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RESPONSE OF WHEAT (*TRITICUM AESTIVUM* L.) AND ASSOCIATED GRASSY WEEDS GROWN IN SALT-AFFECTED SOIL TO EFFECTS OF GRAMINICIDES AND INDOLE ACETIC ACID

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Two field experiments were carried out in two successive seasons to examine the effect of weed management on wheat crop under saline condition and how herbicides can interact with foliar application with indole-3-acetic acid (IAA) to improve weed suppression and enhance crop growth and productivity under salinity stress. Clodinafop-propargyl was the best option to attain acceptable grassy weeds control. Increasing IAA from 0 up to 150 ppm significantly increased number and dry weight of grassy weeds in wheat after 80 days from sowing. Application of IAA at 150 ppm recorded the highest number and dry weight of weeds. Clodinafop-propargyl produced the lowest values of number and dry weight of weeds as well as nutrients uptake by weeds when water spraying was added. While application of IAA at 150 ppm gave the maximum values of flag leaf area, SPAD meter values, number of spike/m^2, spike length, number of spikelets/spike, grains number/spike, grains weight/spike, as well as grain, straw, and total crude protein, phosphorus and potassium percentages when clodinafop-propargyl treatment was applied. It could be concluded that using IAA at 150 ppm resulted in enhancement of growth and productivity of wheat crop when integrated with clodinafop-propargyl treatment under salinity condition.

Key words: Indole-3-acetic acid, salinity, weed control, wheat, yield

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops grown in the world. It is used as a staple food grain for urban and rural societies. Despite the significant increase in production, it is not enough to meet the needs of the consumer, which led to increased reliance on import from foreign markets to fill the food gap and thus, led to the formation of a significant burden on the balance of payments and the exposure of food security of Egypt to many risks. Therefore, increasing the productivity of wheat is one of the main goals of the Egyptian agricultural policy. This can be achieved through horizontal expansion of the cultivation of newly reclaimed land and vertical expansion through the use of best agricultural transactions, including weed-control treatments and growth regulators to overcome the increasing salinity of the soil.

Weeds are the most important problem in causing yield loss of wheat. Weed density, type of the weeds, their persistence and crop-management practices determine the magnitude of yield loss. The reduction of wheat yield due to weed infestation amounted 30.7% (Nisha *et al*. 1999), 31.9% (Tiwari & Parihar 1997) and 61% (Hucl 1998) compared to weed-free control. Weeds may affect wheat production in many ways; wheat yield may

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be reduced significantly when weeds compete with wheat plants for light, water and minerals (Hussein 2002). Weeds, especially *Avena fatua*, may also inhibit wheat growth through release of allelopathic chemicals that are toxic to wheat plants (Ortega *et al*. 2002). In addition, weed seeds contaminating harvesting grains may reduce quality. Weed control is one of the essential cultural practices for raising yield and improving its quality. General weed-control methods are all nonselective and usually applied to a composite weed species or vegetation of inter- and intra-specific variations in richness, morphology, growth habit and responses. Each species may adapt, or not, to any of these methods. Since weeds are widely different in mechanisms by which they encounter hazards they are exposed to, they are different in responses (Qasem 2013). There are various herbicides used for controlling narrow-leaved weeds. Fenoxaprop and clodinafop-propargyl were most effective in controlling *Phalaris minor* and *A. fatua* with maximum mortality of 86.76 and 85.52%, respectively (Ali *et al*. 2004). Moreover, Bhat *et al*. (2006) reported that application of clodinafop at 0.06 kg/ha effectively controlled *P. minor* and resulted in significant improvement in grain yield (14.4%) compared to unweeded check. Also, Shehzad *et al*. (2012) showed that clodinafop-propargyl increased wheat grains per spike, 1000-grain weight, straw yield and grain yield up to 92, 80, 107 and 59%, respectively, compared to control.

