Effect of Foliar Nano Fertilizers and Irrigation Intervals on Soybean Productivity and Quality

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ABSTRACT

During summer seasons of 2015 and 2017, a field experiment was conducted at the Research and Experimental Station (30°19′ N, 31°16′ E), Faculty of Agriculture, Ain Shams University at Shalakan, Kalubia Governorate, Egypt, to investigate the effects of combinations between hydroxyapatite nanoparticles (0, 3, and 6 kg/fad) and calcium carbonate nanoparticles (0, 500 g/fad) as nano-fertilizers under irrigation intervals, (irrigation every 2 or 3 weeks whereas irrigation every 2 weeks as a recommended practice) on yield components and quality of soybean plants. Plants irrigated every two weeks produced higher seed and biological yield in the two resulted seasons; and its combined. Interaction between 6 kg/fad hydroxyapatite nanoparticles (A1) and 500 g/fad calcium carbonate nanoparticles (C3) under irrigation every 2 week (IR1) recorded the maximum values of 100-seed weight, pod yield, seed and biological yield. On the other hand the lowest means values were recorded at combination between zero kg/fad hydroxyapatite nanoparticles (A5) and zero g/fad calcium carbonate nanoparticles (C5) under irrigation every 3 week (IR2). Regarding to chemical composition interactions of irrigation intervals x apatite concentrations x nano calcium carbonate scored the highest and significant oil% and protein %. Interaction between 6 kg/fad hydroxyapatite nanoparticles (A1) and 500 g/fad calcium carbonate nanoparticles (C3) under irrigation every 2 week (IR1) recorded the maximum values of yield and quality studied traits of soybean plants.

Keywords: Soybean, Nano fertilizers, Calcium Carbonate Nanoparticles, Hydroxyl Apatite Nanoparticles, Irrigation Intervals.

INTRODUCTION

Soybean (Glycine max, L. Merr.) is a fundamental wellspring of vegetable protein for human food and animal feed around the world. It is anticipated to turn into a noteworthy crop in Africa (Sinclair et al., 2014). Soybean assumes a vital job in providing oil and protein required by people (Agarwal, 2007; Shi et al., 2010).

Water has become a limited resource in Egypt. Hence, the search for technologies/measures to save/conserve water in irrigated agriculture has intensified. Therefore, decreasing plant water consumption by stretching irrigation intervals will keep water through reducing number of irrigation but still attain similar economic yield (Mahmoud, et al., 2013). Ibrahim and Kandil (2007) in clay loam soil in Egypt reported that irrigation intervals significantly affected growth and yield attributes. Highest values of growth traits and productivity were achieved by irrigation every two week as compared with irrigation one week and three weeks days.

Nanotechnology it considers the great solution we can depend on now to develop agriculture practices. Consequently, our information about that technology must be growing up. Nanotechnology focused on the application of modern strategies for water management and pesticides (Prasad et al., 2014). Promising nanotechnology applications address low use effectiveness of agricultural production inputs and worry of drought and high soil temperature. Nano-scale agrichemical formulations can proficiency expands use and decline ecological losses. Nano-porous materials which able to storing water and gradually discharging it amid times of water shortage could likewise expand yields and save water (Bouwmeester et al., 2009).

Usage of phosphorus from the applied traditional phosphate fertilizers by plants is low because of its intricate reactions in soils. It’s considered that the competence of utilized phosphates manures is as low as about 20% relying upon soil properties. This has prompted a look for increasingly proficient methodologies for improving yield generation in low phosphates soils (Shenoy and Kalgudi, 2005). Phosphorus proficiency use can be improved by advancing soil use, preventing disintegration soils, keeping up soil quality, improving manure recommendations and fertilizer position techniques, yield genotypes, advancing mycorrhizas (Schroeder et al., 2011) and utilizing fertilizers and bio charcoal (Gunes et al., 2014). In addition to these, utilizing manufactured Nano-hydroxyapatite [Ca_{10} (PO_{4})_{6} (OH)_{2}; NHA] can be promising strategy to upgrade phosphates fertilizer use effectiveness. The present literature on Nano-hydroxyapatite is chiefly centered on its biomedical applications while potential farming applications have been not enough tended to (Kotegoda et al., 2011). In addition, he used modified urea hydroxyapatite as slow release fertilizer. Liu and Lal (2014) considered Nano-hydroxyapatite as alternative P fertilizer and they suggested that Nano-hydroxyapatite can potentially upgrade soybean grown in peat-perlite mixture.

