Improving the growth and yield of okra plants (*Abelmoschus esculentus* L.) using Lithovit fertilizer

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ABSTRACT

The experiment was undertaken at the farm of the Faculty of Agriculture, Al-Azhar University, Nasr city, Cairo, Egypt during the two summer seasons of 2016 and 2017 to evaluate the effect of foliar spray with Lithovit as nano-fertilizer at concentrations of 0.75, 1.00 and 1.25 g on growth and yield of okra plant (*Abelmoschus esculentus* L.) cultivar Dokki 2. The obtained results showed that plant height, number of leaves and branches and leaf area beside pod length, diameter and weight, as well as total yield in weight and number of pods per plant significantly increased with the use of Lithovit concentration of 0.75 g. The same trend was obtained for dry weight and total chlorophyll contents in the leaf and pod, as well as the pod contents of ascorbic acid and T.S.S. As a result, this study suggested that the foliar application of Lithovit fertilizer at concentrations of 0.75 g could improve plant growth and yield of okra. Therefore, considerable attention should be given to the application of this Lithovit as a nano-fertilizer.

Key words: Lithovit, nano-fertilizer, yield of okra.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is one of the chief vegetable crops grown in Egypt for its edible green pods, which can be used as fresh, canned, frozen, or dried food. The cultivated area of this crop in 2014 was estimated at 20886 feddan, which produced about 101923.68 tons with an average yield of 4.88 tons per feddan (FAO, 2014). Fertilizers are important factors in agriculture since they provide essential nutrients for plant growth. The current mission of scientific research is to deliver such nutrients to the plants in the most efficient way (Tantawy et al., 2014). The development and application of new types of fertilizers using innovative nanotechnology are one of the potentially effective options of significantly increasing nutrient use efficiency, reducing wastage of fertilizers and cost of cultivation (Singh et al., 2017), thereby enhancing the agricultural productions needed to meet the future demands of the growing population. Indeed, the review of available literature indicates that some nanomaterials can enhance plant growth in certain concentration ranges and could be used as nano-fertilizers in agriculture to increase agronomic yields of crops and/or minimize environmental pollution (Ibrahim et al., 2016). Hence, Lithovit is a natural CO₂ nano-fertilizers that can be used successfully outdoors, as well as indoors. Lithovit fertilizer consists of Calcium - Magnesium Carbonate (Ca, Mg)CO₃, supplemented by numerous important micronutrients. It is produced by milling natural limestone in special mills down to particle diameter < 10 nm (Nassef and Nabeel, 2012). The mechanism of action of this foliar fertilizer is to increase CO₂ levels in the leaves, leading to an increase in photosynthesis and higher crop yields. The work done on Lithovit fertilizer is very limited in the scientific field, but reported literature clearly demonstrated that this customized fertilizer has a potential role to play in sustaining farm productivity (Rai et al., 2015). In this regard, it was showed that the Lithovit application had a significant effect on total broccoli yield (Nassef and Nabeel, 2012). Therefore, the main objective of this study was to evaluate the effect of the foliar application of Lithovit fertilizer at different concentrations on the growth and
Table 1: Chemical analysis of Lithovit according to Hamoda et al. (2016).

<table>
<thead>
<tr>
<th>Component (%)</th>
<th>Value</th>
<th>Component (%)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>79.19</td>
<td>Sulphate</td>
<td>0.33</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.06</td>
<td>Iron</td>
<td>1.31</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0.01</td>
<td>Zinc</td>
<td>0.005</td>
</tr>
<tr>
<td>Potassium oxide</td>
<td>0.21</td>
<td>Copper</td>
<td>0.002</td>
</tr>
<tr>
<td>Magnesium carbonate</td>
<td>4.62</td>
<td>Manganese</td>
<td>0.014</td>
</tr>
<tr>
<td>Selenium dioxide</td>
<td>11.41</td>
<td>Sodium oxide</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Table 2: The physical and chemical properties of experimental soil.

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Chemical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay (%)</td>
<td>E.C (mMOL/cm³)</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>pH</td>
</tr>
<tr>
<td>Sand (%)</td>
<td>Cation meq/L</td>
</tr>
<tr>
<td>Texture</td>
<td>Anion meq/L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2016 season</th>
<th>2017 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca**</td>
<td>Mg**</td>
</tr>
<tr>
<td>1.12</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Figure 1: Average air temperature (ºC) at experimental field during the two seasons of 2016 and 2017.

yield of okra plants.

