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*(Original Article)*

# Foliar Spray by Some Micro-Nutrients Nano-Particles and its Influence on Grain Yield and Quality of Three Bread Wheat Cultivars

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**Abstract**

A field experiment was carried out at the Department of Agronomy Experimental Farm, Faculty of Agriculture, Assiut University, during the growing seasons 2017/18 and 2018/19 to study the impact of foliar spray by some Nano Micro-nutrients on grain yield and quality of three cultivars of bread wheat. Randomized complete block design (RCBD) was used in this experiment in three replications using strip plot arrangement. The bread wheat varieties i.e., Sids-1, Sids-12, and Gemmeaza-11 were arranged vertically, while foliar sprays with tap water (solvent as a control) and Iron, Manganese, Zinc, Iron + Manganese, Iron + Zinc, Manganese+ Zinc and Iron + Manganese + Zinc in Nano form at 200 ppm concentration were distributed horizontally. In both seasons, the foliar spray treatment with certain micronutrient nano-particles had a significant impact on grain yield, flour percentage, coarse bran percentage, wet gluten percentage, and dry gluten percentage. As a result, wheat plants sprayed with Fe + Mn + Zn had the greatest average values of the previous traits. Furthermore, the cultivars studied had a substantial impact on the majority of the traits studied. In addition, in both seasons, the Sids-1 cultivar produced the greatest mean values of the most investigated traits. In both the 1$^{st}$ and 2$^{nd}$ seasons, the interaction between some micro-nutrients, nano-particles, and cultivars had a significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) impact on fermentation time. In this approach, the Sids-12 cultivar, which was sprayed with Mn+Zn in the 1$^{st}$ season, and the same cultivar when sprayed with Mn or Fe+Zn in the 2$^{nd}$ season, yielded the most elevated mean values of fermentation time (37.00 and 36.50 minutes within the two seasons).

***Keywords:*** *Cultivars, wheat, Nano-particles, Micro-nutrients.*

## Introduction

Wheat (*Triticum sp.* L.) is the world's most important cereal crop in terms of cultivated area and productivity. During the 2018 season, Egypt's wheat cultivated area was over three million feddan, with a total yield production of 8.45 metric tons, while total consumption was around 19.6 million metric tons. (USDA, 2018). As a result, Egypt's strategic goal is to increase wheat output to close the gap between production and consumption. As a result, much focus

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should be paid to closing or narrowing the gap between wheat output and consumption. One of the key goals of closing the wheat gap appears to be increasing productivity per unit area. Cultivating high-yielding cultivars and implementing specified cultural methods could help increase wheat output per unit area. Climate, agronomic management approaches, varietal response, soil type, and other factors all influence wheat productivity and quality. Responsiveness various wheat genotypes to foliar administration of microelements in nano form can encourage the formation of microelements-efficient and microelements-inefficient genotypes.

Fe, Mn, and Zn are the most important micronutrients in plant metabolism, influencing hydrogenase and carbonic anhydrase activities, ribosomal fraction stabilization and cytochrome synthesis, plant enzyme activation, carbohydrate metabolism, cellular membrane integrity, protein synthesis, auxin synthesis and pollen formation, and regulation and maintenance of gene expression required for pollen formation. (Hafeez *et al*., 2013).

A nanoparticle is defined by the size at which fundamental properties differ from those of the corresponding bulk material. (Banfield and Zhang, 2001). Nanoparticles and colloids have similar sizes, reached about 1 nm to 1 mm in diameter (Buffle, 2006). At a crucial length scale of less than 100 nm, novel features that distinguish nano-particles from the bulk material often emerge. The "new features" mentioned are totally reliant on the fact that the physics of nanoparticles means that their properties differ from those of the bulk material at the nanoscale. The agronomic efficiency of Fe, Mn, and Zn fertilizers may be influenced by particle size. When particle size is reduced, the number of particles per unit weight of fertilizer applied increases. Reduced particle size also increases a fertilizer's specific surface area, which should improve the dissolution number of fertilizers with low water solubility (Mortvedt, 1992). Rameshraddy *et al.* (2017) said to the foliar application of ZnO Nano to finger millet resulted in improved plant height and yield. Zenhom *et al.* (2018) indicated that there were considerable variances in grain yield traits amongst the various wheat cultivars studied. In terms of the number of kernels spike$^{-1}$, the difference between the examined wheat cultivars was not significant. Furthermore, the Gemmeaza-11 cultivar produced the highest mean grain yield per hectare (3169 kg). On the opposite side, the Sids 12 cultivar had the minimis mean value of grain yield fed$^{-1}$ (2773 kg).