Calcium carbonate is a primary component of garden lime, and known as agricultural lime, which use to...
enhance the soil quality by adjusting pH and water holding capacity of acidic soils. Calcium carbonate sources as limestone and chalk, along with other chemical compounds are used in the preparation of agricultural lime, when added to soil acts as a calcium source for plants (Sabriye and Ozdemir 2012). Plants need calcium for growth, enhance activate number of enzymes, metabolism systems, nitrate take-up a useable type of nitrogen, biomass proportion (Savithramma, 2002) and photosynthetic rate (Savithramma, 2004 and Savithramma et al., 2007).

Kara and Sabir (2010) tested a natural product made of Ca, Mg, Fe and Si elements and they found beneficial in production of robust plants by accelerating vegetative growth in nursery stage. Sprayed onto leaves it activate micronized particles penetrate through stomata into the leaves. In leaves the particles are split into CO$_2$ and CaO and MgO which are immediately available for plant. This process is triggered by chlorophyll absorbing light resulting in CO$_2$ plus H$_2$O which converted to carbohydrates and O$_2$.

Nano-particles can directly enter through stoma into leaf. Calcite particles are then split into CaO and CO$_2$ which, as demonstrated by Chen et al., (2004), is the driving force of the photosynthesis. The aim of work is to evaluate response of soybean plants growth, yield and yield quality to hydroxyl apatite nanoparticles and calcium carbonate nanoparticles under two irrigation intervals.

**MATERIALS AND METHODS**

**Experimental site**

During summer seasons of 2015 and 2017, a field experiment was conducted at the Research and Experimental Station (30°19′ N, 31°16′ E), Faculty of Agriculture, Ain Shams University at Shalakan, Kalubia Governorate, Egypt, to study the effects of combinations between hydroxyl apatite nanoparticles and calcium carbonate nanoparticles as nano-fertilizers under two irrigation intervals, on yield, yield attribute and seed chemical composition of soybean plants (*Glycine max*, Merrill c.v. Giza 111). The soil was clay loam and its properties are shown in Table 1. The preceding crop was wheat in both seasons.

**Table 1. Soil properties of the Research and Experimental Station at Shalakan**

| Soil depth (cm) | Mechanical analysis % | Chemical properties | Chemical properties
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clay</td>
<td>Silt</td>
<td>Sand</td>
</tr>
<tr>
<td>0–30</td>
<td>40</td>
<td>43</td>
<td>17</td>
</tr>
</tbody>
</table>

**Available macronutrients (mg kg$^{-1}$ soil)**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30</td>
<td>1189</td>
<td>2.2</td>
<td>327</td>
</tr>
</tbody>
</table>

**Soluble cations and anions (mg 100g soil$^{-1}$)**

<table>
<thead>
<tr>
<th></th>
<th>CO$_3$$^{-}$</th>
<th>HCO$_3$$^{-}$</th>
<th>Cl$^{-}$</th>
<th>SO$_4$$^{2-}$</th>
<th>Ca$^{++}$</th>
<th>Mg$^{++}$</th>
<th>Na$^{+}$</th>
<th>K$^{+}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–30</td>
<td>0.0</td>
<td>11.5</td>
<td>26.2</td>
<td>19.4</td>
<td>7.8</td>
<td>2.7</td>
<td>15.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Experimental treatments**

The experiment included 12 treatments which were the combinations of:-

1-**Hydroxyl apatite nanoparticles (HA):** foliar application of three concentrations, i.e. 0 kg fad$^{-1}$ (control), 3 kg fad$^{-1}$, 6 kg fad$^{-1}$ (faddan = 4200 m$^2$). A Hydroxyl apatite nanoparticle was sprayed three times after 25, 45, and 65 days from sowing. A Hydroxyl apatite nanoparticle was purchased from Bio-Nano fertilizer company and was characterized by x – ray diffraction, average crystal size 16.9 Nano-meters (fig 1).

2-**Calcium carbonate nanoparticles (CC):** foliar application of two concentrations, i.e. zero g fad$^{-1}$ (control), 500 g fad$^{-1}$ calcium carbonate nanoparticle was sprayed three times after 25, 45, and 65 days from sowing. Calcium carbonate nanoparticles was purchased from Bio-Nano fertilizer company and was characterized by x – ray diffraction, average crystal size 93.3 Nano-meters (fig 2).

3-**Irrigation intervals:** irrigation treatments, (irrigation at 2 and 3 weeks whereas irrigation every 2 weeks as a recommended practice). Irrigation treatments were followed after the first irrigation (25 days after planting).