Salinity is one of the major environmental factors limiting plant growth and productivity. Soil or water salinity is known to cause considerable yield losses in most crops, thereby leading to reduced crop productivity (Cha-um *et al*. 2011). The salinity-induced crop yield reduction takes place due to a number of physiological and biochemical dysfunctions in plants grown under salinity stress, which have been listed in a number of comprehensive reviews on salinity effects and tolerance in plants (Ashraf *et al*. 2008). Other researchers reported that salinity causes a progressive decline in the level of indole-3-acetic acid (IAA) and cytokinins (Sakhabutdinova *et al*. 2003). Of the various plant growth regulators, IAA plays a vital role in maintaining plant growth under stress conditions including salt stress (Kaya *et al*. 2013). Abdoli *et al*. (2013) reported that the application of IAA significantly increased 1000-grain weight, number of grains/spike and spike grain yield. Foliar spraying with growth regulators (IAA and GA_3) showed significant effect on plant, to the extent of reducing the hurt effect of salinity on the vegetative measurements and some physiological components of plant (Gherroucha *et al*. 2011).

There is a lack of information about weed management on wheat under saline condition and how weed management can interact with foliar application with IAA to improve plant growth and productivity under salinity stress. Therefore, the objective of this study is to examine the effect of IAA and weed management treatments on wheat and associated grass weeds grown under salinity conditions.

MATERIAL AND METHODS

Experimental sites and procedures

Two field experiments were conducted during 2012/2013 and 2013/2014 growing seasons at Tag EL-Ezz Research Station of Agricultural Research Centre, Dakahliea Governorate, Egypt (30.96 N; 31.60 E) to study the effect of weed control methods and foliar application of IAA concentrations on spring wheat plants and associated weeds grown under saline soils. Experimental soil was a clay loam (vertisols) with organic matter 1.75%, EC dS/m at 25°C 4.9, pH 7.73, total N 0.081% and available P 15.1 ppm. The experiment was laid out in split plot design with four replicates. The main plots were allocated for weed control treatments at random as follows: clodinafop-propargyl, fenoxaprop, pinoxaden+clodinafop+safener, imazamethabenz, hand weeding once at 45 days from sowing and weedy check (unweeded). Whereas, the sub-plots were occupied by IAA concentrations (0, 50, 100 and 150 ppm with 500 L water/ha) applied after 50 days from sowing. Untreated treatment was sprayed with water only. The trade, common, and chemical names as well as application rate and time of the selective use of herbicides are shown in Table 1. The area of each experimental plot was 10.5 m^2. Wheat grains cv. Sakha 93 was obtained from the Agriculture Research Centre, Giza, Egypt. Wheat grains were broadcasted at a rate of 150 kg/ha followed by irrigation. The sowing dates were 22nd and 24th November 2012 and 2013, respectively. All the experimental plots were sprayed with Tribenuron methyl herbicide at a rate of 20 g/ha after 20 days from sowing for controlling broadleaf weeds. All other recommended cultural practices, other than treatments variables, were adopted throughout the growing season.

Measurements

Weeds of 1 sq m from the middle of each experimental plot were hand pulled at 80 days from sowing and then the numbers and dry weights of grassy weeds were estimated. The dry weights were recorded after oven drying at 70°C for 72 hrs. Moreover, nitrogen (N), Phosphorus (P), and potassium (K) percentages of total weeds species were measured as described by Cottenie *et al*. (1982). Then, the uptake of such nutrients was calculated by multiplying the element percentage by dry weight of total weeds. After heading stage at 80 days after sowing, flag leaf area was measured on 10 tillers chosen randomly from each plot. Total chlorophyll content (SPAD meter value) of flag leaf was also determined by the chlorophyll meter (SPAD-502 plus). The Soil-Plant Analyses Development (SPAD) unit of Minolta Camera Co. has developed the SPAD-502 chlorophyll meter (Minolta Camera Co., Japan), a hand-held, self-calibrating, convenient, and non-destructive lightweight device used to calculate the amount of chlorophyll present in plant leaves (Minolta, 1989). Harvesting was done on 6th and 7th May 2013 and 2014, respectively, where tillers of square metre per each experimental plot were collected to estimate number of spike per square metre, straw and grain yields/ha. Afterward, 10 tillers were taken from each and spike length, number of spikelet's/spike, number of grains/spike and grains weight/spike were measured. For chemical analysis of wheat grains, the total crude protein (TCP), phosphorus (P) and potassium (K) % were estimated as described by Cottenie *et al*. (1982).

