

## Effect of Bread Wheat Grain Soaking in Different Titanium Dioxide Concentrations on the Yield and its Components

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### Abstract

Titanium (Ti) is a very interesting chemical element, so it shows beneficial effects on various physiological parameters of plants at low concentrations. This study was conducted at Agronomy Department Experimental Farm, Agriculture Faculty, Assiut University during 2014/2015 and 2015/2016 seasons to study the effect of bread wheat grains soaking in different titanium dioxide concentrations on the yield and its components. The experiment was layout in randomize complete blocks design (RCBD) using split-plot arrangement with three replicates. Soaking times (12, 18 and 24 hour) were arranged in main plots, while the titanium dioxide nanoparticles concentrations (0.00, 0.01, 0.02 and 0.03%) were arranged in sub- plots. The obtained results showed that all studied traits except spike number/ m<sup>2</sup> in both seasons and kernel weight spike<sup>-1</sup> in the first season only didn't affected significantly by soaking times. Here too, all studied traits reacted significantly to titanium dioxide nanoparticles concentrations as compared to control (without titanium dioxide nanoparticles). In addition, titanium dioxide nanoparticles at 0.02% or 0.03% increased almost studied traits. Thus, wheat grains soaked before sowing at 0.03% titanium dioxide nanoparticles concentration for 24 hour produced the highest mean value of grain yield (25.0ardab fad<sup>-1</sup>) in the first season, while in the second season the superiority observed when wheat grains soaked at 0.01% titanium dioxide nanoparticles concentration for 18 hour (23.5 ardab fad<sup>-1</sup>) with no significant difference between this treatment and grain soaked at 0.02% titanium dioxide nanoparticles concentration for 12 hour which yielded 23.2 ardab fad<sup>-1</sup>.

**Keywords:** Nanoparticles titanium dioxide, wheat, yield and yield components

### Introduction

Wheat crop consider the most important cereal crops in the world with regard to cultivated area and total production. The cultivated area of wheat in Egypt during 2013 season was about 1418708 ha with the total yield production of 9460200 ton (FAO, 2013). While the total consumption reached about 19600000 ton. So, increasing wheat production in order to reduce the gap between production and consumption are the strategic aim. Nowadays, various researchers have studied the effects of nanomaterials on plant germination

and growth with the objective to promote its use for agricultural applications (Khot *et al.*, 2012).

Nanoparticles (NPs) have average size of less than 100 nm and have unique properties that depend on their phase, distribution, size and morphology (Christian *et al.*, 2008). Titanium has significant biological effects on plants, being beneficial at low levels but toxic at higher concentrations. Although titanium is not toxic for animals and humans, its effects on plants and bacteria show noteworthy concentration dependence (Jaberzadeh *et al.*, 2013). Nano sized TiO<sub>2</sub>

is a frequently used nanoparticle, consequently there has been an exponential increase in data collection on the effects of TiO<sub>2</sub> nanoparticles on different species but there is much less information on the effects of nanoparticles on plants compared to animals. Studies the effects of TiO<sub>2</sub> nanoparticles on plants provide information about the positive and stimulating effects as well as any negative impact (Klancnik *et al.*, 2011). Despite the low availability of Ti element to plants, its beneficial effects on plants have already been proved. In oats (*Avena sativa*), Ti uptake as a nutrient solution by roots was more effective than spraying it on the leaves, benefiting various plant physiological parameters such as biomass yield, chlorophyll content, and growth (Kuzel *et al.*, 2003). Kiss *et al.* (1985) and Daood *et al.* (1998) also showed that Ti could activate photosynthesis, probably by changing the redox state of specific regulatory proteins and eliciting an alteration in enzyme activity, the most important enzyme being fructose-1,6-diphosphatase (F-1,6BP), which participates in the Calvin cycle, gluconeogenic, and oxidative pentose phosphate pathways of carbohydrate metabolism which are assumed to be associated with Ti. Owolade *et al.* (2008) reported that the seed yield of cowpea (*Vigna unguiculata*) was increased when treated (as foliar application) with nano-sized titanium dioxide. They concluded that it may be due to the photocatalyst ability of the nano-sized titanium dioxide, which leads to an increased photosynthetic rate. Similar yield increases were reported in rice by Chao and Choi, 2005. Ja-

