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IMPROVEMENT OF WHEAT (*TRITICUM AESTIVUM* L.) PRODUCTIVITY WITH THE APPLICATIONS OF PLANT GROWTH REGULATORS

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Abstract

Plant growth regulators (PGRs) are commercially used in many countries for the enhancement of growth and better yield in various crops including wheat but in Pakistan growers are reluctant due to non-availability of scientific information. In Pakistan, there is also a low yield of wheat as compared to many other countries that's why there is need to improve the crop productivity. For this purpose, present research was conducted during 2019-2021 to evaluate the response of four wheat varieties (Watan-1994, Sehar-2006, Faisalabad-2008 and Galaxy-2013) to foliar applications of Indole Acetic Acid (IAA) and Gibberellic Acid (GA_3). There were different levels of IAA and GA_3 i.e. 0, 25, 50 mmol.L^{-1} separately and combined treatments of GA_3+IAA. Results showed that different levels of IAA and GA_3 increased the morphological attributes of wheat i.e. shoots and roots lengths, shoot and root fresh and dry weights and leaf area. All the biochemical attributes also showed significant increase in response to IAA and GA_3 including photosynthetic pigments, total carbohydrates and proteins contents. Catalases (CAT) and Peroxide dismutase (POD) activities were also increased with the applications of PGRs. Different levels of IAA and GA_3 also increased the seed yield significantly in all the varieties of wheat. It was concluded that 50 mmol.L^{-1} combined application of IAA+GA_3 was best for the improvement of growth and yield of wheat as compared to other levels. Overall, GA_3 treatments were more effective for the improvement of crop productivity in wheat than IAA applications.

Key words: Wheat, Antioxidant activities, Yield, Growth, Biochemical attributes.

Introduction

Wheat (*Triticum aestivum* L.) is cultivated almost all over the word as staple food (Cakmak, 2008; Amiri *et al*., 2015). Wheat has brilliant ability to survive and grow in different environmental condition and climates. Wheat is a crop which strongly resist the salt (Khan *et al*., 2004). About 44 percent of total comestible dry matter is wheat. It also consumed as a food energy, nearly 40 percent of food energy, in world developing countries and supports the food supply of whole world. (Lantican *et al*., 2005). The constituents of wheat are very useful for human health because its grains have a great source of energy in the form of starch (Shewry *et al*., 2015). Grain of wheat is generally be made up of starch, protein and polysaccharides named the three components. Wheat's plant is consider a basic store for carbohydrate. (Cornell, 2003; Shewry *et al*., 2013). Wheat has high percentage of protein content due to which it is considered as a major source of protein in food in plants around the whole world. The protein in wheat is 13 % approximately as compare to other cereals (Belderok *et al*., 2000). Saud *et al*., (2013) reported that life cycle of wheat plant faced different types of abiotic problems such as the cold stress, salinity, drought and temperature's effects. In the life cycle of plant there are both physiological and biochemical stages which come under the different hostile effects due to the abiotic stress factors (Ashraf & Sarwar, 2002; Munns & James, 2003).

Basically, these phytohormones are made in the one part of the plant and then moved to the other portion of plant. At very low concentration these chemical transmitters play basic role during process of regulation and gives the positive plant's response to any type of distress. The phytohormones basically having organic nature and when they synthesized chemically the products said the plant's growth regulator (Javid *et al*., 2011). To decrease the abiotic stresses in different plant the PGRs performed the very vital role (Skirycz & Inze, 2010; Fahad *et al*., 2015). The plants formed gibberellins as well as indole acidic acid which was basically phytohormones (Teale *et al*., 2006). First gibberellin Products were formed in the metabolic process of the pathogenic fungus *Oryza sativa*, Gibberella fujikuroi in 1938 (Yamaguchi, 2008; Santner *et al*., 2009). Stimulus of environmental and developmental are responsible for the bioproduction of Gibberellins (Olszewski *et al*., 2002). Family of gibberellins is ordinary growth supporters and stem elongation mostly effective by GA_3 in this family and this is showed positive results in salt stress for the using the nutrients in the present of gibberellic acid. Point out the positive result of GA_3 on Sprouting, expansion of leaves, stem elongation, and blossoming (Rosenvasser *et al*., 2006). GA_3 application in the form of spray play a role to survive the plants in salinity soil by enhanced the usage of nutrients which are vital for morphological characteristics and functional features (Shomeili *et al*., 2011).

First one of the growth's promoter was auxin discovered for improving health of plants (Ellis *et al*., 2005) and this is apply on wheat cultivars for improved the hypocotyl's dry mass, seedling garden-freshly and also dry mass and height of the hypocotyl in salt stress fields (Akbari *et al*., 2007). It was point out by physiologically that IAA was the most powerful in the family of auxin for plant growing and improvement (Dimkpa *et al*., 2009). Major part in regulating the growth functions in plants are done by the Indole acetic acid (Yunde, 2010). The regulations the of steel system improvement, dominance of the apices and also the cell's elongation, were done due to its (Wang *et al*., 2001). The IAA (indole acidic acid) in form of exogenous spray on shoot and root of *Tritium aestivum* exhibits the positive influence in this case of experiments (Egamberdieva, 2009). Application of Both IAA and GA_3 are improved the storing as well as shelf life of plant (Gou *et al*., 2010). These both hormones are showed the positive influence for the regulating the development and also roots enhancement and also effect the on the signaling of hormones during the communication in various types of pathways (Nemhauser *et al*., 2006; Yaxley *et al*., 2001).