![X-ray diffraction patterns of hydroxyapatite nanoparticles](image-url)
Experimental practices and design:
Treatments were arranged in the strip split plot design in 4 replicates. Plot area was 10.8 m² (6 ridges 3 m as long 0.60 m apart). Soybean seeds were sown in hills (20 cm between hills) on 25th May and 28th May in 2015 and 2017, respectively. Two plants were left in every hill while plant cultivation in the two sides of hill. Seeds were inoculated with (Bradyrhizopium Jaboncium) before sowing directly and nitrogen fertilizer (urea 46% N) was applied at the rate of 15 kg nitrogen as an active dose after 25 days from sowing.
Soybean (C.V. Giza111) seeds (gained from, Field Crops Research Institute, ARC) were broadcasted at a rate of 30 kg fad⁻¹, after irrigation. All other recommended agricultural practices were adopted throughout the two seasons.

Data recorded

Yield and yield attributes: Soybean plants were harvested in October 15th and October 25th during 2015 and 2017, respectively from two inner ridges in every plot to estimate the following yield characters:-
- a. 100 - seed weight (g)
- b. Hulling %
Moreover, plants from the two inner ridges were collected to estimate:-
- a. Biological yield fad⁻¹ (ton)
- b. Seed yield, fad⁻¹ (ton)
- c. Pods yield fad⁻¹ (ton),

Seed chemical composition

a. Crude protein percentage:- Total nitrogen was determined in seeds using the modified micro Kjeldahl method as described in A.O.A.C. (1995). Crude protein content was calculated by multiplying the total nitrogen by 5.7. Then, protein yield in kg per fadden was computed.

b. Seed oil percentage:-
For oil percentage determination, the technique for extraction and the methods used for determination were mainly by using petroleum ether in a Soxhelt apparatus according to A.O.A.C (1995)

Statistical analysis
All data were subjected to the analysis of variance (ANOVA) as single seasons and combined data using least significant difference (LSD) at 0.05 and 0.01 probability levels according to Gomez and Gomez, (1983).

RESULTS AND DISCUSSION

I- Seed yield and its components
A- Effect of irrigation intervals:-
Data presented in Table 2 stated that 100-seed weight was significantly affected by irrigation intervals in the two successive seasons; 2015 and 2017 as well as its combined data. On the contrary Hulling% did not affect by irrigation intervals in the two studied seasons; 2015 and 2017 or combined data. Similar trends were obtained by Kobraei et al. (2011), Golezani and Lotfi (2012) and Mahmoud, Gamalat et al. (2013).

Table 2. Effect of irrigation intervals on soybean pod yield ton per fadden, hulling percentage and 100-seed weight in the two studied seasons; 2015, 2017 and their combined data

<table>
<thead>
<tr>
<th>Irrigation intervals(weeks)</th>
<th>Pod yield (ton/fed)</th>
<th>Hulling %</th>
<th>100-seed weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Season 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.506</td>
<td>68.24</td>
<td>16.296</td>
</tr>
<tr>
<td>3</td>
<td>1.952</td>
<td>63.44</td>
<td>17.488</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.231</td>
<td>n.s</td>
<td>0.790</td>
</tr>
<tr>
<td></td>
<td>Season 2017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3.213</td>
<td>69.09</td>
<td>16.188</td>
</tr>
<tr>
<td>3</td>
<td>2.790</td>
<td>65.60</td>
<td>17.463</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.272</td>
<td>n.s</td>
<td>0.245</td>
</tr>
<tr>
<td></td>
<td>combined data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.859</td>
<td>68.66</td>
<td>16.242</td>
</tr>
<tr>
<td>3</td>
<td>2.371</td>
<td>64.52</td>
<td>17.475</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.170</td>
<td>n.s</td>
<td>0.472</td>
</tr>
</tbody>
</table>

Soybean seed yield /fadden and biological yield /fadden significantly influenced by irrigation intervals in the two studied seasons; 2015 and 2017 as well as combine result as shown in Table 3. Plants irrigated every two weeks produced higher seed yield /fadden and its biological yield /fadden in the two resulted seasons; 2015 and 2017 and its combine. The increments in seed yield /fadden and biological yield were (0.358 and 0.232 ton seeds /fadden) and (1.123 and 0.963 ton /fadden), respectively in the two growing seasons. The increases in seed yield /fadden or biological yield /fadden of irrigated plants every two weeks may be owing to its increases in number of branches and number of seeds /plant (Hussein, et al. 2019) or pod yield /fadden or/and 100-seed weight Table 2. Same workers came to similar conclusions as Kobraei et al. (2011), Golezani and Lotfi (2012) and Mahmoud, Gamalat et al. (2013).

