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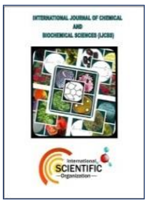

Yield and biochemical constituents of Egyptian wheat grains (Sakha-95) as affected by some plant growth regulators

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Abstract

This study was conducted to study the effect of foliar applications on yield and biochemical constituent of wheat Egyptian genotype Sakha-95 using gibberellic acid (GA_3), Naphthalene acetic acid (NAA) and 6-benzyl amino purine (6-BAP). Experimental results show that the wheat grain yield, straw yield, and the weight of 1000 seed numbers were increased by all treatments as compared with the control. Applied 6-BAP increased grain yield (0.12%) with 50ppm, while applied GA_3 gave a heist percentage of straw yield (0.22%) with 250ppm. NAA with 250ppm decreased reducing sugars more than other treatments, but all treatments increased non-reducing sugars. All treatments increased the percentage of total carbohydrates of wheat grains, but these treatments decreased starch content and therefore decreased amylopectin, as well as amylose content. The rate of disaccharides (maltose and sucrose) increased by 250ppm GA_3 and 50ppm 6-BAP applications. Where all treatments decreased the content of mono-saccharides, all treatments caused a slight decrease of saturated and unsaturated fatty acids. The total fats of wheat grains were increased by GA_3 and 6-BAP applications but NAA treatments caused a slight decrease in total fats. Applied PGRs increased protein grain contents, as well as protein fractions. The percentage of P, K, and Na were decreased by PGRs, but Ca and Mg content was increased as well as microelements (Fe, Cu, Mn, and Se).

Keywords: Wheat grains, yield, Gibberellic acid, Naphthalene acetic acid-6- Benzyl amino purine, biochemical constituents.

Full length article **Corresponding Author*, e-mail: Ataeai@zu.edu.eg.

1. Introduction

Wheat (*Triticum* spp. L.) is considering a main cereal crop in several parts of the world; Wheat crop (*Triticum aestivum* L.) is a major grain crop and a popular food source around the world. Improving productivity and quality of the crop is essential for long-term and global food production and food security [1], wheat is considered the essential source of carbohydrates, protein, and numerous essential nutrients and nutritive fiber1. According to [2], the total cultivated area of wheat in the world reached about 220.10 million ha in 2016 and the total production exceeded about 749.46 million t. Wheat (*Triticum aestivum* L.) is an important cereal crop that is used as staple food worldwide. Furthermore, it is estimated that 70% more wheat grains will be required by 2050 to feed the increasing world population [3]. It is the world's largest cereal crop and is consumed every day in almost everyone's life. Wheat is the most important cereal crop in Egypt, because of increasing human demand food attempts are made to cultivate more areas with high-yielding varieties in addition to using the recommended cultural practices to the wheat productivity there to meet the national needs. Wheat is an economic and important crop that provides approximately 20% of food calories in the world. Egypt has one of the highest wheat per capita consumption levels in the world (200kg/person/year). In Egypt, increasing wheat production is an interesting challenge for Egypt. Among the various agronomic techniques, the selection of high-yielding varieties is angle soon because the different varieties responded differently to the genotypic characters, input requirement, growth process, and the prevailing environment during the growing season and using plant growth regulators for increasing yield and quality of wheat grains. As well as Egypt is also the world's biggest wheat importer and the General Authority for Supply Commodities (GASC) of the Ministry of Supply and Internal Trade of Egypt alone is the world's biggest wheat purchaser [4]. Plant growth regulators (PGRs) are defined as synthetic or naturally occurring organic compounds that influence biological processes in higher plants at very low concentrations [5]. PGRs can increase or decrease growth and development by altering their normal biological processes [5,6]. When these compounds occur naturally inside the plant they are known as phytohormones, but when applied exogenously they are called PGRs [7]. PGRs act as signaling agents, allowing plants to maintain plasticity during growth and development, and are hence considered principal factors in the responses of plants to biotic and abiotic stresses [8,9]. The ameliorating ability of PGRs depends on environmental factors that affect their absorption, the concentration at which they are applied, and the physiological state of the plant [10]. PGRs are classified into a number of distinct classes, such as auxins (Aux), cytokinins (CKs), nitric oxide (NO), brassinosteroids (BRs), gibberellins (GAs), salicylic acid (SA), abscisic acid (ABA), jasmonates (JAs), and ethylene. Investigators around the world found that the yield of major cereal crops can be increased by the application of plant growth regulators. Available reports indicated that different plant growth regulators revealed stimulatory responses in wheat varieties [11,12]. Also, the application of plant growth regulators, such as NAA on wheat was more effective in yield, yield components, and grain quality [13]. [14] resulted that using plant growth regulators improved wheat grain yield and quality by the increasing rate of protein and carbohydrate fractions. The synthesis of this study was to evaluate the effect of some growth regulators on grain yield, carbohydrates fractions, free sugars, fibers, protein fractions, and some elements contents in Egyptian wheat grains (Sakha-95 variety).

