Yield and Yield Components of Durum Wheat as Influenced by Humic Acid, Zinc and Iron Application

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ABSTRACT

A two-year field study was carried out at the Agricultural Experiment Station, Alexandria University in 2017/2018 and 2018/2019 winter seasons to investigate the effect of foliar spraying of humic acid (HA) (0 and 2.4 kg/ha) and both Fe and Zn micronutrients (0, 480 and 960 g/ha of $FeSO_4$ and/or $ZnSO_4$, respectively) on three durum wheat cultivars (Casino, Bani Sweif6 and Sohag3). The experiment was laid out in split-plot design with three replications, where combinations of HA levels and cultivars occupied the main plots, while combinations of Fe and Zn levels were randomly allocated to the sub plots.

Bani Sweif6 was superior to the other two cultivars for all studied grain yield and yield components except for 100-grain weight. Application of humic acid increased grain yield of Bani Sweif6 and Sohag3, but negatively affected that of Casino. Application of 480 g/ha of both $FeSO_4$ and $ZnSO_4$ gave the highest values with HA application in Bani Sweif6 and Sohag3, and without HA application for Casino. It is recommended to spray Bani Sweif6 and Sohag3 with 2.4 kg/ha HA and 480 g/ha of both Fe and Zn, while more studies are needed to determine the suitable level of HA spraying for Casino cultivar.

Keywords: Durum wheat, humic acid, iron, zinc, grain yield, yield components.

INTRODUCTION

Durum wheat (*Triticum durum*) is of significance as a food crop used to make traditional foods. It is widely adapted and it is mostly grown in semi-arid regions. World production of durum wheats is increasing for its use in producing healthy, low-glycemic-index foods (Kadkol and Sissons, 2016). Increasing wheat productivity in Egypt, as a representative to arid or semi-arid regions, is confronted with many problems including water shortage in non-irrigated areas, poor soil fertility in marginal areas in addition to soil salinity or sodicity. Hence, application of soil ammendments and spraying with essential micronutrients is a necessity to ensure a profitable level of productivity for wheat in these areas, beside cultivation of the suitable wheat cultivar.

Humic acid (HA) is an organic substance that has beneficial effects on wheat growth and productivity such as increasing photosynthetic metabolism, water retention and bioavailability of micronutrients throughout the growing period of wheat plants (Mackowiak *et al*., 2001, Delfine *et al*., 2005). Antoun *et al*. (2010) found that application of humic acid increased grain and straw yields, and 1000-grain weight. Khan *et al*. (2010) reported that application of 3.0 kg/ha humic acid increased grain yield of wheat by 24% compared to the control. Similarly, Doorodian *et al*. (2015) found that application of humic acid at the rate of 8L/ha significantly increased number of tillers and spikes/plant, number of grains/spike, 1000-grain weight and grain yield. Moreover, Yasin and EL-sobky (2017) reported that wheat plants treated with 4 kg/fed humic acid had higher number of spikes/m^2, number of grains/spike, 1000-kernel weight, biological, straw and grain yields compared to untreated control.

Micronutrients, including iron and zinc, are essential elements for improving plant growth and mediate several biochemical processes in plants. The role of iron and zinc in promoting wheat plants growth and productivity has been established by several researchers. Hussain *et al*. (2005) reported that spraying wheat plants with micronutrients including Zn and Fe increased grain and biological yields, but did not affect harvest index. Gomaa *et al*. (2015) found that application of zinc and iron significantly increased number of spikes/m^2, number of grains/spike, 1000-grain weight, grain, straw and biological yields and harvest index. Similar results were reported by Ramzan *et al*. (2020) and Jalal *et al*. (2020).

The present investigation was carried out to study the effect of humic acid application combined with foliar spraying with zinc and iron on yield and yield components of two local and one introduced durum wheat cultivars.

MATERIAL AND METHODS

Two field experiments were carried out at the Agricultural Research Station, Alexandria University, Egypt, during the two successive wheat growing winter seasons of 2017/2018 and 2018/2019 to investigate of the effect of spraying with humic acid and micronutrients (Fe, Zn) and their interactions on growth and productivity of three durum wheat cultivars, two local (Bani Sweif6 and Sohag3) and one introduced from Libya (Casino).

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Table 1. Soil Physical and chemical properties as an average of the two seasons

Soil character	Average	Chemical properties	Average	Chemical properties	Average
Physical		Av. N%	0.01	Na^{+} meq/ L	20.21
properties		Av. P meq/ L	9.60	Zn^{+2} PPm	2.5
Sand %	62.5	Av. K meq/ L	0.84	Fe^{+2} PPm	2.9
Silt %	20.0	O.M. %	0.52	Cl^{-} meq/ L	15.00
Clay %	17.5	pH	8.36	CO_3^{-2} meq/ L	2.40
		Ec (dS/m)	2.23	HCO_3^{-} meq/ L	4.00
Texture	Sand loam	Ca^{+2} meq/ L	7.50	$CaCO_3$ (%)	9.86
		Mg^{+2} meq/ L	4.00	SAR	5.96

The experiments were sown after maize in the two seasons. Soil physical and chemical characteristics in both seasons were determined using soil samples collected before sowing at each experimental site from 0-30 cm depth for analysis according to Page et al. (1982) and Klute (1986) The full analysis of soil samples are presented in Table (1)

