International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.4, pp 1588-1600, 2015

Effect of Zinc Application and Weed Control on Wheat Yield and Its Associated Weeds Grown in Zinc-Deficient Soil

El_Metwally I. M.[1], M. S. Abd El- Salam[2], Osama A.M. Ali[3]

[1]Botany Dept., National Research Centre, 33 Bohouth St., Dokki, Giza, Egypt
[2]Field Crops Res. Dept., National Research Centre, 33 Bohouth St., Dokki, Giza, Egypt
[3]Crop Science Dept., Faculty of Agriculture, Minufiya Univ., Egypt

Abstract: Weeds infestation is one of the major threats to crop yield. Field experiments were carried out to investigate the efficiency of weed control methods (Pyroxsulam, Isoproturon+diflufenican, Isoproturon, Mesosulfuron-methyl, hand weeding and unweeded check) and zinc application levels (0, 1, 2 and 3 g Zn L^{-1}) on wheat crop and associated weeds in El-Nubaria, Egypt. Isoproturon+diflufenican achieved the highest weed depression expressed in lowest numbers and dry matter of broadleaved, narrow-leaved and total weeds. Reduction in dry matter of total weeds was 93.4% compared with unweeded. Increasing zinc up to 3 g L^{-1} significantly decreased numbers and dry weights of weeds.

Isoproturon+diflufenican was the most superior treatment in increasing chlorophyll content, flag leaf area, plant height, yield components, grain and straw yields and chemical composition of wheat flag leaf and grains. Application of Isoproturon+diflufenican provided 54.9 and 57.9% more grain yield than weedy check in first and second seasons, respectively. Zn application up to 3 g L^{-1} enhanced growth, yield and chemical composition of wheat flag leaf and grains. The interaction between weed control and Zinc levels had significant effect on total number and dry weight of weeds, spikes number, and grain yield. Isoproturon+ diflufenican herbicide integrated with 3 g Zn L^{-1} application produced the lowest values of total dry weight of weeds while, gave the maximum values of spikes number and grain yield. It could be concluded that post emergence herbicides (Isoproturon+diflufenican) combined with Zn application (3 g L^{-1}) could effectively improve growth and productivity of wheat under sandy soil conditions.

Keywords: Wheat, Weed control, Zinc, Yield, Sandy soil.

1. Introduction

Wheat (*Triticum aestivum* L.) is the principal staple food crop for urban and rural societies in the world. The fast growing population of the country makes it imperative to achieve matching increases in the rate of food production. 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 practices. Increasing the cultivated area of wheat should be done in the reclaimed land due to the limited areas of the Nile Valley and the competition of the other main crops[1]. Nutrients deficiency in sandy soil and crops is a limiting factor for crop production, because nutrient removals are far more than the nutrient addition. Consequently, the present fertility status of soils cannot sustain high yield. Also, a variety of soil chemical and physical problems significantly reduce availability of Zn to plant root.

Zinc is an essential nutrient for plants and humans growth[2,3,4]. World Health Organization reported deficiencies of Zn and vitamin A in human population of developing countries. Zinc deficiency is a documented problem, causing decreased crop yields and nutritional quality. Zn deficiency in humans is a critical nutritional and health problem in the world[5, 6]. It affects, on average, one-third of the world's population, ranging from 4 to 73% in different countries[7]. Zinc is a trace essential nutrient to all forms of life because of its fundamental role in gene expression, cell development and replication[2]. Severe or clinical zinc deficiency in human was defined last century, as a condition characterized by short stature, hypogonadism, impaired immune function, skin disorders, cognitive dysfunction and anorexia[8]. In developing countries, a large proportion of dietary intake of Zn is derived from cereal grains. The Zn-rich parts of wheat grain are removed during milling, thus resulting in a marked reduction in flour Zn concentrations. Consequently, heavy consumption of high proportion of milled wheat and other cereal products may result in reduced intake of Zn. Enrichment of cereal grains with Zn[9]. Therefore, increasing Zn concentration of cereal grains has been identified as a way of addressing human Zn deficiency[10, 11]. Zinc plays a key role as a structural constituent or regulatory co-factor of a wide range of enzymes in many important biochemical pathways. [12] elucidated that Zn deficiency markedly reduced the level of GA. The level of IAA was also decreased although not as markedly. The goal of different Zn levels application to determine the potential of increasing the Zn concentrations application for improving yield and nutritional status of grains.