This study was conducted to find out the effect of different levels of IAA and GA_3 on different wheat varieties to evaluate its growth and yield.

Materials and Methods

Experiments were conducted at University of Gujrat, Gujrat, Pakistan, during 2019-21. Seeds of four wheat varieties (Watan-1994, Sehar-2006, Faisalabad-2008 and Galaxy-2013) were obtained from Punjab Agriculture Department, Gujranwala, Pakistan. Sandy loam soil was prepared by taking approximately 60 percent sand, 10 percent clay and 30 percent silt particles. Soil was mixed with organic manure with 1:1 ratio; no synthetic fertilizer was used and no disease was observed during the experimental period. Seeds were planted in plastic pots of having 30 cm length containing 8 kg of clayey soil. Different levels of GA_3 and IAA were applied as a foliar application after 14 days germination which were:

T0 = Control (Water only)
T1 = 25 mmol.L^{-1} IAA
T2 = 25 mmol.L^{-1} GA_3
T3 = 50 mmol.L^{-1} IAA
T4 = 50 mmol.L^{-1} GA_3
T5 = 25 mmol.L^{-1} IAA + 25 mmol.L^{-1} GA_3 (combined)
T6 = 50 mmol.L^{-1} IAA + 50 mmol.L^{-1} GA_3 (combined)

Experiment was laid down in CRD (Completely Randomized Design) with 3 replicates. Four plant sample were collected for data observations at vegetative (28 days after treatment) and maturity (56 days after treatments) stages like root and shoot lengths, fresh and dry weights, no. of leaves, leaf area, leaf area ratio, activities of catalase and peroxidase, contents of chlorophyll and carotenoid, total carbohydrates and proteins contents. Yield attributes including number of spike, seed/spike and weight of seeds were determined at maturity.

Leaf area was determined with portable Handheld Leaf Area Meter (CI-203 Laser scanner).

Chlorophyll a, b, total chl and carotenoids were determined by the method of Arnon (1949). For determination of carbohydrate, 10 ml of 80% ethanol was used to grind fresh seeds (1g). Extract was diluted with water and final volume was made up to 10 ml. Concentrated H_2SO_4 (96%) was added in test tubes (5ml) and gently shaked and incubated it at room temperature for 40 min. About 1 ml of 5% phenol was added to each tube and reading was taken from spectrophotometer at 490nm. Fresh seeds (1g) were ground with 50 mM of potassium phosphate buffer having pH 7.8 in a cool environment. Centrifugation was done at 10,000 RPM at 4°C for about 15 min. Bradford reagent (2ml) was mixed with 0.1ml of centrifuged extract and the reading was taken at 590 nm using spectrophotometer.

Estimation of CAT (catalases) and POD (peroxidase dismutase) activities were determined by the procedure of Chance and Maehly (1955). Fresh pea leaves (5g) were crushed with the volume of 5ml of 50mM cooled Phosphate buffer (pH 7.8) which was then placed in an ice bath for the accurate extraction of antioxidant enzymes. After that crushed samples were centrifuged at 15,000RPM at 4°C for 20minutes. For the determination of enzymes activities supernatant was used. A solution of (3ml) was prepared to determine the antioxidant enzyme activity by adding 50mM phosphate buffer (pH 7.0), 5.9Mm H_2O_2 and 0.1ml extract. A change in the absorbance of CAT solution was determined at 240nm. To characterize one unit activity of CAT absorbance change of 0.01 units per minute was utilized. Peroxidase dismutase (POD) solution of (3ml) was made with 50mM phosphate buffer (pH 5.0), 20mM guaicol in addition with 40mM H_2O_2 and with 0.1ml enzymes extract to check the antioxidant activity. Changes in the absorbance of the solution was determined at 470nm.

COSTAT computer software package was used to determine ANOVA (Analysis of Variance) and means were compared done by Duncan's New Multiple Range Test at probability level of 5% (Steel & Torrie, 1986).