Statistical analysis

The obtained data from each season were subjected to the proper statistical analysis of variance according to Gomez and Gomez (1984). The differences among the means of different treatments were tested using the least significant differences (*LSD*) at probability 5%. Statistical analysis was done using the CoStat package program, version 6.311 (Cohort software, USA).

RESULTS AND DISCUSSION

Weeds

The most commonly surveyed weeds in the experimental situation through the growing season were wild oat (*A. fatua* L.) and darnel ryegrass (*Lolium temulentum* L.). *A. fatua* and *Lolium temulentum* L. are widespread geographically, have an almost

T a b l e 1

Trade, common names, chemical names, rates and time of application of the used herbicides

Trade name	Common name	Chemical name (according to IUPAC)	Application rate	Application time
Topic 15% WP	Clodinafop-propargyl	Prop-2-ynyl (*R*)-2-[4-{(5-chloro-3-fluoro-2-pyridinyl)oxy} phenoxy] propanoate	350 g/ha	At 45 days after sowing
Puma super 7.5% EW	Fenoxaprop-p-ethyl	Ethyl (*R*)-2-]4-[(6-chloro-2-benzoxazolyl) oxy] phenoxy] propanoate	1250 cm^3/ha	At 25 days after sowing
Traxos 4.5% EC	Pinoxaden +clodinafop + safener	8-(2,6-diethyl-*p*-tolyl)-1,2,4,5-tetrahydro-7-oxo-7*H*-pyrazolo[1,2-*d*][1,4,5]oxadiazepin-9-yl 2,2-dimethylpropionate and Prop-2-ynyl (*R*)-2-[4-{(5-chloro-3-fluoro-2-pyridinyl)oxy} phenoxy] propanoate	1250 cm^3/ha	At 45 days after sowing
Assert 25% SC	Imazamethabenz	[(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-4(and 5)-methylbenzoic acid]	2125 cm^3/ha	At 25 days after sowing

identical cycle of cereal crops. Germination occurs simultaneously with them and for a fairly long period of time and matures at the same time as grain crops. These attributes facilitate the development and the presence in the fields and cause high losses in cereal yields (Santin-Montanya *et al*. 2013).

There was a significant effect of weed management on number and dry weight of the two dominant grassy weeds, that is, *A. fatua* L. and *L. temulentum* L. as well as nutrients uptake by them (Tables 2 and 3). All weeded treatments reduced dry weights of the two grassy weeds compared to the unweeded one. Moreover, the weeded treatments differed in their efficiency in weed suppression. In this respect, clodinafop-propargyl came in the first order for controlling the two grassy weeds followed by fenoxaprop, pinoxaden+clodinafop and imazamethabenz treatments. Such treatments reduced dry weight of wild oat than unweeded check by 88.5, 87.8, 85.9, and 84.6%, as well as dry weight of ryegrass by 80.4, 78.7, 77.0, 76.4%, respectively. The use of herbicides in wheat production is increasing dramatically due to their efficiency and reliability in controlling weeds. The high effectiveness of clodinafop-propargyl and pinoxaden+clodinafop herbicides treatments against wheat annual grass weeds could be attributed to the high susceptibility of both grasses to the herbicidal activity of the two herbicides

T a b l e 2

Effects of weed control method, IAA, and their interaction on the number and dry weight of narrow leaved weeds at 80 days after sowing (average of two seasons 2012/13 and 2013/14)