Weeds infestation is one of the major threats to crop growth and yield. Weeds compete with crop plants for nutrients, solar radiation, water, carbon dioxide, space, and many other growth factors. Weeds are accountable about 20-30% loss of wheat yield[13,14,15]. Annual wheat yield losses by weeds infestation are much higher than caused by other pests. Hand weeding is not only ineffective but also very expensive because of increased cost of labor. Presently, various herbicides are used to control weeds in wheat crop worldwide such as imazamethabenz, fenoxaprop plus MCPA plus thifensulfuron plus tribenuron, bromoxynil plus MCPA, flufenacet, fenoxaprop-p-ethyl, metribuzin and clodinafop propargyl, chlorotoluron + MCPA[16] that cause a plant death through stimulation of protein or RNA biosynthesis. Post-emergence application of sulfosulfuron against *P. minor* provided 251% wheat yield increase compared to weedy check[17]. Hence, herbicides are more effective and economical than conventional method against weeds when used in safe doses.

Therefore, the present study was undertaken to evaluate the post-emergence herbicides efficiency and Zn application levels on growth and yield of wheat crop as well as associated weeds grown on zinc-deficient soil.

2. Materials and Methods

2.1. Experimental procedures

Field experiments were conducted during the two winter successive seasons (2012/2013 and 2013/2014) at the experimental farm of National Research Center, El-Nubaria region, Egypt (latitude 30.8667N, and longitude 31.1667E, and mean altitude 21 m above sea level). The experimental area has an arid climate with cool winters and hot dry summers. The soil of experimental site is classified as sandy soil. Some physical and chemical properties of the experimental soil according to[18, 19] are shown in Table 1 a, b. Irrigation water was obtained from an irrigation channel going through the experimental area with pH 7.2 and EC 0.40 dS m^{-1}. Sprinkler irrigation system was used. The experiment was established with a split plot design having four replicates. The main plots included six weed control treatments i.e. **(1)** Pyroxsulam (N-(5,7-dimethoxy[1,,4]triazolo[1,5-a]pyrimidin-2-yl)-2-methoxy-4-(trifluoromethyl) pyridine-3-sulfonamide), known commercially as Pallas 4.5% OD sprayed at the rate of 400 ml ha^{-1}, **(2)** Isoproturon+diflufenican [3-(4-isopropyl phenyl)-1,1-dimethyl urea] +2,4-difluoro-2-(alpha,alpha,alpha-trifluoro-m-tolyloxy) nicotinanilide, known commercially as Panther 55% SC sprayed at the rate of 1500 ml ha^{-1}, **(3)** Isoproturon ([3-(4-isopropyl phenyl)-1,1-dimethyl urea] known commercially as Arelon 50% FL sprayed at the rate of 3000 ml ha^{-1}, **(4)** Mesosulfuron-methyl (mesosulfuron-methyl 10 g L^{-1} + iodosulfuron-methyl-sodium 2 g L^{-1} + mefenpyr-diethyl 30 g L^{-1}), known commercially as Atlantis 1.2 % OD sprayed at the rate of 1500 ml ha^{-1}, **(5)** Twice hand weeding at 25 and 40 days from sowing, and **(6)** Unweeded check (control). All tested selective herbicides were sprayed at 25 days after sowing (DAS) using of 500 liter water/ha. Sub-plots were randomly assigned to four zinc levels, i.e. 0, 1, 2 and 3 g Zn L^{-1} ($ZnSO_4.H_2O$, 35% Zn) sprayed at 30 and 45 DAS. Untreated treatment was sprayed with water only.

Table 1a. Soil mechanical and physical characteristics of experimental site

Soil depth (cm)	Particle size distribution			Texture class	Field capacity (%)	Wilting point (%)
	Coarse Sand	Fine sand	Clay + Silt			
0 -20	49.71	46.89	3.40	Sandy	10.5	4.6
20-40	50.92	45.36	3.72	Sandy	13.1	5.2
40-60	36.84	59.70	3.46	Sandy	12.2	4.8

Table 1b. Soil chemical properties of experimental site

Soil depth (cm)	$CaCO_3$ (%)	EC (dS m^{-1})	pH	OM (%)	Zn (ppm)
0 -20	5.85	0.36	8.3	0.52	0.13
20-40	3.92	0.32	8.5	0.43	0.11
40-60	4.06	0.41	8.9	0.21	0.08