berzadeh *et al.* (2013) showed that titanium dioxide nanoparticles at 0.02% increased almost all wheat agronomic traits i.e. Plant height, ear weight, ear number, 1000-seed weight, harvest index and seed yield ha<sup>-1</sup> as well as gluten and starch content. Whereas, in the literature there is little evidence on the effect of titanium on crop plants, we have studied the influence of titanium dioxide nanoparticles and common titanium oxide (bulk) on growth, yield and yield components as well as grain wheat quality. The objective of this study, therefore, is to evaluate the effect of bread wheat grains soaking in different titanium dioxide concentrations on the yield and its components.

#### **Materials and Methods**

This work was carried out during 2014/ 2015 and 2015/ 2016 seasons in the Agronomy Department Experimental Farm, Agriculture Faculty, Assiut University to study the effect of bread wheat grains soaking in different titanium dioxide concentrations on the yield and its components. The soil structure of the experimental site is clay, comprising of 42.60% clay, 30.40% silt and 27% sand with pH of 8.02 and EC 0.74 dsm-1. The experiment was laid out in Randomized Complete Block Design (RCBD) in split plot arrangement with three replicates. Soaking times (12, 18 and 24 hour) were arranged in main plots, while the titanium dioxide nanoparticles concentrations (0.00, 0.01, 0.02 and 0.03%) were arranged in sub-plots. In order to prepare titanium dioxide nanoparticles, 20 g titanium dioxide was dissolved into water and then 0.01 ml of solution was filled up to 1000 ml.

Thus, different concentrations of titanium dioxide (0.01, 0.02, and 0.03%) were prepared. Each sub-plot area was 10.5 m<sup>2</sup>. Wheat grains (*Triticum aestivum* L. c.v 'sids 12) were soaked in the previous titanium concentrations for tested time then sown by hand on 9 and 16 December in the first and second seasons, respectively at a depth of 3 cm. Control grains were treated with distilled water. All other cultural practices recommended for wheat crop were done in both seasons.

At harvest ten guarded main stem for each sub-plot were taken and plant height (cm), spike length (cm), number of spikelet's spike<sup>-1</sup>, number of kernels spike<sup>-1</sup> and kernels weight spike<sup>-1</sup> were determined. 1000-kernel weight, number of spikes m<sup>2</sup>, grain and straw yields were determined in plot basis then transferred to ardab and ton fad<sup>-1</sup>, respectively.

All data collected were analyzed with analysis of variance (ANOVA) Procedures using the SAS Statistical Software Package (v.9.2,2008). Differences between means were compared by LSD at 5% level of significant (Gomez and Gomez, 1984).

## Results and Discussion

**Growth traits:** Data presented in Tables 1 and 2 show that the soaking times, titanium dioxide nanoparticles concentrations, and their interaction had a significant ( $p \leq 0.05$ ) effect on plant height and spike length in both seasons except the effect of soaking time on plant height which was significant in the first season only. Soaking wheatgrains in titanium-

dioxide nanoparticles concentrations for 12 and 18 hour before sowing produced the highest mean values of plant height (94.5 and 85.1 cm in the first and second seasons, respectively). Also, among the different titanium concentrations, titanium dioxide nanoparticles at 0.02% concentration produced the tallest wheat plants (86.2 cm in the second season) and the longest spike (12.7 and 11.8 cm in the first and second seasons, respectively). Moreover, the tallest wheat plants (89.7 cm in the second season) and the longest spike (12.8 and 12.0 cm in the first and second seasons, respectively) were obtained when wheat grains were soaked at 0.02% titanium dioxide nanoparticles concentration for 12 hour. Increase of plant height and spike length may be due to the positive effects of titanium in different cellular mechanisms. For instance, improvement of photosynthesis and increase in chlorophyll content are two possible reasons for this. Kiss *et al.* (1985) and Daood *et al.* (1998) also showed that Ti could activate photosynthesis, probably by changing the redox state of specific regulatory proteins and eliciting an alteration in enzyme activity, the most important enzyme being fructose-1,6-diphosphatase (F-1,6BP), which participates in the Calvin cycle, gluconeogenic, and oxidative pentose phosphate pathways of carbohydrate metabolism which are assumed to be associated with Titanium. Similar results were obtained by Jaberzadeh *et al.*, 2013.

