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 FeSO₄ and/or ZnSO₄, 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 FeSO₄ and ZnSO₄ 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 amendments 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/m², 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/m², 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).
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. %   | Na+ meq/ L          | 0.01    | Zn+2 Ppm          | 20.21   |
| sand %        | 62.5    | P meq/ L            | 9.60    | Fe+2 Ppm          | 2.5     |
| silt %        | 20.0    | K meq/ L            | 0.84    | Cl- meq/ L        | 2.9     |
| clay %        | 17.5    | O.M. %              | 0.52    | CO3+2 meq/ L      | 15.00   |
| Texture       | Sand loam | pH               | 8.36    | CaCO3 (%)         | 2.40    |
|               |         | Ec (dS/m)          | 2.23    | SAR                | 2.9     |
|               |         | Ca++ meq/ L        | 7.50    |                     | 2.5     |
|               |         | Mg++ meq/ L        | 4.00    |                     | 2.5     |

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% P2O5) 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%K2O), was applied at the rate of 57.6 kg K2O/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 m² 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/m² (NS/m²), 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 highest values for that character with the intermediate level (480 g/ha) of each of Fe and Zn and Zn gave higher values for all yield and yield components compared to control. Moreover, 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/m² 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 |
|-------|-----|-------|-------|------|-----|-----|
|       |     | S₁    | S₂    | S₁   | S₂  | S₁  |
| Cultivar (C) | 2   | **    | **    | **   | **  | **  |
| Humic acid(H) | 1   | **    | N.S   | N.S  | **  | N.S |
| H*V       | 2   | **    | N.S   | **   | N.S | **  |
| Ea        | 10  | 52.48 | 122.70| 32.31| 59.27| 0.016|
| Iron(Fe)  | 2   | **    | N.S   | **   | **  | **  |
| Zinc(Zn)  | 2   | **    | **    | *    | **  | **  |
| Zn*V      | 4   | N.S   | N.S   | N.S  | **  | **  |
| Fe*V      | 4   | N.S   | N.S   | N.S  | **  | **  |
| Fe*H      | 2   | **    | N.S   | **   | N.S | **  |
| Zn*H      | 2   | **    | N.S   | **   | N.S | **  |
| Zn*Fe     | 4   | **    | N.S   | **   | **  | **  |
| Fe*H*V    | 4   | **    | N.S   | N.S  | **  | **  |
| Zn*H*V    | 4   | **    | **    | **   | **  | **  |
| Zn*Fe*H   | 4   | **    | N.S   | **   | **  | **  |
| Zn*Fe*H*V| 8   | **    | **    | **   | **  | **  |

Eb 96 64.69 121.2 29.96 0.012 0.009 0.425 0.428 0.033 0.038 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) |
|-------------|-------|-------|--------|------------|------------|
|             | S₁    | S₂    | S₁    | S₂        | S₁        |
| Casino      | 316.01c| 322.42c| 49.26b| 55.33b    | 5.08b     |
| Bani sweif6 | 351.53a| 357.13a| 53.69a| 59.96a    | 5.02b     |
| Sohag 3     | 341.35b| 347.38b| 47.11b| 52.19b    | 5.27a     |
| L.S.D. 0.05 | 3.10  | 4.74  | 2.43  | 3.30      | 0.055     |

Humic acid levels kg/ha

| Control | 322.51b| 329.9b | 49.72a| 56.30a    | 4.93b     |
| 2.4     | 350.08a| 354.72a| 50.32a| 55.33a    | 5.32a     |
| L.S.D. 0.05 | 2.53  | 3.87  | N.S   | N.S       | 0.044     |

Iron levels g/ha

| Control | 331.96b| 338.59b| 50.33a| 56.17a    | 5.01b     |
| 480     | 357.61a| 362.22a| 49.68a| 55.63a    | 5.39a     |
| 960     | 319.33c| 326.13c| 50.06a| 55.65a    | 4.97c     |
| L.S.D. 0.05 | 3.07  | 4.20  | N.S   | N.S       | 0.042     |