Results and Discussion

Growth attributes: It was observed from these experiments that the foliar use of IAA and GA_3 improved the growth and yield in four varieties of wheat. It was noted that 50 mmol.L^{-1} of IAA+GA_3 combined treatment was best for the enhancement all the morphological attributes in wheat. GA_3 foliar application were more effective for the ehnacment of crop productivity in wheat. Analysis of variance showed that the effect of IAA and GA_3 was significant on root, shoot and leaf development i.e. root and shoot length, root and shoot fresh and dry weights and leaf area of wheat (Tables 1-3). The interaction of IAA x GA_3 x VAR was non-significant in most of cases except for leaf area. It was observed that higher root length, root fresh and dry weights and shoot length were obtained by the combined treatment of 50 mmol.L^{-1} of IAA+GA_3 at vegetative and maturity stages in variety Watan 1994 (Fig. 1A-D). Higher shoot fresh and dry weights and leaf area were noted in variety Watan 1994 at 50 mmol.L^{-1} of IAA+GA_3 treatment at maturity level (Fig. 2A-C). Higher shoot fresh and dry weight was present in variety Galaxy 2008 with combined treatment of IAA+GA_3 at vegetative stage (Fig. 2A-B). Higher increase in leaf area was observed with 50 mmol.L^{-1} of IAA+GA_3 in variety Watan 1994 (Fig. 2C). It was noted from these results that IAA and GA_3 improved the growth parameters in wheat. These results are in accordance with various studies as Duca (2006) found improved in root development with the applications of IAA and GA_3 in wheat. Dhital *et al*., (2010) stated that collective treatment of IAA and GA_3 improved the fresh weight of root.

Mukhtar (2008) described that 100 mg/L concentration of indole acetic acid and gibberellic acid indicated positive effect on shoot length of red sorrel and soybean in early germination of seeds. Zhang *et al*., (2005) report also similar with our results that shoot length improved due to the foliar appliaction of IAA and GA_3 hormones. Combined doses of GA_3 + IAA were also enhanced the leaf area on the other side it was seen that IAA alone improved in size of leaf area than GA_3 and IAA combined form (Naeem, 2004).

Photosynthetic pigments: Foliar application of plant growth regulators had significant effect on chl. "a" and "b" and carotenoids (Table 4). Higher chl-a contents were measured with combine foliar application of 50 mmol.L^{-1} of IAA+GA_3 in sehar 2006 (Figure 2D). It was observed that variety sehar 2006 had maximum chl. b and carotenoid contents by 50 mmol L^{-1} and 25 mmol L^{-1} GA_3 respectively (Fig. 3A-B). Similarly, it was found that foliar spray of GA_3 impressively enhanced the components of cellulose and nutrients and photosynthetic process was also enhanced by gibberellic acid (Tuna *et al*., 2008). The application of indole acetic acid increased the chl. contents and stomatal conductance in plants (Alenazi, 2011).

Antioxidant activities: Antioxidant activities were increased by the foliar spray of indole acetic acid and gibberellic acid. Table 5 showed that peroxidase (POD) and catalase (CAT) activities were enhanced in all wheat varieties and their interaction among all varieties of wheat. In all wheat varieties it was observed that POD and CAT activities were expressively higher by the spraying of IAA+ GA_3 as compared to control (Fig. 3C-D). Antioxidant activities are indicators of any stimulant applied in the form of chemicals. It was noted that POD, SOD and CAT were amplified after the treatment of IAA by foliar spray in wheat (Szechynska-Hebda *et al*., 2007).

Table 1. Means squares (MS) from the analysis of variance (ANOVA) for root development of wheat under the effect of IAA and GA_3.

Source of variance	df	Root length		Root fresh weight		Root dry weight	
		Vegetative stage	Maturity	Vegetative stage	Maturity	Vegetative stage	Maturity
Indole acetic acid (IAA)	2	282.037***	117.246***	8.243***	987.256***	0.283***	17.958***
Gibberellic acid (GA_3)	2	923.852***	211.468***	2.620***	759.297***	0.443***	16.399***
Varieties (Var)	3	345.663***	183.842***	5.042***	467.948ns	0.217***	3.835***
IAA x GA_3	4	320.201***	942.351***	0.225ns	310.109**	0.184***	0.370ns
IAA x Var	6	895.928ns	1030.069ns	0.869**	343.702ns	0.023**	0.812ns
GA_3 x Var	6	795.494***	222.6**	0.301ns	675.593ns	0.004ns	0.784ns
IAA x GA_3 x Var	12	378.219ns	365.924ns	0.128ns	437.083	0.005ns	0.066ns
Error	36	523.203	1247.222	0.341	461.975	0.009	0.572
Total	**71**						

Table 2. Means squares (MS) from the Analysis of Variance (ANOVA) for shoot development of wheat under the effect of IAA and GA_3

Source of Variance	df	Shoot length		Shoot fresh weight		Shoot dry weight	
		Vegetative stage	Maturity	Vegetative stage	Maturity	Vegetative stage	Maturity
Indole acetic acid (IAA)	2	1674.729***	19113.65***	383.619***	2443.106***	1.803***	1386.364***
Gibberellic acid (GA_3)	2	5770.528***	6311.44***	1005.792***	6307.776***	0.829***	4070.553***
Varieties (Var)	3	4375.101ns	7657.556ns	263.764***	777.564ns	2.341***	49.687**
IAA x GA_3	4	388.933***	9075.23***	58.518***	475.859***	0.111ns	273.586***
IAA x Var	6	561.961***	1565.208ns	23.075***	619.248ns	0.146*	12.612ns
GA_3 x Var	6	298.529*	2605.602ns	38.314***	386.184*	0.080ns	18.989ns
IAA x GA_3 x Var	12	565.693*	7655.82ns	4.427ns	283.265ns	0.025ns	2.339ns
Error	36	1327.863	1147.736	7.409	843.522	0.077	12.458
Total	**71**						

Table 3. Means squares (MS) from the Analysis of Variance (ANOVA) for foliage growth of wheat under the effect of IAA and GA_3.

