Research Article

Application of Plant Growth Regulators to Promote the Yield of Wheat Crop in Pakistan

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Abstract | The growth of plants and their productivity can be improved by the use of plant growth regulators (PGRs). The PGRs have pronounced effects on the yield, biochemistry, physiology and plant morphology of wheat crop. Current studies were performed to investigate the effect of PGRs on the yield of wheat crop in Sayban International, Lahore (Pakistan). The field experiments were performed to evaluate the effects of numerous concentrations of three PGRs (sodium-5-nitroguaiacolate, sodium ortho-nitrophenolate and sodium para-nitrophenolate) on the yield of wheat crop. Numerous compositions of PGRs were formulated and sprayed on the foliar parts of the crop during various growth stages of the crop. Control measurements were also performed involving water spray only under the identical conditions. The PGRs spray has resulted in a significant rise of leaf development, stem growth and height of the wheat plants. The PGRs concentrations of 100ppm and 150ppm were proved to be most effective and possessed the momentous potential to increase the plant growth as well as yield of the wheat crop. It was concluded that the PGRs application reduces the economic cost of the farmer and also increases the nutritional value of wheat crop.

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Introduction

Plants find a great nutritional value (Farhat *et al*., 2020; Javed *et al*., 2020; Riaz *et al*., 2021) as human diet in the form of grains (Hassan, 2011), fruits (Naseer *et al*., 2018) and vegetables (Naseer *et al*., 2019). Wheat (*Triticumaestiyun* L.) is an important grain crop in Pakistan and is cultivated in approximately 8 million hectares (ha) with 18.2 metric tons per annum production (Islam and Mehraj, 2014). In general, the wheat yield remains low as compared to the real public demand so a lot of money is spent every year on its import from other countries (Commission, 2015). It is therefore needed to adopt suitable methodologies which may lead to optimize the yield of wheat. Like other crops,

the growth and optimum yield of wheat are affected by different hormones or plant growth regulators (PGRs) (Rasaei *et al*., 2017). Plant hormones are naturally occurring chemical substances which are stimulated naturally within the plants and are present in very low concentrations (Davies, 2010). They have the ability to inhibit or stimulate the specific enzymes which assist in increasing and regulating different metabolic processes in plant (Westfall *et al*., 2013). PGRs govern all factors of growth and development within plants and can alter the hormonal balance and growth leading to better yield, improved physiological trait of crops and enhanced crop tolerance against abiotic stress (Desta and Amare, 2021). They have potential to modify the cereal size and plant vascular system in addition to the stem elongation (Khan *et al*., 2019a; McKenzie and Deyholos, 2011).

In agricultural countries like Pakistan and India, the crop yield is greatly affected by soil nature, climate and topography. The water deficit and soil salinization are the bigger challenges in Asian countries (Entz and Fowler, 1988). Soil salinity may lead to toxic growth conditions especially for crops like wheat and rice. For example, sodium chloride (NaCl) toxicity may adversely affect the plant's ability to sustain its physiological processes (Tester and Davenport, 2003) and create an osmotic stress in the soil (Ueda *et al*., 2003). In New Zealand and Europe, PGRs are successfully spray on numerous crops in order to prevent the crop lodging and to increase the crop yield (Křen *et al*., 2014). Plant growth regulators have significant impact on wheat crop parameters such as biomass, no of grains and total yield of wheat. It was investigated by researchers that biomass can be increased up to 43% by use of different compositions of PGRs; it is especially important in severe drought conditions. It was also verified that foliar application of PGRs significantly enhanced the grain filling period with the consequent increase of kernel size and grain weight (Arfan *et al*., 2007); it is due to the net increase in the photosynthetic rate (Fariduddin *et al*., 2003). The combined treatment may result in 59% and 41% rise of crop yield per hectare in sensitive and tolerant varieties, respectively (Khan *et al*., 2019b). Similar research has been proposed by researchers that dry matter, leaf area and yield of wheat crop are significantly increased by the use of PGRs with nitrogen fertilizer. It was suggested that leaf area, spike length and grain yield are not affected by use of nitrogen rate along with PGRs (Tripathi *et al*., 2004). It was presented by researcher that almost 20% yield of winter wheat can be increased by use of PGRs along with nitrogen fertilizer (Shekoufa and Emam, 2008). Numerous nitrophenols and their salts have been reported as plant growth regulators (Jun *et al*., 2018; Pu *et al*., 2018). There are also reports regarding the use of a mixture containing sodium-5-nitroguaiacol, sodium-2, 4-nitrophenol, sodium-p-nitrophenol and sodium-*o*-nitrophenol as plant growth regulator. When five various concentrations of this mixture were sprayed on the chilly plants, it resulted in the rise of weight and average length of fruits as compared to the control (Hansani, 1980). The nitrophenols were also applied as bio-stimulants to increase the antioxidant potential, yield and number of soyabean seeds (Szparaga *et al*., 2018).