MATERIAL AND METHODS

This research was carried out during the two summer seasons of 2016 and 2017 at the farm of the Faculty of Agriculture, Al-Azhar University, Nasr city, Cairo, Egypt. It aims to assess the effect the foliar application of Lithovit fertilizer at different concentrations on the growth, yield, and pods quality of okra plants (*Abelmoschus esculentus* L.) cv. Dokki 2. The used Lithovit fertilizer was obtained from Agrolink Company, Cairo, Egypt as a powder and prepared by dissolving three concentrations of 0.75, 1.00 and 1.25 g per liter of distilled water. Also, distilled water was used as control. The plants were sprayed three times, starting with the appearance of the first three true leaves and repeated each 15 days interval with the mentioned Lithovit concentrations. The different constituents of Lithovit fertilizer are shown in Table 1. The seeds were directly sown in the field on March 26th in the two seasons.

Planting spacing was done at 60 cm between rows and 30 cm between plants in the row. Each row was 3 m long and 60 cm wide. The area of each experimental unit was 7.20 m². After complete germination, plants were thinned into one plant per hill. The treatments were laid out in a complete randomized blocks design with three replications for each treatment. Furrow irrigation was applied and weeds were controlled manually. All the treatments received the recommended doses of fertilizers according to Hassan (1989), which were 200 kg ammonium sulfate, 200 kg calcium super phosphate and 100 kg potassium sulfate per feddan. The amounts of fertilizers were divided into three equal parts. The first was employed after thinning; the second dose was added at the beginning of fruit set, whereas the third one was added after month from the second dose. The obtained results of the physical and chemical analyses of experimental soil are presented in Table 2. The average air temperatures (ºC) at experimental field during the growing seasons is shown in Figure 1.

During the vegetative growth period, samples of 10
plants were taken at 90 days after sowing to record the physical parameters as plant height (cm), number of leaves and branches and leaf area, as well as the chemical constituents in leaf as dry weight. Thus total chlorophyll was determined according to Lichtenthaler (1987). The pods were harvested every three days along the harvesting stage and samples were taken from each treatment to determine the physical characteristics including pod length, diameter and weight, as well as chemical constituents in pods mainly dry weight. Thus total chlorophyll was determined according to Lichtenthaler (1987). Ascorbic acid and total soluble solids (T.S.S) were determined using the method published by A.O.A.C (2005).

The data were subjected to statistical analysis using the analysis of variance methods, and the means of treatments were compared using the Least Significant Different (L.S.D) at 5% level of probability as described by Snedecor and Cochran (1980).

RESULTS

The results of plant physical characteristics obtained from the foliar spray with the different concentrations of CO₂ nano-fertilizer in the form of Lithovit (Figure 2) showed that there were significant increases in the plant height, number of leaves and branches, as well as leaf area using Lithovit concentration of 0.75 g as compared with the other concentrations of 1.00 and 1.25 g and control treatment. There were increases in the two concentrations, 1.00 and 1.25 g, for plant height character in the second season, but the difference did not attain the level of significant. Therefore, Lithovit foliar application at 0.75 g obtained the highest values of plant physical characteristics, while unsprayed plants with Lithovit recorded the lowest values.

The data in Figure 3 showed that the application of Lithovit fertilizer as foliar spray at different concentrations had pronounced effects on plant chemical constituents. Dry weight and total chlorophyll contents in leaf were significantly increased with the application of Lithovit at 0.75 g and then decreased with increase in Lithovit concentrations. Thus, the highest accumulation of dry weight and total chlorophyll contents in leaf was observed in the application of 0.75 g concentration of Lithovit, whereas the lowest one was observed in the control plants.

With regard to the effect of the different Lithovit concentrations on pod length, diameter and weight (Figure 4), it was shown that foliar application of Lithovit at 0.75 g significantly increased pod length, diameter and weight when compared with the control treatment, while more
Figure 3: Effect of foliar spray with Lithovit on leaf dry weight and total chlorophyll contents of okra during the two seasons of 2016 and 2017.