B- Effect of calcium carbonate nanoparticles rates:-

Data in Table 4 revealed that pod yield /fadden and 100-seed weight were significantly affected by calcium carbonate nanoparticles in the two successive seasons; 2015 and 2017 as well as its combined result. Soybean plants treated by 500 g/fadden calcium carbonate nanoparticles produced higher pod yield /fadden, hulling% and 100-seed weight. These results mean that soybean plants were affected by calcium carbonate nanoparticles which encourage soybean plants to produce more pods as well as...
heavier seeds. Seed yield /faddan as well as biological yield /faddan (as shown in Table 5) significantly influenced by adding 500 g/faddan calcium carbonate nanoparticles in the two studied seasons; as well as combine result except the first season of study. The increases in seed yield /faddan or biological yield /faddan by adding 500 g/faddan calcium carbonate nanoparticles may be due to the increases in number of branches /plant and number of seeds /plant.


Table 3. Effect of irrigation intervals on seed yield (ton/fad) and biological yield (ton/fad) of soybean plants in the two studied seasons; 2015, 2017 and their combined data

<table>
<thead>
<tr>
<th>Irrigation intervals</th>
<th>Seed yield (ton/fad)</th>
<th>Biological yield (ton/fad)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Season 2015</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.553</td>
<td>4.154</td>
</tr>
<tr>
<td>3</td>
<td>1.195</td>
<td>3.031</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.072</td>
<td>0.131</td>
</tr>
<tr>
<td></td>
<td>Season 2017</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.576</td>
<td>6.592</td>
</tr>
<tr>
<td>3</td>
<td>1.344</td>
<td>5.629</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.111</td>
<td>0.915</td>
</tr>
</tbody>
</table>

Table 4. Effect of calcium carbonate nanoparticles on pod yield ton/fad, hulling percentage and 100-seed weight of soybean plants in the two studied seasons; 2015, 2017 and their combined data.

<table>
<thead>
<tr>
<th>Calcium Carbonate (g/fed)</th>
<th>Pod yield (ton/fad)</th>
<th>Hulling %</th>
<th>100-seed weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Season 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>2.026</td>
<td>68.30</td>
<td>17.00</td>
</tr>
<tr>
<td>500</td>
<td>2.389</td>
<td>63.38</td>
<td>16.78</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.190</td>
<td>3.61</td>
<td>n.s</td>
</tr>
<tr>
<td></td>
<td>Season 2017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>2.804</td>
<td>69.82</td>
<td>16.98</td>
</tr>
<tr>
<td>500</td>
<td>3.198</td>
<td>64.87</td>
<td>16.67</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.062</td>
<td>4.12</td>
<td>n.s</td>
</tr>
<tr>
<td></td>
<td>combined data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>2.436</td>
<td>69.06</td>
<td>16.99</td>
</tr>
<tr>
<td>500</td>
<td>2.793</td>
<td>64.12</td>
<td>16.73</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.087</td>
<td>3.28</td>
<td>n.s</td>
</tr>
</tbody>
</table>

Table 5. Effect of calcium carbonate nanoparticles on seed yield ton per faddan and biological yield ton per faddan of soybean plants in the two studied seasons; 2015, 2017 and their combined data.

<table>
<thead>
<tr>
<th>Calcium carbonate (g/fed)</th>
<th>Seed yield (ton/fad)</th>
<th>Biological yield (ton/fad)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Season 2015</td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>1.319</td>
<td>3.391</td>
</tr>
<tr>
<td>500</td>
<td>1.430</td>
<td>3.794</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>n.s</td>
<td>0.270</td>
</tr>
<tr>
<td></td>
<td>Season 2017</td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>1.387</td>
<td>5.770</td>
</tr>
<tr>
<td>500</td>
<td>1.533</td>
<td>6.450</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.039</td>
<td>0.253</td>
</tr>
</tbody>
</table>

C- Effect of hydroxyl apatite nanoparticles:

Data presented in Table 6 indicated that Pod yield /faddan and 100-seed weight were increased significantly with increasing hydroxyl apatite nanoparticles from 3 kg/faddan up to 6 kg/faddan. These results were fairly true in the two growing seasons; 2015 and 2017 as well as combine result. The increase in pod yield /faddan and 100-seed weight were (19.6% and 26.8%) and (7.0% and 7.0%) in the two growing seasons; 2015 and 2017, respectively.