This study was performed to evaluate the effects of 3 important plant regulators (sodium 5-nitroguaiacolate, *ortho*-nitrophenolate and *para*-nitrophenolate) on the yield and growth of wheat crop. We used various combination of their isomers with different ratios and found a remarkable effect on yield and biomass of wheat. The study revealed that the controlled application of PGRs plays a highly important role in preventing the crop lodging, pre-harvest grain drops and turnover time.

Materials and Methods

For all the experiments, we used a wheat of Faisalabad 2008 variety which has approval from Punjab Seed Corporation. The studies were performed in a single green house of Sayban International, Lahore (Pakistan) which is situated between longitudes 31.5204° North's and 74.3587° East's in Punjab (Pakistan). The study area has a mean sea level of 217 m with level to very gentle sloping terrain; its mean maximum temperature is about 37°C and average rain fall is 628.8 mm.

Climate and soil

The required temperature for various growth stages namely germination (20-25˚C), tillering (16-20˚C), accelerated growth (20-23˚C) and grain filling stage (23-25˚C) was provided by an industrial fan heater of 2000 W with an adjustable thermostat of Nedis brand (EAN number= 5412810317004). For provision of required temperature, a single heating system was provided to the whole set of experiments in the same greenhouse. The provided temperature

was monitored with Honeywell Focus PRO-5000 (a temperature device).

The soil of experimental area (Sayban Research Farm Lahore, Pakistan) was collected for the experiments, dried and sieved (<2 mm) after grinding. The selected soil contained 15-20% sand, 45-56% silt and 29% clay. It is classified as kaolinite and scientifically called clay loam soil. The investigated soil composite possessed 2.1 dS/m salinity and a pH value of 8.1 (measured by Oahu's pH meter). Also, the soil possessed available phosphorous 0.1 mg/kg (± 0.005), 0.56 total nitrogen contents (±0.003), 1.53 extractable potassium (±0.07), 0.081 organic Matter (±0.005), 10.85 moisture contents (±0.23) and 19% water holding capacity.

Planting of seeds, growth of plants and harvesting time

De-ionized water was used to wash the wheat seeds before sowing. The seed variety (Faisalabad-2008) was sown in plastic trays (having soil) having dimensions of 9 x 5 inches. After 21 days of germination, there was transfer of average healthy plants into 12 plastic pots in replicates; five plants were transferred into each pot having the volume of 20170 cm^3 (height= 20.32 cm and radius = 17.78cm) with five kg soil and 1/4th part empty for watering. For comparison of results, the same experiment was also performed in replicates in one-meter square area under the same conditions. Both sets of these field experiments were started at the end 15th November 2016 and also repeated in year 19th November 2017 under the same conditions and procedure. The wheat crops grown in 2016 (trial experiments) and 2017 (repeated experiments) were harvested on 10th may 2016 and 17th may 2017, respectively.