Each experiment included four factors, i.e. three durum wheat cultivars, two levels of humic acid (0 and 2.4 kg/ha) sprayed after 30 days from sowing (DAS). Three levels of Fe (0, 480 and 960 g/ha as iron sulphate) sprayed in two equal doses after 30 and 45 DAS and three levels of Zn (0, 480 and 960 g/ha as zinc sulphate) sprayed in two equal doses after 30 and 45 DAS. Sowing date was 18 November in the two seasons. Seeding rate in the two seasons was 120 kg /ha for the three cultivars. Phosphorus was applied at the rate of 38 kg/ha, as calcium monophosphate (15.5% P_2O_5) during seed bed preparation. Nitrogen was applied at the rate of 192 kg/ha, as ammonium nitrate (33.5%N) in three doses, 48 kg N/ha during land preparation and the remaining quantity was applied in two equal doses, each of 72 kg N/ha, applied just before the second and third irrigations after sowing. Potassium, as potassium sulphate (48%K_2O), was applied at the rate of 57.6 kg K_2O /ha at 30 DAS. Cultural practices, such as pests control and irrigation were carried out as recommended for durum wheat production in Alexandria region.

The experimental design in the two seasons was a split plot with three replications. Combinations of wheat cultivars and humic acid levels occupied the main plots, whereas combinations of Fe and Zn levels were allocated to the sub plots. Sub plots area was 3.6 m^2 comprising four rows, each 3 m long and 0.3 m wide.

At harvest, yield and yield components were recorded. These included: number of spikes/m^2 (NS/m^2), number of grains/spike (NGS), 100 grain weight (HGW) (in grams), biological yield (BY) (ton/ha), grain yield (GY) (ton/ha).

Data were statistically analyzed according to Gomez and Gomez (1984) using SAS ver 9.1 (2002). Least significant differences values at 0.05 level of probability were used to compare the differences between treatments means. Quadratic regression analysis and equations were performed using Curve Expert, ver. 1.34 (Hyams, 2005).

RESULTS AND DISCUSSION

Results

Analysis of variance (Table 2) indicated that all yield and yield components were significantly affected by the four-factor interaction, in the two seasons, except number of grains/spike which was significantly influenced by cultivars in the two seasons, H*V in the first season only, zinc levels in the two seasons, Fe*H*V and Zn*H*V in the second season only.

Means of the levels of studied factors (Table3) indicated that Bani Sweif 6 gave higher values than the other two cultivars for the studied traits except for 100-grain weight, in the two seasons, where Sohag3 exhibited heavier grain weight. Spraying with 2.4 kg/ha humic acid gave, generally, higher values for all studied yield attributes compared to control. Moreover, spraying with the intermediate level (480 g/ha) of each of Fe and Zn gave higher values for all yield and yield components compared to control or the highest level of each (960 g/ha). However, the response of the studied durum wheat cultivars differed with application of humic acid, Fe and Zn levels as indicated by the significance of the various interactions between studied factors.

Means for number of spikes/m^2 as affected by the four-factor interaction are presented in (Table 4). The data revealed that the three cultivars recorded the significantly highest values for that character with spraying with humic acid at 2.4 kg/ha, and the intermediate level (480 g/ha) of both Fe and Zn.

Table 2. Mean squares for No. of spikes/m², No. of grains/spike, 100- grain weight biological yield, grain yield and as affected by wheat cultivar, humic acid, iron and zinc levels and their interactions two seasons

S.O.V	d.f	NS/m²		NG /S		HGW		BY		GY	
		S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
Cultivar (C)	2	**	**	**	**	**	**	**	**	**	**
Humic acid(H)	1	**	**	N.S	N.S	**	**	N.S	**	**	**
H*V	2	**	N.S	**	N.S	**	**	N.S	**	**	**
Ea	10	52.48	122.70	32.31	59.27	0.016	0.005	0.455	0.594	0.036	0.052
Iron(Fe)	2	**	**	N.S	N.S	**	**	**	**	**	**
Zinc(Zn)	2	**	**	*	*	**	**	**	**	**	**
Zn*V	4	N.S	**	N.S	N.S	**	**	**	N.S	**	N.S
Fe*V	4	**	**	N.S	N.S	**	**	**	**	**	**
Fe*H	2	**	**	N.S	N.S	**	**	**	N.S	**	**
Zn*H	2	**	**	N.S	N.S	**	**	N.S	N.S	**	**
Zn*Fe	4	**	**	N.S	N.S	**	**	**	**	**	**
Fe*H*V	4	**	**	N.S	*	**	**	N.S	**	**	**
Zn*H*V	4	**	**	N.S	**	**	**	**	**	**	**
Zn*Fe*H	4	**	**	N.S	N.S	**	**	**	**	**	**
Zn*Fe*V	8	**	**	N.S	N.S	**	**	**	**	**	**
Zn*Fe*H*V	8	**	**	N.S	N.S	**	**	**	**	**	**
Eb	96	64.69	121.2	29.96	30.23	0.012	0.009	0.425	0.428	0.033	0.038

*, ** significant at 0.05 and 0.01 probability levels, respectively.
S1: 2017/2018 season
S2: 2018/2019 season

Table 3. Means for No. of spikes/m², No. of grains/spike, 100-grain weight biological yield, grain yield, as affected by wheat cultivar, humic acid, iron and zinc levels in the two seasons

