academicJournals

Vol. 12(23), pp. 3653-3661, 5 June, 2013
DOI: 10.5897/AJB2012.2925
ISSN 1684-5315 ©2013 Academic Journals
http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Response of barley plants to foliar application of growth regulators mixture of indole acetic acid, naphthalene acetic acid and zinc

Mona, E. Eleiwa[1]*, Maymona, A. Kord[*] and S. A. Ibrahim[2]

[1]Department of Botany, Faculty of Science, Cairo University, Egypt.
[2]Department of Plant Nutrition, National Research Center, Giza, Egypt.

Accepted 29 March, 2013

This study was conducted to show the effect of foliar application with a growth mixture containing indole acetic acid (IAA) and naphthalene acetic acid (NAA) at the levels of 0 + 0, 50 + 25, 100 + 50 and 150 + 75 ppm, respectively, and/or zinc concentration of 0, 50, 100, and 150 ppm sprayed three times after 20, 40 and 60 days of sowing, on growth, yield as well as some physiological and chemical composition parameters of barley plants. A complete randomized block design experiment in factorial arrangement with four replicates was carried out at the farm of the National Research Centre, Shalakan, Kalubia, Egypt, during two successive seasons. The obtained results revealed that either foliar spraying by the growth regulators mixture or Zinc concentrations had a significant promotive effect on the studied growth and yield as well as the physiological and chemical parameters of barley when compared with the control treatment. While the highest values of the previous parameters were attained by using the concentration of 150 ppm zinc, followed by 100 and 50 ppm in decreasing order. The rate of promotion was increased by increasing the concentration of growth regulators. The highest levels of all studied parameter were detected by spraying 150 ppm IAA + 75 ppm NAA. It is worthy to note that the interaction among adapted levels of growth promoter's mixture and zinc provided significant increases in most traits examined in this investigation. The most effective treatment was spraying 150 ppm IAA+ 75 ppm NAA combined with 150 ppm zinc.

Key words: Foliar application, chemical properties, barley, growth parameters, photosynthetic pigments.

INTRODUCTION

Barley (*Hordeum vulgar* L.) is considered as one of the most important cereal crops in the world. It is used for many purposes such as malting and brewing, animal feeding, bread making and by mixing with wheat flour in some places; it is used in human foods and beverages, and has many other uses. Barley occupies the fifth position among cereal crops, in terms of production and area (Media Ministry, Egypt, 1996), and is more tolerant to salinity stress than many other field crops and could be grown for the reclamation of sandy and salty soils.

Angela and Gray (2011) showed that plant growth and development require the integration of a variety of environmental and endogenous signals that together with the intrinsic genetic program, determine plant form. Central to this process are several growth regulators known as phytohormones. The uses make it worthy enough to study the effect of some physiological factors, as the use of growth substances such as indole acetic acid (IAA) and naphthalene acetic acid (NAA) at different concentrations that may increase barley plant production. It is quite clear that endogenous and exogenous plant growth regulators play an important role in modifying and regulating many

*Corresponding author. E-mail: sala201018@gmail.com.

physiological processes in plants and these processes are greatly influenced by environmental conditions. Baz et al. (1984) indicated that soybean plants treated with foliar spray of 50, 100 or 150 ppm IAA at 45, 70 and 110 days after sowing showed pronounced increase in their vegetative growth, total nitrogen, reducing sugars, oil percentage and nitrogen contents of dried seeds. Similarly, Govindan et al., (2000) indicated that soybean plants sprayed with NAA at 40 ppm after 35 days of sowing had significant increases in growth characters, yield and its attributes including number of pods and seeds, plant, seeds/pod and 100 seed weight. Senthil et al., (2003) investigated the effects of NAA at 40 ppm and IAA at 100 ppm supplied as foliar spray at 35 and 60 days after sowing on some biochemical and physiological aspects including total chlorophyll and soluble protein of soybean plant. They reported that all treatments increased the biochemical parameters of soybean and IAA treat-ment had the highest effects on the plant.

Among various factors contributing to plant growth, nutrient availability plays a vital role. Thus, micronutrients are an important factor along with macronutrients fertilization to fulfil the optimum nutritional plant requirements. Foliar spraying of different nutrients make them readily absorbed by plant leaves and are not lost through fixation, decomposition and leaching. The positive effect of spraying zinc on growth and yield of different crops has been reported by several investigators. Thalooth et al., (2005 and 2006), El-Tohamy and El-Greadly, (2007) and El-Desouky et al., (2009) stated that significant increases were produced in many growth aspects such as stem length and diameter, number of branches and leaves/ plant, fresh and dry weight of both stems and leaves, total leaf area/plant of sunflower, mung bean, snap beans, and tomato plants when these plants were sprayed with different concentrations of zinc sulphate as compared with un sprayed ones.