2. Materials and Methods

2.1. Field experiment

The experimental field was conducted during the season of 2021 at the Experimental Farm of Faculty of Technology and Development, Zagazig University in Ghazala location, El-Zagazig Government, Egypt, to study the effect of gibberellic acid (GA_3), Naphthalene acetic acid (NAA) and 6- Benzyl amino purine (6-BAP), on yield and chemical constituents of genotype cv. Sakha-95, Egyptian wheat.

2.2. Seeds supply

Seeds of genotype Sakha-95 Egyptian wheat were obtained kindly from the Serial Department, Agriculture Research Center, Ministry of Agriculture, Egypt.

2.3. Chemical plant growth regulators

Chemical plant growth regulators, Gibbrilic acid (GA_3), Naphthalene acetic acid (NAA), and 6- Benzyl amino purine (6-BAP) were purchased from Sigma Chemicals Company.

2.4. Applied Management

The experiment was carried out as a factorial based on a randomized complete bloke design with three replications in 2021 cropping season. Seeds sowing in plots each 3*3.5 m. Growth regulators were applied as foliar after 30 days of sowing with the following concentrations:

1- Control (distilled water)
2- Gibberellic acid (GA_3) applied by 250ppm
3- Gibberellic acid (GA_3) applied by 500ppm
4- Naphthalene acetic acid (NAA) applied by 250ppm
5- Naphthalene acetic acid (NAA) applied by 500ppm
6- 6- Benzyl amino purine (6-BAP) applied by 25ppm
7- 6- Benzyl amino purine (6-BAP) applied by 50ppm

Control measurements were also performed involving water spray only under identical conditions.

2.5. Crop parameters

The crop was harvested after full maturity and the yield of grains, straw yield, and the ratio between grain yield and straw yield, which of 1000 grains were determined as recommended. A sample of grain was taken and dried at 75c then grounded and kept for further chemical analysis.

2.5.1. Chemical methods

1- Total Ash Determination: Ash % was determined by dry ashing procedures using a high-temperature muffle furnace capable of maintaining temperatures of between 500 and 600 C.
2- Determination of carbohydrates fractions using the HPLC method according to [15].
3- Determination of total fibers by liquid chromatography according to [16].
4- Determination of starch using the HPLC method as described by [17].
5- Total lipids were determined according to methods stated by [18].
6- Determination of fatty acids in lipids using HPLC as described by [19].
7- Amylose and amylopectin were analyzed by HPLC as described by [17].
8- The contents of total soluble sugars and non-reducing sugars were determined according to [20,21].
9- Sodium, magnesium, potassium, calcium, iron, and zinc contents were determined according to the method described by [22].
10- Phosphorus content was determined according to [23].

2.6. Statistical analysis

Statistical analysis was applied according to [24].