2.2. Measurements

Weeds were hand pulled from one square meter of each experimental unit at 70 DAS, then identified and classified into broadleaved and narrow-leaved weeds species groups. The numbers of weeds were recorded in m^2, and air dried and then in an electric oven at temperature of 70°C until constant weight. After drying, the dry weights of weeds were recorded. After heading stage, flag leaf area (cm^2) was measured on ten tillers chosen randomly from each plot. The total chlorophyll content (SPAD value) of flag leaf was determined by chlorophyll meter (SPAD-502, Minolta Camera Co., Osaka, Japan) as reported by[20]. Harvesting dates were April 28*th* and 25th in the first and second seasons, respectively. Plants of square meter per each experimental plot were collected to estimate spikes number m^{-2}, grain and straw yields ton ha^{-1}. Ten tillers chosen randomly from each plot, and the following traits were measured: plant height, spike characters (length, spikelet's number, grains weight and grains number) and weight of 1000 grain. Flag leaves (at 10 days after completing heading stage) and grains (after harvest) were collected for determining total nitrogen (TN) using Kjeldahl method, and total crude protein (TCP) as a percentage was determined by multiplying TN-content by 5.7 according to the method described by[21]. Phosphorus and potassium percentage were determined according to[22]. Zinc was determined using flam atomic absorption spectrometry according to[18].

2.3. Agronomic practices

The experimental field was prepared before planting. Field was ploughed twice with disk plow followed by chisel plow. A combined driller that facilitated concurrent application of fertilizer and seeds was used. Spring wheat variety (Sakha 93) was planted on the mid November in both growing seasons 2012/2013 and 2013/2014. Seed drill setting was such that it applied at a rate of 170 kg grains ha^{-1}. Grains were drilled at 5 cm soil depth with 13.5 cm row spacing. All plots received the same amounts of mineral fertilizers. A rate of 70 kg P_2O_5 ha^{-1} as single superphosphate 15.5% P_2O_5 was applied to the soil in two equal doses before planting and at tillering stage. Nitrogenous fertilizer was applied at a rate of 285 kg N ha^{-1} as ammonium nitrate, ten percent applied to the soil before sowing, the remaining quantity being applied via fertigation after wheat emergence with five equal doses. Potassium fertilizer was added at a rate of 115 kg K_2O ha^{-1} as potassium sulfate applied in two doses (50% applied to the soil before planting and 50% during the growth through irrigation water).

2.4. Statistical Analyses

All the obtained data were statistically analyzed according to[23] using LSD to compare among the treatments means at probability 5%. Statistical analysis was done using the CoStat package program, version 6.311 (cohort software, USA).

3. Results and Discussion

3.1. Weeds growth

The major weed flora classification in the field experimental site included common sweet clover (*Melilotus indica* L.), wild beet (*Beta vulgaris* L.) and London rocket (*Sisymbrium irio* L.) as broadleaved weeds and wild oat (*Avena fatua* L.) as well as ryegrass (*Lolium temulentum* L.) as narrow-leaved weeds.

Effect of weed management

Data in Table 2 reveal that all weed control treatments significantly decreased the numbers and dry weight of broadleaved, narrow-leaved and total weeds at 70 DAS as compared to the unweeded check. Isoproturon + diflufenican herbicide was more effective than other weed control treatments against broadleaved and narrow-leaved weeds. Pyroxsulam came in the second rank followed by Isoproturon, Mesosulfuron-methyl herbicides and hand weeding. The highest significant reductions in total dry weight of weeds were obtained by Isoproturon + diflufenican (93.4 %) followed by Pyroxsulam (91.4 %), Isoproturon (89.9 %), Mesosulfuron-methyl (88.7 %) and hand weeding (63.11 %) in comparison with unweeded treatment. [24] reported that Isoproturon + diflufenican was highly efficient in controlling annual narrow-leaved and broadleaved weeds grown in wheat and barley field crops. So, Isoproturon + diflufenican herbicide was more effective in controlling total weeds and resulted in the highest reduction in dry matter compared with other treatment. It is well known that the mode of action of the effective herbicides in this study like Isoproturon which interferes with the photosynthetic process, diflufenican inhibits the carotenoid synthesis in plants. The primary biochemical target site of Mesosulfuron-methyl is the enzyme acetohydroxy acid synthase (AHAS). It acts via the foliage and also the soil, effectively inhibiting the development of new leaves. In addition the target site of Pyroxsulam inhibits acetolactate synthase (metosulam) the key plant enzyme inhibiting branched chain amino acids leucine, isoleucine and valine. These results are in general agreement with those recorded by [25, 26]. The reduction in weeds number and dry weight might be due to the inhibitory effects of herbicides on growth and development of weeds. These results are in general agreement with those recorded by[27, 28, 29].

Effect of Zinc levels

Results in Table 2 indicated that foliar application of Zn significantly decreased number and dry weight of broadleaved, grasses and total weeds at 70 DAS as compared to untreated plants. Foliar spraying of zinc at the rate of 3 g L^{-1} produced the lowest number and dry weight of weeds. In contrast, the highest values were recorded when using water treatment (untreated). The role of Zn in biosynthesis of the natural auxin (IAA) can account for the promotion of the shoot system elongation and dry matter production, and that reflecting in enhancing wheat tillering [6], and consequently inhibit weed growth. These results are in general agreement with those recorded by[10, 11, 30].