The irrigated water had electrical conductivity (EC) of 1.9 mS/cm and a pH of 7.4 demonstrating its no or very minute saline effects; four (4) irrigations were applied to wheat crop from its sowing to the maturity period. After 21 days of sowing, the first irrigation was made; the subsequent irrigations were applied with three weeks intervals during the following critical growth stages: (i) crown root initiation (ii) tillering and (iii) flowering/grain filling. A focus was done on timely irrigations during these critical stages in order to achieve the proper plant growth and maturity. Urea, sulfate of potash (SOP) and di-ammonium phosphate (DAP) were applied as fertilizers during the sowing time whereas nitrogen fertilizers were used during irrigation.

Composition of plant growth regulators and its spray on crop plants

Sodium 5 nitroguaiacolate, sodium *para*-nitrophenolate and sodium *ortho*-nitrophenolate were mixed together in 3:2:1 ratio; the resultant mixture was added to water to produce 1.50% w/v composition in water. This stock solution (1.50% w/v) was used to prepare 100 ppm, 150ppm and 200 ppm concentrations which were applied as foliar spray on wheat plants by nozzle spray method. Three spray treatments were made before the crop maturity: 1st spray after four weeks of germination (T1), the 2nd spray during tiller formation (T2) and the 3rd spray at spike initiation (T3). Control plants of wheat were also sprayed with water (as a blank, T0) at the same intervals as spray of PGRs on T1, T2 and T3.

Effects of growth regulators (PGRs) on vegetative growth and mineral contents

The control and treated wheat samples were collected carefully after harvesting the experimental wheat crop. Observations were made to conclude whether the PGRs have enhanced the stem growth, plant height and number of tillers as compared to control plants or not. The spike length was measured with a meter ruler. ANOVA was applied for statistical analysis of the data to know the significant differences among treatment means, standard deviation and coefficient of variance.

Results and Discussion

Foliar application of PGRs on wheat crop has shown substantial effects on number of grains per spike, number of tillers, spike length and plant height; the data are displayed in Figure 1A and B. Statistical analysis by using two-way ANOVA was performed which showed significant results in both columns and rows (P<0.05) and represented in Table 1.

Table 1: *Effect of PGRs compositions on plant height, number of tillers, spike length and number of grains/spike in plastic pots.*

Experimental treatment	ppm of PGRs mixture	The height of plant in cm	Tillers in 5-plant	Length of spike (cm)	No. of spikes/ grains
T_0	Control	97±1	30±1	13±1	50±1
T_1	100	111±1	39±1	17±1	61±1
T_2	150	109±1	41±1	18±1	64±1
T_3	200	120±1	37±1	17±1	60±1