The purpose of this research was to learn more about:

The effect of foliar spraying with various Micro-Nutrients Nano-Particles on grain yield and quality of three bread wheat cultivars is investigated.

## Materials and Methods

During the growing seasons 2017/18 and 2018/19, a field experiment was conducted at the Department of Agronomy Experimental Farm, Faculty of Agriculture, Assiut University, Assiut, Egypt (lat 27° 03' N, long 31° 01', alt 70 m asl) to investigate the influence of foliar spraying with some nano micronutrients on the production and quality of three bread wheat cultivars. Table 1 shows the experimental soil's mechanical and chemical qualities.

**Table 1. Shows the experimental soil's mechanical and chemical qualities**

| Characteristics | 2017/18 | 2018/19 |
|---|---|---|
| **Analytical mechanics:** | | |
| Sand | 27.00 | 27.80 |
| Silt | 23.00 | 22.20 |
| Clay | 50.00 | 50.00 |
| **Analytical chemistry:** | | |
| pH | 7.63 | 7.85 |
| Organic matter % | 1.80 | 1.70 |
| Total N% | 0.09 | 0.08 |

**Experiment, treatments and design:**

The experiment was set up in a three-replications randomized complete block design (RCBD) utilizing a strip plot arrangement. Whilst bread wheat cultivars (Sids-1, Sids-12, and Gemmeaza-11) were arranged vertically, foliar sprays by tap water (solvent as a control) and foliar sprays with Fe, Mn, Zn, Fe+Mn, Fe+Zn, Mn+Zn, and Fe+Mn+Zn in Nano form at 200 ppm were allocated horizontally and applied 45 and 60 days after sowing. Experimental unit size was 3* 3.5 m (10.5 $m^2$) using broadcasting as the sowing method. In the $1^{st}$ and $2^{nd}$ seasons, grains were planted on December $6^{th}$ and $9^{th}$, respectively. Maize was the previous summer crop in both seasons. All additional agricultural procedures for the wheat crop that were recommended were followed.

**Measured traits:**

Grain yield (ardab $fed.^{-1}$): Each experimental unit's wheat plants were harvested, threshed, and the grain production was weighted in kilograms before being converted to ardab per feddan (one ardab = 150 kg).

Test weight (kg/hectoliter): One –quarter liter apparatus was used to determine the test weight of grains.

Flour percentage (%): 100 g of clean wheat grains were milled employing a Micro Brabender Mill and percent extraction of flour was evaluated according American Association of Cereal Chemists (A.A.C.C., 2000).

Coarse bran percentage (%): 100 g of clean wheat grains were milled using a Micro Brabender Mill and percent extraction of coarse bran was estimated according to American Association of Cereal Chemists (A.A.C.C., 2000).

Fine bran percentage (%): 100 g of clean wheat grains were milled using a Micro Brabender Mill and percent extraction of fine bran was estimated according to American Association of Cereal Chemists (A.A.C.C., 2000).

Dry gluten percentage (%): Wet gluten was dried for 48 hours at 70°C to determined dry gluten (A.A.C.C., 2000).

Fermentation time (minutes): Ten grams of each sample from flour were putted in container, then 5.5 $cm^3$ ferment (ferment was prepared by solving 100 grams' yeast in 1000 ml water) was added and mixed, then the dough pieces were rolled into balls by hand then it was putted in glass contained 80 ml water at 32 °C until the dough balls were exploded (A.A.C.C., 2000).

**Analytical Statistics**

All obtained data was conducted for analyzed of variance (ANOVA) using SAS program version 9.2 (SAS 2008)'s Proc Mixed, and means were compared using revised Least Significant Difference (RLSD) at a 5% level of significance. (Steel & Torrie, 1981).

## Results and Discussion

### 1- Grain yield (ardab $fed.^{-1}$)

Table 2 shows that foliar spray treatment with certain micronutrients nanoparticles had a highly significant ($P \leq 0.01$) impact on grain yield in both seasons. Furthermore, using Fe+Mn+Zn resulted in the highest grain yield (26.08 and 26.44 ardab $fed.^{-1}$ within the 1st and 2nd seasons, respectively). The greatest reduced averages of grain yield (18.50 and 20.23 ardab $fed.^{-1}$ in the two seasons, respectively) were obtained from the control treatment in both seasons.

Furthermore, the findings in Table 2 show that in both seasons, the evaluated varieties had a highly significant ($P \leq 0.01$) effect on grain yield. In both seasons, Gemmeaza-11 cultivars produced the highest average grain yields (23.70 and 24.21 ardab $fed.^{-1}$ in the two seasons, respectively). The superiority in grain yield of the Gemmeaza-11 bread wheat cultivar was attributable to the superiority in kernel weight of spike-1. Similar trend was observed by Gheith *et al.* (2013), Fergani *et al.* (2014), El hag (2017) and Farag *et al.* (2018).