**Table 1. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on plant height (cm)**

| Seasons                        | 2014/2015 |      |      |       | 2015/2016 |      |       |      |
|--------------------------------|-----------|------|------|-------|-----------|------|-------|------|
| Soaking time<br>Concentrations | 12h       | 18h  | 24h  | Mean  | 12h       | 18h  | 24h   | Mean |
| <b>0.00%(Control)</b>          | 92.0      | 97.0 | 96.0 | 95.0  | 79.9      | 81.2 | 80.7  | 80.6 |
| <b>0.01%</b>                   | 96.0      | 92.0 | 96.0 | 94.7  | 78.7      | 85.2 | 84.4  | 82.8 |
| <b>0.02%</b>                   | 94.0      | 90.0 | 96.0 | 93.3  | 89.7      | 86.9 | 82.1  | 86.2 |
| <b>0.03%</b>                   | 96.0      | 89.0 | 96.0 | 93.7  | 87.5      | 87.1 | 82.5  | 85.7 |
| <b>Mean</b>                    | 94.5      | 92   | 96   | ----- | 84.0      | 85.1 | 82.4  | ---- |
| <b>F value and LSD.05</b>      | F value   |      | LSD  |       | F value   |      | LSD   |      |
| <b>Soaking times</b>           | *         |      | 1.34 |       | ns        |      | ----- |      |
| <b>Concentrations</b>          | *         |      | 1.05 |       | *         |      | 2.62  |      |
| <b>Interaction</b>             | *         |      | 1.81 |       | *         |      | 4.5   |      |

\*, ns means significant and nonsignificant at 5% level

**Table 2. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on spike length (cm)**

| Seasons                        | 2014/2015 |      |       |       | 2015/2016 |      |      |      |
|--------------------------------|-----------|------|-------|-------|-----------|------|------|------|
| Soaking time<br>Concentrations | 12h       | 18h  | 24h   | Mean  | 12h       | 18h  | 24h  | Mean |
| <b>0.00%(Control)</b>          | 11.5      | 13.1 | 11.5  | 12.0  | 10.0      | 10.7 | 10.6 | 10.4 |
| <b>0.01%</b>                   | 12.5      | 11.7 | 12.9  | 12.4  | 11.0      | 10.5 | 10.8 | 10.8 |
| <b>0.02%</b>                   | 12.8      | 12.7 | 12.5  | 12.7  | 12.0      | 12.0 | 11.3 | 11.8 |
| <b>0.03%</b>                   | 12.4      | 11.7 | 12.3  | 12.1  | 11.8      | 11.6 | 11.8 | 11.8 |
| <b>Mean</b>                    | 12.3      | 12.3 | 12.3  | ----- | 11.2      | 11.2 | 11.1 | ---- |
| <b>F value and LSD.05</b>      | F value   |      | LSD   |       | F value   |      | LSD  |      |
| <b>Soaking times</b>           | ns        |      | ----- |       | ns        |      | ---- |      |
| <b>Concentrations</b>          | *         |      | 0.51  |       | *         |      | 0.45 |      |
| <b>Interaction</b>             | *         |      | 0.87  |       | *         |      | 0.78 |      |