Interaction effect

Data in Figs (1 and 2) showed that there were significant effect due to the interaction between weed control treatments and Zn levels on total number and dry weight of weeds at 70 DAS. Application of Zn at the rate of 3 g L^{-1} significantly decreased total number and dry weight of wheat weeds m^{-2} when Isoproturon + diflufenican was applied. While, the highest total number and dry weight of wheat weeds was recorded with unweeded treatment without Zn application. Similar results were obtained by[31].

Table 2. Number and dry weight of wheat weeds as affected by weed control treatments and Zn application during 2012/2013 and 2013/2014 seasons.

Treatments	Broad leaved weeds				Narrow leaved weeds				Total weeds			
	Number m^{-2}		Dry weight m^{-2}		Number m^{-2}		Dry weight m^{-2}		Number m^{-2}		Dry weight m^{-2}	
	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
Weed control												
Pyroxsulam	18.59	21.47	26.46	28.13	8.14	9.70	9.22	11.35	26.73	31.17	35.68	39.48
Isoproturon+diflufenican	14.72	16.75	21.29	22.13	5.74	7.12	6.44	8.33	20.46	23.87	27.73	30.46
Isoproturon	21.74	25.33	30.76	33.18	11.10	10.34	12.24	12.35	32.84	35.67	43	45.53
Mesosulfuron-methyl	23.29	26.73	32.95	35.03	12.74	13.79	14.79	16.14	36.03	40.52	47.74	51.17
Hand weeding	34.56	49.85	48.67	65.30	91.31	90.04	103.18	105.35	125.87	139.89	151.85	170.65
Unweeded	151.20	183.14	218.67	239.9	171.83	185.56	198.24	217.11	323.03	368.7	416.91	457.01
LSD at 5%	3.11	4.17	5.19	7.23	4.33	2.89	3.31	4.11	6.18	8.51	9.23	11.48
Zinc levels												
Untreated	46.61	56.43	66.98	73.72	51.98	54.79	59.43	63.94	98.59	111.22	126.41	137.66
1 g Zn L^{-1}	46.08	55.02	66.27	72.73	51.60	54.12	59.00	63.49	97.68	109.14	125.27	136.22
2 g Zn L^{-1}	44.09	53.54	63.03	69.94	49.98	51.98	57.14	60.94	94.07	105.52	120.17	130.88
3 g Zn L^{-1}	39.28	50.48	56.21	65.94	47.03	50.15	53.83	58.67	86.31	100.63	110.04	124.61
LSD at 5%	2.71	2.15	2.19	3.23	2.27	2.08	2.14	1.74	3.03	4.13	6.17	5.87

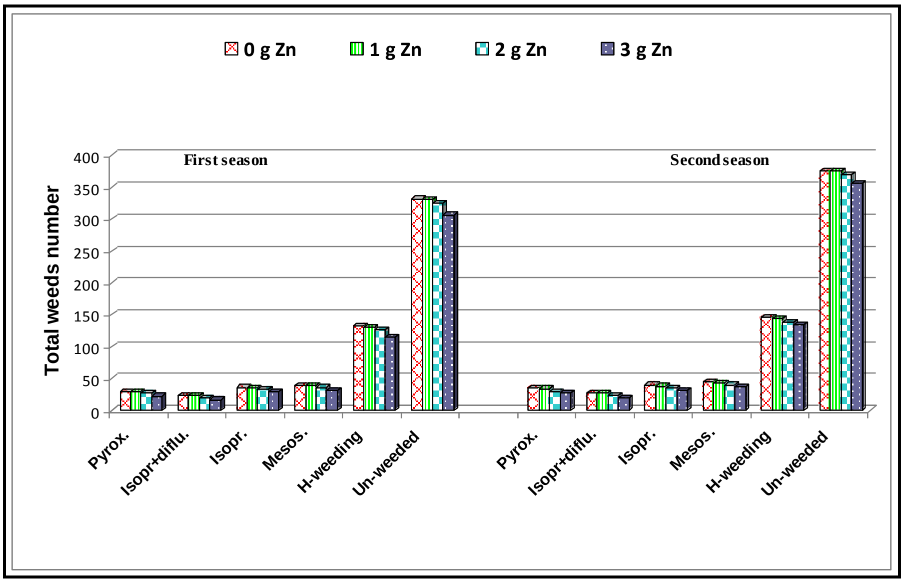

Fig 1. Effect of weed control and zinc application on total weeds number.