Additionally, in both seasons, the interaction had a highly significant ($P \leq 0.01$) and significant ($P \leq 0.05$) impact on grain yield. The highest mean grain yield values (26.80 and 26.95 ardab fed.-1 through the two seasons) were obtained from the Gemmeaza-11 cultivar, which was treated with Fe+Mn+Zn nano-particles within both seasons.

**Table 2. Means of grain yield (ardab fed.$^{-1}$) of wheat as affected by Micro-nutrients Nano-particles, cultivars and their interaction during 2017/18 and 2018/19 seasons**

| Season | 2017/2018 | | | | 2018/2019 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivars (C) / Treatments (T) | Gemmeaza-11 | Sids-1 | Sids-12 | Mean | Gemmeaza-11 | Sids-1 | Sids-12 | Mean |
| **Control** | 20.29 | 18.39 | 16.83 | 18.50 | 20.57 | 21.16 | 18.97 | 20.23 |
| **Fe** | 21.07 | 20.93 | 20.04 | 20.68 | 25.41 | 22.62 | 20.17 | 22.74 |
| **Mn** | 22.35 | 21.82 | 21.46 | 21.88 | 23.01 | 22.88 | 21.49 | 22.46 |
| **Zn** | 23.66 | 22.22 | 22.10 | 22.66 | 22.80 | 23.34 | 22.01 | 22.72 |
| **Fe+Mn** | 24.07 | 23.51 | 23.32 | 23.63 | 24.57 | 24.25 | 22.76 | 23.86 |
| **Fe+Zn** | 25.96 | 24.76 | 25.90 | 25.54 | 26.65 | 25.78 | 24.65 | 25.69 |
| **Mn+Zn** | 25.38 | 23.86 | 24.38 | 24.54 | 23.75 | 25.01 | 24.14 | 24.30 |
| **Fe+Mn+Zn** | 26.80 | 24.92 | 26.53 | 26.08 | 26.95 | 25.91 | 26.45 | 26.44 |
| **Average** | 23.70 | 22.55 | 22.57 | ----- | 24.21 | 23.87 | 22.58 | ----- |
| **F test and RLSD$_{0.05}$** | F test | R LSD$_{0.05}$ | | | F test | R LSD$_{0.05}$ | | |
| **T** | ** | 0.49 | | | ** | 1.05 | | |
| **C** | ** | 0.44 | | | ** | 0.42 | | |
| **T x C** | ** | 0.95 | | | * | 2.04 | | |

Where* and ** denote statistical significance at the 5% and 1% levels of probability, respectively.

## 2-Test weight (kg /hectoliter)

In the two seasons, the test weight trait reacted to nano-particle foliar spray treatments with highly significant ($P \leq 0.01$) and substantial ($P \leq 0.05$) ways (Table 3). The greatest test weight trait averages (61.54 and 68.40 kg/hectoliter during the 1$^{st}$ and 2$^{nd}$ seasons, respectively) were gotten from wheat plants sprayed with iron treatment in the 1$^{st}$ season and Fe+Mn treatment in the 2$^{nd}$ season.

Additionally, the presented data in Table 3 reveal that the studied cultivars varied highly significantly ($P \leq 0.01$) in test weight trait out of both seasons. Sids-1 bread wheat cultivar produced the greatest averages of test weight trait which were 62.08 and 69.14 kg /hectoliter within the two respective seasons. On the opposite side, the minimis mean values of test weight trait (58.80 and 67.32 kg /hectoliter) were obtained from Gemmeaza-11 cultivar through the two respective seasons. This could be due to the Sids-1 cultivar's genotypic behavior in combination with environmental variables that are more favorable for Sids-1 than the other cultivars. These results are similar to those obtained by Akgun *et al.* (2017).

In addition, in the 1$^{st}$ season alone, the interaction between some micro-nutrients, nano-particles foliar spray and cultivars exhibited a highly significant ($P \leq 0.01$) effect on the test weight trait. As a result, the Sids-1 cultivar, which was sprayed with Fe+Mn in the 1$^{st}$ season, had the greatest mean value of test weight trait (62.77 kg/hectoliter). Otherwise, the Gemmeaza-11 cultivar, which was sprayed with Zn throughout the 1$^{st}$ season, had the lowest mean value of test weight traits in the 1$^{st}$ season (53.50 kg/hectoliter).