**Yield components traits:** Illustrated data in Tables 3 to 7 focuses that soaking time had a significant ( $p \leq 0.05$ ) effect on number of spikes  $m^{-2}$  in both seasons and seed weight  $spike^{-1}$  in the first season only while, the effect in all others studied yield components traits don't reached the 5% significant level. The highest mean values of spikes number  $m^{-2}$  (393.8 and 353.5 in the first and second seasons, respectively) were obtained when wheat grain was soaked before sowing for 12 hour. Furthermore, the obtained results show that the titanium dioxide nanoparticles concentration had a signifi-

cant ( $p \leq 0.05$ ) influence on number of spikelets  $spike^{-1}$ ; kernels number  $spike^{-1}$ , kernels weight  $spike^{-1}$  in the two growing seasons and 1000-kernel weight in the second season only. The maximum number of spikelets  $spike^{-1}$  (20.2 and 19.6 in the first and second seasons, respectively) were obtained from 0.02 and 0.03% titanium dioxide nanoparticles concentrations in the first and second seasons, respectively. Also, 0.03% titanium dioxide nanoparticles concentration give the highest mean values of kernels number  $spike^{-1}$  (73.6 and 75.8 in the first and second seasons, respectively). Also, the highest mean values of

kernels weight spike<sup>-1</sup> (3.38 and 3.39 g in the first and second seasons, respectively) were obtained from 0.03 and 0.02 % titanium dioxide nanoparticles concentrations, respectively while, the heaviest 1000-kernel weight in the second season (44.6 g) was reacted significantly to 0.02% titanium dioxide nanoparticles concentration. On the other hand, the lowest mean values of 1000- kernel weight (44.2 and 40.2 g in the first and second seasons, respectively) were obtained from control treatment (0.00% titanium dioxide nanoparticles concentration). The previous founding concerned kernel weight

spike<sup>-1</sup> is logic since the tested titanium dioxide nanoparticles concentrations gives the highest kernels number spike<sup>-1</sup> and 1000-kernels weight and consequently increased kernel weight spike<sup>-1</sup>. Here too, the interaction between soaking time and titanium dioxide nanoparticles concentrations had a significant effect on spike number m<sup>-2</sup>, kernels number spike<sup>-1</sup>, kernels weight spike<sup>-1</sup> and 1000-kernel weight in the two growing seasons. The highest mean values of spike number m<sup>2</sup> (438.0 and 378.0 in the first and second seasons, re-

spectively) were obtained from grain soaked before sowing at 0.03 and 0.01% titanium dioxide nanoparticles concentrations for 12 hour in the first and second seasons, respectively. Also, the highest kernels number spike<sup>-1</sup> (77.9 and 82.7 in the first and second seasons, respectively) were obtained from grain soaked before sowing at 0.03 and 0.02% titanium dioxide nanoparticles concentrations for 18 hour in the first and second seasons, respectively. Moreover, the heaviest kernels weight spike<sup>-1</sup> (3.89 and 3.83 g in the first and second seasons, respectively) were obtained from grain soaked before sowing at 0.03 titanium dioxide nanoparticles concentration for 24 hour and 0.02% titanium dioxide nanoparticles concentration for 18 hour in the first and second seasons, respectively. The highest thousand kernel weight (51.3 and 46.2 g in the first and second seasons, respectively) were obtained from wheat grain soaked at 0.03 and 0.02% titanium dioxide nanoparticles concentration for 18 hour in the first and second seasons, respectively. These obtained results are in a good line with those stated by Jaberzadeh *et al.* (2013) and Razzaq *et al.* (2016).