Treatments	NS/m²		NG /S		HGW(g)		BY(ton/ha)		GY(ton/ha)	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
Cultivar										
Casino	316.01c	322.42c	49.26b	55.33b	5.08b	5.28b	7.04c	9.89b	1.87c	2.72c
Bani sweif6	351.53a	357.13a	53.69a	59.96a	5.02b	5.16c	9.55a	11.54a	2.94a	3.99a
Sohag3	341.35b	347.38b	47.11b	52.19b	5.27a	5.42a	7.50b	9.99b	2.39b	3.27b
L.S.D. 0.05	3.10	4.74	2.43	3.30	0.055	0.032	0.289	0.330	0.081	0.098
Humic acid levels kg/ha										
Control	322.51b	329.9b	49.72a	56.30a	4.93b	5.11b	7.97a	10.07b	2.23b	3.26b
2.4	350.08a	354.72a	50.32a	55.33a	5.32a	5.46a	8.09a	10.88a	2.57a	3.39a
L.S.D. 0.05	2.53	3.87	N.S	N.S	0.044	0.026	N.S	0.269	0.066	0.080
Iron levels g/ha										
Control	331.96b	338.59b	50.33a	56.17a	5.01b	5.19b	8.13b	10.19b	2.39b	3.19b
480	357.61a	362.22a	49.68a	55.63a	5.39a	5.54a	9.02a	11.47a	2.80a	3.79a
960	319.33c	326.13c	50.06a	55.65a	4.97c	5.13c	6.94c	9.77c	2.02c	3.00c
L.S.D. 0.05	3.07	4.20	N.S	N.S	0.042	0.037	0.249	0.250	0.069	0.074
Zinc levels g/ha										
Control	334.16b	340.37b	49.43b	56.32a	5.03b	5.22b	7.60b	9.91b	2.28b	3.15b
480	354.11a	358.63a	51.69a	56.82a	5.38a	5.49a	9.46a	11.47a	2.89a	3.73a
960	320.63c	327.94c	48.94b	54.32b	4.97c	5.16c	7.03c	10.05b	2.03c	3.10b
L.S.D. 0.05	3.07	4.20	2.09	2.10	0.04	0.04	0.25	0.25	0.07	0.07

Spraying of the highest level of Fe or Zn, or both, decreased significantly number of spikes/m^2 even with application of humic acid. However, in Casino cultivar, application of humic acid improved the values of that character at highest levels of Fe or Zn, whereas, in Bani Sweif6 and Sohag3, the lowest values were obtained with spraying of humic acid and Fe and Zn at 960 g/ha. The same trend of data was observed for 100-grain weight, with the exception that humic acid application improved that character at highest Fe and Zn levels compared to non-spraying of humic acid (Table 4) in all cultivars.

Table 4. Means of No. of spikes/m^2 (NS/m^2) and 100 - grain weight (HWG)as affected by wheat cultivar * humic acid kg/ha * iron g/ha* zinc g/ha interactionat in the two seasons

Cultivars	Humic acid kg/ha	Iron g/ha	Zinc g/ha	NS/m^2		HGW (g)	
				S_1	S_2	S_1	S_2
Casino	0	0	0	253.6	260.3	4.23	4.45
Casino	0	0	480	326.0	332.3	5.04	5.23
Casino	0	0	960	307.0	322.6	4.98	5.20
Casino	0	480	0	343.6	350.3	5.26	5.47
Casino	0	480	480	354.0	362.0	5.53	5.69
Casino	0	480	960	300.3	311.6	5.24	5.42
Casino	0	960	0	300.0	314.0	4.95	5.13
Casino	0	960	480	263.0	268.6	5.12	5.22
Casino	0	960	960	244.3	253.0	4.62	4.94
Casino	2.4	0	0	331.0	327.0	4.40	4.53
Casino	2.4	0	480	342.0	348.3	5.17	5.42
Casino	2.4	0	960	319.0	329.0	5.15	5.55
Casino	2.4	480	0	340.0	348.3	5.13	5.41
Casino	2.4	480	480	423.3	401.0	6.15	6.24
Casino	2.4	480	960	318.0	324.6	5.18	5.33
Casino	2.4	960	0	311.3	319.3	5.22	5.34
Casino	2.4	960	480	311.6	321.0	5.17	5.28
Casino	2.4	960	960	300.0	310.0	4.96	5.25
Bani sweif6	0	0	0	326.6	336.0	5.11	5.32
Bani sweif6	0	0	480	336.6	345.0	5.16	5.22
Bani sweif6	0	0	960	323.6	331.3	4.53	4.67
Bani sweif6	0	480	0	338.0	343.3	5.15	5.37
Bani sweif6	0	480	480	362.2	369.3	5.24	5.20
Bani sweif6	0	480	960	344.0	347.3	4.35	4.48
Bani sweif6	0	960	0	326.3	334.3	4.56	4.96
Bani sweif6	0	960	480	347.0	351.6	4.37	4.44
Bani sweif6	0	960	960	337.3	342.0	4.28	4.35
Bani sweif6	2.4	0	0	363.6	370.0	5.20	5.38
Bani sweif6	2.4	0	480	376.3	379.0	5.17	5.28
Bani sweif6	2.4	0	960	355.3	361.0	5.14	5.39
Bani sweif6	2.4	480	0	389.0	390.0	5.20	5.36
Bani sweif6	2.4	480	480	442.6	446.6	6.44	6.43
Bani sweif6	2.4	480	960	337.0	342.3	5.27	5.43
Bani sweif6	2.4	960	0	356.3	360.0	5.15	5.33
Bani sweif6	2.4	960	480	346.0	351.6	5.45	5.54
Bani sweif6	2.4	960	960	319.0	327.3	4.75	4.77

Continue table 4.