Zinc levels g/ha

| Control | 334.16b| 340.37b| 49.43b| 56.32a    | 5.03b     |
| 480     | 354.11a| 358.63a| 51.69a| 56.82a    | 5.38a     |
| 960     | 320.63c| 327.94c| 48.94b| 54.32b    | 4.97c     |
| L.S.D. 0.05 | 3.07  | 4.20  | 2.09  | 2.10      | 0.04      |
Spraying of the highest level of Fe or Zn, or both, decreased significantly number of spikes/m² 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.

| Cultivars | Humic acid kg/ha | Iron g/ha | Zinc g/ha | NS/m² | HGW (g) |
|-----------|------------------|-----------|-----------|-------|--------|
| Casino    | 0                | 480       | 0         | 253.6 | 4.23   |
| Casino    | 0                | 960       | 0         | 307.0 | 4.98   |
| Casino    | 0                | 480       | 960       | 343.6 | 5.26   |
| Casino    | 0                | 480       | 960       | 354.0 | 5.53   |
| Casino    | 0                | 960       | 480       | 300.0 | 5.24   |
| Casino    | 0                | 960       | 480       | 300.0 | 5.24   |
| Casino    | 0                | 480       | 960       | 263.0 | 5.12   |
| Casino    | 0                | 960       | 960       | 244.3 | 4.62   |
| Casino    | 2.4              | 0         | 0         | 331.0 | 4.40   |
| Casino    | 2.4              | 0         | 480       | 342.0 | 5.17   |
| Casino    | 2.4              | 0         | 960       | 319.0 | 5.15   |
| Casino    | 2.4              | 480       | 0         | 340.0 | 5.13   |
| Casino    | 2.4              | 480       | 480       | 423.3 | 6.15   |
| Casino    | 2.4              | 480       | 960       | 318.0 | 5.18   |
| Casino    | 2.4              | 960       | 0         | 311.3 | 5.22   |
| Casino    | 2.4              | 960       | 480       | 311.6 | 5.17   |
| Casino    | 2.4              | 960       | 960       | 319.0 | 5.15   |
| Casino    | 2.4              | 960       | 960       | 319.0 | 5.15   |
| Bani sweif6| 0               | 480       | 0         | 326.0 | 5.11   |
| Bani sweif6| 0               | 960       | 0         | 336.6 | 5.16   |
| Bani sweif6| 0               | 960       | 960       | 323.6 | 4.53   |
| Bani sweif6| 0               | 480       | 0         | 338.0 | 5.15   |
| Bani sweif6| 0               | 480       | 480       | 362.2 | 5.24   |
| Bani sweif6| 0               | 480       | 960       | 344.0 | 4.35   |
| Bani sweif6| 0               | 960       | 0         | 326.3 | 4.56   |
| Bani sweif6| 0               | 960       | 480       | 347.0 | 4.37   |
| Bani sweif6| 0               | 960       | 960       | 337.3 | 4.28   |
| Bani sweif6| 2.4             | 0         | 0         | 363.6 | 5.20   |
| Bani sweif6| 2.4             | 0         | 480       | 376.3 | 5.17   |
| Bani sweif6| 2.4             | 0         | 960       | 355.3 | 5.14   |
| Bani sweif6| 2.4             | 480       | 0         | 389.0 | 5.20   |
| Bani sweif6| 2.4             | 480       | 480       | 442.6 | 6.44   |
| Bani sweif6| 2.4             | 480       | 960       | 337.0 | 4.23   |
| Bani sweif6| 2.4             | 960       | 0         | 356.3 | 5.15   |
| Bani sweif6| 2.4             | 960       | 480       | 346.0 | 5.45   |
| Bani sweif6| 2.4             | 960       | 960       | 319.0 | 4.75   |
Table 5. Means of number of grains/spike as affected by cultivars * humic acid interaction in the first season (S₁).