Source of variance	df	Leaf area per plant	
		Vegetative stage	Maturity
Indole acetic acid (IAA)	2	270.911***	928.943***
Gibberellic acid (GA_3)	2	677.169***	759.885***
Varieties (Var)	3	786.600***	705.017***
IAA x GA_3	4	287.380**	864.975***
IAA x Var	6	313.942***	188.718*
GA_3 x Var	6	672.622**	563.76***
IAA x GA_3 x Var	12	323.743***	547.828ns
Error	36	574.369	9408.01
Total	**71**		

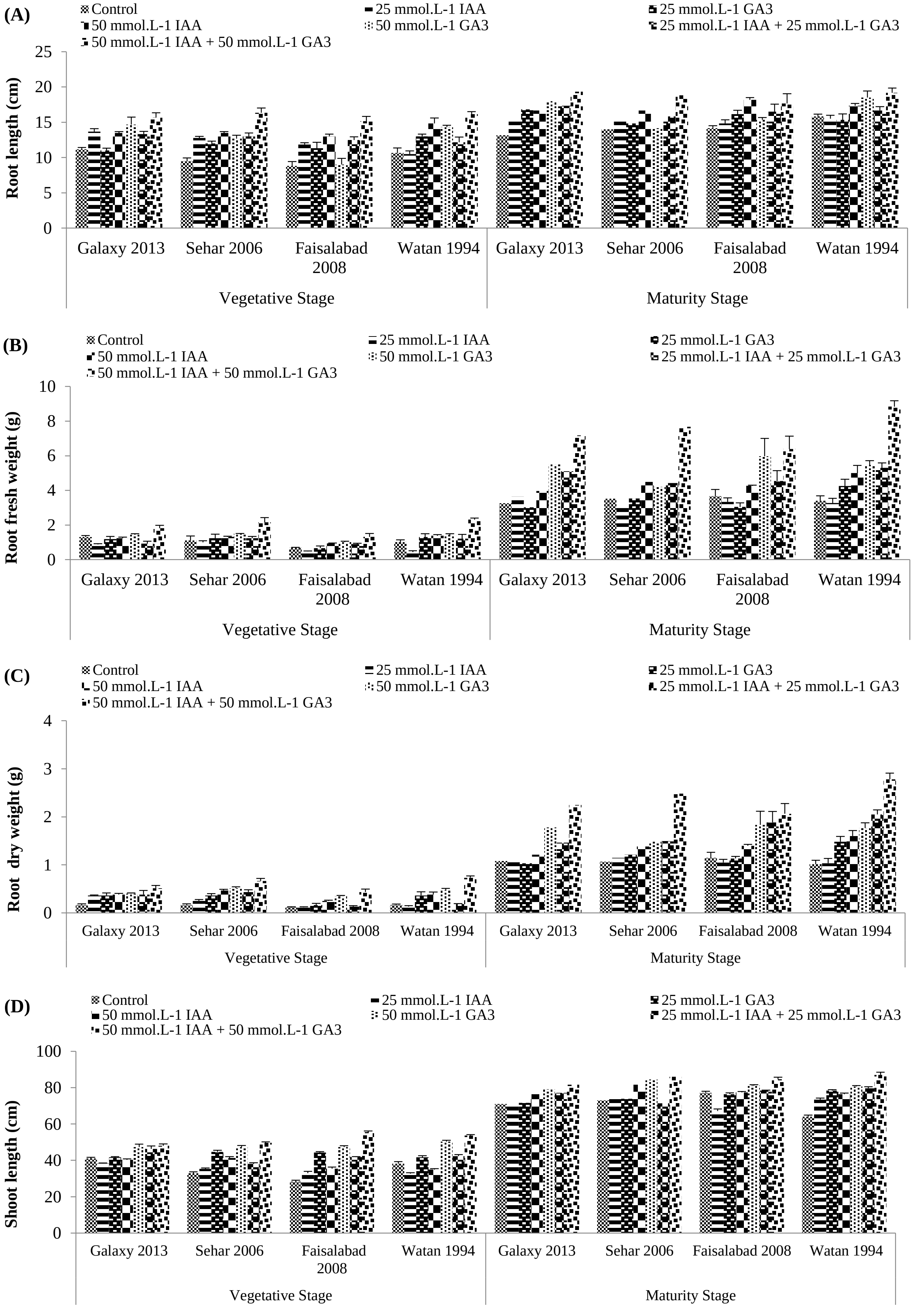

Fig. 1. Effect of IAA and GA_3 on various morphological parameters of wheat.