**Table 3. Averages of test weight (kg /hectoliter) of wheat as affected by Micro-nutrients Nano-particles, cultivars and their interaction in 2017/18 and 2018/19 seasons.**

| Season | 2017/2018 | | | | 2018/2019 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivars (C) / Treatments (T) | Gemmeaza-11 | Sids-1 | Sids-12 | Mean | Gemmeaza-11 | Sids-1 | Sids-12 | Mean |
| **Control** | 61.13 | 61.27 | 61.00 | 61.13 | 67.2 | 69.54 | 67.08 | 67.94 |
| **Fe** | 60.85 | 62.53 | 61.23 | 61.54 | 67.68 | 69.30 | 67.44 | 68.14 |
| **Mn** | 60.90 | 62.20 | 61.03 | 61.38 | 66.6 | 68.52 | 68.1 | 67.74 |
| **Zn** | 53.50 | 61.90 | 61.40 | 58.93 | 67.8 | 68.76 | 67.62 | 68.06 |
| **Fe+Mn** | 54.50 | 62.77 | 55.00 | 57.42 | 67.68 | 69.60 | 67.92 | 68.40 |
| **Fe+Zn** | 60.10 | 61.87 | 61.37 | 61.11 | 67.02 | 68.82 | 66.84 | 67.56 |
| **Mn+Zn** | 59.20 | 62.23 | 61.45 | 60.96 | 66.66 | 69.60 | 67.26 | 67.84 |
| **Fe+Mn+Zn** | 60.20 | 61.83 | 60.70 | 60.91 | 67.92 | 68.94 | 67.98 | 68.28 |
| **Mean** | 58.80 | 62.08 | 60.40 | ------ | 67.32 | 69.14 | 67.53 | ------ |
| **F test and RLSD$_{0.05}$** | F test | | R LSD$_{0.05}$ | | F test | | R LSD$_{0.05}$ | |
| **T** | ** | | 0.83 | | * | | 0.49 | |
| **C** | ** | | 0.66 | | ** | | 0.40 | |
| **T x C** | ** | | 1.11 | | NS | | - | |

Whereas NS, *, and ** denote non-significant, significant, and significant at the 5% and 1% levels of probability, respectively.

## 3- Flour percentage (%)

Table 4 illustrates that foliar spraying with various micro-nutrient nano-particles had a highly significant ($P \leq 0.01$) effect on flour percentage across the two growth seasons. Thus, the most elevated mean value of net flour (85.26 and 87.41% out of the 1$^{st}$ and 2$^{nd}$ seasons, respectively) were gotten from foliar spray by Mn and Zn through the 1$^{st}$ and 2$^{nd}$ seasons, respectively. Otherwise, the lowest averages of net flour (83.14 and 85.58%) were gotten from foliar application with control treatment out of the 1$^{st}$ season and with Fe+Mn in the 2$^{nd}$ one.

Furthermore, the data in Table 4 reveals that only in the 2$^{nd}$ season did the evaluated cultivars have a highly significant ($P \leq 0.01$) impact on flour percentage. Here too, the data show that Sids-1 cultivar surpassed the others two cultivars with respect to flour percentage and gave the most noteworthy averages of flour percentage (84.66 and 87.57% in the two respective seasons). This could be due to the Sids-1 cultivar's genotypic behavior in combination with environmental variables that are more favorable for Sids-1 than the other cultivars. Similar trend was observed by Mansour (2015) and Mansour *et al.* (2018).

Flour percentage trait responded significantly ($P \leq 0.01$) to the interaction between Micro-nutrients Nano-particles and cultivars through the two growing seasons. Moreover, The Sids-12 cultivar, which was sprayed with Zn nanoparticles in the 1$^{st}$ season, and the Sids-1 cultivar, which was sprayed with Zn nanoparticles in the 2$^{nd}$ season, had the most elevated mean values of net flour (87.26 and 90.27 percent in the 1$^{st}$ and 2$^{nd}$ seasons, respectively).

**Table 4. Means of Flour percentage (%) of wheat as affected by Micro-nutrients Nano-particles, cultivars and their interaction in 2017/18 and 2018/19 seasons.**

