44	4.66	4.77
T_2 IAA 25 ppm	2.80	2.86	5.66	5.70	6.33	6.40	7.22	7.33
T_3 IAA 50 ppm	2.99	3.11	6.22	6.32	6.99	7.11	7.77	7.89
T_4 Abscisic acid 10 ppm	2.41	2.47	4.44	4.50	5.65	5.72	5.44	5.51
T_5 Abscisic acid 20 ppm	2.36	2.41	4.22	4.33	5.38	5.43	5.51	5.55
T_6 TRIA 5ppm	2.45	2.50	4.70	4.88	5.70	5.76	5.76	5.88
T_7 TRIA 10 ppm	2.55	2.61	4.99	5.11	5.74	5.81	5.99	5.75
T_8 Brassinosteroi d 5 ppm	2.61	2.64	5.11	5.20	5.90	5.98	6.00	6.11
T_9 Brassinosteroi d 10 ppm	2.60	2.66	5.40	5.44	6.05	6.10	6.34	6.45
T_{10} Cyto kinin 5 ppm	2.66	2.71	5.60	5.64	6.35	6.39	6.44	6.56
T_{11} Cyto kinin 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 2: 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
T_0 Control	5.91	6.11	12.17	19.37	20.15	20.40
T_2 IAA 25 ppm	6.77	6.76	12.78	22.87	23.00	23.98
T_3 IAA 50 ppm	7.11	7.25	13.35	23.80	24.51	24.94
T_4 Abscisic acid 10 ppm	6.00	6.32	13.21	20.61	21.23	21.75
T_5 Abscisic acid 20 ppm	6.10	6.22	13.03	20.38	21.10	21.33
T_6 TRIA 5 ppm	6.31	6.36	13.45	21.57	22.33	22.66
T_7 TRIA b10 ppm	6.37	6.41	12.54	21.79	22.55	22.88
T_8 Brassinosteroid 5 ppm	6.49	6.54	13.62	22.41	22.70	22.91
T_9 Brassinosteroid 10 ppm	6.55	6.60	13.74	22.67	22.96	23.33
T_{10} Cytokinin 5 ppm	6.61	6.69	13.77	22.73	23.51	23.90
T_{11} 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 3: Effect of plant growth regulators on leaf area per plant at different growth stages in wheat (*Triticum aestivum* L.) under late sown condition

Treatment s (T)	leaf area per plant 30 I Year	leaf area per plant 30 II Year	leaf area per plant 60 I Year	leaf area per plant 60 II Year	leaf area per plant 90 I Year	leaf area per plant 90 II Year
T_0 Control	47.95	48.17	451.65	452.76	658.15	660.60
T_2 IAA 25 ppm	50.05	50.27	502.82	503.92	732.22	745.10
T_3 IAA 50 ppm	50.50	50.72	513.65	514.31	748.14	750.10
T_4 Abscisic acid 10 ppm	49.58	49.80	470.77	471.66	727.35	728.40
T_5 Abscisic acid 20 ppm	49.43	49.74	465.91	466.57	725.10	726.50
T_6 TRIA 5 ppm	49.61	49.83	475.19	476.30	729.70	730.30
T7 TRIA 10 ppm	49.73	49.88	477.63	478.51	731.85	732.30
T_8 Brassinosteroid 5 ppm	49.76	49.91	482.27	483.37	732.80	733.30
T_9 Brassinosteroid 10 ppm	49.91	50.05	486.02	488.01	736.70	737.20
T_{10} Cytokinin 5 ppm	49.98	50.20	488.90	489.78	738.20	738.60
T_{11} Cytokinin 10 ppm	50.20	50.35	496.85	497.74	742.00	742.30
S.Em±	1.322	1.064	12.915	10.426	14.120	19.824
CD at 5%	4.009	3.228	39.177	31.626	42.834	60.136

