Phosphorus Fertilizer Level Related with Nano-Chitosan Concentration and their Influence on Growth, Yield and Chemical Constituents of Hot pepper

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ABSTRACT

Two field experiments were done at a privat farm in Mansoura, Dakahlia Governorate, Egypt, during the two summer consecutive seasons of 2019 and 2020. The research objective of this work was to examine the influence of foliar application of nano-chitosan at different concentrations (0, 25, 50 and 100 ppm) under different phosphorus fertilizer level (0, 16, 32 and 48 kg P₂O₅/feddan) on hot pepper “cv. Hyffa” productivity. The influence of phosphorus fertilizer, nano-chitosan and their interaction treatments were determined on plant growth, yield components, some chemical constituents. Phosphorus fertilization at 48 kg P₂O₅/feddan significantly increased hot pepper growth (plant height, number of branches per plant and total plant dry weight), yield components parameters (fruit set %, fruit length, fruit diameter, fruit yield per plant and early yield and total yield per feddan) and chemical constituents (total chlorophyll, total soluble solids, vitamin C, total nitrogen%, total phosphorus % and potassium %) as well as capsaicin content in fruits compared to control and the lowest levels under study. In addition, increasing nano-chitosan concentrations gradually increased all measured parameters to reach the highest values with 100 ppm concentration as foliar spray compared to the other treatments under study. Generally, the results of this work demonstrated that foliar applications of 100 ppm nano-chitosan could help enhance hot pepper (Capsicum annuum, L.) growth and productivity as well as content of alkaloids (determined as capsaicin) when interacted with 48 kg P₂O₅/feddan under Dakahlia Governorate conditions.

Keywords: Hot pepper, phosphorus, nano-chitosan, plant growth, yield, chlorophyll, capsaicin.

INTRODUCTION

Hot pepper belongs to the family solanaceae and has a large economic value. It is also very marketable among the people for its nutritional and medicinal values; moreover, the extract of hot pepper is utilized in several pharmaceutical products. Hot pepper gives a share in basically to the world diet. Peppers are widely grown in several regions of Egypt and the hot pepper fruits are used as fresh, dried and processed products as well as like vegetables, as spices or condiments. Nutritionally, hot pepper supplies the body with vitamins (A and C), proteins and many of mineral nutrients (Bose et al., 1993). However, Agusiobo (1976) and Keshinro and Ketiku (1983) demonstrated that vitamin C gained from pepper is better than that obtained from tomato.

Phosphorus element (P) is one of the main macronutrients for plant development and growth and suitable phosphorus fertilization is fundamental to get optimum yields. The influence of phosphorus on the roots development, nodulation as well as formation and translocation of carbohydrates, also, growth and other agronomic characters are well known. Phosphorus encourages earliness in flowering formation and fruit set including seed formation (Buckman and Brady, 1980). In this concern, a many literatures reported that phosphorus fertilization has positive influence on growth, yield and quality of some medicinal and aromatic plants such as chilli (Tanwar et al., 2013; Islam et al., 2018 and Alabi and Ayodele, 2019), fennel (Zaki et al., 2019) and anise (Sonmez, 2018).

Chitosan, a mutual name to a deacetylated form of chitin, is a naturalist biodegradable material obtained from crustaceous seashells, whose main characteristics matches to its poly cationic nature (Bautista-Baños et al., 2006). Moreover, Auffan et al. (2009) indicated that nanotechnology utilizes nano-particles including at smaller one dimension in the order of hundred nm or least. In general, chitosan treatment has been demonstrated to stimulate chilli growth and yield (Choookhongkha et al., 2012 and Dzung et al., 2017) and chemical constituents (Kazemi and Salimi, 2019).

Therefore, to gain acceptable growth, yield and chemical constituents of hot pepper, Hyffa variety during summer season, this work aimed to evaluate the advantageous influences of foliar spraying of nano-chitosan interacted with phosphorus fertilization in terms of enhanced productivity of (Capsicum annuum) under Dakahlia Governorate, Egypt conditions.

MATERIALS AND METHODS

This research was conducted to investigate the influence of different levels of phosphorus fertilization (0.0, 16, 32 and 48 kg P₂O₅/feddan), nano-chitosan (0.0, 25, 50 and 100 ppm) and their interaction treatments on plant growth, yield components and chemical constituents of hot
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pepper plant. Table 1 shows physical and chemical analysis of the experimental soil (average of the two seasons) at a depth of 0-30 cm according to Chapman and Pratt (1978).