**Table 3. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on spikes number m<sup>-2</sup>**

| Seasons                        | 2014/2015      |       |              |       | 2015/2016      |       |              |       |
|--------------------------------|----------------|-------|--------------|-------|----------------|-------|--------------|-------|
| Soaking time<br>Concentrations | 12h            | 18h   | 24h          | Mean  | 12h            | 18h   | 24h          | Mean  |
| <b>0.00%(Control)</b>          | 387.0          | 360.0 | 384.0        | 377.0 | 366.0          | 332.0 | 322.0        | 340.0 |
| <b>0.01%</b>                   | 370.0          | 361.0 | 376.0        | 369.0 | 378.0          | 316.0 | 346.0        | 346.7 |
| <b>0.02%</b>                   | 380.0          | 391.0 | 357.0        | 376.0 | 334.0          | 348.0 | 360.0        | 347.3 |
| <b>0.03%</b>                   | 438.0          | 338.0 | 370.0        | 382.0 | 336.0          | 348.0 | 302.0        | 328.7 |
| <b>Mean</b>                    | 393.8          | 362.5 | 371.8        | ----- | 353.5          | 336.0 | 332.5        | ----- |
| <b>F value and LSD.05</b>      | <b>F value</b> |       | <b>LSD</b>   |       | <b>F value</b> |       | <b>LSD</b>   |       |
| <b>Soaking times</b>           | *              |       | <b>23.48</b> |       | *              |       | <b>13.13</b> |       |
| <b>Concentrations</b>          | ns             |       | -----        |       | ns             |       | -----        |       |
| <b>Interaction</b>             | *              |       | <b>46.96</b> |       | *              |       | <b>26.26</b> |       |

**Table 4. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on spikelets number spike<sup>-1</sup>**

| Seasons                        | 2014/2015 |      |      |       | 2015/2016 |      |      |       |
|--------------------------------|-----------|------|------|-------|-----------|------|------|-------|
| Soaking time<br>Concentrations | 12h       | 18h  | 24h  | Mean  | 12h       | 18h  | 24h  | Mean  |
| <b>0.00%(Control)</b>          | 18.6      | 20.6 | 18.4 | 19.2  | 17.9      | 18.0 | 16.8 | 17.6  |
| <b>0.01%</b>                   | 19.6      | 19.9 | 19.7 | 19.7  | 19.5      | 18.0 | 18.2 | 18.6  |
| <b>0.02%</b>                   | 19.7      | 20.8 | 20.2 | 20.2  | 19.8      | 19.3 | 18.1 | 19.1  |
| <b>0.03%</b>                   | 18.6      | 18.2 | 18.9 | 18.8  | 19.5      | 19.1 | 20.1 | 19.6  |
| <b>Mean</b>                    | 19.1      | 20.4 | 19.3 | ----- | 19.2      | 18.6 | 18.3 | ----- |
| <b>F value and LSD.05</b>      | F value   |      | LSD  |       | F value   |      | LSD  |       |
| <b>Soaking times</b>           | ns        |      | ---  |       | ns        |      | ---- |       |
| <b>Concentrations</b>          | *         |      | 0.88 |       | *         |      | 0.76 |       |
| <b>Interaction</b>             | ns        |      | ---  |       | ns        |      | ---- |       |

**Table 5. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on kernels number spike<sup>-1</sup>**

| Seasons                        | 2014/2015 |      |             |       | 2015/2016 |      |             |       |
|--------------------------------|-----------|------|-------------|-------|-----------|------|-------------|-------|
| Soaking time<br>Concentrations | 12h       | 18h  | 24h         | Mean  | 12h       | 18h  | 24h         | Mean  |
| <b>0.00%(Control)</b>          | 69.3      | 69.4 | 57.5        | 65.4  | 64.1      | 62.3 | 70.2        | 65.5  |
| <b>0.01%</b>                   | 64.5      | 71.0 | 63.0        | 66.2  | 66.6      | 61.2 | 61.1        | 63.0  |
| <b>0.02%</b>                   | 71.5      | 75.0 | 70.5        | 72.3  | 69.2      | 82.7 | 75.2        | 75.7  |
| <b>0.03%</b>                   | 67.0      | 77.9 | 76.0        | 73.6  | 78.3      | 69.7 | 79.4        | 75.8  |
| <b>Mean</b>                    | 68.1      | 73.3 | 66.8        | ----- | 69.6      | 69.0 | 71.5        | ----- |
| <b>F value and LSD.05</b>      | F value   |      | LSD         |       | F value   |      | LSD         |       |
| <b>Soaking times</b>           | ns        |      | -----       |       | ns        |      | ----        |       |
| <b>Concentrations</b>          | *         |      | <b>3.29</b> |       | *         |      | <b>3.83</b> |       |
| <b>Interaction</b>             | *         |      | <b>5.69</b> |       | *         |      | <b>6.62</b> |       |