Cultivars	Humic acid kg/ha	Iron g/ha	Zinc g/ha	N S		HGW (g)	
				S_1	S_2	S_1	S_2
Sohag3	0	0	0	316.0	322.6	4.90	4.97
Sohag3	0	0	480	330.6	338.0	5.00	5.25
Sohag3	0	0	960	312.6	319.6	5.05	5.23
Sohag3	0	480	0	331.3	338.3	5.01	5.32
Sohag3	0	480	480	354.6	360.0	5.58	5.80
Sohag3	0	480	960	337.6	344.6	5.18	5.34
Sohag3	0	960	0	318.6	327.0	4.97	5.12
Sohag3	0	960	480	344.0	346.6	5.11	5.24
Sohag3	0	960	960	328.0	335.0	4.74	5.12
Sohag3	2.4	0	0	349.3	356.6	5.11	5.30
Sohag3	2.4	0	480	357.0	362.6	5.61	5.70
Sohag3	2.4	0	960	348.6	353.0	5.37	5.50
Sohag3	2.4	480	0	373.6	378.6	5.69	5.78
Sohag3	2.4	480	480	416.0	424.3	6.12	6.17
Sohag3	2.4	480	960	331.0	337.0	5.41	5.51
Sohag3	2.4	960	0	346.3	350.3	5.35	5.46
Sohag3	2.4	960	480	340.3	347.0	5.46	5.52
Sohag3	2.4	960	960	308.3	311.3	5.28	5.41
	L.S.D. 0.05			39.08	17.83	0.18	0.15

Table 5. Means of number of grains/spike as affected by cultivars * humic acid interaction in the first season (S_1)

Cultivars	Humic acid kg/ha	No. of grains/spike S_1
Casino	0	51.296
Casino	2.4	47.222
Bani sweif6	0	53.814
Bani sweif6	2.4	53.555
Sohag3	0	44.037
Sohag3	2.4	50.185
L.S.D. 0.05		3.447

With regard to number of grains/spike, the cultivar* humic acid interaction in the first season (Table 5) revealed that Casino cultivars responded significantly and negatively, Bani Sweif6 showed no significant response, while Sohage3 responed significantly and positively to spray application of 2.4 kg/ha humic acid. Moreover the three factor interaction, cultivar*humic acid*iron concentration in the second season (Table 6) showed that Casino cultivars gave the highest value for that character with 480 g Fe/ha without humic acid application, while Bani Sweif6 gave the highest means with 480 g Fe/ha without humic acid, application of humic acid only, and application of humic acid + 960 g Fe/ha. On the other hand, Sohag3 gave the highest value with control and spraying with 960 g Fe/ha only. In addition, the three factor interaction, cultivar*humic acid*zinc (Table 7), revealed that Casino responded positively to 480 and 960 g Zn/ha without humic acid, Bani Sweif6 gave the highest value at 480 g Zn/ha + 2.4 kg/ha humic acid, and Sohag3 had the highest number of grains/spike when sprayed with 480 g Zn/ha with and without application of humic acid in the second season.

Concerning biological yield (BY) (Table 8), the four-factor interaction indicated that Casino gave the highest values in absence of humic acid with different combinations of levels of Fe and or Zn. However, application of the highest level of both micronutrients reduced biological yield significantly in the two seasons. On the other hand, Bani Sweif6 and sohag3 cultivars gave the highest biological yield, in the two seasons, with spraying of humic acid and both micronutrients at the intermediate level of 480 g/ha. Moreover, biological yield of Bani sweif6 cultivar decreased significantly with application of the two micronutrients at 960 g/ha with or without humic acid application.

With regard to grain yield (GY), means of the four-factor interaction presented in (Table 8) revealed that grain yield followed the same trend of biological yield for Bani Sweif6 and Sohag3, whereas Casino, in the first season showed a positive response for humic acid application and Zn application at 480 g/ha and which was at par with application of Zn and Fe at 480 g/ha (2.92 and 2.76 t/ha, respectively). However, in the second season, humic acid application had a negative effect on grain yield for both Bani Sweif6 and Sohag3, where the highest grain yield values were recorded for spraying with humic acid at 2.4 kg/ha and spraying both Fe and Zn at the rate of 480 g/ha (4.72 and 5.67 and 3.78 and 4.76t/ha for the first and second season, respectively).

Table 6. Means of No. of grains/spike as affected by Cultivars * humic acid * iron interaction in the second season (S_2)

Cultivars	Humic acid kg/ha	Iron g/ha	No. of grains/spike S_2
casino	0	0	55.777
casino	0	480	60.666
casino	0	960	52.000
casino	2.4	0	53.888
casino	2.4	480	53.444
casino	2.4	960	56.222
Bani sweif6	0	0	58.555
Bani sweif6	0	480	60.888
Bani sweif6	0	960	59.444
Bani sweif6	2.4	0	61.444
Bani sweif6	2.4	480	58.666
Bani sweif6	2.4	960	60.777
Sohag3	0	0	54.777
Sohag3	0	480	49.666
Sohag3	0	960	54.888
Sohag3	2.4	0	52.555
Sohag3	2.4	480	50.444
Sohag3	2.4	960	50.555
	L.S.D. 0.05		1.053

Table 7. Means of No. of grains/spike as affected by Cultivars * humic acid * zinc interaction in the second season (S_2)

Cultivars	Humic acid kg/ha	Zinc g/ha	No. of grains/spike S_2
Casino	0	0	52.888
Casino	0	480	57.777
Casino	0	960	57.777
Casino	2.4	0	55.444
Casino	2.4	480	53.000
Casino	2.4	960	55.111
Bani sweif6	0	0	61.333
Bani sweif6	0	480	56.000
Bani sweif6	0	960	61.555
Bani sweif6	2.4	0	56.777
Bani sweif6	2.4	480	63.000
Bani sweif6	2.4	960	61.111
Sohag3	0	0	51.777
Sohag3	0	480	55.333
Sohag3	0	960	52.222
Sohag3	2.4	0	47.666
Sohag3	2.4	480	55.777
Sohag3	2.4	960	50.111
	L.S.D. 0.05		1.053