IAA (ppm) / Weed control method	Wild oat [No./m^2]					Wild oat DW [g/m^2]				
	0	50	100	150	Mean	0	50	100	150	Mean
Clodinafop-propargyl	30.2	32.7	37.3	40.8	35.2	39.9	45.7	54.4	56.2	49.0
Fenoxaprop	32.0	35.7	39.3	43.2	37.5	44.4	49.7	55.3	58.5	52.0
Pinoxaden + clodinafop	35.0	38.9	42.7	45.3	40.5	47.0	56.0	66.5	72.4	60.5
Imazamethabenz	37.8	42.4	46.8	46.3	43.3	53.7	58.7	71.9	78.7	65.7
Hand weeding	117.5	126.9	133.3	140.2	129.5	151.4	165.4	171.0	178.8	166.6
Unweeded	214.0	227.2	234.0	239.0	228.5	387.5	419.4	448.7	454.7	427.6
Mean	77.7	83.9	88.9	92.5	–	120.6	132.4	144.6	149.9	–
$LSD_{0.05}$ weed control	5.9					12.4				
$LSD_{0.05}$ IAA	2.9					7.5				
$LSD_{0.05}$ weed conntrol × IAA	7.2					17.6				

Table 2 continued

IAA (ppm) / Weed control method	Ryegrass [No./m^2]					Ryegrass DW [g/m^2]				
	0	50	100	150	Mean	0	50	100	150	Mean
Clodinafop-propargyl	32.5	44.0	53.9	57.4	46.9	23.2	26.5	33.4	40.0	30.8
Fenoxaprop	37.5	47.5	57.4	61.2	50.9	25.4	30.7	36.7	40.9	33.4
Pinoxaden+ clodinafop	37.0	48.7	64.9	62.7	53.3	27.2	33.2	40.2	43.3	36.0
Imazamethabenz	39.0	50.0	65.4	66.0	55.1	27.7	35.2	41.0	43.8	36.9
Hand weeding	89.5	107.5	119.3	126.9	110.8	82.2	84.3	87.9	91.0	86.3
Unweeded	160.2	167.8	175.2	183.2	171.6	146.0	152.9	161.3	166.0	156.5
Mean	65.9	77.6	89.3	92.9	–	55.3	60.4	66.7	70.8	–
$LSD_{0.05}$ weed control	4.6					4.3				
$LSD_{0.05}$ IAA	3.5					3.1				
$LSD_{0.05}$ weed control × IAA	NS					NS				

IAA – Indol acetic acid; *LSD* – Least significant differences

that inhibit acetyl coenzyme carboxylase (ACCase), the enzyme catalysing is the first committed step in fatty acids synthesis. Inhibition of fatty acid synthesis presumably blocks the production of phospholipids used in building new membranes required for cell growth (WSSA 1994). These results are in harmony with those obtained by several researchers (El-Metwally & Saudy 2009; El-Metwally *et al*. 2010; Tagour *et al*. 2011; Shehzad *et al*. 2012).

Considerable effect of IAA concentrations on number and dry weight of grassy weeds as well as nutrients uptake by weeds was recorded (Tables 2 and 3). In this connection, the highest values were obtained with foliar application of 150 ppm IAA treatment. However, the lowest values were recorded with water spraying treatment. The results of the present investigation are in line with those obtained by Tagour *et al*. (2010) who found that application of plant growth regulator increased fresh and dry weight of total weeds on rice.

The interactive effects between weed management and IAA treatments significantly affected the number and dry weights of wild oat, and ryegrass and nutrients uptake by them (Tables 2 and 3). Plots that received application of clodinafop-propargyl and water spraying treatments produced the lowest number and dry weight of wild oat, and ryegrass and nutrients uptake by weeds. Meanwhile, the

T a b l e 3

Effect of weed control and IAA and their interaction on nitrogen (N) uptake, phosphorus (P) uptake, potassium (K) uptake, flag leaf area and SPAD meter value of wheat plants (average of two seasons 2012/13 and 2013/14)