**Table 6. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on 1000-kernel weight (g)**

| Seasons                        | 2014/2015 |      |       |       | 2015/2016 |      |      |       |
|--------------------------------|-----------|------|-------|-------|-----------|------|------|-------|
| Soaking time<br>Concentrations | 12h       | 18h  | 24h   | Mean  | 12h       | 18h  | 24h  | Mean  |
| <b>0.00%(Control)</b>          | 44.0      | 40.7 | 47.7  | 44.2  | 42.5      | 43.0 | 35.2 | 40.2  |
| <b>0.01%</b>                   | 48.9      | 43.6 | 46.4  | 46.3  | 44.4      | 42.2 | 42.4 | 43.0  |
| <b>0.02%</b>                   | 43.7      | 44.6 | 46.9  | 45.1  | 43.2      | 46.2 | 44.3 | 44.6  |
| <b>0.03%</b>                   | 42.8      | 51.3 | 44.5  | 46.2  | 43.2      | 44.1 | 45.9 | 44.4  |
| <b>Mean</b>                    | 44.8      | 45.1 | 46.4  | ----- | 43.3      | 43.8 | 41.9 | ----- |
| <b>F value and LSD.05</b>      | F value   |      | LSD   |       | F value   |      | LSD  |       |
| <b>Soaking times</b>           | ns        |      | ----- |       | Ns        |      | ---- |       |
| <b>Concentrations</b>          | ns        |      | ----  |       | *         |      | 1.66 |       |
| <b>Interaction</b>             | *         |      | 8.49  |       | *         |      | 2.87 |       |

**Table 7. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on kernels weight spike<sup>-1</sup>**

| Seasons                        | 2014/2015 |      |      |       | 2015/2016 |      |       |      |
|--------------------------------|-----------|------|------|-------|-----------|------|-------|------|
| Soaking time<br>Concentrations | 12h       | 18h  | 24h  | Mean  | 12h       | 18h  | 24h   | Mean |
| <b>0.00%(Control)</b>          | 3.19      | 2.78 | 2.62 | 2.86  | 2.83      | 2.48 | 2.78  | 2.70 |
| <b>0.01%</b>                   | 3.16      | 2.92 | 2.93 | 3.00  | 3.05      | 2.78 | 2.46  | 2.76 |
| <b>0.02%</b>                   | 2.24      | 3.48 | 3.56 | 3.09  | 3.04      | 3.83 | 3.29  | 3.39 |
| <b>0.03%</b>                   | 2.67      | 3.58 | 3.89 | 3.38  | 3.36      | 3.20 | 3.42  | 3.33 |
| <b>Mean</b>                    | 2.82      | 3.19 | 3.25 | ----- | 3.07      | 3.07 | 2.99  | ---- |
| <b>F value and LSD.05</b>      | F value   |      | LSD  |       | F value   |      | LSD   |      |
| <b>Soaking times</b>           | *         |      | 0.23 |       | Ns        |      | ----- |      |
| <b>Concentrations</b>          | *         |      | 0.23 |       | *         |      | 0.29  |      |
| <b>Interaction</b>             | *         |      | 0.39 |       | *         |      | 0.50  |      |