<table>
<thead>
<tr>
<th>Lithovit concentrations (g/L)</th>
<th>2016 season</th>
<th>2017 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry weight (g/100 g. F.W)</td>
<td>18.05</td>
<td>17.08</td>
</tr>
<tr>
<td></td>
<td>16.21</td>
<td>16.29</td>
</tr>
<tr>
<td></td>
<td>15.65</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td>15.03</td>
<td>14.79</td>
</tr>
<tr>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.S.D</td>
<td>0.82</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Figure 4: Effect of foliar spray with Lithovit on the physical characteristics of okra pods during the two seasons of 2016 and 2017 seasons.

<table>
<thead>
<tr>
<th>Lithovit concentrations (g/L)</th>
<th>2016 season</th>
<th>2017 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (cm)</td>
<td>3.97</td>
<td>3.71</td>
</tr>
<tr>
<td></td>
<td>3.44</td>
<td>3.44</td>
</tr>
<tr>
<td></td>
<td>3.37</td>
<td>3.37</td>
</tr>
<tr>
<td></td>
<td>3.34</td>
<td>3.34</td>
</tr>
<tr>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>1.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.S.D</td>
<td>0.42</td>
<td>0.24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lithovit concentrations (g/L)</th>
<th>2016 season</th>
<th>2017 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (cm)</td>
<td>1.46</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td>1.28</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>1.23</td>
<td>1.21</td>
</tr>
<tr>
<td>0.75</td>
<td></td>
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<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.25</td>
<td></td>
<td></td>
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<tr>
<td>Control</td>
<td></td>
<td></td>
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<tr>
<td>L.S.D</td>
<td>0.14</td>
<td>0.06</td>
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</table>

<table>
<thead>
<tr>
<th>Lithovit concentrations (g/L)</th>
<th>2016 season</th>
<th>2017 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g)</td>
<td>4.87</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>4.63</td>
<td>4.71</td>
</tr>
<tr>
<td></td>
<td>4.56</td>
<td>4.61</td>
</tr>
<tr>
<td></td>
<td>4.52</td>
<td>4.45</td>
</tr>
<tr>
<td>0.75</td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td></td>
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<tr>
<td>1.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.S.D</td>
<td>0.07</td>
<td>0.05</td>
</tr>
</tbody>
</table>

than this concentration led to non-significant decrease in pod length and diameter characteristics in the first season only. However, the highest values of pod length, diameter and weight were obtained from the use of 0.75 g Lithovit and the lowest one from use of control treatment.

The changes in dry weight and total chlorophyll contents in pod due to the foliar spray by the different concentrations of Lithovit (Figure 5) showed that the contents of dry weight and total chlorophyll in pod significantly increased by the concentration of Lithovit at 0.75 g and thereafter decreased with high concentrations in spite of the non-significant differences that occurred in
Concerning the effect of different concentrations of Lithovit on the pod contents of ascorbic acid and total soluble solids (Figure 5), it was shown that the foliar spray with 0.75 g Lithovit induced the highest significant increase in the contents of ascorbic acid and T.S.S in pod, and then a significant decrease occurred with high concentrations. Hence, the best results in the contents of ascorbic acid and T.S.S in pod was achieved in plants sprayed with the concentration of Lithovit at 0.75 g and the opposite was true in the use of high concentrations and unsprayed plants.

Regarding the effect of the foliar spray with the different concentrations of Lithovit on the total yield of pods per plant (Figure 6), the results obtained showed that there was a significant increase in total yield as weight and number for plants treated with 0.75 g Lithovit. But a significant decrease occurred in the Lithovit concentrations of 1.00 and 1.25 g. The data showed that the highest total yield as weight and number was observed in foliar spray with the concentration of Lithovit at 0.75 g, while the lowest one in the unsprayed plants.

**DISCUSSION**

The present investigation was designed to throw light on the effect of the foliar spray with the different concentrations of Lithovit as nano-fertilizer on the growth and yield of okra plants. The results obtained in the present study indicated that okra plants treated with 0.75 g Lithovit was superior in its effects as compared with the other concentrations of 1.00 and 1.25 g and control treatment. Hence, the figures in this experiment showed that the plant and pod physical characteristics, such as plant height, number of leaves and branches and leaf area beside pod length, diameter and weight, as well as total yield in weight and in number obtained the highest significant increase due to Lithovit foliar application at 0.75 g. These results may be attributed to the role of...
Lithovit at this rate of feeding okra plant leaves with CO₂ gas from inside the leaves at a much higher rate than in the air, thus enhancing the basic process of photosynthesis and prompting assimilates accumulation, which is essential for building up protoplasm and protein, as well as inducing cell division, which resulted in an increase in cell number and cell size with an overall increase in the vegetative growth (Ibrahim et al., 2016). These improvements in the vegetative growth may be lead to direct effect on the pod length, diameter and weight. Consequently, the increase in total yield as weight and number from plants treated with 0.75 g Lithovit may be closely linked to the increase in vegetative growth characteristics and pod parameters (Figures 2 and 4).