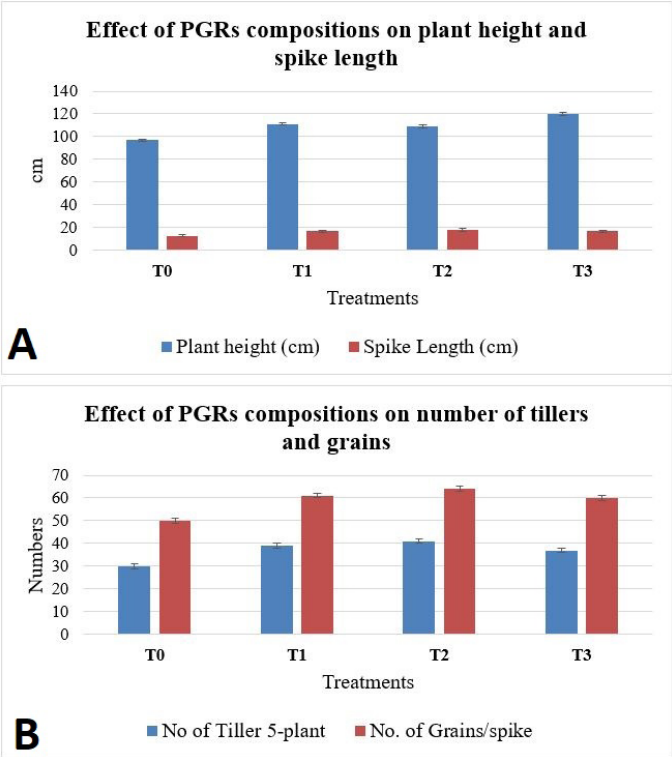

Figure 1: *Graph showing effect of various PGRs compositions on plant height and spike length (A); number of tillers and number of grains/spike (B) in plastic pots in a single green house of Sayban International, Lahore (Pakistan); where T0 (Control), T1 (100ppm), T2 (150ppm) and T3 (200ppm) represent the concentration of PGRs spray.*

The additional parameters of biomass weight and grain weight were calculated in experiments conducted in one-meter square area in year 2016; the data are displayed in Figure 2 along with corresponding statistical analysis in Table 2.

Table 2: *Effect of PGRs composition on biomass and grain weight in one-meter square area.*

Experimental treatment	ppm of PGRs mixture	Wt. of biomass in g	Wt. of grains in g	Rise in Grain wt. (%)
T_0	Control	1823±2.5	448±1	-
T_1	100	2030±2.5	567±1	26.5
T_2	150	2335±2.5	610±1	31
T_3	200	2035±2.5	560±1	25

It was observed that there was significant positive effect on all the investigated parameters by applying the PGR concentrations. The treatments T_1 and T_2 had shown remarkable effects on all the parameters as compared to the blank T_0 as shown in Figure 1A, B. It was noticed that mix PGRs have also significant effects on biomass as well as the yield of wheat crop. From Figure 2 it can easily be calculated that the treatments T_1 and T_2 have increased the grain yield up to 26.5% and 36.16%, respectively as compared to the control T_0. The hormonal treatments have stimulated the significant increase of all segments of the plants when PGRs of specific compositions were sprayed (Emam and Cartwright, 1990).

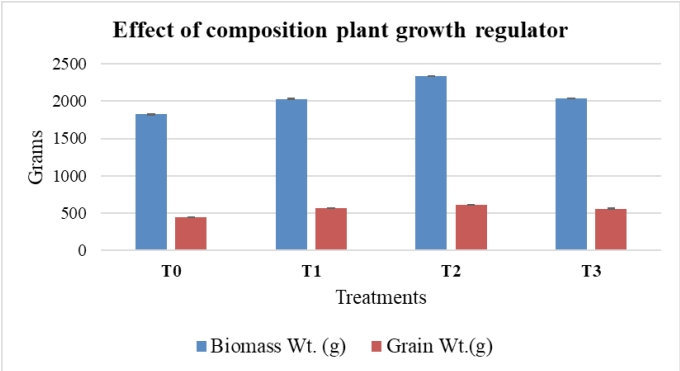

Figure 2: *Graph showing effect of various PGRs on biomass weight and grain weight in one-meter square area experiments (replicates) in a single green house of Sayban International, Lahore (Pakistan) where T0 (Control), T1 (100ppm), T2 (150ppm) and T3 (200ppm) represent the concentration of PGRs spray.*

The same experiments were repeated by applying same concentrations of PGR in the year 2017. The results were found similar to those obtained for year 2016; there was a significant increase in grain wt. and biomass wt. in T_1 and T_2 as compared to T_0. The results are shown in Figure 3 with corresponding statistical analysis in Table 3. The slight increase of nutrient concentrations in plant after application of PGRs in different filed trials indicates that physiological rate of plants is positively affected by the use of PGRs (Maize and Center, 2003).