| Season | 2017/2018 | | | | 2018/2019 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivars (C) / Treatments (T) | Gemmeaza-11 | Sids-1 | Sids-12 | Mean | Gemmeaza-11 | Sids-1 | Sids-12 | Mean |
| **Control** | 83.40 | 83.06 | 82.97 | 83.14 | 84.23 | 87.10 | 87.26 | 86.20 |
| **Fe** | 84.20 | 85.14 | 83.43 | 84.25 | 81.16 | 89.48 | 88.90 | 86.51 |
| **Mn** | 85.52 | 85.24 | 85.03 | 85.26 | 82.54 | 88.22 | 89.42 | 86.73 |
| **Zn** | 84.73 | 81.56 | 87.26 | 84.52 | 86.15 | 90.27 | 85.81 | 87.41 |
| **Fe+Mn** | 82.57 | 86.70 | 84.08 | 84.45 | 83.00 | 88.05 | 85.71 | 85.58 |
| **Fe+Zn** | 82.64 | 85.71 | 83.11 | 83.82 | 87.02 | 84.94 | 87.75 | 86.57 |
| **Mn+Zn** | 83.78 | 85.54 | 85.24 | 84.85 | 84.60 | 86.91 | 85.53 | 85.68 |
| **Fe+Mn+Zn** | 83.12 | 84.31 | 82.88 | 83.43 | 83.35 | 85.64 | 89.03 | 86.01 |
| **Mean** | 83.74 | 84.66 | 84.25 | ------ | 84.01 | 87.57 | 87.43 | ------ |
| **F test and RLSD$_{0.05}$** | F test | | R LSD$_{0.05}$ | | F test | | R LSD$_{0.05}$ | |
| **T** | ** | | 1.08 | | ** | | 0.42 | |
| **C** | NS | | - | | ** | | 0.32 | |
| **T x C** | ** | | 1.95 | | ** | | 1.16 | |

Where NS and ** denote non-significant and 1% probability levels, respectively.

## 4- Coarse bran percentage (%)

Data illustrated in Table 5 focus that foliar spray treatment by some Micro-nutrients Nano-particles had a highly significant ($P \leq 0.01$) influence on coarse bran percentage within the both seasons. Thus, the greatest averages of coarse bran percentage (15.09 and 12.95% through the two seasons, respectively) were gotten from the wheat plants that were sprayed using Fe+Mn within the two growing seasons. While the lowest mean values of coarse bran percentage (12.88 and 11.07%) were recorded via wheat plants that were sprayed with Mn and Zn throughout the two seasons.

Moreover, the examined data in Table 5 reveal that only in the 2$^{nd}$ season did the tested cultivars get a highly significant ($P \leq 0.01$). The most elevated average of coarse bran percentage (14.41% in the 2$^{nd}$ season) was taken out from Gemmeaza-11 cultivar. Otherwise, the Sids-1 cultivar had the lowest average coarse bran percentage (11.13 % in the 2$^{nd}$ season). This could be due to the Gemmeaza-11 cultivar's genotypic behavior in combination with environmental variables that are more appropriate for Gemmeaza-11 than the other cultivars.

Additionally, the interaction had a highly significant ($P \leq 0.01$) influence on coarse bran percentage out of both seasons. The Sids-1 cultivar, which was sprayed with Zn in the 1$^{st}$ season, and the Gemmeaza-11 cultivar, which was sprayed with Fe in the 2$^{nd}$, had the most elevated averages of coarse bran percentage (16.77 and 17.34 % throughout the two seasons).

**Table 5. Averages of coarse bran percentage (%) of wheat as affected by Micro-nutrients Nano-particles, cultivars and their interaction in 2017/18 and 2018/19 seasons.**

| Season | 2017/2018 | | | | 2018/2019 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivars (C) / Treatments (T) | Gemmeaza-11 | Sids-1 | Sids-12 | Mean | Gemmeaza-11 | Sids-1 | Sids-12 | Mean |
| Control | 14.69 | 11.58 | 14.23 | 13.50 | 14.27 | 11.78 | 11.62 | 12.56 |
| Fe | 14.55 | 13.33 | 15.24 | 14.37 | 17.34 | 9.48 | 9.65 | 12.16 |
| Mn | 12.61 | 13.01 | 13.02 | 12.88 | 15.76 | 10.38 | 9.43 | 11.86 |
| Zn | 13.68 | 16.77 | 11.61 | 14.02 | 12.34 | 8.50 | 12.38 | 11.07 |
| Fe+Mn | 14.87 | 15.46 | 14.94 | 15.09 | 15.05 | 10.76 | 13.04 | 12.95 |
| Fe+Zn | 15.86 | 12.69 | 15.40 | 14.65 | 11.59 | 13.64 | 11.10 | 12.11 |
| Mn+Zn | 14.54 | 12.79 | 13.48 | 13.60 | 13.75 | 11.41 | 12.97 | 12.71 |
| Fe+Mn+Zn | 14.75 | 14.33 | 15.28 | 14.78 | 15.22 | 13.10 | 9.65 | 12.65 |
| Mean | 14.44 | 13.74 | 14.15 | ------ | 14.41 | 11.13 | 11.23 | ----- |
| F test and RLSD$_{0.05}$ | F test | | R LSD$_{0.05}$ | | F test | | R LSD$_{0.05}$ | |
| T | ** | | 1.05 | | ** | | 0.37 | |
| C | NS | | - | | ** | | 0.36 | |
| T x C | ** | | 2.09 | | ** | | 1.22 | |

Where NS and ** denote non-significant and 1% probability levels, respectively.