Table 8. Means of Biological yield and Grain yield as affected by Cultivars * humic acid * iron *zinc interaction in the two seasons

Cultivars	Humic acid kg/ha	Iron g/ha	Zinc g/ha	BY (t /ha)		GY (t /ha)	
				S_1	S_2	S_1	S_2
Casino	0	0	0	7.04	7.70	1.78	2.03
Casino	0	0	480	8.57	11.86	2.22	3.12
Casino	0	0	960	8.25	11.76	2.03	3.05
Casino	0	480	0	4.90	10.32	1.27	2.78
Casino	0	480	480	9.52	12.24	2.68	3.59
Casino	0	480	960	8.34	12.64	2.06	3.30
Casino	0	960	0	8.39	12.2	2.20	3.24
Casino	0	960	480	4.81	12.12	1.32	3.49
Casino	0	960	960	3.65	8.16	0.88	2.10
Casino	2.4	0	0	5.56	10.19	1.46	2.82
Casino	2.4	0	480	10.38	9.28	2.92	2.83
Casino	2.4	0	960	5.83	10.24	1.54	2.81
Casino	2.4	480	0	8.40	8.63	2.36	2.49
Casino	2.4	480	480	9.75	11.06	2.76	3.23
Casino	2.4	480	960	6.42	8.63	1.73	2.45
Casino	2.4	960	0	5.90	7.09	1.63	2.03
Casino	2.4	960	480	6.17	7.86	1.64	2.13
Casino	2.4	960	960	4.96	6.36	1.25	1.67
Bani sweif6	0	0	0	8.58	9.56	2.44	2.93
Bani sweif6	0	0	480	10.96	12.12	3.19	3.99
Bani sweif6	0	0	960	7.79	12.13	2.13	3.86
Bani sweif6	0	480	0	10.45	12.25	2.86	3.89
Bani sweif6	0	480	480	11.95	14.49	3.51	4.87
Bani sweif6	0	480	960	8.38	11.85	2.30	3.87
Bani sweif6	0	960	0	7.70	12.08	2.27	3.87
Bani sweif6	0	960	480	12.42	12.66	3.57	4.02
Bani sweif6	0	960	960	5.70	8.48	1.62	2.65
Bani sweif6	2.4	0	0	8.25	9.94	2.64	3.69
Bani sweif6	2.4	0	480	9.90	10.94	3.26	4.13
Bani sweif6	2.4	0	960	9.07	9.87	2.74	3.49
Bani sweif6	2.4	480	0	8.67	10.46	3.55	4.47
Bani sweif6	2.4	480	480	13.97	14.58	4.72	5.67
Bani sweif6	2.4	480	960	11.89	14.07	3.93	5.28
Bani sweif6	2.4	960	0	10.19	11.88	3.21	4.22
Bani sweif6	2.4	960	480	9.47	10.79	3.04	3.79
Bani sweif6	2.4	960	960	6.69	9.66	2.00	3.19

Continue table 8.

Cultivars	Humic acid kg/ha	Iron g/ha	Zinc g/ha	BY (t /ha)		GY (t /ha)	
				S_1	S_2	S_1	S_2
Sohag3	0	0	0	6.50	7.07	1.91	2.16
Sohag3	0	0	480	9.03	10.98	2.75	3.50
Sohag3	0	0	960	8.31	10.76	2.48	3.35
Sohag3	0	480	0	5.37	8.20	1.66	2.59
Sohag3	0	480	480	10.17	13.20	3.13	4.18
Sohag3	0	480	960	8.72	12.48	2.49	3.70
Sohag3	0	960	0	9.44	12.20	2.67	3.56
Sohag3	0	960	480	5.65	7.63	1.73	2.43
Sohag3	0	960	960	4.70	7.04	1.33	205
Sohag3	2.4	0	0	5.89	8.87	1.95	2.95
Sohag3	2.4	0	480	10.49	11.40	3.59	4.02
Sohag3	2.4	0	960	6.12	8.80	2.08	2.91
Sohag3	2.4	480	0	9.34	10.08	3.33	3.79
Sohag3	2.4	480	480	9.81	11.91	3.78	4.76
Sohag3	2.4	480	960	6.31	9.39	2.29	3.34
Sohag3	2.4	960	0	6.27	9.87	2.00	3.26
Sohag3	2.4	960	480	7.32	11.38	2.33	3.57
Sohag3	2.4	960	960	5.58	8.71	1.69	2.75
	L.S.D. 0.05			1.06	1.06	0.29	0.32

Quadratic regression for grain yield as influenced by Fe levels and humic acid application for the different cultivars (Fig 1 a to c) revealed that grain yield increased with application of Fe up to 420.86, 458.9 and 378.71 g/ha without humic acid application, and up 466.32, 471.92 and 431.48 g/ha with application of 2.4 kg/ha humic acid for Casino, Bani Sweif6 and Sohag3 cultivars, respectively, then decreased with higher application of Fe. Similar trend of results were found for Zn application (Fig 2 a to c) where grain yield increased with application of Zn levels up to 486.42, 442.99 and 517.94 g/ha without humic acid application, and up to 432.77, 440.8 and 435.59 g/ha with application of 2.4 kg/ha humic acid for Casino, Bani Sweif6 and Sohag3 cultivars, respectively, then decreased with higher levels of Zn.