In Table 7, Seed yield /faddan as well as biological yield /faddan were significantly affected by applying 6 kg/fed hydroxyl apatite nanoparticles in the two studied season; 2015 and 2017 as well as combine result. Soybean plants treated with 6 kg /faddan hydroxyl apatite nanoparticles produced the highest seed yield /faddan or biological yield /faddan in the two growing seasons. These results may be due to the more great permeability and high speed of hydroxyl apatite nanoparticles which mean more easily to penetrate into soybean leaves and release P and Ca which play an important role in pushing plant growth of soybean plants and there reflects on yield attributes. Some investigators come to similar trends as Subbaya et al., (2012), Liu and lal (2014), Liu and lal (2015), Upadhyaya et al., (2017) and Taşkın et al., (2018).

Table 6. Effect of Hydroxyl apatite nanoparticles on pod yield ton/fad, hulling percentage and 100-seed weight of soybean plants in the two studied seasons; 2015, 2017 and their combined data.

<table>
<thead>
<tr>
<th>Hydroxyl apatite (kg/fad)</th>
<th>Pod yield (ton/fad)</th>
<th>Hulling %</th>
<th>100-seed weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Season 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>2.055</td>
<td>69.77</td>
<td>16.29</td>
</tr>
<tr>
<td>3</td>
<td>2.174</td>
<td>64.54</td>
<td>16.94</td>
</tr>
<tr>
<td>6</td>
<td>2.458</td>
<td>63.21</td>
<td>17.44</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.178</td>
<td>3.32</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>Season 2017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>2.620</td>
<td>69.06</td>
<td>16.38</td>
</tr>
<tr>
<td>3</td>
<td>3.062</td>
<td>67.08</td>
<td>16.57</td>
</tr>
<tr>
<td>6</td>
<td>3.321</td>
<td>65.88</td>
<td>17.53</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.170</td>
<td>n.s</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>combined data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>2.338</td>
<td>69.42</td>
<td>16.33</td>
</tr>
<tr>
<td>3</td>
<td>2.618</td>
<td>65.81</td>
<td>16.76</td>
</tr>
<tr>
<td>6</td>
<td>2.889</td>
<td>64.54</td>
<td>17.48</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.136</td>
<td>3.85</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Table 7. Effect of Hydroxyl apatite nanoparticles on seed yield ton per faddan and biological yield ton per faddan of soybean plants in the two studied seasons; 2015, 2017 and their combined data.

<table>
<thead>
<tr>
<th>Hydroxyl apatite (kg/fad)</th>
<th>Seed yield (ton/fad)</th>
<th>Biological yield (ton/fad)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Season 2015</td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>1.233</td>
<td>3.101</td>
</tr>
<tr>
<td>3</td>
<td>1.350</td>
<td>3.608</td>
</tr>
<tr>
<td>6</td>
<td>1.539</td>
<td>4.068</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.097</td>
<td>0.299</td>
</tr>
<tr>
<td></td>
<td>Season 2017</td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>1.379</td>
<td>5.179</td>
</tr>
<tr>
<td>3</td>
<td>1.403</td>
<td>6.595</td>
</tr>
<tr>
<td>6</td>
<td>1.598</td>
<td>6.556</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.076</td>
<td>0.541</td>
</tr>
</tbody>
</table>

|                     | combined data        |                          |
| Zero                | 1.306                | 4.140                     |
| 3                   | 1.377                | 5.102                     |
| 6                   | 1.568                | 6.812                     |
| LSD at 5%           | 0.066                | 0.346                     |
D- Effect of interaction between irrigation intervals and calcium carbonate nanoparticles:

Data presented in Tables 8 revealed that pod yield/faddan, hulling%, 100-seed weight, seed yield ton/faddan and biological yield ton/faddan were significantly affected by interaction between irrigation intervals and calcium carbonate nanoparticles in the two growing seasons 2015 and 2017 except number of seeds/pod in the first season of study. Soybean plants irrigated every two weeks and treated by 500 g/fed calcium carbonate nanoparticles scored the highest value of pod yield/faddan, hulling %, 100-seed weight, seed yield ton/faddan and biological yield ton/faddan in the two studied seasons 2015 and 2017, respectively while soybean plants irrigated every 2 or 3 weeks and treated by 500 g/fed calcium carbonate nanoparticles had more seed/pod and hulling% either during 2015 or 2017 seasons as shown in Tables 8. These results may be regarded to the effect of calcium carbonate nanoparticles in pushing growth of plants to accumulate more dry matter which intern in yield attributes some worker came to similar trends as Kobraei et al., (2011), Golezani and Lotfi (2012), Sabir et al., (2014) and Abd El-Aal and Eid (2018).