Mir et al. (2010) have made a study to cover the aspects of interaction of phytohormones and nutrients on growth and development of crop plants which cause positive responses including plant height, leaf area, leaf area index, dry weight, plant growth rate, relative growth rate, crop growth rate, net assimilation rate, carbondioxide exchange rate, chlorophyll content, photosynthesis, nitrate reductase activity, nutrient accumulation, seed yield, biological yield, harvest index and oil yield.

The main objective of the present study was to investigate the influence of foliar spray with IAA + NAA as a mixture and Zn on barley plants growth, yield and its components as well as some biochemical and physiological parameters.

MATERIALS AND METHODS

A field experiment was conducted at the farm of the National Research Centre Shalakan, Kalubia Governorate, Egypt during two successive seasons. The used experimental soil is sandy loam with low content of both organic matter and available NPK indicating poor fertility.

Barley (Giza 125 cultivar) was sown by 50 kg/feddan of commercial seeds. Plot was 10.5 m^2 (3 x 3.5m). Calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48.5% K_2O) were broad casted before sowing at 200 and 100 kg/feed, respectively. Ammonium sulphate (20.5% N) at 200 kg/fed was applied in two equal portions; the first, 21 days after sowing and the second two weeks later. Other practices were applied as the recommended methods in Egypt.

Growth regulators (GR) and zinc sulphate (Zn) were sprayed three times at 20, 40 and 60 days after sowing. Tween 20 at the concentration of 5% was used as a wetting agent for all treatments, IAA and NAA were sprayed as a mixture at the rates 0 + 0; 50 + 25; 100 +5 0 and 150 + 75 ppm, respectively, while zinc was applied at the rates of 0, 50, 100 and 150 ppm in combination with the growth regulators. Control plants were sprayed with water. The experimental design used was a complete randomized block in factorial arrangement with four applications. The data recorded is described below.

Growth parameters and photosynthetic pigments

Random samples of five plants from the second row of each plot were taken at 90 days after sowing. The following traits were determined: Plant height (cm), spike length (cm), tillers number/ plant, leaf number/plant and leaf area/plant (cm^2). Chlorophyll a, b and carotenoids were determined in fresh leaves (mg/g) as described by the methods of Witham et al. (1971) and AOAC, (2000).

Yield and its components

At harvest time, the following parameters were determined: Number of spikes/plant, weight of 1000 seeds (g), grain yield (ton/fed), straw yield (ton/fed) and biological yield (ton/fed).

Chemical components

Chemical constitutes (crude protein, reduced sugars, non reducing sugars, total sugar and total carbohydrates (%)) as well as macro (N, P and K) and micronutrients (Fe, Mn, Zn and Cu) in grains were evaluated using standard methods of Cottenie et al. (1982) and AOAC (2000).

Statistical analysis

The obtained data were analyzed statistically by using SPSS version 15 package software. Two way analysis of variance (ANOVA) was applied to illustrate the effect of either growth regulators concentrations or zinc and their interactions under the different studied parameters. Duncan's test was used to estimate the similarity among the different experimental groups.

RESULTS AND DISCUSSION

Growth parameters and photosynthetic pigments of barley

According to analysis of variance, spraying with either growth regulator mixture containing IAA + NAA (50 + 25; 100 + 50 and 150 + 75 ppm) or with Zn sulphate (0, 50, 100 and 150ppm) had a significant effect on growth parameters (plant height, number of tillers, leaves per plant and

Table 1. Soil mechanical and chemical properties according to Ryan et al. (1996).

Mechanical and chemical analysis (%)		Soluble cations and anions 1:5 soil water extract (meq/L)		Available micro nutrients DTPA extraction (ppm)	
Sand	74.62	Na^+	2.0	Fe	2.32
Silt	17.77	K^+	0.2	Mn	3.20
Clay	7.61	Ca^{++}	2.60	Zn	0.60
pH	8.5	Mg^{++}	-	Cu	0.29
Organic matter	0.33	Cl^-	0.09	Cobalt	0.007
$CaCO_3$	5.08	CO^{--}_3	-	$NaHCO_3$	0.007
E.c.m.	0.26	HCO^-_3	1.34		

area of leaf per plant) as well as on the photosynthetic pigments (Chl a, Chl b, Chl a + b and carotenoids) in comparison with controls.

On the other hand, spraying with both growth regulators and zinc together promoted a significant increase in the levels of the growth parameters tested and photosynthetic pigments in comparison with the controls, except for length of spike, number of tillers per plant and carotenoids that were not significantly affected. The most significant elevation of all growth parameters and photosynthetic pigments was observed at 150 IAA + 75 NAA with 150 ppm Zn. It is evident that the rate of promotion was increased with increasing levels of growth regulators mixture as indicated in Table 1.