IAA (ppm) / Weed control method	N uptake [g/m^2]					P uptake [g/m^2]					K uptake [g/m^2]				
	0	50	100	150	Mean	0	50	100	150	Mean	0	50	100	150	Mean
Clodinafop-propargyl	1.22	1.39	1.52	1.65	1.44	0.13	0.18	0.18	0.21	0.18	2.01	2.21	2.36	2.39	2.24
Fenoxaprop	1.29	1.49	1.63	1.79	1.55	0.15	0.20	0.22	0.23	0.20	2.11	2.29	2.49	2.73	2.41
Pinoxaden + clodinafop	1.36	1.57	1.74	1.89	1.64	0.15	0.21	0.23	0.25	0.21	2.15	2.36	2.54	2.67	2.43
Imazamethabenz	1.40	1.64	1.82	2.03	1.72	0.16	0.25	0.28	0.27	0.24	2.17	2.39	2.65	2.84	2.51
Hand weeding	2.29	2.49	2.66	2.91	2.59	0.20	0.29	0.33	0.35	0.29	3.06	3.42	3.73	3.99	3.55
Unweeded	3.24	3.61	4.06	4.21	3.78	0.26	0.35	0.38	0.42	0.35	5.29	5.61	5.99	6.30	5.80
Mean	1.80	2.03	2.24	2.41	–	0.17	0.25	0.27	0.29	–	2.80	3.05	3.29	3.49	–
$LSD_{0.05}$ weed control	0.09					0.03					0.11				
$LSD_{0.05}$ IAA	0.06					0.02					0.05				
$LSD_{0.05}$ weed control × IAA	0.13					0.05					0.13				

Table 3 continued

IAA (ppm) / Weed control method	Flag leaf area [cm^2]					SPAD value				
	0	50	100	150	Mean	0	50	100	150	Mean
Clodinafop-propargyl	36.8	38.6	42.5	45.8	40.9	38.0	41.8	42.6	43.2	41.4
Fenoxaprop	34.5	36.9	41.3	44.0	39.1	37.9	40.6	41.5	41.9	40.5
Pinoxaden + clodinafop	35.1	36.2	40.5	42.6	38.6	37.5	39.6	40.7	41.3	39.8
Imazamethabenz	34.6	35.5	40.1	42.6	38.2	37.2	39.8	40.3	40.5	39.4
Hand weeding	31.5	32.2	35.5	38.2	34.3	36.3	38.7	39.1	40.1	38.5
Unweeded	27.9	30.1	33.3	36.0	31.8	34.8	37.1	37.8	38.9	37.2
Mean	33.4	34.9	38.8	41.5	–	36.9	39.6	40.3	41.0	–
$LSD_{0.05}$ weed control	1.7					0.7				
$LSD_{0.05}$ IAA	0.9					0.7				
$LSD_{0.05}$ weed control × IAA	NS					NS				

IAA – Indol acetic acid; *LSD* – Least significant differences

maximum values of the previous characters were reported with unweeded treatment and foliar application of 150 ppm IAA treatment. Confirming results in this respect were cited by Tagour *et al.* (2010) who mentioned that unweeded treatment combined with plant growth regulator application recorded the highest values of fresh weight of weeds on rice.

Wheat growth

Flag leaf area and SPAD values (after heading stage) were significantly affected by weed management treatments in both seasons (Table 3). Clodinafop-propargyl was superior treatment for increasing flag leaf area and SPAD value. Moreover, fenoxaprop, pinoxaden+clodinafop and imazamethabenz treatments were statistically at par for improving the flag leaf area. On the other hand, the lowest values of the aforementioned traits were recorded with unweeded treatment. The enhancement of wheat growth in the weeded plots might be attributed to the efficiency in weed elimination (Table 2) and consequently, the reduction of weed competitive ability against wheat plants. Such conditions mean more efficient use of the environmental growth factors by wheat plants reflecting on improving their growth. Similar findings confirmed our results were reported by other authors (Riaz *et al*. 2006; El- Metwally & Saudy 2009; Zakariyya *et al*. 2013).