**Grain and straw yields (ton fad<sup>-1</sup>) traits:** Exhibited data in Tables 8 and 9 reveal that there are no significant differences between three tested soaking times on grain yield in both seasons, although the wheat grain soaked for 12 hour before sowing produced the highest mean values of grain yield (23.4 and 22.4 ardab fad<sup>-1</sup> in the first and second seasons, respectively). Straw yield affected significantly by soaking time in the first season only in favor of 24 hour treatment which gained the highest mean value of straw yield (5.1 ton fad<sup>-1</sup>). Moreover, the data presented here reveal that the titanium dioxide nanoparticles concentrations had a significant effect on grain yield in the two growing seasons. The maximum grain yield (23.8 and 22.4 ardab fad<sup>-1</sup> in the first and second seasons, respectively) was obtained from 0.03 and 0.01% titanium dioxide nanoparticles concentration in the first and second seasons, respectively. This is to be expected since the same titanium concentrations produced the highest number of spike m<sup>-2</sup> and kernel weight spike<sup>-1</sup> and consequently grain yield fad<sup>-1</sup>. Also, straw yield was

increased significantly with treated seeds by titanium nanoparticles in the first season only. Thus, the highest straw yield (5.1 ton fad<sup>-1</sup> in the first season) was obtained from 0.03% titanium dioxide nanoparticles concentration. Increase of growth and yield may be due to the positive effects of titanium in different cellular mechanisms. For instance, improvement of photosynthesis and increase in chlorophyll content are two possible reasons for this. Owolade *et al.* (2008) reported that the seed yield of cowpea (*Vigna unguiculata*) was increased when treated (as foliar application) with nano-sized titanium dioxide. They concluded that it may be due to the photocatalyst ability of the nano-sized titanium dioxide, which leads to an increased photosynthetic rate. Similar yield increases were reported in rice by Chao and Choi, 2005 and in wheat by Jaberzadeh *et al.*, 2013. As well as the tablet data focus that the interaction between soaking times and titanium dioxide nanoparticles concentrations had a significant influence on wheat grain yield in the two growing seasons, while the effect was true concern of straw yield in the

second season only. Wheat grains soaked before sowing at 0.03% titanium dioxide nanoparticles concentration for 24 hour produced the highest mean value of grain yield (25.0ardab fad<sup>-1</sup>) in the first season,

while in the second season the superiority observed when wheat grains soaked at 0.01% titanium dioxide nanoparticles concentration for 18 hour (23.5 ardab fad<sup>-1</sup>) or 0.02% for 12 hours (23.2 ardab fad<sup>-1</sup>).

**Table 8. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on grain yield (ardab fad<sup>-1</sup>)**

| Seasons                        | 2014/2015 |      |       |       | 2015/2016 |      |       |      |
|--------------------------------|-----------|------|-------|-------|-----------|------|-------|------|
| Soaking time<br>Concentrations | 12h       | 18h  | 24h   | Mean  | 12h       | 18h  | 24h   | Mean |
| <b>0.00%(Control)</b>          | 23.0      | 24.3 | 20.7  | 22.7  | 21.7      | 20.8 | 20.2  | 20.9 |
| <b>0.01%</b>                   | 23.0      | 24.2 | 23.4  | 23.5  | 22.0      | 23.5 | 23.3  | 22.9 |
| <b>0.02%</b>                   | 23.3      | 20.1 | 23.6  | 22.4  | 23.2      | 19.5 | 17.2  | 20.0 |
| <b>0.03%</b>                   | 24.4      | 21.9 | 25.0  | 23.8  | 22.9      | 22.9 | 21.6  | 22.4 |
| <b>Mean</b>                    | 23.4      | 22.6 | 23.2  | ----- | 22.4      | 21.7 | 20.6  | ---- |
| <b>F value and LSD.05</b>      | F value   |      | LSD   |       | F value   |      | LSD   |      |
| <b>Soaking times</b>           | ns        |      | ----- |       | ns        |      | ----- |      |
| <b>Concentrations</b>          | *         |      | 1.73  |       | *         |      | 0.90  |      |
| <b>Interaction</b>             | *         |      | 3.63  |       | *         |      | 1.56  |      |