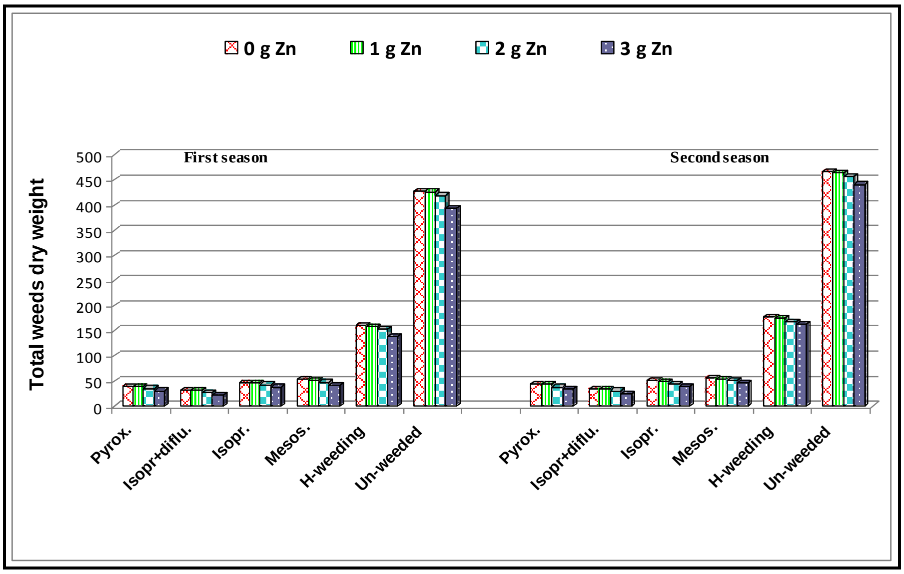

Fig 2. Effect of weed control and zinc application on total weeds dry weight.

3.2. Wheat growth

Effect of weed control management

Results in Table 3 showed significant impact of weed control treatments on chlorophyll (SPAD value), flag leaf area and plant height. Isoproturon + diflufenican herbicide exceeded the rest of other weeded methods for enhancing SPAD value, flag leaf area and plant height. Isoproturon herbicide came in the second rank without significant differences with first rank generally. The enhancement of wheat growth in the weeded plots might be attributed to the efficiency in weed elimination (Table 2) and consequently reduction of weed competitive ability against wheat plants. Such conditions mean more efficient use of the environmental growth factors by wheat plants which reflecting on improving their growth. These results are in good harmony with those obtained by[15, 31].

Table 3. Chlorophyll, flag leaf area and plant height of wheat as affected by weed control treatments and Zn application during 2012/2013 and 2013/2014 seasons.

Treatments	Chlorophyll content (SPAD value)		Flag leaf area (cm^2)		Plant height (cm) at harvest	
	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
Weed control						
Pyroxsulam	34.80	34.45	22.13	21.93	83.00	82.25
Isoproturon+diflufenican	38.57	37.87	27.89	26.64	89.00	88.47
Isoproturon	36.76	35.98	26.58	25.32	86.67	86.24
Mesosulfuron-methyl	36.54	35.86	23.00	22.00	84.56	84.33
Hand weeding	34.47	34.73	22.24	21.04	82.44	81.97
Unweeded	32.52	32.82	18.04	18.45	71.67	72.45
LSD at 5%	1.27	1.31	1.63	1.46	3.75	3.14
Zinc levels						
Untreated	32.58	32.46	20.31	19.56	75.85	75.74
1 g Zn L^{-1}	35.44	35.11	23.04	22.37	82.00	81.29
2 g Zn L^{-1}	36.49	36.56	24.74	23.95	86.77	86.4
3 g Zn L^{-1}	37.71	37.01	25.18	24.35	86.92	87.06
LSD at 5%	1.02	1.11	0.57	0.63	1.91	1.29

Effect of Zinc levels

Application of Zn at the rate of 3 g L^{-1} gave the greatest values of SPAD value, flag leaf area and plant height (Table 3). Vice- versa untreated treatment was recorded the lowest values. The increment in growth characters due to foliar application of Zn might be due to their critical role in crop growth, involving in photosynthesis processes, respiration and other biochemical and physiological activates. High $CaCO_3$, High pH, low organic content are the major soil factors affecting availability of Zn to roots[9] as shown from Table 1. Low solubility of Zn in soils rather than low total amount of Zn is the major reason for the widespread occurrence of Zn deficiency problem in growth plants. The reduction of photosynthesis observed in zinc deficient plants can be due, in part, to a major decrease in chlorophyll content, reduction in the activity of the enzyme carbonic anhydrase and the abnormal structure of chloroplasts[6]. These results are in accordance with those recorded by [5, 31, 32].

Effect of Interaction

The interaction between the two tested factors did not reach the 5% level of significance for growth characters in the two growing seasons.