Data in Table 3 revealed that IAA treatment caused significant increases in flag leaf area and SPAD values compared to untreated treatment. The highest values of flag leaf area and SPAD value were obtained from plants treated with IAA at 150 ppm. Whereas, the lowest values of the previous characters was obtained from the untreated treatment. These results may be attributed to the role of IAA in enhancement of growth and development of plants by stimulating wide range of processes, including cell division and tissue growth, phototropism and gravitropism, apical dominance, lateral root initiation, differentiation of vascular tissues, embryogenesis, senescence, fruit setting and ripening (Naeem *et al*. 2004). In addition, the promoting effect of IAA may be referred to enlarging leaves and increasing photosynthetic activities (Naeem *et al*. 2004), increasing cell elongation and accumulation of building units accompanied by greater saccharides content (Mostafa & Abou Al-Hamd 2011). These increments in growth criteria under the effect of IAA treatments are similar to those reported by Iqbal and Ashraf (2007) and Abd El-Samad (2013) on wheat, Eleiwa *et al*. (2013) on barley and Kaya *et al*. (2013) on maize. Also, IAA presumably acts as a coenzyme in the metabolism of higher plants, thus it plays an important role in the formation of the photosynthetic pigments. These increases in the content of pigments may be attributed to the promotion of pigments synthesis and/or retardation of pigments degradation on faba bean (Sadak *et al*. 2013).

Concerning the interaction effect, the maximum values of flag leaf area were recorded with clodinafop-propargyl and spraying of 150 ppm IAA treatment in the first season. In contrast, the lowest values of flag leaf area were obtained by unweeded and under/untreated IAA combination. All IAA concentrations, especially higher concentrations had significant beneficial effect in enhancing wheat growth parameters under herbicidal treatments. The results of IAA and clodinafop-propargyl treatments were supported by those of Tagour *et al*. (2010).

Yield and yield attributes

Yield and yield attributes of wheat have been estimated under different treatments of weed management, IAA concentrations and their interactions as shown in Tables 4 and 5. The highest values of number of spike per square meter, spike length, number of spikelet's/spike, grains number/spike and grains weight/spike were obtained from clodinafop-propargyl spraying. Contrarily, the lowest values of the previous traits were obtained from the unweeded check. Clodinafop-propargyl followed by fenoxaprop, pinoxaden+clodinafop, imazamethabenz and hand weeding treatments gave higher values of grain, straw yields. They significantly increased grain yield/ha over the unweeded check by 25.0, 21.6, 20.1, 18.9, and 12.7%, respectively. Such superior weeded treatments minimised weed-crop competition (Table 2) and saved more available environmental resources for crop plants that improved growth traits (Table 3). This, in turn, increased flag leaf area at heading stage and produced more assimilates synthesised, translocated, and accumulated in various plant organs, which positively reflected on straw and grain yields. Among all weed control methods, hand weeding showed poor performance. The positive effect of weed practices on wheat yields and its components have been confirmed by several authors (Riaz *et al*. 2006; Shehzad *et al*. 2012; Ahmadi & Alam, 2013; Marzouk 2013; Han *et al*. 2014).

Significant increases in the studied yield traits with increasing IAA levels from 0 up to 150 ppm are shown in Tables 4 and 5. Application of 150 ppm IAA led to production of maximum number of spikes/m^2, spike length, number of spikelets/spike, number of grains/spike, grains weight/spike, grain and straw yields/ha. On the other hand, the lowest of aforementioned characters was obtained by untreated treatments. The increase in the yield could be a reflection of the promotive effect of growth regulators on plant growth (Table 3), which could lead to increase in photo-assimilates, and greater transfer of assimilates to the sink. Concerning this, Amanullah *et al*. (2010) reported 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 and grain development and ultimately, enhancing the productivity of crops. Moreover, Arif *et al*. (2001) mentioned that IAA is the major naturally occurring auxin that increases stem elongation, cell ex-

T a b l e 4

Effect of weed control and IAA and their interaction on some of wheat yield components (average of two seasons 2012/13 and 2013/14)