The data obtained in this study concerning growth parameters are in good agreement with these obtained by Baz et al. (1984), Velu (1999), Govindan et al., (2000) and Abdo and Abdel-Aziz, (2009) who stated that plant treated with foliar spray 50, 100 or 150 ppm IAA showed pronounced increase in their vegetative growth, leaf area and dry matter. They added that plants sprayed with NAA at 40 ppm had significant increases in growth characters. Moreover, they stated that 150 + 60 ppm (IAA + NAA) gave the highest values of the growth parameters. While, the results of photosynthetic pigments were consistent with those obtained by Kalarani and Jeyakumar, (1998) who used NAA and Senthil et al., (2003) who used 100 ppm IAA or 40 ppm NAA.

Data in Table 2 show the effect of spraying with Zn-sulphate (0, 50, 100, 150 and 200 ppm) on vegetative growth parameters (plant height, spike length, tillers and leaves numbers per plant and leaf area) as well as on photosynthetic pigments (chl. a, b, a+b and carotenoids) of barley plants.

The results showed that all the above parameters were significantly increased by increasing Zn concentration as compared with controls. Such enhancing effect might be attributed to the favorable influence of Zn on metabolism and biological activity and to the stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of plants (Michail et al., 2004). Also, the beneficial effect of Zn may be due to its enhancement of cell division and differentiation which induce the viability and repeatability of the reproductive organs (Domingo et al., 1990). Moreover, it was reported that zinc enhances translocation of bio assimilates and nutrients within plant tissues as an activator of membrane transporter enzymes (Cakmak and Marschner, 1988). The obtained results were in agreement with those reported by Thalooth et al. (2005, 2006), Mahmoud et al. (2008), El-Desauky et al. (2009) and Hanafy et al. (2008). In addition, it was reported that foliar application of zinc improved growth and productivity of sweet pepper (Hanafy et al., 2008), as well as chlorophyll content (a, b and a+b) and carotenoids of mung bean and sun flower (Ved et al., 2002; Tholooth et al., 2005; Hanafy et al., 2008).

Yield and its components in barley

Table 3 shows that grain yield, straw yield, biological yield, number of kernels/spikes, weight of 1000 grains and number of spike/plant were significantly elevated after spraying with either the growth regulator mixture containing IAA + NAA (50 + 25; 100 + 50 and 150 + 75 ppm) or with Zn sulphate (0, 50, 100 and 150 ppm) in comparison with the controls.

However, yield and its components except for weight of 1000 grains and number of spikes/plant were significantly increased following spraying with both growth regulators and Zn sulphate together. The highest values of yield and its components were observed at 150 IAA + 75 NAA with 150 ppm Zn. The concentration of 150 ppm Zn was observed to increase the yield and its components at each concentration of growth regulator in comparison with the controls.

These results are in harmony with those reported by Shukla et al. (1997) using 10 or 20 ppm NAA. Govindan et al., (2000) sprayed soybean plants with NAA at 40 ppm and reported significant increases in yield and its attributes including number of pods and seeds/plant, seeds/pod and 100 seed weight and Kalpana and Krisharajan (2003) confirmed these findings using 40 ppm NAA.

Table 2. Effect of foliar spray with IAA + NAA as mixture and Zn on growth parameters and photosynthetic pigments of barley plants.