Table 4: Effect of plant growth regulators on Dry matter production per plant (g) at different growth stages in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Dry matter production $plant^{-1}$ (g) 30 I Year	Dry matter production $plant^{-1}$ (g) 30 II Year	Dry matter production $plant^{-1}$ (g) 60 I Year	Dry matter production $plant^{-1}$ (g) 60 II Year	Dry matter production $plant^{-1}$ (g) 90 I Year	Dry matter production $plant^{-1}$ (g) 90 II Year	Dry matter production $plant^{-1}$ (g) Harvest I Year	Dry matter production $plant^{-1}$ (g) Harvest II Year
T_0 Control	2.34	2.36	9.53	9.66	18.50	18.89	24.52	25.10
T_2 IAA 25 ppm	2.40	2.41	10.44	10.53	20.62	20.84	27.76	28.14
T_3 IAA 50 ppm	2.41	2.43	10.79	10.88	21.32	21.55	29.10	29.45
T_4 Abscisic acid 10 ppm	2.39	2.40	10.11	10.24	19.85	20.12	26.53	26.95
T_5 Abscisic acid 20 ppm	2.39	2.41	10.23	10.35	20.17	20.40	26.97	27.36
T_6 TRIA 5 ppm	2.38	2.39	9.99	10.11	19.60	19.85	26.15	26.56
T_7 TRIA 10 ppm	2.38	2.40	10.22	10.31	20.15	20.38	26.99	27.30
T_8 Brassinosteroid 5 ppm	2.36	2.37	9.79	9.87	19.17	19.36	25.55	25.86
T_9 Brassinosteroid 10 ppm	2.38	3.39	9.91	9.99	19.42	19.71	25.90	26.35
T_{10} Cytokinin 5 ppm	2.40	2.41	10.32	10.40	20.37	20.57	27.35	27.75
T_{11} Cytokinin 10 ppm	2.41	2.44	10.58	10.76	20.90	21.30	28.50	29.10
S.Em±	0.063	0.051	0.273	0.219	0.394	0.548	0.538	0.734
CD at 5%	0.192	0.156	0.829	0.663	1.194	1.662	1.631	2.226

Table 5: Effect of plant growth regulators on Days to heading and Days to maturity in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Days of heading I Year	Days of heading II Year	Days of maturity I Year	Days of maturity II Year
T_0 Control	75.10	76.23	122.33	123.66
T_2 IAA 25 ppm	77.33	77.67	125.00	126.15
T_3 IAA 50 ppm	77.11	78.34	126.00	127.00
T_4 Abscisic acid 10 ppm	76.30	77.21	124.66	125.33
T_5 Abscisic acid 20 ppm	76.33	76.55	126.00	126.30
T_6 TRIA 5 ppm	75.00	75.27	122.66	122.66
T_7 TRIA 10 ppm	75.33	76.34	122.00	122.33
T_8 Brassinosteroid 5 ppm	72.16	72.46	121.33	121.66
T_9 Brassinosteroid 10 ppm	72.66	73.58	120.60	121.00
T_{10} Cytokinin 5 ppm	73.33	74.81	120.00	120.30
T_{11} Cytokinin 10 ppm	71.66	72.92	119.00	119.15
S.Em±	1.562	2.029	2.541	3.289
CD at 5%	4.737	6.154	7.709	9.978

Table 6: Effect of plant growth regulators on Leaf Area Index at different growth stages in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Lai 30[1] Year	Lai 30[2] Year	Lai 60[1] Year	Lai 60[2] Year	Lai 90[1] Year	Lai 90[2] Year	Lai Harvest[1] Year	Lai Harvest [2] Year
T_0 Control	0.23	0.24	2.00	2.03	2.91	3.11	4.77	5.91
T_2 IAA 25ppm	0.25	0.26	2.30	2.32	3.33	3.36	7.33	6.77
T_3 IAA 50 ppm	0.26	0.28	2.38	2.40	3.46	3.48	7.89	7.11
T_4 Abscisic acid 10 ppm	0.24	0.25	2.19	2.21	3.16	3.19	5.51	6.00
T_5 Abscisic acid 20 ppm	0.24	0.25	2.05	2.13	3.11	3.17	5.55	6.10
T_6 TRIA 5 ppm	0.25	0.26	2.20	2.22	3.20	3.22	5.88	6.31
T_7 TRIA 10 ppm	0.25	0.26	2.22	2.23	3.21	3.24	5.75	6.37
T_8 Brassinosteroid 5 ppm	0.25	0.26	2.23	2.25	3.24	3.28	6.11	6.49
T_9 Brassinosteroid 10 ppm	0.25	0.26	2.25	2.27	3.26	3.29	6.45	6.55

T_{10} Cytokinin 5 ppm	0.25	0.26	2.26	2.28	3.27	3.30	6.56	6.61
T_{11} Cytokinin 10 ppm	0.25	0.27	2.33	2.35	3.39	3.42	7.56	6.88
S.Em±	0.005	0.007	0.048	0.044	0.086	0.087	0.171	0.140
CD at 5%	0.016	0.021	0.146	0.133	0.262	0.265	0.520	0.426