Table 8. Effect of interaction between irrigation intervals and calcium carbonate nanoparticles on soybean yield attributes during the two growing seasons 2015 and 2017.

<table>
<thead>
<tr>
<th>Calcium carbonate nanoparticles (g/fad)</th>
<th>2015</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation intervals (weeks)</td>
<td>Zero</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>2.328</td>
<td>2.684</td>
</tr>
<tr>
<td>3</td>
<td>1.811</td>
<td>2.093</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.261</td>
<td>0.163</td>
</tr>
<tr>
<td>2</td>
<td>70.76</td>
<td>65.72</td>
</tr>
<tr>
<td>3</td>
<td>65.84</td>
<td>61.04</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>3.74</td>
<td>6.97</td>
</tr>
<tr>
<td>100-seed weight (g)</td>
<td>2</td>
<td>16.17</td>
</tr>
<tr>
<td>3</td>
<td>17.84</td>
<td>17.13</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.85</td>
<td>0.68</td>
</tr>
<tr>
<td>Seed yield (ton/fad)</td>
<td>2</td>
<td>1.473</td>
</tr>
<tr>
<td>3</td>
<td>1.165</td>
<td>1.225</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.172</td>
<td>0.090</td>
</tr>
<tr>
<td>Biological yield (ton/fad)</td>
<td>2</td>
<td>3.778</td>
</tr>
<tr>
<td>3</td>
<td>3.004</td>
<td>3.058</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.315</td>
<td>0.620</td>
</tr>
</tbody>
</table>

E- Effect of interaction between irrigation intervals and hydroxyapatite nanoparticles:

Data tabulated in Tables 9 observed that all studied yield attributes pod yield/faddan, hulling%, 100-seed weight, seed yield ton/faddan and biological yield ton/faddan were statistically influenced by interaction between irrigation intervals and hydroxyapatite nanoparticles in the two growing seasons 2015 and 2017 except number of seeds/pod in the first season of study.

These results were so great and enough to reach the 5% level of significance. Irrigated soybean plants every two weeks and received 6 kg/faddan hydroxyapatite nanoparticles had the highest value of pod yield ton/faddan, seed yield ton/faddan and biological yield ton/faddan in the two studied seasons 2015 and 2017, as shown in tables (9). More effects in the same trend done by Kobraei et al., (2011), Golezani and Lotfi (2012), Mahmoud, Gamalat et al., (2013), Liu and Ial (2015) and Upadhyaya et al., (2017).

Table 9. Effect of interaction between irrigation intervals and hydroxyapatite nanoparticles on soybean yield attributes during the two growing seasons 2015 and 2017.

<table>
<thead>
<tr>
<th>Hydroxyapatite nanoparticles (kg/fad)</th>
<th>2015</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation intervals (weeks)</td>
<td>Zero</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>2.330</td>
<td>2.280</td>
</tr>
<tr>
<td>3</td>
<td>1.780</td>
<td>2.068</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.321</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>70.78</td>
<td>66.90</td>
</tr>
<tr>
<td>3</td>
<td>68.76</td>
<td>62.19</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>6.93</td>
<td></td>
</tr>
<tr>
<td>Seed yield (ton/fad)</td>
<td>2</td>
<td>1.461</td>
</tr>
<tr>
<td>3</td>
<td>1.006</td>
<td>1.291</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.155</td>
<td></td>
</tr>
<tr>
<td>Biological yield (ton/fad)</td>
<td>2</td>
<td>3.870</td>
</tr>
<tr>
<td>3</td>
<td>2.333</td>
<td>3.148</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.503</td>
<td></td>
</tr>
</tbody>
</table>

F- Effect of interaction between calcium carbonate nanoparticles and hydroxyapatite nanoparticles:

Data in Tables 10 reported that all studied measurements of soybean seed yield and its attributes were significantly influenced by the interaction between calcium carbonate nanoparticles and hydroxyapatite nanoparticles in the two studied seasons 2015 and 2017, except 100-seed weight in the first season.

Table 10. Effect of interaction between hydroxyapatite and calcium carbonate nanoparticles on soybean yield attributes during the two growing seasons 2015 and 2017.