**Experimental design:**

The current experiments were set up in a split-plot design with three replicates. The main plots were occupied by 4 phosphorus fertilization levels. While, the sub plots were entitled to 4 nano-chitosan concentrations. The interaction between the main factor and the sub factor resulted in 16 interaction treatments.

| Table 1. Physical and chemical properties of experimental farm soil (average of two seasons) |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Clay (%)                        | Silt (%)                        | Coarse sand (%)                 | Loamy                          |
| 43.70                           | 31.90                           | 24.40                           |                                |
| pH                              | E.C. (dsm⁻¹)                    | Soluble cations (m.mol/l)       | Chemical analysis              |
| 7.10                            | 1.56                            | Ca²⁺                                | Soluble anions (m.mol/l)       |
|                                 | 2.10                            | Mg²⁺                                | Available (ppm)                |
|                                 | 2.80                            | Na⁺                                |                                |
|                                 | 0.90                            | Fe                                 |                                |
|                                 | 0.30                            | Zn²⁺                               |                                |
|                                 | 1.65                            |                                    |                                |

The experimental unit area was 16.80 m² (4.00 ×4.20 m) included six ridges. Each ridge was 0.7 m wide and four meters length. The distance between hot pepper plants in the ridge was 50 cm, under surface irrigation system. The hot pepper “cv. Hyffa” seedlings were achieved from private nursery in Belbas District, Sharkia Governorate, Egypt. All transplants were similar in growth and 12 transplanting date by using SPAD unit length.

Different levels of phosphorus fertilization as calcium superphosphate (15.5 % P₂O₅) was applied during soil preparation. In addition, chitosan (C₉H₁₇NO₃) nano crystalline powder was synthesized by high-energy ball milling. The size of nano-particles of chitosan, as obvious from the TEM images established to be 50 nm. Chitosan as solution (96.40%) was brought from Modern Agricide Company (New Cairo, Cairo, Egypt). Furthermore, the nano-chitosan treatments were applied as foliar application at 30, 45, 60, 75 and 90 days after transplanting. All recommended agricultural practices of growing hot pepper plants were done when ever needed. All plants were fertilized with 200 kg potassium sulphate (50 % K₂O) and 400 kg ammonium nitrate (33 % N) per feddan. However, nitrogen and potassium fertilizers were divided into three equal levels and were added to the soil at 35, 60 and 85 days after hot pepper transplanting.

**Recorded Data**

**Plant growth:**

After 100 days from transplanting of hot pepper, a sample of 3 plants were randomly taken from each experimental unit and plant growth parameters noticed as plant height, number of branches/plant and total dry weight/plant were recorded.

**Yield and its components:**

Fruits of hot pepper were harvested every 2 days intervals, upon reaching 11-14 cm length. At harvesting stage the yield components expressed as fruit set percentage (number of set flowers/ total number of flowers marked × 100), fruit length, fruit diameter, fruit yield/plant, early fruit yield per feddan and yield/faddan were recorded.

**Chemical constituents:**

Total chlorophyll content (SPAD unit) was determined in fresh leaves of hot pepper plant after 100 days from transplanting date by using SPAD- 502 meter (Markwell et al., 1995). All chemical analyses were done at chemical laboratory of Department of Biochemistry, Faculty of Agriculture, Menufiya University, Egypt. In addition, increasing nano-

**RESULTS AND DISCUSSION**

**Plant growth:**

Data recorded in Table 2 show that, using phosphorus fertilization treatments at high levels (32 and 48 kg P₂O₅/feddan) significantly increased plant height, branch number per hot pepper plant and total plant dry weight compared to control and the lowest level (16 kg P₂O₅/feddan) in both seasons. Generally, hot pepper plant growth parameters were increased with the increasing of the levels of phosphorus to reach its maximum by using that of 48 kg P₂O₅/feddan. Furthermore, all nano-chitosan treatments significantly increased hot pepper plant height, branch number per plant and total plant dry weight compared to unsprayed plants (control). Using 100 ppm of chitosan as nano-particles significantly increased plant growth parameters of hot pepper compared to control and the other concentrations under study. The increases in total plant dry weight were about 14.56 and 10.79 % for 100 ppm nano-chitosan over control treatment in the 1st and 2nd seasons, respectively. These results hold true in the 2019 and 2020 seasons. The interaction treatment between phosphorus fertilization at 48 kg P₂O₅/feddan and nano-chitosan at 100 ppm significantly increased hot pepper growth parameters compared to control and the other ones under study in both seasons. In addition, increasing nano-
chitosan concentrations under each phosphorus fertilization level gradually increased hot pepper height, number of branches per plant and total plant dry weight.