## 5- Fine bran percentage (%)

Table 6 presents that in the 1st and second seasons, foliar spray treatment by certain micro-nutrient nano-particles had a highly significant ($P \leq 0.01$) and substantial ($P \leq 0.05$) effect on fine bran%, respectively. Wheat plants treated with Fe+Mn in the 1st season and Mn+Zn in the 2nd season had the greatest fine bran percentage averages (2.05 and 1.61 % in the two respective seasons). Aside from that, the lowest mean fine bran percentage values (1.38 and 1.25% in the two seasons) were taken out of the Fe and control treatments in the two seasons.

Also, the presented data in Table 6 prove that the tested cultivars had a highly significant ($P \leq 0.01$) influence on fine bran percentage throughout the two growing seasons. The most elevated averages of fine bran percentage (1.82 and 1.58% in the two respective seasons) were gotten from Gemmeaza-11 cultivar in the both seasons. In both seasons, the Sids-1 cultivar had the lowest mean values of fine bran percentage (1.60 and 1.30% respectively). This could be due to the Gemmeaza-11 cultivar's genotypic behavior in combination with environmental variables that are more appropriate for Gemmeaza-11 than the other cultivars.

In terms of the interaction effect on fine bran percentage, the data in the table show that fine bran percentage was very significant ($P \leq 0.01$) in both seasons due to the interaction between some micronutrient nanoparticles foliar spray and bread wheat cultivars. Hence, the Gemmeaza-11 cultivar, which was sprayed with Fe+Mn throughout both seasons, yielded the most elevated averages of fine bran percentage (2.74 and 1.95% in the two seasons). The minimal mean values of the fine bran percentage (1.14 and 1.04 % within the two seasons) were extracted from the Sids-12 cultivar, which was treated with Zn in the 1st growing season, and the Sids-1 cultivar, which was sprayed with Fe in the 2nd.

**Table 6. Means of fine bran percentage (%) of wheat as affected by Micro-nutrients Nano-particles, cultivars and their interaction in 2017/18 and 2018/19 seasons.**

| Season | 2017/2018 | | | | 2018/2019 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivars (C) / Treatments (T) | Gemmeaza-11 | Sids-1 | Sids-12 | Mean | Gemmeaza-11 | Sids-1 | Sids-12 | Mean |
| **Control** | 1.73 | 1.49 | 2.10 | 1.77 | 1.50 | 1.13 | 1.12 | 1.25 |
| **Fe** | 1.26 | 1.54 | 1.33 | 1.38 | 1.50 | 1.04 | 1.45 | 1.33 |
| **Mn** | 1.88 | 1.75 | 1.95 | 1.86 | 1.71 | 1.40 | 1.16 | 1.42 |
| **Zn** | 1.59 | 1.68 | 1.14 | 1.47 | 1.52 | 1.24 | 1.81 | 1.52 |
| **Fe+Mn** | 2.74 | 1.72 | 1.69 | 2.05 | 1.95 | 1.20 | 1.26 | 1.47 |
| **Fe+Zn** | 1.51 | 1.60 | 1.49 | 1.53 | 1.40 | 1.42 | 1.16 | 1.33 |
| **Mn+Zn** | 1.69 | 1.68 | 1.29 | 1.55 | 1.65 | 1.69 | 1.50 | 1.61 |
| **Fe+Mn+Zn** | 2.13 | 1.37 | 1.85 | 1.78 | 1.43 | 1.26 | 1.33 | 1.34 |
| **Mean** | 1.82 | 1.60 | 1.61 | ------ | 1.58 | 1.30 | 1.35 | ------- |
| **F test and RLSD$_{0.05}$** | F test | R LSD$_{0.05}$ | | | F test | R LSD$_{0.05}$ | | |
| **T** | ** | 0.16 | | | * | 0.26 | | |
| **C** | ** | 0.12 | | | ** | 0.13 | | |
| **T x C** | ** | 0.24 | | | ** | 0.22 | | |

Where* and ** denote statistical significance at the 5% and 1% levels of probability, respectively.

## 6- Dry gluten percentage (%)

The data in Table 7 clearly shows that foliar spraying with certain micro-nutrient nano-particles had a highly significant ($P \leq 0.01$) effect on dry gluten percentage across the two growth seasons. Wheat plants treated using Fe+Mn+Zn NPs in the 1st season and Fe+Mn NPs in the 2nd season produced the greatest dry gluten percentage averages (10.51 and 10.81 % respectively) in the two seasons.