3.3. Wheat yield

Effect of weed management

Results in Tables 4 and 5 showed significant impacts of weed management treatments on spike length, spikelets number per spike, grains number and weight per spike, spikes number m^{-2}, grain and straw yields ha^{-1}. The highest values of the yield parameters were obtained from Isoproturon+ diflufenican application followed by Isoproturon, Mesosulfuron-methyl, Pyroxsulam herbicides and hand weeding. However, the lowest ones were obtained from the unweeded check. The increases in grain yield resulting from Isoproturon+ diflufenican, Isoproturon, Mesosulfuron-methyl and Pyroxsulam herbicides application amounted to 54.9, 50.2, 44.1 and 29.9 % in the first season and 57.9, 53.2, 38.8 and 34.9% in the second season, respectively over than unweeded. Such superiority of these weeded treatments may be related with minimizing weed-crop competition (Table 2). This in turns increased flag leaf area at heading stage, plant height at harvest (Table 3) and produced more assimilates synthesized, translocated and accumulated in various plant organs which positively reflected on straw and grain yields. The positive effect of weeded practices on wheat yields and its components have been confirmed by[13, 14, 15, 33].

Table 4. Yield attributes of wheat as affected by weed control treatments and Zn application during 2012/2013 and 2013/2014 seasons.

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Treatments	Spike length (cm)		Spikelets number $spike^{-1}$		Grains number $spike^{-1}$		Grains weight $spike^{-1}$ (g.)		1000-grains weight (g.)		Spikes number m^{-2}	
	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
Weed control												
Pyroxsulam	9.11	9.08	16.11	16.19	36.78	36.64	1.31	1.28	35.05	34.61	308.68	280.3
Isoproturon+diflufenican	10.56	10.41	17.44	17.48	48.44	48.21	1.75	1.70	36.76	36.52	337.00	304.7
Isoproturon	10.11	10.07	17.09	17.11	43.67	43.55	1.47	1.44	34.89	34.56	313.00	297.2
Mesosulfuron-methyl	10.00	9.96	17.03	16.87	38.89	38.59	1.34	1.35	34.87	34.42	293.83	271.8
Hand weeding	9.11	9.14	14.24	14.37	35.56	35.32	1.20	1.21	33.65	33.11	279.00	259.7
Unweeded	8.44	8.58	14.20	14.27	30.78	30.88	1.12	1.11	33.33	32.79	264.75	241.4
LSD at 5%	0.29	0.36	0.12	0.17	2.13	2.06	0.09	0.11	NS	NS	11.71	13.08
Zinc levels												
Untreated	8.12	8.13	14.14	14.41	31.88	31.50	1.17	1.16	30.97	30.58	261.70	243.4
1 g Zn L^{-1}	9.68	9.57	15.77	15.50	39.60	38.64	1.29	1.24	33.89	33.13	289.00	256.7
2 g Zn L^{-1}	10.06	10.11	16.93	17.00	42.21	42.23	1.46	1.46	37.14	36.56	321.54	293.9
3 g Zn L^{-1}	10.39	10.35	17.22	17.32	42.38	42.30	1.55	1.54	37.36	37.09	325.30	309.4
LSD at 5%	0.31	0.24	0.11	0.13	1.41	1.30	0.11	0.13	1.32	1.28	14.17	12.21

Table 5. Grain and straw yields of wheat as affected by weed control treatments and Zn application during 2012/2013 and 2013/2014 seasons.

Treatments	Grain yield ha^{-1}(ton)		Straw yield ha^{-1} (ton)	
	2012/13	2013/14	2012/13	2013/14
Weed control				
Pyroxsulam	3.86	3.75	7.50	7.20
Isoproturon+diflufenican	4.60	4.39	9.62	9.10
Isoproturon	4.46	4.26	8.16	7.70
Mesosulfuron-methyl	4.28	3.86	7.90	7.44
Hand weeding	3.77	3.70	7.42	7.30
Unweeded	2.97	2.78	6.72	6.84
LSD at 5%	0.32	0.32	0.45	0.39
Zinc levels				
Untreated	3.24	3.17	7.10	6.46
1 g Zn L^{-1}	3.68	3.57	7.88	7.80
2 g Zn L^{-1}	4.30	4.09	8.14	8.04
3 g Zn L^{-1}	4.53	4.30	8.40	8.30
LSD at 5%	0.14	0.19	0.23	0.25

Effect of zinc levels

The results in Tables 4 and 5 indicated that foliar application of Zn had significant effect on yield and its attributes. Zn application at a rate of 3 g L^{-1} significantly produced the highest grain yield and its components compared to untreated plants. This increase in grain yield amounted to 39.8 and 35.6% more than untreated plants. In this connection, [34] reported that Zn exerts a great influence on basic plant life processes, such as (i) nitrogen metabolism - uptake of nitrogen and protein quality; (ii) photosynthesis - chlorophyll synthesis and carbon anhydrase activity. The present results are supported by[35] who reported that foliar application of micronutrients at tillering, jointing and booting stages help in improving yield of wheat. Also, [9, 36] reported that Zn plays an important role in the biomass production. These results coincide with those obtained by [30, 32, 37].