| Cultivars | Humic acid kg/ha | No. of grains/spike S₁ |
|-----------|------------------|------------------------|
| 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 (S₁) revealed that Casino cultivars responded significantly and negatively, Bani Sweif6 showed no significant response, while Sohage3 responded 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 4.76 t/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 (S2)

| Cultivars | Humic acid kg/ha | Iron g/ha | No. of grains/spike |
|-----------|------------------|-----------|--------------------|
| 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 (S2)

| Cultivars | Humic acid kg/ha | Zinc g/ha | No. of grains/spike | S2  |
|-----------|------------------|-----------|--------------------|-----|
| 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) |
|--------------|------------------|-----------|-----------|-----------|-----------|
|              |                  |           |           | S₁        | S₂        | S₁        | S₂        |
| 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      |
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 to 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 studied 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 metabolic 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

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Without humic: \( \hat{Y} = 2.37 + 1.17 \times 10^{-3} \times X - 1.39 \times 10^{-6} \times X^2 \) (Optimal: 420.86 g/ha)

With humic: \( \hat{Y} = 2.30 + 1.80 \times 10^{-3} \times X - 1.93 \times 10^{-6} \times X^2 \) (Optimal: 466.32 g/ha)
Fig. 1-b. 2- Bani Sweif 6

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

With humic: $\hat{Y} = 3.33 + 5.38 \times 10^{-3} X - 5.70 \times 10^{-6} X^2$ (Optimal: 471.92 g/ha)

Fig. 1-c. 3- Sohag 3

Without humic: $\hat{Y} = 2.69 + 1.53 \times 10^{-3} X - 2.02 \times 10^{-6} X^2$ (Optimal: 378.71 g/ha)

With humic: $\hat{Y} = 2.92 + 2.96 \times 10^{-3} X - 3.43 \times 10^{-6} X^2$ (Optimal: 431.48 g/ha)

Fig. 2-a. 1- Casino

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

With humic: $\hat{Y} = 2.13 + 2.06 \times 10^{-3} X - 2.38 \times 10^{-6} X^2$ (Optimal: 432.77 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 FeSO₄ and ZnSO₄. 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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تأثير إضافة حمض الهيوميك والزنك وال الحديد علي المحصول ومكوناته في القمح الصلب

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نفذت تجربتان حقليتان بالمزرعة البحثية لجامعة الاسكندرية خلال المواسم الشتوية 2017/2018 و 2018/2019 لدراسة تأثير الرش بحمض الهيوميك بمعدل (صفر، 2.4 كجم/هكتار) وكل من الحديد والزنك بمعدل (صفر، 480، 960 جم/هكتار لكل منهما على صورة سلفات الحديدوز وسلفات الزنك) على ثلاثة اصناف من القمح الديورم (Casino، Bani sweif6، Sohag3) وذلك في تصميم القطع المشتركة مرة واحدة في ثلاث مكررات حيث وزعت المعاملات الست الناتجة من تداخل مستويات الصنفين الثلاثة في القطع الرئيسية في حين وزعت المعاملات التسع الناتجة من تداخل المستويات الثلاثة من الزنك وسلفات الزنك في القطع الفرعية.

فقد أظهرت النتائج فوائد الصفن Bani sweif6 الصنفين الآخرين في محصول الحبوب وجميع مكوناته عدا

وزن المائة حبة في المواسم - وقد أدى الرش بحمض الهيوميك لزيادة محصول الحبوب في كل من الصنفين Sohag3، Bani sweif6، Casino نتائج الرش بحمض الهيوميك من ناحية أخرى أدى الرش بحمض الهيوميك وال الحديد والزنك بمعدل (صفر، 480 جم/هكتار لكل منهما) إلى تحقيق أقصى نتائج من كل من الصنفين Sohag3، Bani sweif6 في حين أدى الرش بحمض الهيوميك بمعدل 480 جم/هكتار مع عدم الرش بحمض الهيوميك إلى تحقيق أقصى محصول للصنفين Sohag3، Bani sweif6. لذا يمكن الدراسة برش صنفي القمح بحمض الهيوميك (صفر، 2.4 كجم/هكتار) وسلفات الحديدوز وسلفات الزنك بمعدل (صفر، 480 جم/هكتار من كل منهما) - في حين يجب إجراء المزيد من الدراسات لتحديد المعدل المناسب من حمض الهيوميك اللازم إضافته للصنفين.