The data presented in Table 7 further demonstrate that the tested cultivars varied significantly ($P \leq 0.05$) regarding to dry gluten percentage out of the both seasons. Sids-12 cultivar superior the other two cultivars in this respect and recorded the most elevated averages of grains dry gluten content (10.57 and 10.05% within the two respective seasons). This is to be expected, given that the wet gluten percentage trended in the same direction (Table 7). These findings are similar to those of El-Marakby *et al.* (2015) and Mansour (2015).

Furthermore, only in the 2nd season did the interaction between some Micro-nutrients Nano-particles foliar spray and cultivars have a highly significant impact. The Sids-1 cultivar, which was treated with Fe+Mn, had the greatest average dry gluten percentage (11.20 % in the 2nd season).

**Table 7. Averages of dry gluten percentage (%) of wheat as affected by Micro-nutrients Nano-particles, cultivars and their interaction in 2017/18 and 2018/19 seasons.**

| Season | 2017/2018 | | | | 2018/2019 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivars (C) / Treatments (T) | Gemmeaza-11 | Sids-1 | Sids-12 | Mean | Gemmeaza-11 | Sids-1 | Sids-12 | Mean |
| **Control** | 8.68 | 9.02 | 9.99 | 9.23 | 7.78 | 8.95 | 9.73 | 8.82 |
| **Fe** | 9.05 | 8.84 | 9.96 | 9.28 | 9.09 | 9.47 | 10.24 | 9.60 |
| **Mn** | 9.82 | 10.05 | 10.22 | 10.03 | 9.22 | 8.54 | 9.95 | 9.24 |
| **Zn** | 10.37 | 9.83 | 11.04 | 10.41 | 9.50 | 11.09 | 9.14 | 9.91 |
| **Fe+Mn** | 9.80 | 9.15 | 10.40 | 9.78 | 10.13 | 11.20 | 11.11 | 10.81 |
| **Fe+Zn** | 10.08 | 9.65 | 11.40 | 10.38 | 10.60 | 9.42 | 9.52 | 9.85 |
| **Mn+Zn** | 10.04 | 9.90 | 11.15 | 10.36 | 8.26 | 9.22 | 10.85 | 9.44 |
| **Fe+Mn+Zn** | 10.47 | 10.69 | 10.38 | 10.51 | 8.74 | 9.94 | 9.84 | 9.50 |
| **Mean** | 9.79 | 9.64 | 10.57 | ------ | 9.16 | 9.73 | 10.05 | ------ |
| **F test and $RLSD_{0.05}$** | F test | | R $LSD_{0.05}$ | | F test | | R $LSD_{0.05}$ | |
| **T** | ** | | 0.63 | | ** | | 0.65 | |
| **C** | * | | 0.62 | | * | | 0.66 | |
| **T x C** | NS | | - | | ** | | 1.48 | |

Whereas NS, *, and ** denote non-significant, significant, and significant at the 5% and 1% levels of probability, respectively.

## 7- Fermentation time (minutes)

Illustrated data in Table 8 show that foliar spraying with some Micronutrients Nano-particles had a highly significant ($P \leq 0.01$) and significant ($P \leq 0.05$) impact on fermentation time through the 1st and 2nd seasons, respectively. In addition, application of Fe+Mn+Zn gained the maximum fermentation time (30.67 minutes in the first season). The corresponding value in the 2nd season being 32.00 minutes which were achieved from Zn or Fe+Zn or Mn+Zn treatments. While the minimum mean values of fermentation time (25.00 and 27.00 minutes within the two respective seasons) were taken out from Fe treatment throught the 1st season and control treatment in the 2nd one.

Also, the data in Table 8 indicates that only in the 1st season did the studied cultivars have a highly significant ($P \leq 0.01$) effect on fermentation time. The Sids-12 cultivar had the longest average fermentation time (31.75 minutes during the 1st season). This is reasonable given that a similar tendency was seen in the dry gluten content attribute of cereals (Table 7) Ahmed *et al*. (2018).

Additionally, in the 1st and 2nd seasons, the interaction had a significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) impact on fermentation time. The highest mean fermentation time values (37.00 and 36.50 minutes in the two seasons) were gotten from the Sids-12 cultivar, which was sprayed with Mn+Zn in the 1st season and the same cultivar when treated with Mn, Fe+Zn, or Mn+Zn Nano-particles treatments in the 2nd season.