IAA + NAA (ppm)	Zn conc. (ppm)	Growth parameter					Photosynthetic pigments(mg/g leaves)			
		Plant height (cm)	Spike length (cm)	Tillers number/plant	Leaves number/plant	Leaf area (cm^2)	Chl. a	Chl. b	Chl. a+b	Carotenoid
0	0	77.70±0.61[a]	7.90±0.06[a]	4.61±0.10[a]	21.40±0.06[a]	14.66±0.02[a]	0.95±0.01[a]	0.44±0.01[a]	1.39±0.01[a]	0.55±0.01[a]
	50	84.11±0.89[b]	8.11±0.06[a]	4.85±0.06[ab]	21.70±0.06[b]	15.34±0.01[b]	1.60±0.02[d]	0.66±0.01[e]	2.26±0.01[e]	1.44±0.01[e]
	100	94.41±0.5[ef]	9.38±0.28[bc]	5.10±0.10[bc]	22.10±0.06[c]	15.90±0.06[c]	1.76±0.01[g]	0.79±0.02[h]	2.55±0.03[h]	1.53±0.01[g]
	150	100.11±0.61[g]	8.70±0.12[ab]	5.29±0.07[cd]	22.50±0.06[d]	16.01±0.01[c]	1.80±0.01[h]	0.84±0.01[i]	2.64±0.01[j]	1.70±0.01[j]
50+25	0	80.60±0.53[a]	8.73±0.07[ab]	5.11±0.06[bc]	22.70±0.06[e]	16.40±0.06[d]	0.99±0.01[b]	0.47±0.02[b]	1.44±0.01[b]	0.60±0.01[b]
	50	90.00±0.58[cd]	9.90±0.20[cd]	5.43±0.10[d]	23.10±0.06[f]	16.93±0.01[e]	1.64±0.02[e]	0.70±0.01[f]	2.34±0.01[f]	1.50±0.01[f]
	100	103.54±2.86[h]	10.11±0.55[cde]	5.82±0.06[e]	23.40±0.06[g]	17.04±0.01[e]	1.80±0.01[h]	0.80±0.01[h]	2.60±0.03[i]	1.58±0.01[h]
	150	105.11±0.64[h]	10.93±0.04[ef]	6.12±0.07[f]	23.90±0.06[i]	17.65±0.03[f]	1.90±0.01[ij]	0.86±0.01[i]	2.76±0.01[l]	1.74±0.01[k]
100+50	0	84.26±1.13[b]	9.60±0.12[bc]	5.80±0.10[e]	22.93±0.07[f]	18.64±0.01[g]	1.01±0.01[b]	0.50±0.01[c]	1.51±0.01[c]	0.64±0.01[c]
	50	92.33±1.11[de]	10.80±0.10[def]	6.04±0.02[ef]	23.70±0.07[h]	19.12±0.07[h]	1.71±0.01[f]	0.75±0.01[g]	2.46±0.01[g]	1.54±0.01[g]
	100	102.94±1.05[gh]	11.00±0.58[ef]	6.61±0.15[g]	24.10±0.06[j]	19.32±0.06[h]	1.88±0.01[i]	0.84±0.01[i]	2.72±0.01[k]	1.61±0.01[i]
	150	110.30±0.51[i]	11.70±0.15[fg]	6.70±0.10[g]	24.50±0.06[k]	19.67±0.11[i]	1.95±0.02[k]	0.91±0.01[j]	2.86±0.01[n]	1.78±0.01[l]
150+75	0	88.33±0.58[c]	10.33±0.34[cde]	6.80±0.06[g]	24.70±0.06[l]	20.00±0.29[j]	1.11±0.01[c]	0.55±0.01[d]	1.66±0.01[d]	0.68±0.01[d]
	50	96.40±0.50[f]	11.44±0.50[fg]	7.20±0.15[h]	25.10±0.06[m]	21.50±0.10[k]	1.78±0.01[gh]	0.81±0.01[h]	2.59±0.01[i]	1.60±0.01[hi]
	100	111.61±0.72[i]	11.62±0.27[fg]	7.70±0.10[i]	25.77±0.03[n]	21.81±0.06[l]	1.92±0.02[j]	0.90±0.01[j]	2.82±0.01[m]	1.68±0.01[j]
	150	115.30±0.58[j]	12.11±0.55[g]	7.91±0.05[i]	26.77±0.09[o]	22.54±0.06[m]	2.01±0.01[l]	1.11±0.01[k]	3.12±0.01[o]	1.81±0.01[m]
ANOVA		$F_{3.32}$=129.50	$F_{3.32}$=62.67	$F_{3.32}$=516.27	$F_{3.32}$=2589.77	$F_{3.32}$=3367.86	$F_{3.32}$=225.16	$F_{3.32}$=290.59	$F_{3.32}$=487.71	$F_{3.32}$=232.01
(IAA+NAA effect)		P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00
ANOVA		$F_{3.32}$=512.23	$F_{3.32}$=22.79	$F_{3.32}$=83.10	$F_{3.32}$=451.99	$F_{3.32}$=208.08	$F_{3.32}$=6566.46	$F_{3.32}$=2121.03	$F_{3.32}$=8192.10	$F_{3.32}$=17898.84
(Zn-effect)		P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00
ANOVA		$F_{9.32}$=2.52	$F_{9.32}$=1.23	$F_{9.32}$=1.13	$F_{9.32}$=13.84	$F_{9.32}$=11.85	$F_{9.32}$=3.49	$F_{9.32}$=21.81	$F_{9.32}$=10.79	$F_{9.32}$=1.55
(Interaction)		P <0.05	P >0.05	P >0.05	P <0.00	P <0.00	P <0.01	P <0.00	P <0.00	P >0.05

In the same column, values marked with the same letters are similar (P<0.05), whereas those with different letters are significantly different.

In this respect, Ammanullah et al. (2010) added that plant growth substances are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates to sink thereby helping in effective flower formation, fruit and seed development and ultimately enhancing the productivity of crops, while improving wheat grain yield and it's quality by using different organic sources of some growth regulations. Soil or foliar applications could overcome the salinity condition of soil as discussed by Zaki and Radwan (2011). Also, Tiwari et al. (2011) showed that various plant growth hormones could significantly increase grain yield of barley plants.