Interaction effect

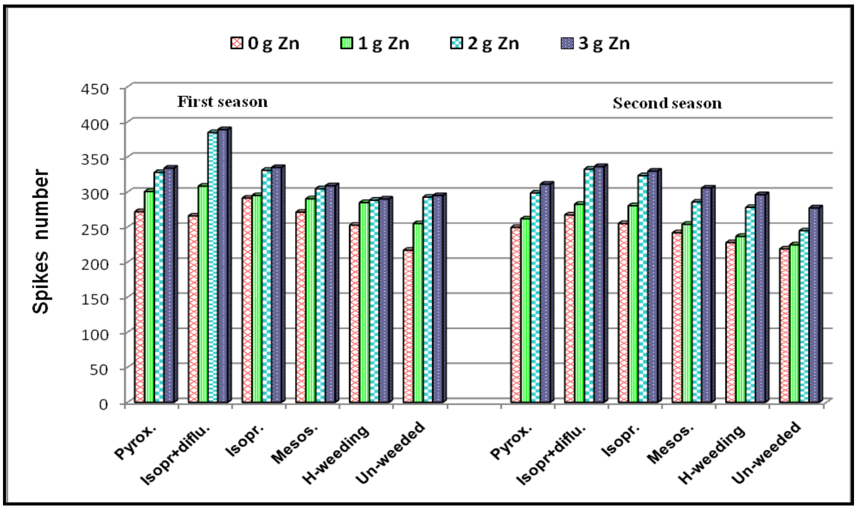

Fig 3. Effect of weed control and zinc application on spikes number m^{-2}.

Analysis of data revealed that the combined effect of weed control treatments and Zn levels significantly affected spikes number m^{-2} and grain yield ha^{-1}. Maximum spikes number (Fig. 3) and grain yield ha^{-1} (Fig. 4) were obtained with Isoproturon+ diflufenican combined with application of Zn treatment at the rate of 3 g L^{-1}. Meanwhile, the lowest ones were obtained with the unweeded treatment and unsprayed zinc plants. The same conclusion was mentioned by[31].

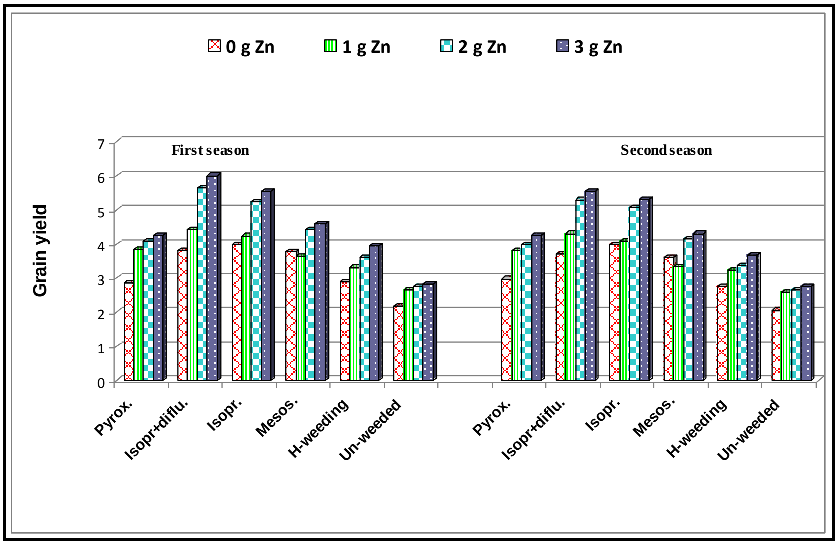

Fig 4. Effect of weed control and zinc application on grain yield (ton ha^{-1})

3.4. Chemical composition of flag leaf and wheat grains

Effect of weed management

Considerable effects of weed control treatments on chemical composition of wheat flag leaves and grains were observed (Table 6). All herbicide application significantly improved protein, phosphorus percentage and zinc mg/kg of wheat flag leaves and grains, while potassium content was not significantly affected. Isoproturon+ diflufenican recorded the highest values of previous parameters. Meanwhile, the lowest values were obtained with unweeded treatments. These results may be due to the less competition for nutrients, water and light through limiting weeds infestation with herbicidal and hand weeded treatments resulting to increasing the uptake of different nutrients. Similar results were obtained by[28, 29, 38].