**Table 8. Means of Fermentation time (minutes) of wheat as affected by Micro-nutrients Nano-particles, cultivars and their interaction in 2017/18 and 2018/19 seasons.**

| Season | 2017/2018 | | | | 2018/2019 | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments (T) \ Cultivars (C) | Gemmeaza-11 | Sids-1 | Sids-12 | Mean | Gemmeaza-11 | Sids-1 | Sids-12 | Mean |
| **Control** | 23.00 | 22.50 | 32.00 | 25.83 | 26.50 | 28.00 | 26.50 | 27.00 |
| **Fe** | 27.00 | 17.50 | 30.50 | 25.00 | 34.00 | 27.00 | 33.00 | 31.33 |
| **Mn** | 27.00 | 29.00 | 26.00 | 27.33 | 31.50 | 26.50 | 36.50 | 31.50 |
| **Zn** | 28.50 | 25.00 | 31.00 | 28.17 | 29.00 | 35.50 | 31.50 | 32.00 |
| **Fe+Mn** | 26.00 | 31.00 | 30.50 | 29.17 | 31.50 | 26.00 | 33.50 | 30.33 |
| **Fe+Zn** | 32.00 | 20.00 | 33.00 | 28.33 | 27.00 | 32.50 | 36.50 | 32.00 |
| **Mn+Zn** | 27.50 | 22.50 | 37.00 | 29.00 | 30.50 | 29.00 | 36.50 | 32.00 |
| **Fe+Mn+Zn** | 34.00 | 24.00 | 34.00 | 30.67 | 32.00 | 28.50 | 27.50 | 29.33 |
| **Mean** | 28.13 | 23.94 | 31.75 | ----- | 30.25 | 29.13 | 32.69 | ----- |
| **F test and RLSD0.05** | F test | | R $LSD_{0.05}$ | | F test | | R $LSD_{0.05}$ | |
| **T** | ** | | 1.81 | | * | | 3.97 | |
| **C** | ** | | 2.15 | | NS | | - | |
| **T x C** | * | | 9.45 | | ** | | 6.97 | |

Whereas NS, *, and ** denote non-significant, significant, and significant at the 5% and 1% level of probability, respectively.

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**الـرش الـورقي بـبعض العناصـر الصـغرى النانومتريـة ومـدى تأثيرهـا علـى محصـول الحبـوب والجودة لثلاث أصناف من قمح الخبز**

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**الملخص**

تم اجراء تجربة حقلية خلال موسمي 2018/17 و 2019/18 في مزرعة قسم المحاصيل البحثية – كلية الزراعة – جامعة أسيوط لدراسة تأثير الرش الورقى ببعض العناصر الصغرى النانومترية على محصول وجودة ثلاثة أصناف من قمح الخبز. نُفِذت التجربة بتصميم القطاعات كاملة العشوائية بترتيب الشرائح المنشقة حيث تم وضع معاملات الرش الورقي بماء الصنبور(كنترول) والرش الورقي بالحديد، المنجنيز، الزنك، الحديد+المنجنيز، الحديد+الزنك، المنجنيز+الزنك، الحديد+المنجنيز+الزنك في الصورة النانومترية بمعدل 200 جزء في المليون أفقياً بينما رُتِبت أصناف قمح الخبز (سدس 1 و سدس 12 و جميزه 11) رأسياً. أوضحت النتائج التي تم الحصول عليها أن معاملات الرش الورقى ببعض العناصر الصغرى النانومترية كان لها تأثير عالى المعنوية على صفات محصول الحبوب ونسبة الدقيق ونسبة الردة الخشنة ونسبة الجلوتين الطرى ونسبة الجلوتين الجاف في كلاً من الموسمين. وأعطت نباتات القمح التى رُشت بالحديد والمنجنيز والزنك أعلى المتوسطات لمعظم الصفات سابقة الذكر، علاوة على ذلك فإن الأصناف محل الدراسة كان لها تأثير معنوى على معظم الصفات التى تم دراستها. بالإضافة إلى أن صنف سدس-1 أعطى أعلى القيم في أغلب الصفات التي تم دراستها خلال موسم الزراعة الأول. كما كان للتفاعل بين الرش الورقى ببعض العناصر الصغرى النانومترية وأصناف قمح الخبز تأثير معنوي فقط في الموسم الأول وتأثير عالي المعنوية في الموسم الثاني على صفة زمن التخمر، حيث تم الحصول على أعلى القيم لهذه الصفة والتي بلغت 37.00، 36.50 دقيقة في الموسمين من زراعة الصنف سدس12 سواء تم رشه ورقياً بواسطة المنجنيز+الزنك في الصورة النانومترية في الموسم الأول أو تم رشه بواسطة المنجنيز أو الحديد+الزنك أو المنجنيز+الزنك في الصورة النانومترية في الموسم الثاني.