Weed control method \ IAA (ppm)	Spikes [No./m^2]					Spike length [cm]					Spikelets [No./spike]				
	0	50	100	150	Mean	0	50	100	150	Mean	0	50	100	150	Mean
Clodinafop-propargyl	325	347	377	385	358	9.3	11.0	11.8	12.9	11.2	17.9	20.5	22.5	23.2	21.0
Fenoxaprop	313	328	361	365	342	8.9	10.4	10.9	11.6	10.4	17.9	19.3	20.5	21.0	19.7
Pinoxaden + clodinafop	312	324	354	362	338	8.9	10.1	10.5	11.1	10.1	17.5	19.2	19.7	20.4	19.2
Imazamethabenz	307	320	353	356	334	8.8	9.9	10.6	11.1	10.1	17.5	19.0	19.9	20.2	19.1
Hand weeding	300	311	327	332	317	8.8	9.6	9.9	10.4	9.7	16.0	17.4	19.2	19.5	18.0
Unweeded	291	301	313	321	307	8.6	9.1	9.4	9.9	9.2	15.2	16.7	17.5	18.0	16.8
Mean	308	322	347	353	–	8.9	10.0	10.5	11.1	–	17.0	18.7	19.9	20.4	–
$LSD_{0.05}$ weed control	8					0.4					1.1				
$LSD_{0.05}$ IAA	6					0.4					0.6				
$LSD_{0.05}$ weed control × IAA	13					0.7					NS				

Table 4 continued

Weed control method \ IAA (ppm)	Grains [No./spike]					Grains weight/spike [g]				
	0	50	100	150	Mean	0	50	100	150	Mean
Clodinafop-propargyl	52.2	59.5	66.0	68.5	61.6	1.95	2.25	2.71	2.76	2.41
Fenoxaprop	47.0	53.5	61.0	63.9	56.3	1.83	2.04	2.38	2.52	2.19
Pinoxaden + clodinafop	43.8	53.0	57.0	62.5	54.1	1.81	2.05	2.31	2.41	2.14
Imazamethabenz	45.0	50.4	57.0	62.7	53.8	1.75	1.96	2.21	2.31	2.05
Hand weeding	41.7	48.8	55.2	60.8	51.6	1.70	1.87	2.10	2.15	1.95
Unweeded	28.9	37.2	46.4	55.0	41.9	1.58	1.70	2.07	2.12	1.87
Mean	43.1	50.4	57.1	62.2	–	1.77	1.98	2.29	2.38	–
$LSD_{0.05}$ weed control	2.8					0.09				
$LSD_{0.05}$ IAA	2.2					0.07				
$LSD_{0.05}$ weed control × IAA	5.2					0.17				

IAA – Indol acetic acid; *LSD* – Least significant differences

pansion, growth rate and yield. These results of IAA treatments are in agreement with those obtained by Kaya *et al*. (2010) on maize and Abdoli *et al*. (2013) on wheat.

The results (Tables 4 and 5) show that there were significant interactions between IAA and weed control treatments on yield and yield attributes in both seasons, except number of spikelet's/spike in the second season. The highest values were obtained from spraying of 150 ppm IAA integrated with clodinafop-propargyl treatment. On the other hand, the lowest values were recorded from the unweeded treatment with spraying of water treatment. Such superiority of herbicides treatments combined with IAA treatments, mainly due to the higher weed control efficiency and poor competition ability of weeds gave a competitive advantage for the wheat plants in utilising the essential demands of nutrients and water, leading to increasing the wheat growth and yield. The results of the present investigation are in trend with those obtained by Tagour *et al*. (2010).

Grain chemical composition

Weed management had a significant effect on TCP, P percentages and K percentages of wheat grains (Table 5). Clodinafop-propargyl treatment increased significantly the concentration of TCP,

T a b l e 5

Effect of weed control and IAA and their interaction on wheat grain yield and straw yield and chemical composition of wheat grain (average of two seasons 2012/13 and 2013/14)