As regard changes in the chemical contents of the plant and pod of okra, the results indicated that supplying okra plants with Lithovit fertilizer as foliar spray at 0.75 g significantly increased the leaf and pod dry weight content. These results obtained may be as a result of improvements in the physiological process of the plants, such as photosynthesis, resulting from the increasing chlorophyll contents of okra plants under proper rate of nanofertilizer, which in turn leads to increase in dry weight content (Tantawy et al., 2014). Also, the data indicate that the increase of leaf and pod total chlorophyll content, as a result of Lithovit application with concentration of 0.75 g, may be due to the additional supply of micronutrients from the Lithovit complex, which is the chief constituent for chlorophyll synthesis (Hamoda et al., 2016). At the same time, the best results in the contents of ascorbic acid and T.S.S in pod was achieved from the use of Lithovit concentration of 0.75 g. These results confirmed the effect of Lithovit, as a CO₂ reservoir, on increasing the contents of ascorbic acid and T.S.S in pod and it can be explained by its stimulatory effect on carbon assimilation (Ibrahim et al., 2016).

Hence, all these superior effects of CO₂ nano-fertilizer in the form of Lithovit at 0.75 g indicated that Lithovit can be used as foliar fertilizer because Lithovit’s mode of action is to increase CO₂ levels within the plant leaf structure and by implication enhance photosynthetic efficiency (Carmen et al., 2014) and this in turn, might affect all morphological parameters of the growing plants and increase the pod characteristics and quality. More so, Lithovit fertilizer particles are so small (<10 nm) that they can be absorbed directly through the stomata of the plant leaves (Ibrahim et al., 2016). Inside the leaves, Lithovit particles break down and release CO₂ enhancing the CO₂ concentration at the photo-synthetically active area within the plant leaves, leading to a stronger natural growth and, consequently, increased yield. Furthermore, the release of CO₂ from the Lithovit remaining on the leaves surface is probably due to its transformation to (Ca, Mg)(HCO₃)₂ during the night by means of CO₂ (produced by the plants in addition to that in the atmosphere) and H₂O (which covers the leaves as dew in addition to that produced by the plants). During the day, temperature rises gradually, water evaporation occurs and the (Ca, Mg)(HCO₃)₂ is back transformed to Lithovit generating CO₂ at high concentration directly in the leaves surface (Nassef and Nabeel, 2012). Also, the supplements
of micronutrients from Lithovit complex increase the enzymatic activity that plays a role in photosynthetic activity (Hamoda et al., 2016). For a clear mode of entry of nanoparticles into plants, it is quite possible to say that plant cell wall acts as a barrier for easy entry of any external agents including nanoparticles into the plant cells. The sieving properties are determined by pore diameter of cell wall ranging from 5 to 20 nm (Fleischer et al., 1999). Hence, only nanoparticles with diameter less than the pore diameter of the cell wall could easily pass through and reach the plasma membrane (Moore, 2006). There is also a chance for enlargement of pores or induction of new cell wall pores upon interaction with engineered nanoparticles, which in turn, enhance nanoparticle uptake. Thus, when nanoparticles are applied on leaf surfaces, they enter through the stomatal openings or through the bases of trichomes and then translocated to various tissues (Fernandez and Eichert, 2009). Therefore, further studies on the mechanism of action of Lithovit as a nano-fertilizer still need to be carried out.

Finally, the nanomaterial is one of the new technologies used almost in all aspects of our lives, especially in agricultural production. This study has shown that CO₂ nano-fertilizer in the form of Lithovit can be effective on okra growth, yield quantity and quality. Therefore, considerable attention should be directed towards the application of Lithovit as a nano-fertilizer.

REFERENCES