3. Results and discussion

3.1. Effect of some growth regulators on yield parameters of Sakha-95 wheat crop

The values representing the yield of grains, straw yield, and weight of 1000 grains of wheat cultivar Sakha-95 are shown in Table (1). Results showed that grains yield per plot (kg) and grains yield per feddan (ton) were increased by all treatments as compared with the control. The highest grains yield was obtained by the foliar application of 25 and 50ppm 6-BAP (9.03-9.01 kg/ plot) and the least increase was obtained by the foliar application of GA_3 treatments (8.67-8.60 kg/plot) as compared with other treatments. Plant growth regulators significantly increased yield characters as stated before by [25]. The obtained results in Table (1) show that the straw yield was increased by the foliar application of all PGRs. Foliar application of GA_3 gave the highest yield (4.89-4.84 ton / feddan) as compared with other treatments. Where the least value was obtained by 250ppm NAA (4.17 ton/ feddan) as compared with other treatments. In this connection, [14] in their study found that the application of plant growth regulators improved straw wheat plants. Taking the weight of 1000 grains as a parameter of quality, the foliar application of all treatments increased the weight of 1000 grains as compared with the control. The highest weight of 1000 grains was obtained by 50ppm 6-BAP. These results are in the same trend as those obtained by [26]. [27] found that the application of appropriate concentrations of NAA induced greater growth there for yield of wheat crops. [28] stated that PGRs have been used to increase the growth and yield of major cereal crops such as wheat crops.

3.2. Effect of some growth regulators on carbohydrate fractions of wheat grains (Sakha-95)

Results in Table (2) showed the effect of foliar application of growth regulators on soluble sugar contents of wheat grains (Sakha-95). It can be noticed that all treatments decreased reducing sugars. The least decrease was obtained by the foliar 250ppm NAA treatments, where the foliar application of all treatments generally increased the content of non-reducing sugars. The highest increase was obtained by the 50ppm 6-BAP treatment (2.38- 3.66 %) as compared with the other treatments. The total soluble sugar content was also increased by all treatments revealing the decrease in reduced sugar content because growth regulators induced the synthesis of the oligosaccharides. This might be ascribed to more efficient utilization of food for reproductive growth, higher photosynthetic efficiency and enhanced source-to-sink relationship of the plant, reduced respiration, enhanced translocation, and accumulation of sugars and other metabolites. Inhibition of growth performance on exposure to the other PGRs occurred [29] stated that there was a significant increase in total soluble and insoluble carbohydrate content in sunflowers by the application of NAA. The same table showed that total carbohydrates were increased by all PGRs applications as compared with the control.

3.3. Effect of some plant growth regulators on starch, total fibers and total ash of Sakha-95 wheat grains

In an attempt to study the effect of GA_3, NAA, and 6-BAP on total starch content in wheat grains (Sakha-95). The results showed that all treatments showed a slight increase in the percentage of total starch in all PGRs applications as compared with the control, these results were illustrated in Table (3). The percentage of amylose and amylopectin was increased by the foliar application of plant growth regulators. It can be noticed that GA_3, NAA, and 6-BAP treatments caused a reduction of the fiber content of wheat grains as compared with the control. Also, it can be observed that both NAA and 6-BAP applications had slightly increased the total ash content of wheat grains when compared with control due to the increase of some elements contents, while GA_3 treatment did not affect this might be due to the favorable effect of these growth regulators on the uptake and mobilization of some mineral nutrients.

3.4. Effect of some plant growth regulators on some free sugars of wheat grains (Sakha-95)

Data in Table (4) showed the percentage of free sugars (Glucose, Fructose, Maltose, and Sucrose) as detected in wheat grains. The rate of di saccharides (Maltose and Sucrose) increased by the foliar 250ppm GA_3 and 50ppm 6-BAP when compared with control and other treatments. Application with NAA showed that a low dose (250ppm) decreased the content of maltose and sucrose, but a high content ratio (500ppm) increased disaccharides. On the other hand, the percentage of monosaccharides relatively increased by foliar application of all PGRs and the highest increase of monosaccharides resulted from 500ppm GA_3 (2.15%) and 25ppm 6-BAP (2.12%) treatments. The growth regulators' effect on sugar content was previously in agreement with [30]. Also, from this table, the ratios of mono/di saccharides were increased by all treatments except when the foliar application of 250ppm GA_3 and 50ppm 6-BAP treatments (0.112-0.116) respectively, this may be due to the regulation of the osmatic status of the cell during growth of the plant.