Weed control method \ IAA (ppm)	Grain yield [t/ha]					Straw yield [t/ha]					TCP [%]				
	0	50	100	150	Mean	0	50	100	150	Mean	0	50	100	150	Mean
Clodinafop-propargyl	6.56	6.82	7.19	7.47	7.01	9.64	10.18	11.16	11.97	10.74	9.51	10.25	10.96	11.89	10.65
Fenoxaprop	6.48	6.70	6.93	7.17	6.82	9.42	9.96	10.88	11.66	10.48	9.33	10.19	10.93	11.76	10.55
Pinoxaden + clodinafop	6.39	6.58	6.86	7.12	6.74	9.27	9.81	10.71	11.54	10.33	9.45	10.23	10.90	11.68	10.56
Imazamethabenz	6.33	6.55	6.70	7.12	6.67	9.19	9.78	10.58	11.28	10.21	9.45	10.18	10.76	11.30	10.42
Hand weeding	6.01	6.25	6.42	6.61	6.32	8.33	9.12	9.77	10.51	9.43	8.92	9.38	10.06	10.71	9.77
Unweeded	5.19	5.50	5.78	5.97	5.61	8.26	8.94	9.28	10.13	9.15	8.65	8.81	9.34	9.54	9.08
Mean	6.16	6.40	6.64	6.91	–	9.02	9.63	10.39	11.18	–	9.22	9.84	10.49	11.14	–
$LSD_{0.05}$ weed control	0.14					0.13					0.10				
$LSD_{0.05}$ IAA	0.10					0.09					0.08				
$LSD_{0.05}$ weed control × IAA	0.24					0.22					0.19				

Table 5 continued

Weed control method \ IAA (ppm)	P [%]					K [%]				
	0	50	100	150	Mean	0	50	100	150	Mean
Clodinafop-propargyl	0.18	0.19	0.21	0.22	0.20	0.53	0.56	0.60	0.67	0.59
Fenoxaprop	0.19	0.20	0.21	0.21	0.20	0.53	0.56	0.59	0.60	0.57
Pinoxaden + clodinafop	0.18	0.19	0.20	0.22	0.20	0.52	0.56	0.58	0.59	0.56
Imazamethabenz	0.18	0.19	0.20	0.20	0.19	0.52	0.54	0.58	0.58	0.55
Hand weeding	0.17	0.17	0.18	0.19	0.18	0.51	0.52	0.53	0.56	0.53
Unweeded	0.16	0.17	0.17	0.18	0.17	0.50	0.51	0.52	0.53	0.51
Mean	0.18	0.18	0.19	0.20	–	0.52	0.54	0.56	0.58	–
$LSD_{0.05}$ weed control	0.005					0.04				
$LSD_{0.05}$ IAA	0.004					0.03				
$LSD_{0.05}$ weed control × IAA	0.008					0.06				

IAA – Indol acetic acid; *LSD* – Least significant differences; TCP – Total crude protein; P – Phosphorus; K – Potassium

P and K [%] compared with other treatments. The increments in TCP, P and K [%] exceeded the unweeded treatment by 14.7, 15.0 and 13.6%, respectively. These results may be due to less competition for environmental factors, particularly nutrients, water and light through limiting weeds infestation with herbicidal treatments due to increasing the uptake of different nutrients and reflected on chemical composition of grains. The positive effect of weeded practices on chemical analysis of cereal grains have been confirmed by El-Metwally *et al*. (2010), Tagour *et al*. (2011) and Marzouk (2013).

TCP, P and K percentages were appreciably influenced by IAA levels in both seasons as shown in Table 5. In this respect, with each increase in IAA levels, there was a progressive increase in aforementioned traits. Application of IAA at 150 ppm led to the highest values of TCP, P and K percentages. On the other side, the lowest values were recorded with spraying of water treatment. These results may be due to application of growth regulators, especially IAA encourages the absorption of nitrogen from the soil and activated the photosynthetic process through their influence on some enzymatic action. The activation of these processes might cause the increases in TCP, P and K percentages in wheat grains. Similar results were obtained by Tagour *et al*. (2010) and Abdoli *et al*. (2013). Table 5 showed that wheat plants treated with clodinafop-propargyl and IAA at 150 ppm produced the greatest TCP, P and K percentages. In contrast, the minimum values of aforementioned characters were recorded with water spraying combined with unweeded treatment. Similar findings were reported by Tagour *et al*. (2010).

CONCLUSIONS

Application of the selective graminicide herbicides supported the control against grassy weeds and improved wheat grain productivity. Exogenous application of growth regulator (IAA) was effective in alleviating the adverse effects of salinity on wheat plants. Foliar application of clodinafop-propargyl combined with and 150 ppm IAA was the most effective treatment for maximising wheat yield under salinity condition.

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