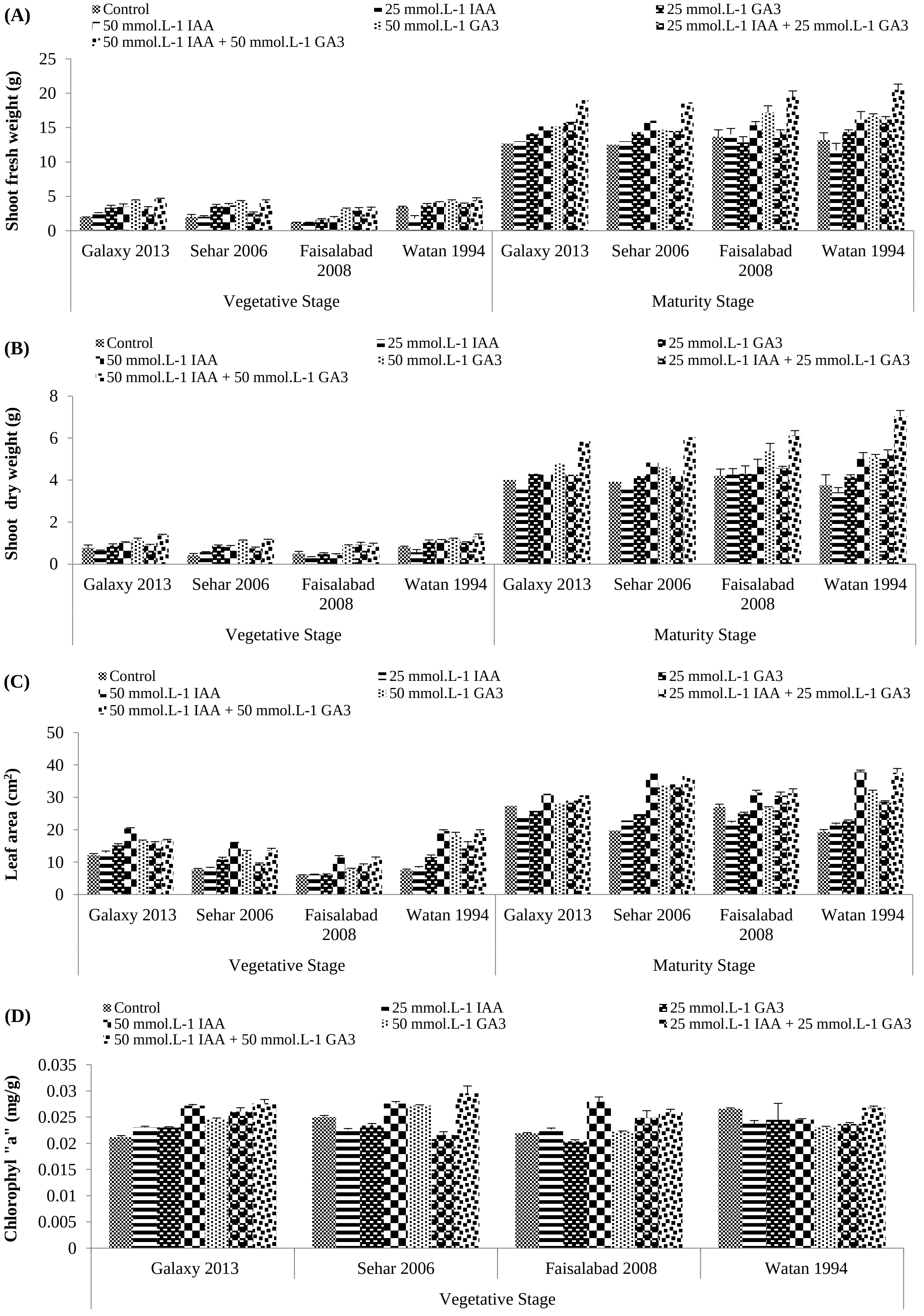

Fig. 2. Effect of IAA and GA_3 on various morphological and biochemical parameters of wheat.

Table 4. Means squares (MS) from the Analysis of Variance (ANOVA) for photosynthetic pigments of wheat under the effect of IAA and GA_3.

Source of variance	df	Chlorophyll ‘a’	Chlorophyll ‘b’	Carotenoids
		Vegetative stage	Vegetative stage	Vegetative stage
Indole acetic acid (IAA)	2	0.002***	0.005***	0.013***
Gibberellic acid (GA_3)	2	0.008***	0.018***	0.051***
Varieties (Var)	3	5.116ns	1.064**	4.443***
IAA x GA_3	4	5.014***	0.001***	0.004***
IAA x Var	6	7.772**	5.700ns	2.492***
GA_3 x Var	6	8.833ns	2.321***	1.245ns
IAA x GA_3 x Var	12	4.094ns	6.276*	1.712**
Error	36	2.638	3.241	7.415
Total	**71**			

Table 5. Means squares (MS) from the Analysis of Variance (ANOVA) for antioxidant activities and quality of wheat under the effect of IAA and GA_3

Source of variance	df	Catalase	Peroxidase	Total Protein	Total Carbohydrate
		Vegetative stage	Vegetative stage	Vegetative stage	Vegetative stage
Indole acetic acid (IAA)	2	0.159***	0.183***	0.363***	0.988***
Gibberellic acid (GA_3)	2	0.709***	0.599***	0.122***	0.639***
Varieties (Var)	3	0.002***	0.024***	1.775***	0.0433**
IAA x GA_3	4	0.047***	0.053***	0.013ns	0.059***
IAA x Var	6	4.498*	0.0025***	0.129***	0.008**
GA_3 x Var	6	2.267ns	0.002***	0.0857***	0.006***
IAA x GA_3 x Var	12	2.925ns	6.098ns	0.005ns	0.002**
Error	36	2.375	5.403	0.363***	9.246
Total	**71**				

Table 6. Means squares (MS) from the Analysis of Variance (ANOVA) for yielding attributes of wheat under the effect of IAA and GA_3.