Table 7: Effect of plant growth regulators on Relative growth rate at different growth stages in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	RGR 30 I year	RGR 30 II year	RGR 60 I year	RGR 60 II year	RGR 90 I year	RGR 90 II year
T_0 Control	46.81	46.97	22.11	22.35	9.39	9.47
T_2 IAA 25 ppm	49.00	49.15	22.68	22.75	9.91	10.01
T_3 IAA 50 ppm	49.96	51.80	22.70	22.78	10.37	10.44
T_4 Abscisic acid 10 ppm	48.07	48.36	22.49	22.51	9.66	9.74
T_5 Abscisic acid 20 ppm	48.47	48.57	22.62	22.71	9.68	9.78
T_6 TRIA 5 ppm	47.81	48.07	22.43	22.49	9.61	9.70
T_7 TRIA 10 ppm	48.57	48.59	22.63	22.71	9.74	9.79
T_8 Brassinosteroid 5 ppm	47.42	47.55	22.40	22.46	9.57	9.64
T_9 Brassinosteroid 10 ppm	47.54	47.67	22.42	22.48	9.58	9.67
T_{10} Cytokinin 5 ppm	48.62	48.71	22.66	22.73	9.80	9.98
T_{11} Cytokinin 10 ppm	49.31	49.46	22.69	22.76	10.34	10.40
S.Em±	1.034	1.303	0.481	0.458	0.265	0.202
CD at 5%	3.137	3.953	1.458	1.390	0.804	0.613

Table 8: Effect of plant growth regulators on Canopy temperature depression (CTD and Chlorophyll intensity (SPAD) (%) at Pre and post anthesis stages in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	Canopy temperature depression (CTD) Pre-an thesis I Year	Canopy temperature depression (CTD) Pre-an thesis II Year	Canopy temperature depress ion (CTD) Post-an thesis I Year	Canopy temperature depression (CTD) Post-an thesis II Year	Chlorophyll intensity (SPAD) (%) Pre-an thesis I Year	Chlorophyll intensity (SPAD) (%) Pre-an thesis II Year	Chlorophyll intensity (SPAD) (%) Post-an thesis I Year	Chlorophyll intensity (SPAD) (%) Post-an thesis II Year
T_0 Control	4.15	4.19	4.81	5.21	40.15	40.36	38.25	38.50
T_2 IAA 25 ppm	4.61	4.68	5.93	6.01	43.80	43.92	41.81	41.88
T_3 IAA 50 ppm	5.05	5.16	6.75	6.83	44.25	44.78	42.55	42.66
T_4 Abscisic acid 10 ppm	4.10	4.15	5.21	5.26	42.50	42.61	40.66	40.71
T_5 Abscisic acid 20 ppm	4.05	4.11	5.11	5.19	42.11	42.40	40.21	40.27
T_6 TRIA 5 ppm	4.16	4.22	5.30	5.38	42.85	43.05	40.71	40.78
T_7 TRIA 10 ppm	4.20	4.28	5.43	5.55	43.11	43.31	40.84	40.92
T_8 Brassinosteroid 5 ppm	4.24	4.32	5.51	5.64	43.30	43.56	41.05	41.13
T_9 Brassinosteroid 10 ppm	4.33	4.40	5.62	5.70	43.55	43.60	41.31	41.38
T_{10} Cytokinin 5 ppm	4.55	4.63	5.76	5.82	43.71	43.79	41.43	41.51
T_{11} Cytokinin 10 ppm	4.76	4.81	6.15	6.22	44.10	44.66	42.13	42.22
S.Em±	0.118	0.095	0.153	0.124	0.849	1.166	1.094	0.881
CD at 5%	0.357	0.287	0.463	0.375	2.575	3.537	3.318	2.673

Table 9: Effect of plant growth regulators on Relative water content (RWC) and Protein content (%) at Pre anthesis stage in wheat (*Triticum aestivum* L.) under late sown condition

Treatments (T)	RWC Pre an thesis I Year	RWC Pre an thesis I Year	Protein content (%) Pre an thesis I Year	Protein content (%) Pre an thesis II Year
T_0 Control	63.95	64.15	11.05	11.14
T_2 IAA 25 ppm	70.07	70.29	11.37	11.40
T_3 IAA 50 ppm	72.42	72.65	11.45	11.48
T_4 Abscisic acid 10 ppm	66.47	66.68	11.22	11.26
T_5 Abscisic acid 20 ppm	65.66	65.87	11.18	11.21
T_6 TRIA 5 ppm	67.05	67.26	11.28	11.31
T_7 TRIA 10 ppm	67.37	67.58	11.30	11.34
T_8 Brassinosteroid 5 ppm	68.09	68.30	11.33	11.36
T_9 Brassinosteroid 10 ppm	68.63	68.84	11.34	11.37
T_{10} Cytokinin 5 ppm	68.99	69.21	11.37	11.40
T_{11} Cytokinin 10 ppm	70.97	71.19	11.40	11.43
S.Em±	1.820	1.473	0.228	0.310
CD at 5%	5.521	4.468	0.691	0.941

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 5 ppm as a growth enhancer. Hence it may be recommended for enhancing productivity of wheat.

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