<table>
<thead>
<tr>
<th>Hydroxyapatite nanoparticles (kg/fad)</th>
<th>2015</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate (g/fed)</td>
<td>Zero</td>
<td>3</td>
</tr>
<tr>
<td>0</td>
<td>1.783</td>
<td>2.149</td>
</tr>
<tr>
<td>500</td>
<td>2.328</td>
<td>2.199</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.169</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>76.60</td>
<td>65.20</td>
</tr>
<tr>
<td>500</td>
<td>62.94</td>
<td>63.89</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>6.45</td>
<td></td>
</tr>
<tr>
<td>Seed yield (ton/fad)</td>
<td>2</td>
<td>1.092</td>
</tr>
<tr>
<td>500</td>
<td>1.375</td>
<td>1.390</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.189</td>
<td></td>
</tr>
<tr>
<td>Biological yield (ton/fad)</td>
<td>2</td>
<td>3.725</td>
</tr>
<tr>
<td>500</td>
<td>3.478</td>
<td>3.845</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>0.243</td>
<td></td>
</tr>
</tbody>
</table>
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Soybean pod yield /faddan, seed yield ton/faddan and biological yield ton/faddan of plants treated with 500 g/faddan calcium carbonate nanoparticles and 6 kg/faddan hydroxyl apatite nanoparticles were so great and enough to reach the 5% level of significance in the two studied seasons 2015 and 2017. These results may be due to the role of calcium carbonate nanoparticles and/or hydroxyl apatite nanoparticles in seed filling and plant metabolism. Similar trends were obtained by Liu and Lal (2014), Sabir et al., (2014), Liu and Lal (2015), Abd El-Aal and Eid (2018) and Taşkın et al., (2018).

G- Irrigation intervals X calcium carbonate nanoparticles X hydroxyl apatite nanoparticles interaction:

Figures from 3 to 7 show the effect of the triple interaction among calcium carbonate, hydroxyl apatite levels and irrigation intervals treatments on soybean yield attributes. Results revealed clearly that the interaction effect was significant. These significant effects reflect that tested calcium carbonates nanoparticles along with hydroxyl apatite nanoparticles levels do not take the same behavior under the different treatments of irrigation intervals. Interaction between 6 kg/fed hydroxyl apatite nanoparticles (A3) and 500 g/fed calcium carbonate nanoparticles (C2) under irrigation every 2 week (IR 1) recorded the maximum values of 100-seed weight (17.613 g), pod yield (3.454 ton/fed.), seed yield (1.866 ton/fed.) and biological yield (6.606 ton/fed.). On the other hand the lowest means values were recorded at combination between zero kg/fed hydroxyl apatite nanoparticles (A1) and zero g/fed calcium carbonate nanoparticles (C1) under irrigation every 3 week (IR 2) on all yield attributes on contrary, this combination scored the highest hulling% may be due to decreased in number of sinks (seeds) which made all dry mater accumulations distribute on small number of seeds which reflect increases in hulling%. As shown from figures (11 to 18) there weren’t significant results between plants treated with nano-mineral fertilizers under irrigation every 3 week and plants untreated but irrigated every 2 week (normal case) in all yield attributes, which reflect appositive result of these chemical substances in mitigation harmful effect of water shortage consequently, achieve great productivity. Erkan et al., (2004), Liu and Zhao (2013), Mahmoud Gamalat et al., (2013), Liu and Lal (2014), Liu and Lal (2015) and Mehmet et al., (2018) came to the same trends.
Table 11. Effect of the triple interaction among irrigation intervals, hydroxyl apatite nanoparticles and calcium carbonate nanoparticles on oil percentage of soybean seeds.

<table>
<thead>
<tr>
<th>Irrigation intervals</th>
<th>every 2 weeks</th>
<th>every 3 weeks</th>
<th>Mean apatite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>Zero g /fed</td>
<td>500 g /fed</td>
<td>Zero g /fed</td>
</tr>
<tr>
<td>Zero kg apatite/fed</td>
<td>19.55</td>
<td>19.90</td>
<td>19.55</td>
</tr>
<tr>
<td>3 kg apatite/fed</td>
<td>20.75</td>
<td>20.95</td>
<td>20.05</td>
</tr>
<tr>
<td>6 kg apatite/fed</td>
<td>21.25</td>
<td>21.45</td>
<td>20.70</td>
</tr>
<tr>
<td>Mean irrigation</td>
<td>20.64</td>
<td>20.13</td>
<td></td>
</tr>
<tr>
<td>Mean calcium</td>
<td>Zero= 20.31</td>
<td>500 g= 20.47</td>
<td></td>
</tr>
<tr>
<td>LSD apatite (A)</td>
<td>n.s</td>
<td>n.s</td>
<td>1.18</td>
</tr>
<tr>
<td>LSD irrigation (I)</td>
<td>n.s</td>
<td>n.s</td>
<td>0.84</td>
</tr>
<tr>
<td>LSD calcium (C)</td>
<td>n.s</td>
<td>n.s</td>
<td>0.71</td>
</tr>
<tr>
<td>LSD I x A x C</td>
<td></td>
<td></td>
<td>0.94</td>
</tr>
</tbody>
</table>