Source of variance	df	Number of spikes per plant	Weight of spike per plant	Number of seeds per plant	Total seed yield per plant
Indole acetic acid (IAA)	2	1071.908***	248.219***	9603734.258***	3604.974***
Gibberellic acid (GA_3)	2	3766.85***	625.889***	34244796.467***	13957.611***
Varieties (Var)	3	309.865*	27.625***	1146129.852**	34.688***
IAA x GA_3	4	223.808**	41.804***	2366034.758***	816.300***
IAA x Var	6	25.489*	4.965**	129109.551***	6.830ns
GA_3 x Var	6	123.575***	21.424***	349832.852***	20.412***
IAA x GA_3 x Var	12	9.062ns	1.407ns	36435.106ns	1.962ns
Error	36	13.344	1.667	29607.578	4.781
Total	**71**				

Quality attributes: It was noted that the effect of foliar spray of PGRs as well as its interactions showed highly significant results for protein and carbohydrates contents (Table 5). Higher protein contents were obtained with combined treatments of GA_3 and IAA in Watan 1994 (Fig. 4A). In case of carbohydrate contents, it was noted that variety Galaxy 2014 had higher accumulation of carbohydrates at 50 mmol L^{-1} IAA (Fig. 4B). Foliar application of IAA stimulates the protein synthesis and nucleic acid (RNA). In various reports Gibberellic acid also showed same result in wheat plants (El-Mohandes, 1999). It was testified in tomato plant the starch, carotene, proteins, ascorbic acid and soluble carbohydrates level enhanced by Gibberellic acid (Graham & Ballesteros, 2006).

Yield attributes: ANOVA for yield attributes including number of spikes per plant, weight of spike per plant, number of seeds per plant and total seed weight per plant indicated highly significant response for foliar spray of PGRs (Table 6). All yield parameters were increased with GA_3 and IAA but higher inrease was noted at 50 mmole L-^{1} IAA+GA_3 in variety Watan 1994 (Fig. 5A-B). In previous studies, research indicated that GA_3 and IAA was useful for yield enhancement in linseed (Rastogi *et al*., 2013). The plant yield quality and productivity improved and enhanced by the proficiency of the photosynthetic process. It was directly linked to treatment of GA_3 IAA and to plants (Azooz *et al*., 2004). Treatment of IAA and GA_3 to plants are directly related to the function of the photosynthesis apparatus and these are responsble for positively increase the production and yielding of plant (Azooz *et al*., 2004).

Conclusion

It was concluded that 50 mmol.L^{-1} combined application of IAA+GA_3 was best for the improvement of growth and yield of wheat as compared to other levels. Overall, GA_3 treatments were more effective in comparison with IAA for enhancements of crop productivity.