Concerning the effect of zinc, results in Table 3 reveal that all concentrations of zinc examined (50, 100 and 150 ppm) induced a growth promotive effect on all the investigated yield traits. The increases in yield and yield components of barley plants may be due to the superior effect of Zn on the biosynthesis of tryptophan that is well known

Table 3. Effect of foliar spray with IAA+NAA as mixture and Zn on yield and its components in barley plants.

IAA + NAA (ppm)	Zn conc. (ppm)	Number of kernels/spike	Weight of 1000 grain (g)	Spikes number/plant	Grain yield (ton/fed)	Straw yield (ton/fed)	Biological yield (ton/fed)
0	0	44.31±0.06^{a}	19.70±0.21^{a}	2.60±0.21^{a}	1.81±0.01^{a}	0.71±0.01^{a}	2.52±0.01^{a}
	50	45.01±0.01^{b}	24.30±0.10^{d}	3.80±0.21^{c}	1.89±0.01^{b}	0.76±0.01^{b}	2.65±0.01^{b}
	100	45.50±0.06^{c}	30.30±0.12^{g}	4.40±0.21^{de}	1.97±0.01^{c}	0.81±0.01^{c}	2.78±0.01^{c}
	150	45.98±0.01^{d}	38.60±0.30^{k}	4.90±0.20^{ef}	2.03±0.04^{d}	0.85±0.01^{d}	2.88±0.03^{d}
50+25	0	45.11±0.06^{b}	20.80±0.20^{b}	2.84±0.02^{ab}	1.89±0.01^{b}	0.81±0.01^{c}	2.70±0.01^{b}
	50	46.12±0.05^{e}	25.57±0.24^{e}	4.06±0.03^{cd}	1.99±0.01^{cd}	0.89±0.01^{e}	2.87±0.01^{d}
	100	46.81±0.01^{f}	31.70±0.21^{h}	4.80±0.31^{ef}	2.12±0.01^{e}	0.92±0.01^{f}	3.04±0.01^{e}
	150	47.06±0.01^{g}	39.50±0.21^{l}	5.07±0.12^{f}	2.36±0.02^{g}	0.96±0.00^{g}	3.32±0.02^{h}
100+50	0	47.94±0.01^{h}	21.90±0.20^{c}	3.17±0.07^{b}	1.98±0.01^{c}	0.90±0.01^{e}	2.88±0.01^{d}
	50	48.45±0.01^{i}	26.83±0.17^{f}	4.40±0.26^{de}	2.15±0.04^{e}	0.96±0.01^{g}	3.11±0.05^{f}
	100	49.06±0.01^{j}	33.10±0.10^{i}	5.10±0.06^{f}	2.39±0.01^{g}	0.98±0.01^{h}	3.37±0.02^{h}
	150	49.81±0.01^{k}	40.30±0.10^{m}	5.63±0.20^{g}	2.43±0.01^{h}	1.12±0.01^{i}	3.55±0.02^{j}
150+75	0	50.10±0.06^{l}	25.00±0.50^{de}	3.90±0.10^{cd}	2.29±0.01^{f}	0.94±0.01^{g}	3.24±0.03^{g}
	50	52.90±0.06^{m}	30.00±0.50^{f}	4.90±0.21^{ef}	2.44±0.01^{h}	0.99±0.01^{h}	3.43±0.00^{i}
	100	55.01±0.01^{n}	36.90±0.20^{j}	5.80±0.20^{g}	2.52±0.00^{i}	1.14±0.01^{i}	3.66±0.01^{k}
	150	56.85±0.01^{o}	43.70±0.25^{n}	6.03±0.09^{g}	2.70±0.01^{j}	1.29±0.02^{j}	3.99±0.02^{l}
ANOVA (IAA+NAA effect)		$F_{3,32}$=43890.44 P <0.00	$F_{3,32}$=371.28 P <0.00	$F_{3,32}$=36.78 P <0.00	$F_{3,32}$=888.55 P <0.00	$F_{3,32}$=1258.03 P <0.00	$F_{3,32}$=1370.42 P <0.00
ANOVA (Zn-effect)		$F_{3,32}$=5293.25 P <0.00	$F_{3,32}$=4055.01 P <0.00	$F_{3,32}$=129.42 P <0.00	$F_{3,32}$=439.42 P <0.00	$F_{3,32}$=605.83 P <0.00	$F_{3,32}$=664.45 P <0.00
ANOVA (Interaction)		$F_{9,32}$=863.83 P <0.00	$F_{9,32}$=1.428 P >0.05	$F_{9,32}$=0.22 P >0.05	$F_{9,32}$=16.85 P <0.00	$F_{9,32}$=45.00 P <0.00	$F_{9,32}$=15.32 P <0.00

In the same column, values marked with the same letters are similar (P<0.05), whereas those with different letters are significantly different.

to be the precursor of IAA which act as growth promoter in plant (Abd-El Kader et al., 2008).