3.5. Effect of some plant growth regulators on fatty acid composition of wheat germ lipids

In profiling the principal components carried out the determination of the FA compositions of the wheat grains by HPLC. The fatty acid profile was found to be made up of linoleic followed by palmitic and oleic as the major fatty acids. A striking feature of wheat lipids was the relatively high level of polyunsaturated fatty acids (PUFA), especially linoleic fatty acid which was estimated at higher levels (52.64%) with 250ppm GA_3 treatment. Lipid contents and fatty acids composition of (Sakha-95) grains were tabulated in Table (5). It can be noticed that NAA had no effect on lipid contents as compared with control (2.51, 2.55, and 2.56 respectively), but 6-BAP and GA_3 application gave the highest values of lipid contents (2.72, 2.76, 2.63, and 2.66 respectively). Also, data showed that the concentration of 6-BAP or GA3 has no effect on lipid content. In response to the fatty acid composition of Sakha-95 grains data, HPLC analysis is illustrated in Table (5). These results revealed that the predominant fatty acids in this wheat genotype control are cis-linoleic acid (45.94), palmitic acid (27.27), and oleic acid (12.02). Also, it can be noticed that total saturated fatty acid was (34.58), while total unsaturated fatty acids were (65.42) in the Sakha-95 grains control. These acids presented an important role in human nutrition as well as in grain quality. The essential fatty acid is one of the most important polyunsaturated fatty acids in human food because of its prevention of cardiovascular heart disease (CHD)., The linoleic fatty acids (belonging to the omega-6) and α-linoleic fatty acids (belonging to the omega-3) are considered essential, as they cannot be synthesized by mammals and must be obtained from food. ω-6 and ω-3 fatty acids are required for the normal growth, health, and development of the body [31]. According to [32], polyunsaturated fatty acids must make up 10% of the total energy ingested for an adequate diet as far as the correct ingestion of lipids is concerned. Furthermore, the omega-3 family of fatty acids may have a positive effect on the treatment of depression and schizophrenia [33].

Table 1. Effect of some growth regulators on yield parameters of Sakha-95 wheat crop

Treatments	Seed yield/plot (kg)	Seed Yield (ton/feddan)	Straw yield (ton/feedan)	Grain/ Straw Ratio	1000 seed weight (g)
Control	8.03	3.06	4.01	0.76	50.60
250 ppm GA3	8.67	3.30	4.89	0.67	54.30
500 ppm GA3	8.60	3.27	4.84	0.68	53.45
250 ppm NAA	8.73	3.32	4.17	0.80	55.05
500 ppm NAA	8.80	3.35	4.20	0.80	53.50
25 ppm 6-BAP	9.03	3.44	4.11	0.84	55.30
50 ppm 6-BAP	9.10	3.46	4.38	0.79	55.75
LSD 0.05	1.634	0.355	0.338	0.613	0.289
LSD 0.01	0.229	0.052	0.427	0.219	0.113

Table 2. Effect of some growth regulators on carbohydrate fractions (%) of Sakha-95 wheat grains

Treatments	Soluble sugars			Insoluble sugars	Total carbohydrates	Sol/In sol Ratio
	Reducing sugars	Non reducing sugars	Total soluble sugars			
Control	1.43	1.76	3.19	75.71	78.9	0.042
250 ppm GA3	1.27	2.27	3.54	79.96	83.5	0.044
500 ppm GA3	1.29	2.31	3.60	77.9	81.5	0.046
250 ppm NAA	1.15	2.05	3.20	76.8	80	0.41
500 ppm NAA	1.23	2.02	3.25	80.25	83.5	0.40
25 ppm 6-BAP	1.31	2.18	3.49	77.91	81.4	0.044
50 ppm 6-BAP	1.28	2.38	3.66	77.94	81.6	0.049

Table 3. Effect of some plant growth regulators on Starch, Fibers and Ash (%, DW) of Sakha-95 wheat grains