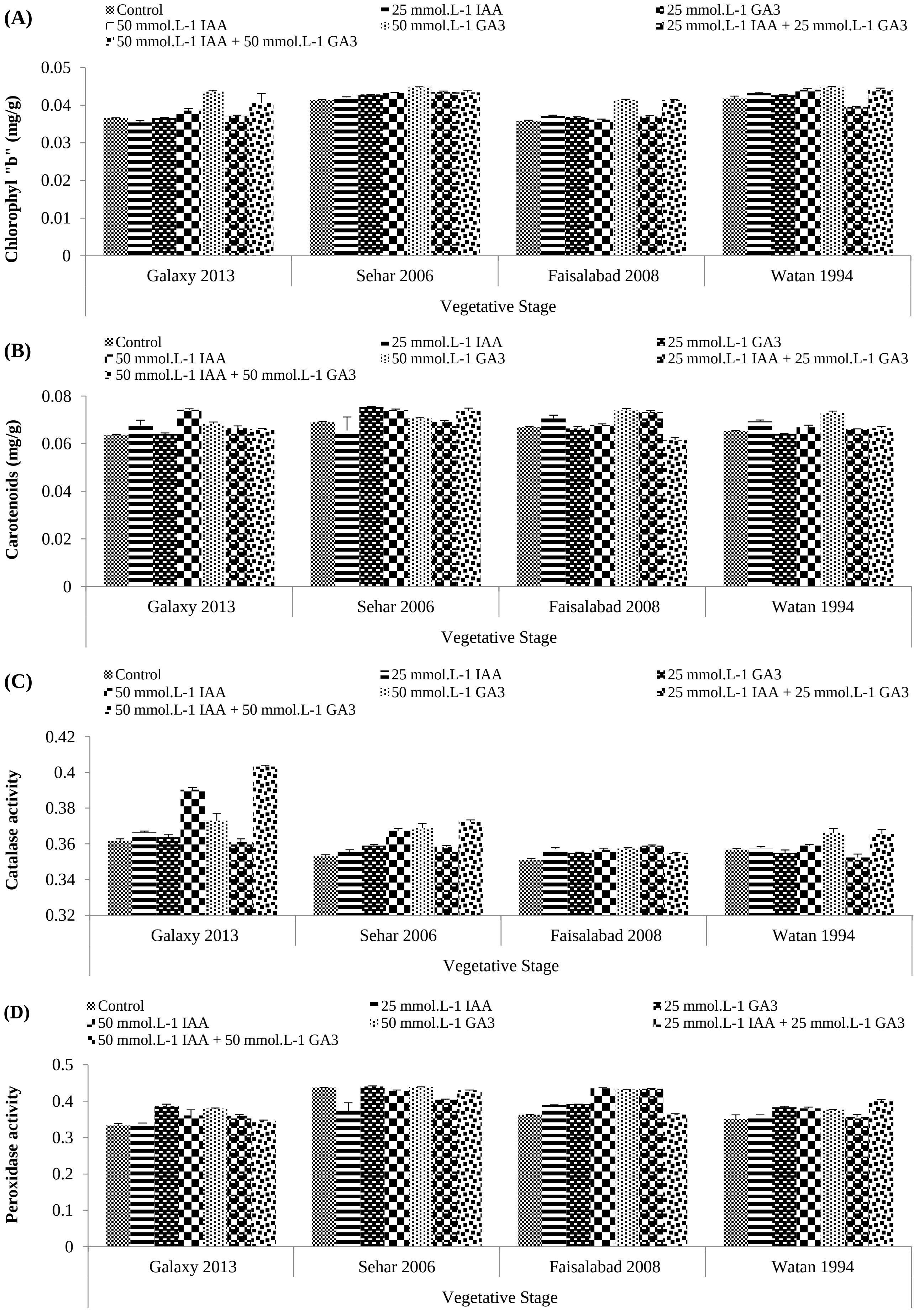

Fig. 3. Effect of IAA and GA_3 on biochemical parameters and antioxidant activities of wheat.