Similar results were reported by Kassab (2005), Thalooth et al. (2005), Thalooth et al. (2006) and Mahmoud et al. (2008).

Chemical constituents and nutrients concentration in barely

The results presented in Tables 4 and 5 show that all the sprayed concentrations of IAA + NAA (50 + 25; 100 + 50 and 150 + 75 ppm) significantly increased all the chemical constituents under study: reducing sugars (%), non reducing sugars (%), total sugar (%), total carbohydrate (%) and crude protein (%) as well as nutrient concentration (N, P, K,

Table 4. Effect of foliar spray with IAA + NAA as mixture and Zn on some chemical constituents of barley grains.

IAA + NAA (ppm)	Zn concentration (ppm)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)	Total carbohydrates (%)	Crude protein (%)
0	0	0.81 ± 0.01^{a}	0.82 ± 0.01^{a}	1.52 ± 0.02^{a}	45.11 ± 0.51^{a}	8.31 ± 0.01^{a}
	50	0.90 ± 0.01^{b}	1.20 ± 0.06^{c}	1.71 ± 0.01^{abc}	52.11 ± 0.64^{d}	8.50 ± 0.06^{a}
	100	1.00 ± 0.01^{c}	1.40 ± 0.03^{de}	1.84 ± 0.06^{bcd}	55.01 ± 0.20^{e}	8.69 ± 0.01^{a}
	150	1.34 ± 0.02^{f}	1.40 ± 0.01^{de}	2.20 ± 0.15^{ef}	58.66 ± 0.38^{fg}	9.44 ± 0.01^{b}
50+25	0	0.90 ± 0.01^{b}	0.92 ± 0.04^{ab}	1.61 ± 0.02^{ab}	46.59 ± 0.58^{ab}	9.50 ± 0.15^{b}
	50	1.00 ± 0.01^{c}	1.30 ± 0.01^{cd}	1.79 ± 0.02^{bcd}	54.78 ± 0.53^{e}	9.95 ± 0.02^{bc}
	100	1.10 ± 0.06^{d}	1.40 ± 0.02^{de}	1.96 ± 0.03^{cde}	58.31 ± 0.58^{f}	10.13 ± 0.02^{bc}
	150	1.44 ± 0.06^{g}	1.50 ± 0.01^{ef}	2.50 ± 0.03^{gh}	60.21 ± 0.12^{gh}	10.31 ± 0.01^{c}
100+50	0	1.00 ± 0.01^{c}	0.97 ± 0.02^{b}	1.77 ± 0.02^{abcd}	47.22 ± 0.70^{bc}	11.31 ± 0.06^{d}
	50	1.10 ± 0.06^{d}	1.48 ± 0.01^{ef}	1.82 ± 0.02^{bcd}	58.00 ± 0.19^{f}	12.44 ± 1.01^{ef}
	100	1.26 ± 0.01^{ef}	1.62 ± 0.01^{fg}	2.33 ± 0.12^{fg}	60.21 ± 0.12^{gh}	12.00 ± 0.10^{de}
	150	1.56 ± 0.01^{h}	1.74 ± 0.04^{gh}	2.72 ± 0.08^{hi}	62.33 ± 0.51^{i}	12.44 ± 0.02^{ef}
150+75	0	1.06 ± 0.01^{cd}	1.03 ± 0.01^{b}	1.98 ± 0.01^{de}	48.66 ± 0.60^{c}	13.00 ± 0.10^{fg}
	50	1.20 ± 0.01^{e}	1.40 ± 0.17^{de}	2.10 ± 0.10^{ef}	60.77 ± 0.59^{hi}	13.50 ± 0.06^{g}
	100	1.33 ± 0.02^{f}	1.76 ± 0.02^{gh}	2.95 ± 0.21^{ij}	62.00 ± 0.88^{i}	14.44 ± 0.03^{h}
	150	1.74 ± 0.01^{i}	1.86 ± 0.02^{h}	3.00 ± 0.00^{j}	67.33 ± 0.088^{j}	14.81 ± 0.06^{h}
ANOVA (IAA+NAA effect)		$F_{3.32}$=104.22 P <0.00	$F_{3.32}$=34.68 P <0.00	$F_{3.32}$=54.94 P <0.00	$F_{3.32}$=114.70 P <0.00	$F_{3.32}$=315.34 P <0.00
ANOVA (Zn-effect)		$F_{3.32}$=336.11 P <0.00	$F_{3.32}$=159.04 P <0.00	$F_{3.32}$=100.69 P <0.00	$F_{3.32}$=563.33 P <0.00	$F_{3.32}$=15.42 P <0.00
ANOVA (Interaction)		$F_{9.32}$=1.41 P >0.05	$F_{9.32}$=2.22 P <0.05	$F_{9.32}$=3.90 P <0.01	$F_{9.32}$=4.99 P <0.00	$F_{9.32}$=1.58 P >0.05

In the same column, values marked with the same letters are similar (P<0.05), whereas those with different letters are significantly different.