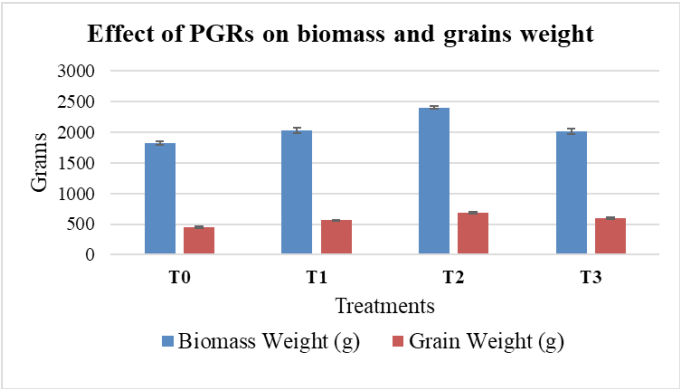

Figure 3: *Graph showing effect of PGRs on biomass and grains weight (g) in one-meter square area experiments (replicates) in a single green house of Sayban International, Lahore (Pakistan) where T0 (Control), T1 (100ppm), T2 (150ppm) and T3 (200ppm) represent the concentration of PGRs spray.*

The experimental results demonstrated that the PGRs having the mix composition of nitro-phenols

have the ability to enhance the overall yield of wheat. It was reported earlier that the enzymes or PGRs promote the cell divisions and chlorophyll content in plants so that the flowering and fruiting of wheat crop is increased. The phenolic compounds play an important role as chain breakers of strongly oxidative free radicals and finally result in the rise of the crop yield (Grassmann *et al*., 2002). It has been observed that diversity of wheat is a major issue in Asia due to increased population with decreased land cultivation. The current research emphasizes that remarkable diversity of wheat can be controlled with the application of these PGRs. It is worth-mentioning that Pakistani farmers are not able to achieve the potential yield with only macro fertilizers. However, it is a possible option to recommend the PGR application/spray for the better yield of wheat crop.

Table 3: *Effect of PGRs on biomass and grains weight on (one meter square).*

Experimental treatment	ppm of PGRs mixture	Weight of biomass in g	Weight of grains in g
T_0	Control	1823.33±30	446.33±16
T_1	100	2030±50	563.33±10
T_2	150	2399.66±22	683.66±12
T_3	200	2014±41	596±12

As far as the cost comparison is concerned, the cost of nitrophenolate salts is 10-11 US $ per kg and 5-nitroguaiacolate is 22-25 US $ per kg. So, a total cost of almost 77-81 Pak rupees per acre is expected by farmer. However, the spray with investigated growth regulators is cost effective since it increases the crop yield minimum of 25%. Hence, by investing 77-81 rupees per acre, a significant profit of Pak Rs. 10000/- to 15000/- is expected from each acre.

Conclusions and Recommendations

The foliar sprays of PGRs significantly increase the yield, growth and food quality of wheat and it also adds profit of about Pak Rs. 10000/- to 15000/- per acre for the farmer. Currently the farmers are not achieving the potential yield with only macro fertilizers so it is a possible option that recommendations with PGR application could be made to improve the wheat yield. Substantial increase in height of plant, leaf development and stem growth of the plants can be observed by the use of PGRs. The PGRs concentrations of 100ppm and 150ppm were proved to be most effective and possessed the momentous potential to increase the plant growth as well as yield of the wheat crop. This application also decreases the economic cost of the farmer and improves the nutritional importance of crop.

Novelty Statement

The field studies were performed to study the effect of various formulations of 3 PGRs (sodium 5-nitroguaiacolate, sodium ortho-nitrophenolate and sodium para-nitrophenolate). The PGRs mixtures of 150 ppm and 100 ppm were proved to be most effective and have shown the momentous potential for the rise of plant growth as well as yield of the wheat crop.

Author's Contribution

Muhammad A. Ahmad: Performing the research work
Shabbir Hussain: Refining the work and submission
Humera A. Awan: Writing the manuscript
Muhammad Riaz: Data inter-pretation
Muhammad Saeed: Literature review and revision

Conflict of interest
The authors have declared no conflict of interest.

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