Effect of zinc levels

Averages of protein, phosphorus and potassium percentage as well as zinc mg/kg of wheat flag leaves and grains were appreciably influenced by zinc levels as shown in Table 6. In this respect, with each increase in Zn level there was a progressive increase in previous parameters except phosphorus percent. Zinc-enriched plant is also of great importance resulting in better higher stress tolerance on potentially Zn-deficient soils and improved grain elements content. The mechanism by which zinc deficiency affects protein synthesis is considered to be due to a reduction in RNA and the deformation and reduction of ribosomes[6]. In this concern, [32] stated that foliar Zn application significantly improved the grain Zn concentration of maize by 27% and 37% as well as wheat by 28% and 89% during the first and second growing seasons, respectively. [39] reported that Zn-deficient plants reduced the rate of protein synthesis and protein content drastically. Also, [40] indicated that Zn application significantly increased grain protein and enhanced grain Zn concentration, while simultaneously reduced grain P concentration. The similar conclusion was mentioned by[30, 41,42].

Effect of Interaction

The interaction between the weed control treatments and Zn application was not significant for chemical composition of flag leaves and wheat grains in the two seasons.

Table 6. Chemical composition of flag leaf and grains of wheat as affected by weed control treatments and Zn application during 2012/2013 and 2013/2014 seasons.

Treatments	**Flag leaf**								**Grains**							
	Crude protein %		P %		K %		Zn (mg/kg DW)		Crude protein %		P %		K %		Zn (mg/kg DW)	
	2012/13	**2013/14**	**2012/13**	**2013/14**	**2012/13**	**2013/14**	**2012/13**	**2013/14**	**2012/13**	**2013/14**	**2012/13**	**2013/14**	**2012/13**	**2013/14**	**2012/13**	**2013/14**
Weed control																
Pyroxsulam	2.49	2.41	0.210	0.217	2.74	2.70	32.83	31.70	10.62	10.45	0.378	0.391	2.05	2.07	38.56	38.11
Isoproturon+diflufenican	2.87	2.70	0.281	0.295	3.37	3.21	37.02	35.11	11.69	11.56	0.444	0.452	2.31	2.22	46.13	45.78
Isoproturon	2.76	2.65	0.237	0.241	3.18	3.11	35.83	34.50	11.30	11.26	0.419	0.423	2.26	2.13	45.00	45.00
Mesosulfuron-methyl	2.63	2.53	0.209	0.211	2.91	2.80	34.50	33.90	11.02	11.10	0.397	0.407	2.17	2.16	41.30	41.11
Hand weeding	2.34	2.36	0.189	0.195	2.62	2.56	27.73	28.17	10.13	10.35	0.364	0.379	1.88	1.96	35.07	35.12
Unweeded	2.17	2.22	0.161	0.171	2.25	2.30	24.45	25.11	9.19	9.28	0.347	0.353	1.65	1.79	31.61	32.17
LSD at 5%	0.27	0.34	0.17	0.19	NS	NS	2.66	2.29	0.65	0.77	0.016	0.014	NS	NS	2.31	2.22
Zinc levels																
Untreated	2.40	2.35	0.198	0.206	2.15	2.23	29.22	29.31	9.92	9.70	0.381	0.398	1.90	1.91	38.36	37.73
1 g Zn L^{-1}	2.50	2.42	0.210	0.219	2.87	2.93	32.18	31.20	10.56	10.70	0.390	0.385	2.05	2.03	38.80	39.80
2 g Zn L^{-1}	2.61	2.55	0.222	0.225	3.02	3.10	33.10	32.40	10.78	11.12	0.397	0.410	2.09	2.11	39.88	40.30
3 g Zn L^{-1}	2.65	2.60	0.230	0.240	3.08	3.16	33.70	32.76	11.38	11.19	0.400	0.414	2.14	2.17	41.38	40.40
LSD at 5%	0.13	0.11	NS	NS	0.18	0.24	0.22	0.43	0.76	0.63	NS	NS	0.07	0.09	0.16	0.12

4. Conclusion

Weeds infestation is one of the major threats to crop yield. Post emergence herbicides were supported the weed control and improved growth and yield of wheat. Research programs should be initiated focusing on development of most efficient Zn application for promoting Zn uptake and maximizing nutritional values and yield. It could be concluded from this study that selective herbicides (Isoproturon + diflufenican) integrated with Zn application at a rate of 3 g L^{-1} could effectively improve control of broadleaved and narrow-leaved weeds, growth and productivity of wheat.

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