Fe, Mn, Zn and Cu) in barley grains as compared with untreated control plant. The rate of enhancement of all the previous parameters was increased by increasing the growth regulators concentration. In this respect, the increment in seed protein reported by Senthil et al., (2003) was in harmony with the present findings. The author investigated the effect of NAA at 40 ppm and IAA at 100 ppm supplied as foliar spray on some biochemical and physiological aspects including total chlorophyll and soluble protein contents. They reported that all treatments increased the biochemical parameters of soybean and IAA treatment had the highest effects. Moreover, Abd El-Kader et al. (2008) concluded that NAA treatments at 40 and 50 ppm were significantly superior to the other treatments in increasing total soluble solids (T.S.S), total sugar and reducing sugar (%) of Zaghloul date palm.

Table 5. Effect of foliar spray with IAA + NAA as mixture and Zn on concentrations of macro and micronutrients of barley grains.

IAA + NAA (ppm)	Zn Conc. (ppm)	Macronutrients (%)			Micronutrients (ppm)			
		N	P	K	Fe	Mn	Zn	Cu
0	0	1.33 ± 0.006^{a}	0.30 ± 0.01^{a}	0.42 ± 0.006^{a}	73.00 ± 1.00^{a}	35.00 ± 1.00^{a}	15.00 ± 0.58^{a}	10.00 ± 0.58^{a}
	50	1.36 ± 0.006^{ab}	0.31 ± 0.01^{a}	0.49 ± 0.015^{b}	134.00 ± 1.00^{e}	45.00 ± 0.58^{c}	25.00 ± 0.58^{c}	18.00 ± 0.58^{c}
	100	1.39 ± 0.006^{b}	0.38 ± 0.015^{bc}	0.63 ± 0.003^{c}	160.00 ± 1.00^{h}	52.00 ± 1.00^{e}	30.00 ± 0.58^{d}	20.00 ± 0.58^{cd}
	150	1.51 ± 0.01^{c}	0.41 ± 0.01^{cd}	0.63 ± 0.01^{c}	173.00 ± 0.58^{j}	60.00 ± 0.58^{f}	38.00 ± 0.58^{f}	25.00 ± 1.00^{f}
50+25	0	1.52 ± 0.02^{c}	0.37 ± 0.01^{b}	0.63 ± 0.01^{c}	95.00 ± 0.58^{b}	40.00 ± 0.58^{b}	23.00 ± 0.00^{b}	14.00 ± 0.58^{b}
	50	1.59 ± 0.01^{d}	0.40 ± 0.01^{bc}	0.65 ± 0.015^{cd}	145.00 ± 1.00^{f}	49.33 ± 1.20^{d}	30.00 ± 0.58^{d}	20.00 ± 0.58^{cd}
	100	1.62 ± 0.01^{e}	0.42 ± 0.01^{de}	0.66 ± 0.006^{cd}	175.00 ± 0.58^{j}	58.00 ± 1.00^{f}	39.00 ± 1.20^{f}	24.00 ± 1.00^{ef}
	150	1.67 ± 0.006^{f}	0.43 ± 0.01^{de}	0.67 ± 0.01^{d}	184.00 ± 1.53^{l}	66.00 ± 0.58^{h}	44.00 ± 0.58^{h}	28.00 ± 0.58^{g}
100+50	0	1.80 ± 0.057^{g}	0.40 ± 0.006^{bc}	0.67 ± 0.01^{d}	100.00 ± 0.58^{c}	48.00 ± 1.53^{d}	29.33 ± 0.33^{d}	17.00 ± 0.58^{c}
	50	1.83 ± 0.006^{g}	0.46 ± 0.006^{fg}	0.75 ± 0.01^{ef}	150.00 ± 1.00^{g}	54.00 ± 0.58^{e}	38.33 ± 0.67^{f}	23.00 ± 0.58^{e}
	100	1.91 ± 0.01^{h}	0.49 ± 0.01^{gh}	0.78 ± 0.01^{fg}	180.00 ± 0.58^{k}	64.00 ± 1.53^{gh}	43.00 ± 0.58^{gh}	27.00 ± 0.58^{g}
	150	1.99 ± 0.006^{i}	0.50 ± 0.02^{h}	0.79 ± 0.006^{g}	198.00 ± 0.58^{n}	75.00 ± 0.58^{i}	56.00 ± 0.58^{j}	32.00 ± 0.58^{h}
150+75	0	2.08 ± 0.015^{j}	0.45 ± 0.02^{ef}	0.74 ± 0.015^{e}	130.00 ± 0.58^{d}	45.00 ± 0.58^{c}	33.00 ± 0.58^{e}	20.00 ± 0.58^{cd}
	50	2.16 ± 0.006^{k}	0.50 ± 0.003^{h}	0.79 ± 0.015^{g}	164.00 ± 1.53^{i}	63.00 ± 0.58^{g}	42.00 ± 0.58^{g}	27.00 ± 0.58^{g}
	100	2.31 ± 0.01^{l}	0.52 ± 0.01^{h}	0.85 ± 0.006^{h}	187.00 ± 0.58^{m}	76.00 ± 0.58^{i}	50.00 ± 0.58^{i}	32.00 ± 0.58^{h}
	150	2.37 ± 0.006^{m}	0.59 ± 0.006^{i}	0.88 ± 0.008^{i}	202.00 ± 0.58^{o}	84.00 ± 0.58^{j}	60.00 ± 0.58^{k}	36.00 ± 0.58^{i}
ANOVA		$F_{3.32}$=1737.59	$F_{3.32}$=169.01	$F_{3.32}$=492.38	$F_{3.32}$=1120.95	$F_{3.32}$=351.30	$F_{3.32}$=766.57	$F_{3,32}$=193.75
(IAA+NAA effect)		P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00
ANOVA		$F_{3.32}$=103.49	$F_{3.32}$=64.23	$F_{3.32}$=123.36	$F_{3.32}$=7924.32	$F_{3.32}$=815.30	$F_{3.32}$=1140.89	$F_{3,32}$=386.55
(Zn-effect)		P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00	P <0.00
ANOVA		$F_{9.32}$=4.652	$F_{9.32}$=3.08	$F_{9.32}$=13.09	$F_{9.32}$=53.23	$F_{9.32}$=14.63	$F_{9.32}$=8.03	$F_{9,32}$=1.08
(Interaction)		P <0.01	P <0.01	P <0.00	P <0.00	P <0.00	P <0.00	P >0.05