Discussion

Increasing durum wheat productivity, as in all other field crops, require a critical balance of essential macro- and micronutrients. Soils with high pH values limit the availability of micronutrients as (Fe^{+2} and Zn^{+2}) to plants (Table 1). Hence, it is recommended to spray Fe and Zn directly to plants for increasing their availability. These two micronutrients play important roles in wheat growth and productivity since they are involved in several biochemical processes such as chlorophyll production and photosynthesis (Broadley *et al*., 2007; Fageria, 2009), affect the capacity for water uptake and transport (Kasim, 2007 and Disante *et al*. ,2010) and protein synthesis (Hansch and Mendel, 2009, Li *et al*. ,2012 and Finatto *et al*. ,2015).

Spraying with adequate concentrations of Fe and Zn micronutrients lead to enhancement of plant development and productivity. In the present study, spraying with both micronutrients at 480 g/ha of each, increased grain yield and yield components of the studed durum wheat cultivars. Several researchers reported that spraying with Fe and or Zn increased wheat grain yield (Habib,2009 and 2012, Armin *et al*. 2014 and Jalal *et al*. ,2020), 1000-grain weight (Pahlavan-Red and Pessarakli, 2009 and Monjezi *et al*. ,2013) number of tillers/m^2 (Nadim *et al*. ,2012 and Hassanein *et al*. ,2019), number of grains per spike (Mekkei and EL-Haggan, 2014 and Ramzan *et al*. ,2020) and biological yield (Arif *et al*. ,2017 and Khaksar and Lack, 2019).

The application of a higher dosage of Fe and Zn (960 g/ha of each) resulted in a negative impact on grain yield and yield components, and that may be attributed to several reasons including imbalance of the nutritive status of the wheat plant (Fageria, 2009), disrupting photosynthesis processes through inhibition of chlorophyll synthesis (Sandallio *et al*. ,2001) or through increasing oxidative injury which lead to disturbing metablic pathways affecting plant growth and development (Posmyk and Kontek, 2009). However, cultivars showed differential response to higher levels of Fe and Zn, where Casino showed higher tolerance to 960 g/ha of both micronutrients compared to Bani Sweif6 and Sohag3. Kabir *et al*. (2016) reported differential tolerance of wheat cultivars to excess iron. The ability of a wheat plant to tolerate excess Fe or Zn levels may be due to protective mechanisms established by the plant such as sequestration of excess micronutrients into the vacuoles (Tsonev and Lidon, 2012) or the presence of antioxidant enzymes defense mechanisms that play a vital role in alleviating the damage induced by heavy metal stress Li *et al*. ,2012, Kumar *et al*. ,2014 and Wu *et al*. ,2014).

The overall effect of humic acid (HA) application showed a positive response, significant or insignificant, to spraying of 2.4 kg/ha HA compared to the control. Several researchers reported significant positive effects of HA on grain yield (Antoun *et al*., 2010, Khan *et al*. ,2010 and Manzoor *et al*. ,2014), 1000-grain weight (Knapowski *et al*. ,2015 and AL-Erwy *et al*. ,2016), number of tiller plant (Yasin and EL-Sobky,2017 and Baqir and Zeboo, 2019) biological yield (Kandil *et al*. ,2016 and Dincsoy and Sonmez, 2019) and number of grains/spike (Doroodian *et al*. ,2015 and Yassin and EL-Sobky 2017) of wheat plants. However, durum wheat cultivars showed differential response to application of HA (Fig 1 and 2, a, b and c) where both cultivars Bani Sweif6 and Sohag3 showed a positive response to HA application compared to control with regard to grain yield, while Casino cultivar revealed a negative response to HA spraying. That may be attributed to the differences in genetic make up of cultivars which may influence their response to the applied dose of HA. Several studies have reported positive, negative and no effects of HA application to wheat in relation to employed cultivars (Mackowiak *et al*. ,2001, Delfine *et al*. ,2005, Jones et al. ,2007, Lodhi *et al*. ,2013. and Radwan *et al*,2014).

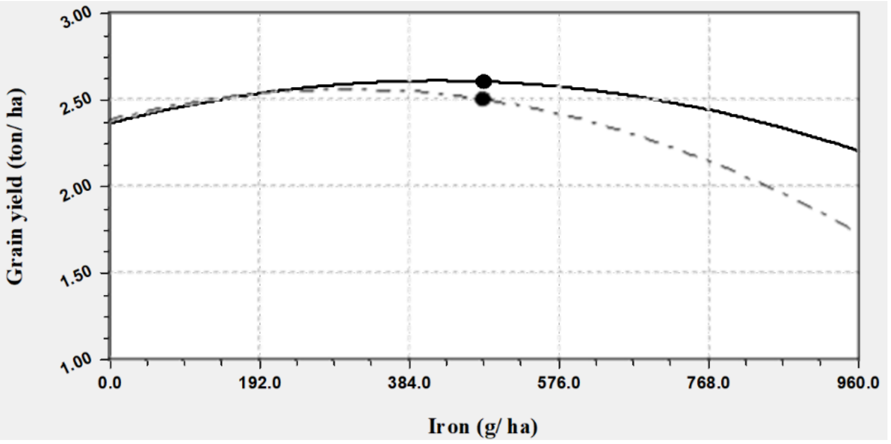

Fig. 1-a. 1- Casino

Without humic: $\hat{Y}= 2.37 + 1.17 *10^{-3} X -1.39 *10^{-6} X^2$(Optimal: 420.86 g/ ha)
With humic: $\hat{Y}= 2.30 + 1.80 *10^{-3} X -1.93 *10^{-6} X^2$ (Optimal: 466.32 g/ ha)