**Table 9. Effect of soaking times, titanium dioxide nanoparticles concentrations and their interaction on straw yield (ton fad<sup>-1</sup>)**

| Seasons                        | 2014/2015 |     |      |       | 2015/2016 |     |      |       |
|--------------------------------|-----------|-----|------|-------|-----------|-----|------|-------|
| Soaking time<br>Concentrations | 12h       | 18h | 24h  | Mean  | 12h       | 18h | 24h  | Mean  |
| <b>0.00%(Control)</b>          | 4.0       | 4.2 | 4.7  | 4.3   | 4.0       | 4.0 | 4.3  | 4.1   |
| <b>0.01%</b>                   | 4.2       | 4.0 | 4.6  | 4.3   | 3.9       | 4.3 | 4.5  | 4.2   |
| <b>0.02%</b>                   | 4.7       | 4.2 | 5.5  | 4.8   | 4.3       | 4.1 | 3.5  | 4.0   |
| <b>0.03%</b>                   | 4.3       | 5.2 | 5.7  | 5.1   | 4.3       | 4.1 | 3.6  | 4.0   |
| <b>Mean</b>                    | 4.3       | 4.4 | 5.1  | ----- | 4.2       | 4.1 | 4.0  | ----- |
| <b>F value and LSD.05</b>      | F value   |     | LSD  |       | F value   |     | LSD  |       |
| <b>Soaking times</b>           | *         |     | 0.61 |       | ns        |     | ---- |       |
| <b>Concentrations</b>          | *         |     | 0.45 |       | ns        |     | ---- |       |
| <b>Interaction</b>             | ns        |     | ---- |       | *         |     | 0.47 |       |

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## تأثير نقع حبوب قمح الخبز في تركيزات مختلفة من ثاني اكسيد التيتانيوم علي المحصول ومكوناته

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### الملخص

يعتبر عنصر التيتانيوم من العناصر الكيميائية الهامة، حيث انه اوضح العديد من التأثيرات المفيدة علي مختلف العمليات الفسيولوجية للنبات عند استخدامه بتركيزات منخفضة. اجريت هذه الدراسة بمزرعة قسم المحاصيل البحثية- كلية الزراعة - جامعة اسيوط خلال موسمي ٢٠١٤/٢٠١٥ و ٢٠١٥/٢٠١٦ لتقييم تأثير نقع الحبوب في تركيزات مختلفة من ثاني اكسيد التيتانيوم علي انتاجية قمح الخبز. صممت التجربة باستخدام القطاعات كاملة العشوائية بترتيب القطع المنشقة مرة واحدة في ثلاث مكررات. تم وضع زمن النقع ( ١٢ او ١٨ و ٢٤ ساعة) في القطع الرئيسية بينما تم وضع تركيزات التيتانيوم ( صفر ، ٠.٠٠١ ، ٠.٠٠٢ و ٠.٠٠٣%) في القطع المنشقة. اوضحت النتائج المتحصل عليها ان كل الصفات محل الدراسة عدا عدد السنابل للمتر المربع في الموسمين ووزن حبوب السنبل في الموسم الاول فقط لم تتاثر معنويا بزمن النقع. معظم الصفات محل الدراسة تازرت معنويا بالنقع في ثاني اكسيد التيتانيوم النانومتري مقارنة بمعاملة الكنترول ( النقع في ماء مقطر). بالاضافة الي ان معظم الصفات حدث لها زيادة عند تركيز ٠.٠٠٢ او ٠.٠٠٣ % من ثاني اكسيد التيتانيوم. تم الحصول علي اعلي محصول من الحبوب (٢٥ اردب للفدان) في الموسم الاول عند نقع حبوب القمح قبل الزراعة لمدة ٢٤ ساعة في تركيز ٠.٠٠٣% من ثاني اكسيد التيتانيوم بينما تم الحصول علي اعلي محصول (٢٣.٥ اردب للفدان) في الموسم الثاني عند نقع الحبوب قبل الزراعة لمدة ١٨ ساعة في تركيز ٠.٠٠١% من ثاني اكسيد التيتانيوم وبفارق غير معنوي عن النقع لمدة ١٢ ساعة في تركيز ٠.٠٠٢% ثاني اكسيد التيتانيوم (٢٣.٢ اردب للفدان).