In the same column, values marked with the same letters are similar (P<0.05), whereas those with different letters are significantly different.

Hathout et al. (1993) and El-Bassiouny and Shukry (2001) found that IAA increased the uptake and elements translocation in tomato tissues and cowpea plants, respectively. The increases were enhanced with IAA concentration increase.

Results in Tables 4 and 5 indicate that, all sprayed concentrations of zinc significantly increased the chemical constituents of barley grains while crude protein was significantly increased at 150 ppm Zn only. Concentrations of N, P, K, Fe, Mn, Zn and Cu in barley grains were significantly increased with the foliar application of Zn as compared with the control treatment. In this concern, Devi et al. (1997) stated that Zn application on citrus plants increased leaf content of micronutrients. Also, Hanafy et al. (2008) stated that Zn levels (0.50, 100, 150 and 200 ppm) increased leaf N, P and Zn content at 100 ppm Zn as compared to other Zn levels.

Furthermore, Mohmoud et al. (2008) showed that Zinc sulphate spray significantly affected wheat content of N, P, K, Mg, Fe, Mn, Zn and Cu. They added that the highest values were obtained by Zn sulphate spraying at 100 ppm as com-pared to the control and other treatments (sprayed with 150 and 200 ppm). These results may be due to the role of Zn-sulphate on enhancing the plant growth (Table 2) which in turn increased nutrients content and uptake. Our results were also in agreement with those reported by Mahesh and Sen (2005).

Concerning the effect of Zn on chemical constituents of barley, Devlin and Witham (1986) stated that zinc is an essential component of a number of dehydrogenase, proteinase, peptidase and phosphohydrolases enzyme and it is directly involved in the synthesis of the hormone, IAA and protein. Also, foliar spray with zinc had a clear effect on increasing essential oil percent and other chemical components of soybean and wheat plants (Maghraby, 1997). The obtained results coincide with those obtained by Kassab (2005) and Thalooth et al. (2006).

Data obtained from Tables 4 and 5 indicated that spraying with both growth regulators and Zn sulphate together promotes a significant increase in the levels of chemical, macro- and micro nutrients constituents of grains with respect to controls except for levels of reducing sugars, percent of crude protein and Cu content, all of which were not significantly affected when compared with the control plants.

In this respect, Dhopte and Suradkar (1998) found that treated soybean plants with 20 ppm NAA + 500 ppm zinc increased most of growth traits, yield components and seed yield as compared to untreated plants, being generally in agreement with the present findings. Hala and Wafaa (2001) found that, mixing of different IAA concentrations with manure induced a highly significant increase in the efficiency of cowpea plants which used all nutrients in soil to improve its growth metabolism and yield to overcome stress.

Our results are also in agreement with that of Mir et al. (2010) who indicated that the process of growth and development in addition to plant yield are significantly affected by the phytohormones interaction together with nutrients.

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