Treatments	Amylopectin (%, DW)	Amylose (%, DW)	Total starch (%, DW)	Total fibers (%, DW)	Ash (%, DW)
Control	66.75	10.35	77.1	2.90	2.24
250 ppm GA3	68.30	10.90	79.2	2.30	2.21
500 ppm GA3	67.20	10.70	77.9	2.10	2.23
250 ppm NAA	72.10	9.30	81.4	2.80	2.26
500 ppm NAA	71.00	8.10	79.1	2.30	2.27
25 ppm 6-BAP	68.70	10.90	79.6	2.00	2.31
50 ppm 6-BAP	69. 50	11.1	80.6	1.80	2.31

Table 4. Effect of some plant growth regulators on some free sugars (%) of Sakha-95 wheat grains

Treatments	Mono saccharides			Di saccharides			Mono/Di ratio
	Glucose	Fructose	Total	Maltose	Sucrose	Total	
Control	0.063	0.134	0.197	1.43	0.23	1.66	0.119
250 ppm GA3	0.068	0.139	0.207	1.56	0.29	1.85	0.112
500 ppm GA3	0.072	0.143	0.215	1.34	0.17	1.51	0.142
250 ppm NAA	0.054	0.149	0.203	1.19	0.26	1.45	0.140
500 ppm NAA	0.059	0.147	0.206	1.39	0.19	1.58	0.130
25 ppm 6-BAP	0.061	0.151	0.212	1.28	0.20	1.48	0.143
50 ppm 6-BAP	0.058	0.143	0.201	1.46	0.28	1.74	0.116

Table 5. Effect of some PGRs on lipids content and fatty acid composition of wheat Sakha-95 grains

Fatty acid	Treatments						
	Control	GA3		NAA		6-BAP	
		250ppm	500ppm	250ppm	500ppm	25ppm	50ppm
C14 myristic	0.67	0.58	0.54	0.43	0.21	0.62	0.59
C15 pentadecanoic	3.72	3.49	3.46	3.70	3.90	3.81	3.76
C16 palmitic	27.27	26.85	27.60	27.61	27.31	29.69	29.18
C16:1 palmitoleic	0.32	0.32	0.35	0.38	0.41	0.30	0.37
C18:1n-9t eliadic	1.05	1.15	1.09	1.19	1.21	1.01	1.09
C18:1n-9c cis oleic	12.02	12.56	12.36	12.80	12.66	12.65	12.43
C18:2n-6t trans linoleic	1.20	1.07	1.03	0.99	1.13	0.89	0.87
C18:2n-6c cis linoleic	45.94	46.36	45.48	45.19	45.36	43.49	43.74
C18:3n-3 linolenic	4.89	5.21	5.33	4.90	4.82	5.13	5.09
C21 heneicosylic	2.92	2.41	2.76	2.81	2.99	2.41	2.88
Total saturated	34.58	33.33	34.36	34.55	34.41	36.53	36.41
Total unsaturated	65.42	66.67	65.64	65.45	65.59	63.47	63.59
∑MUFA	13.39	14.03	13.8	14.37	14.28	13.96	13.89
∑PUFA	52.03	52.64	51.84	51.08	51.31	49.51	49.7
n6 / n3	9.39	8.90	8.53	9.22	9.41	8.48	8.59
Pufa /sf	1.50	1.58	1.51	1.48	1.49	1.36	1.37
Sfa /pufa	0.66	0.63	0.66	0.68	0.67	0.74	0.73
oleic/linoleic	0.26	0.27	0.27	0.28	0.28	0.29	0.28
S/U	0.53	0.50	0.52	0.53	0.52	0.58	0.57
Saturated fatty acid (%, DW)	0.83	0.7	0.67	0.66	0.64	0.8	0.75
Unsaturated fatty acid (%, DW)	1.57	1.4	1.28	1.25	1.22	1.39	1.31
Total Fatty acid (%, DW)	2.4	2.1	1.95	1.91	1.86	2.19	2.06
Total Fats (%, DW)	2.56	2.63	2.66	2.51	2.55	2.72	2.76

Table 6. Effect of some plant growth regulators on some elements (mg/100 g) of Sakha -95 wheat grains