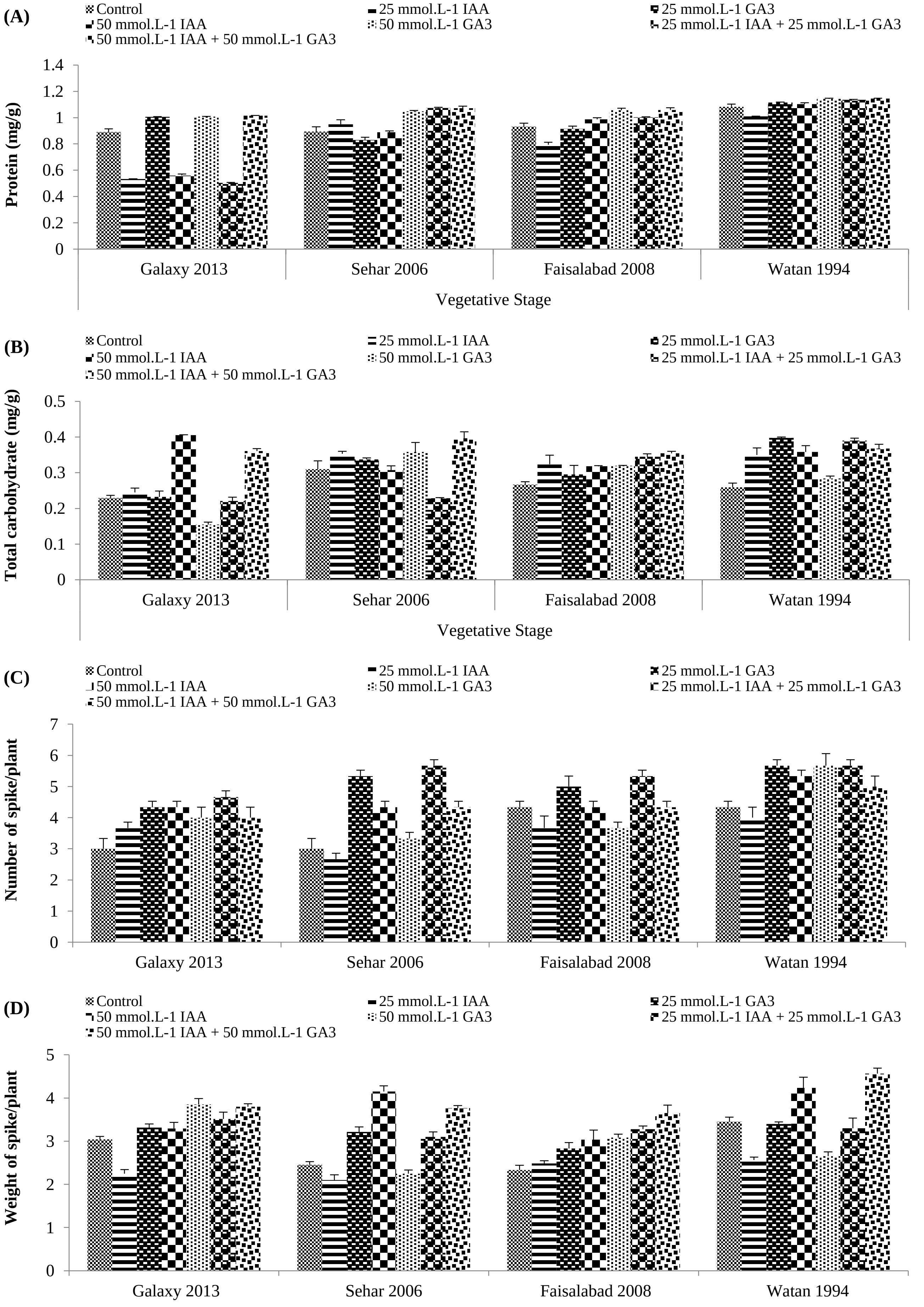

Fig. 4. Effect of IAA and GA_3 on quality and yield parameters of wheat.

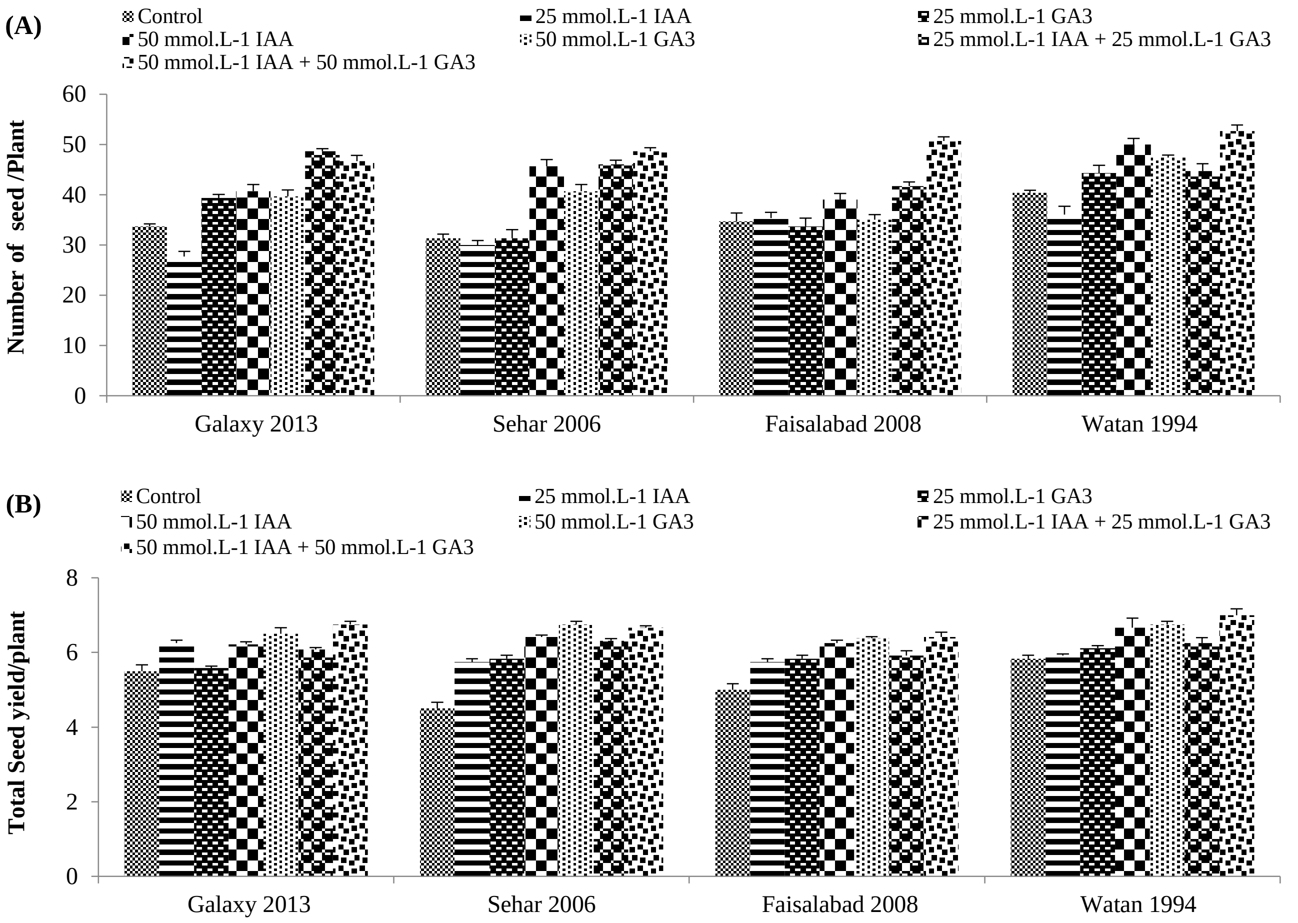

Fig. 5. Effect of IAA and GA_3 on yielding attributes of wheat.

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