Table 12. Effect of the triple interaction among irrigation intervals, hydroxyl apatite nanoparticles and calcium carbonate nanoparticles on protein percentage of soybean seeds.

<table>
<thead>
<tr>
<th>Irrigation intervals</th>
<th>every 2 weeks</th>
<th>every 3 weeks</th>
<th>Mean apatite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>Zero g /fed</td>
<td>500 g /fed</td>
<td>Zero g /fed</td>
</tr>
<tr>
<td>Zero kg apatite/fed</td>
<td>42.17</td>
<td>39.90</td>
<td>44.76</td>
</tr>
<tr>
<td>3 kg apatite/fed</td>
<td>41.25</td>
<td>39.81</td>
<td>42.66</td>
</tr>
<tr>
<td>6 kg apatite/fed</td>
<td>37.35</td>
<td>36.85</td>
<td>37.33</td>
</tr>
<tr>
<td>Mean irrigation</td>
<td>39.09</td>
<td>40.88</td>
<td></td>
</tr>
<tr>
<td>Mean calcium</td>
<td>Zero= 40.92</td>
<td>500 g= 39.04</td>
<td></td>
</tr>
<tr>
<td>LSD apatite (A)</td>
<td>0.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD irrigation (I)</td>
<td>1.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD calcium (C)</td>
<td>n.s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD I x A x C</td>
<td>0.84</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REFERENCES


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**تأثير التسميد الورقي بالسدامات النانوية في نجاعة الفول الصويا محصول القرون (%)**

**محمد أحمد عبدالهادي و حسام حسین محمد**

**قسم المحاصيل، كلية الزراعة، جامعة عين شمس**

أثناء صيف ٢٠١٦-٢٠١٧، أُقيمت تجربة حقلية في محطة تجريب جامعة عين شمس ببلدان، محافظة الفيلقية، مصر. النباتات كانت من الفول الصويا بذرة مزارعة (١٠٠ حبات/قاذفة) من زراعة الدمان التسميد الورقي. حيث تم إضافة المكونات النباتية من جزيئات الهيدروکسي أباتيت التانوميّة (٨٠٪) و كربونات الكالسيوم النانوميّة (٢٠٪) في مستويات مختلفة (٠، ١، ٢، ٣ جرام/فدان). حيث أظهرت النتائج أن التسميد النانوميّة من جزيئات الهيدروکسي أباتيت التانوميّة (٨٠٪) و كربونات الكالسيوم النانوميّة (٢٠٪) في مستويات مختلفة (٠، ١، ٢، ٣ جرام/فدان) أدى إلى زيادة في نجاعة الفول الصويا محصول القرون بنسبة تصل إلى ٦٨%، و أن النباتات التي تلقت التسميد النانوميّة من جزيئات الهيدروکسي أباتيت التانوميّة (٨٠٪) و كربونات الكالسيوم النانوميّة (٢٠٪) في مستويات مختلفة (٠، ١، ٢، ٣ جرام/فدان) أدى إلى زيادة في نجاعة الفول الصويا محصول القرون بنسبة تصل إلى ٦٨%. و أن النباتات التي تلقت التسميد النانوميّة من جزيئات الهيدروکسي أباتيت التانوميّة (٨٠٪) و كربونات الكالسيوم النانوميّة (٢٠٪) في مستويات مختلفة (٠، ١، ٢، ٣ جرام/فدان) أدى إلى زيادة في نجاعة الفول الصويا محصول القرون بنسبة تصل إلى ٦٨%. و أن النباتات التي تلقت التسميد النانوميّة من جزيئات الهيدروکسي أباتيت التانوميّة (٨٠٪) و كربونات الكالسيوم النانوميّة (٢٠٪) في مستويات مختلفة (٠، ١، ٢، ٣ جرام/فدان) أدى إلى زيادة في نجاعة الفول الصويا محصول القرون بنسبة تصل إلى ٦٨%.