Treatments	Ca	Mg	P	K	Na	Fe	Cu	Mn	Se
Control	36.12	228	826	839	18	8.24	0.76	12.45	75.69
250 ppm GA3	50.03	236	893	917	16	9.27	0.89	15.8	89.20
500 ppm GA3	52.12	234	889	914	14	9.24	0.84	15.26	85.19
250 ppm NAA	48.06	249	920	900	22	8.64	0.89	14.20	86.90
500 ppm NAA	45.98	245	917	895	20	8.56	0.87	13.42	84.23
25 ppm 6-BAP	43.23	240	879	906	14	7.20	0.87	13.10	80.00
50 ppm 6-BAP	42.65	238	876	904	15	6.98	0.76	12.95	79.48

The consumption of 18:2n-6 (linoleic acid) is commonly thought to be capable of reducing LDL and total cholesterol. Application of GA_3, NAA, and 6-PAB at used doses had a slight effect on fatty acids composition, where Plant growth regulator 6-BAP (6- benzyl amino purine) at concentrations 25 and 50ppm improved fat content (2.72 and 2.76) as compared to with control (2.56). GA_3 (250 and 500ppm) foliar application gave a higher content of Omega-3 than other treatments (5.21 and 5.33 respectively). The presence of this polyunsaturated fatty acid in the germ oil is expected to impart semi-drying properties and can be used in surface coating industries. [1] found that PGRs were improved to be most effective and possessed the momentous potentiality to increase plant growth and yield of the wheat crop. Some differences were noticed between these results and those obtained by [33] when stated the effect of NAA on the lipid content of wheat grain. The results showed that these by-products could be used as a source of bioactive compounds beneficial for health.

3.6. The effect of some growth regulators on some minerals content of Sakha-95 wheat grains

Data in Table (6) showed the percentage of Ca, Mg, P, K, Na, Fe, Cu, Mn, and Se in wheat grains. P and Na were decreased by all treatments on the other hand K, Ca, and Mg nutrients were increased by all treatments. The highest increase was recorded by the application of NAA treatments compared with other treatments and control. These results are in agreement with [34] who found that the application of GA_3 increased some nutrients (N, P, and K) uptake as compared with control. From the same table, the percentage of microelements (g/100g) in wheat grains recorded that, the percentage of Fe, Cu, Mn, and Se were increased by all treatments of Sakh-95 wheat grains except the foliar application of 25ppm 6-BAP caused a slight decrease of Fe. The highest decrease was obtained by GA_3 treatment. These results were in agreement with those reported by [35] who stated that PGRs improved the nutrient uptake in wheat grains which led to better yield and quality with GA_3.

4. Conclusion

Plant regulators affect physiological and biochemical processes in plants. The obtained results of wheat grains analysis confirmed varied improvements in yield quantity and quality. In general, applied 50ppm 6-BAP increased grain yield, while applied GA_3 gave a heist percentage of straw yield with 250ppm. NAA with 250ppm decreased reducing sugars more than other treatments, but all treatments increased non-reducing sugars. All treatments increased the percentage of total carbohydrates of wheat grains, but these treatments decreased starch content and therefore decreased amylopectin, as well as amylose content. The rate of disaccharides (maltose and sucrose) increased by 250ppm GA_3 and 50ppm 6-BAP applications. Where all treatments decreased the content of mono-saccharides, all treatments caused a slight decrease of saturated and unsaturated fatty acids. The total fats of wheat grains were increased by GA_3 and 6-BAP applications but NAA treatments caused a slight decrease in total fats. Applied PGRs increased protein grain contents, as well as protein fractions. The percentage of P, K, and Na were decreased by PGRs, but Ca and Mg content was increased as well as microelements (Fe, Cu, Mn, and Se).

Supplementary Data

The datasets used and/or analyzed in this study are available from the corresponding author upon reasonable request.

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Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest**.**

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Author contribution

AE designed the study, performed the numerical analysis, revised the original manuscript, provided experimental data used in validating the model, and prepared the manuscript. also, this manuscript was reviewed by these researchers (AA, AA, GE, RS), some components were analyzed, and it was designed.

Declarations

Ethics approval and consent to participate

This study did not involve human participants, human data, or human tissue.

Consent for publication

The manuscript is approved by the author for publication.

Competing interests

The authors declare no competing interests.

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