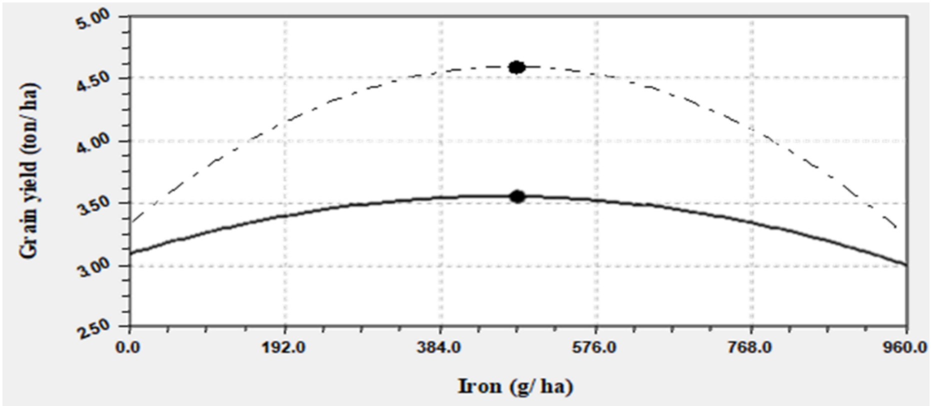

Fig. 1-b. 2- Bani Sweif 6

Without humic: $\hat{Y} = 3.09 + 2.01 * 10^{-3} X - 2.19 * 10^{-6} X^2$ (Optimal: 458.90 g/ ha)
With humic: $\hat{Y} = 3.33 + 5.38 * 10^{-3} X - 5.70 * 10^{-6} X^2$ (Optimal: 471.92 g/ ha)

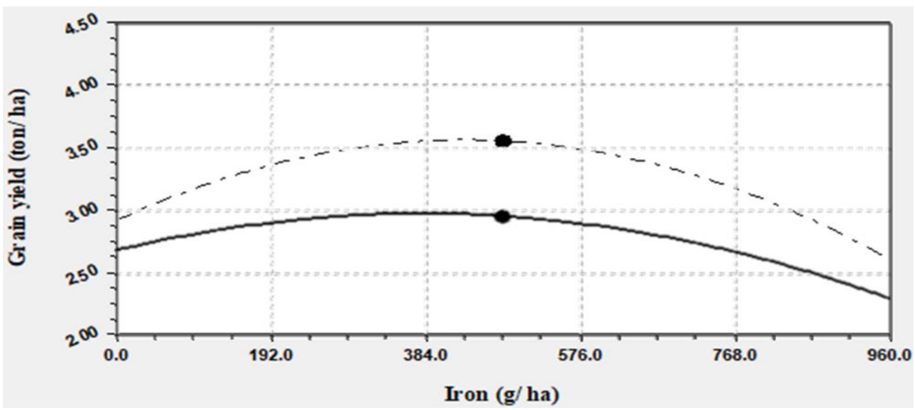

Fig. 1-c. 3- Sohag 3

Without humic: Ŷ= 2.69 + 1.53 *10-3 X -2.02 *10-6 X2 (Optimal: 378.71 g/ ha)
With humic: Ŷ= 2.92 + 2.96 *10-3 X -3.43 *10-6 X2 (Optimal: 431.48 g/ ha)

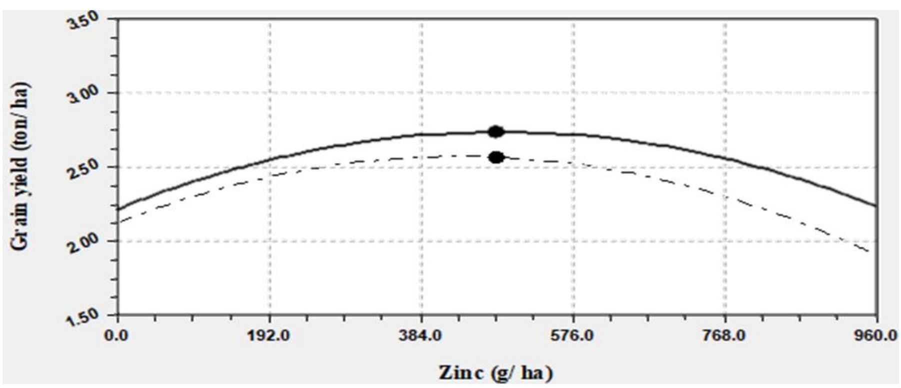

Fig. 2-a. 1- Casino

Without humic: $\hat{Y} = 2.22 + 2.15 * 10^{-3} X - 2.21 * 10^{-6} X^2$ (Optimal: 486.42 g/ ha)
With humic: $\hat{Y} = 2.13 + 2.06 * 10^{-3} X - 2.38 * 10^{-6} X^2$ (Optimal: 432.77 g/ ha)

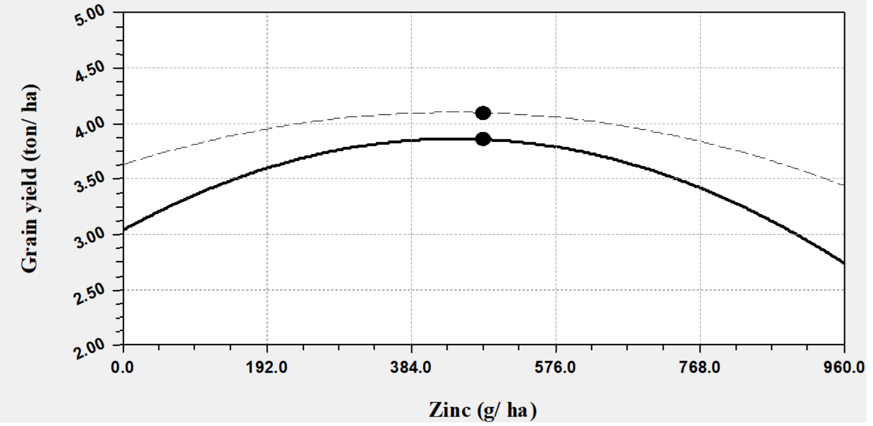

Fig. 2-b. 2- Bani Sweif 6

Without humic: Ŷ= 3.04 + 3.73 $*10^{-3}$ X -4.21 $*10^{-6}$ X^2 (Optimal: 442.99 g/ ha)
With humic: Ŷ= 3.63 + 2.16 $*10^{-3}$ X -2.45 $*10^{-6}$ X^2 (Optimal: 440.8 g/ ha)

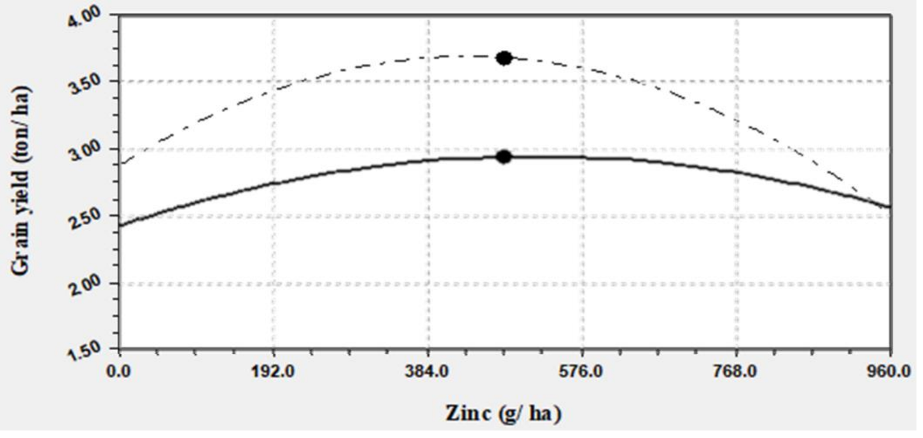

Fig 2-c. 3- Sohag 3

Without humic: Ŷ= 2.43 + 2.02 $*10^{-3}$ X -1.95 $*10^{-6}$ X^2 (Optimal: 517.94 g/ ha)
With humic: Ŷ= 2.88 + 3.72 $*10^{-3}$ X -4.27 $*10^{-6}$ X^2 (Optimal: 435.59 g/ ha)

CONCLUSIONS

The present investigation revealed that durum wheat varieties showed a positive response to spraying with both Fe and Zn at 480 g/ha of each in the form of $FeSO_4$ and $ZnSO_4$. Increasing the level of either/ or both micronutrients caused a significant reduction in yield and yield attributes due to imbalance of the nutritive status of the wheat plant or to indirect effects of excessive levels of the two micronutrients on biochemical process in plants. Durum wheat cultivars showed differential response to HA spraying at 2.4 kg/ha. That illustrates the need for further experimentation to determine the suitable dose of HA to the different durum wheat cultivars.

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الملخص العربي

تأثير إضافة حمض الهيوميك والزنك والحديد علي المحصول ومكوناته في القمح الصلب

إدريس عمر المهدي– سامي شعبان الطباخ– علي عيسي نوار– محمود حسن عبدالمنعم

نفذت تجربتان حقليتان بالمزرعه البحثية لجامعه الاسكندرية خلال الموسمين الشتويين ٢٠١٨/٢٠١٧ ،٢٠١٩/٢٠١٨ لدراسة تأثير الرش بحمض الهيوميك بمعدل (صفر، ٢.٤ كجم /هكتار) وكل من الحديد والزنك بمعدل (صفر، ٤٨٠، ٩٦٠ جم /هكتار لكل منهما علي صورة سلفات الحديدوز وسلفات الزنك)علي ثلاثة اصناف من القمح الديورم (Casino, Bani sweif6, Sohag3)وذلك في تصميم القطع المنشقة مرة واحدة في ثلاث مكررات حيث وزعت المعاملات الست الناتجة من تداخل مستويي حمض الهيوميك×الاصناف الثلاثة في القطع الرئيسية في حين وزعت المعاملات التسع الناتجة من تداخل المستويات الثلاثة من الزنك×المستويات الثلاثة من الحديد عشوائيا علي القطع الفرعية

وقد أظهرت النتائج تفوق الصنف Bani sweif6 علي الصنفين الآخرين في محصول الحبوب وجميع مكوناته عدا وزن المائة حبة في الموسمين– وقد ادي الرش بحمض الهيوميك لزيادة محصول الحبوب في كل من الصنفين Sohag3, Bani sweif6 في حين انخفض محصول الحبوب للصنف Casino . نتيجة الرش بحمض الهيوميك .من ناحية أخري أدي الرش بحمض الهيوميك والحديد والزنك بمعدل ٤٨٠ جم /هكتار من كل منهما الي تحقيق اقصي انتاجية من كل من الصنفين Sohag3, Bani sweif6 في حين أدي الرش بكل من الحديد والزنك بمعدل ٤٨٠ جم/ هكتار مع عدم الرش بحمض الهيوميك الي تحقيق اقصي محصول للصنف Casino. لذا يمكن التوصية برش صنفي القمح Sohag3, Bani sweif6 بحمض الهيوميك (٢.٤ كجم/هكتار) وسلفات الحديدوز وسلفات الزنك بمعدل (٤٨٠ جم/هكتار من كل منهما) – في حين يجب إجراء المزيد من الدرسات لتحديد المعدل المناسب من حمض الهيوميك اللازم إضافته للصنف Casino.