The excellent influences of phosphorus fertilizer application on hot pepper growth parameters are due to that, P is a part of molecular frame of vitally serious compounds, RNA and DNA. Also, it function a fundamental role in photosynthesis and cell division (Marshner, 1995). Similar results were found by Alabi and Ayodele (2019) on Capsicum annuum plants. Moreover, Khan et al. (2002) found that chitosan promoted key enzymes activities of metabolism of nitrogen and improved the transportation of nitrogen in leaves functional which increase plant development and growth. Also, Dzung et al. (2017) reported that among treatment, chitosan proved to be the best, which increased chilli fresh weight of shoots, dry weight of shoots and fruit fresh weight by 71.5%, 184%, and 49.8%, respectively, in comparison with control.

Table 2. Effect on phosphorus fertilization level (P), nano-chitosan concentration (N) and their interaction (P×N) treatments on plant height (cm), number of branches /plant and total plant dry weight (g) of hot pepper plant during 2019 and 2020 seasons

<table>
<thead>
<tr>
<th>Phosphorus fertilization level (kg P2O5/fed.)</th>
<th>Nano-chitosan concentration (ppm)</th>
<th>2019 season</th>
<th>2020 season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (P)</td>
<td>0.0</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>0</td>
<td>58.00</td>
<td>58.11</td>
<td>59.44</td>
</tr>
<tr>
<td>16</td>
<td>60.11</td>
<td>63.00</td>
<td>63.22</td>
</tr>
<tr>
<td>32</td>
<td>62.89</td>
<td>69.78</td>
<td>74.00</td>
</tr>
<tr>
<td>48</td>
<td>66.22</td>
<td>69.67</td>
<td>74.89</td>
</tr>
<tr>
<td>Mean (N)</td>
<td>61.80</td>
<td>65.14</td>
<td>67.89</td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>(P)= 0.87</td>
<td>(N)= 0.85</td>
<td>(P×N)= 1.71</td>
</tr>
</tbody>
</table>

Yield and its components:

It is evident from the obtained data in Tables 3 and 4 that, all phosphorus fertilization treatments significantly increased set %, fruit length (cm), fruit diameter (cm), fruit yield per plant (kg), early fruit yield and total yield per feddan of hot pepper compared to control, in most cases, in both seasons. In general, a gradual increase in the recorded yield and its components were observed with increasing phosphorus fertilization levels from 16 to 48 kg P2O5/feddan in the two consecutive seasons. Also, using the highest concentrations of nano-chitosan under study recorded the highest values in hot pepper yield components compared to control and the lowest concentration under study. The increases in fruit set percentage were about 6.61 and 9.63 % as well as in total fruit yield per feddan about 24.80 and 31.86 % for 100 ppm concentration over control (unsprayed plants) in the first and second seasons, respectively. In addition, all interaction among phosphorus fertilization levels and nano-chitosan concentration treatments significantly increased hot pepper yield components parameters, in most cases, in both seasons. The plants which sprayed with nano-chitosan at 100 ppm + fertilized with phosphorus at 48 kg P2O5/feddan resulted in the highest values in this connection in both seasons, followed by the interaction treatment between that plants which sprayed with nano-chitosan at 50 ppm + 48 kg P2O5/feddan. The increases in early fruit yield/feddan (ton) were about 75.74 and 58.60 % for the interaction between nano-chitosan at 100 ppm + phosphorus fertilization at 48 kg/feddan over control treatment (sprayed plants with tap water without phosphorus fertilization) in the 1st and 2nd seasons, respectively.

Generally, as mentioned above, both nano-chitosan and phosphorus fertilization (each alone) increased yield components of hot pepper plant, in turn; they together might maximize their effects leading to longer and wider fruits, earlier fruit yield and heaviest total yield per faddan. Moreover, a suitable supply of phosphorus is in demand for optimum growth and yield output. P element is participated in sundry key plant functions and encourages root growth and provides resistances to root system diseases (Saskatchewan, 1999). These results coincided with those found by Alabi (2006) on pepper, Hegazi et al. (2017) on sweet pepper and Assefa et al. (2020) on hot pepper. In the same time, chitosan as nano-particles are readily imbibed by the leaves epidermis then translocated to stems which easier the uptake of active molecules and improves growth and yield of several plants (Malera and Cerana, 2016). Since, Mondal et al. (2012) indicated that okra yield attributes as number of fruits /plant and fruit size were increased with increasing concentration of chitosan until 25 ppm, resulted the highest yield of fruit (about 27.9% yield increased over the control). Also, Dehghani et al. (2019) pointed out that flower dry yield of German chamomile plant significantly increased when foliar sprayed by 125 mg/l chitosan compared to control.
Chemical constituents:

As shown in Tables 5 and 6 that, total chlorophyll content in leaves as well as total soluble solids, vitamin C content, total nitrogen, total phosphorus and potassium in fruits of hot pepper significantly increased by utilizing all phosphorus fertilization levels compared to control in both seasons. Furthermore, the best treatment in this concern was that 48 kg P₂O₅/feddan. However, total capsaicin content in hot pepper fruits recorded the highest content values with 48 kg P₂O₅/feddan level in the first season and 32 kg P₂O₅/feddan level in the second one compared to the control and the other levels under study (Fig.1). Similarly, increasing nano-chitosan concentrations from 25 to 100 ppm gradually increased chemical constituents of hot pepper leaves and fruits in both seasons. The best treatment in total chlorophyll content, total soluble solids, vitamin C content, N, P and K were that 100 ppm of nano-chitosan.
with significant differences with control and the other ones under study.

In addition, the chemical constituents of hot pepper plants were increased as a result of the interaction treatment between phosphorus fertilization levels and nano-chitosan at 100 ppm compared to that of phosphorus fertilization alone at any level in both seasons. In the same time, all interaction treatments between phosphorus fertilization (at 0, 16, 32 or 48 kg P₂O₅/feddan) and nano-chitosan concentrations (0, 25, 50 or 100 ppm) caused an increase in this regard compared to unfertilized plants and without nano-chitosan spraying. The best interaction treatment in increase total capsaicin content in hot pepper fruits was that of phosphorus fertilization at 48 kg/feddan + nano-chitosan at 100 ppm (Fig. 2). These results agree with those reported by Hegazi et al. (2017) on sweet pepper, Behboudi et al. (2018) on barley and Alabi and Ayodele (2019) on chilli plants.

Table 5. Effect on phosphorus fertilization level (P), nano-chitosan concentration (N) and their interaction (P×N) treatments on total chlorophyll content, total soluble solids and vitamin C content of hot pepper plant during 2019 and 2020 seasons

<table>
<thead>
<tr>
<th>Phosphorus fertilization level (kg P₂O₅/fed.)</th>
<th>0.0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>Mean (P)</th>
<th>0.0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>Mean (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 season Total chlorophyll content (SPAD unit)</td>
<td>42.70</td>
<td>42.93</td>
<td>43.10</td>
<td>43.78</td>
<td>43.13</td>
<td>43.33</td>
<td>43.86</td>
<td>44.36</td>
<td>44.53</td>
<td>44.02</td>
</tr>
<tr>
<td>2020 season Total chlorophyll content (SPAD unit)</td>
<td>43.42</td>
<td>43.57</td>
<td>43.60</td>
<td>44.73</td>
<td>43.83</td>
<td>43.13</td>
<td>44.18</td>
<td>44.93</td>
<td>46.18</td>
<td>44.36</td>
</tr>
<tr>
<td>16</td>
<td>32.28</td>
<td>43.50</td>
<td>43.77</td>
<td>45.54</td>
<td>44.02</td>
<td>43.81</td>
<td>44.67</td>
<td>46.02</td>
<td>46.45</td>
<td>45.24</td>
</tr>
<tr>
<td>48</td>
<td>44.21</td>
<td>44.84</td>
<td>46.43</td>
<td>47.48</td>
<td>45.74</td>
<td>44.48</td>
<td>45.09</td>
<td>46.73</td>
<td>48.67</td>
<td>46.24</td>
</tr>
<tr>
<td>Mean (N)</td>
<td>43.40</td>
<td>43.71</td>
<td>44.23</td>
<td>45.38</td>
<td>43.69</td>
<td>44.45</td>
<td>45.51</td>
<td>46.21</td>
<td>46.21</td>
<td>46.21</td>
</tr>
</tbody>
</table>

LSD at 5% (P)= 0.26 (N)= 0.32 (P×N)= 0.61 (P)= 0.42 (N)= 0.37 (P×N)= 0.73

Table 6. Effect on phosphorus fertilization level (P), nano-chitosan concentration (N) and their interaction (P×N) treatments on total nitrogen, total phosphorus and potassium percentages in fruits of hot pepper plant during 2019 and 2020 seasons

<table>
<thead>
<tr>
<th>Phosphorus fertilization level (kg P₂O₅/fed.)</th>
<th>0.0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>Mean (P)</th>
<th>0.0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>Mean (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 season Total nitrogen (%)</td>
<td>1533</td>
<td>1577</td>
<td>1713</td>
<td>1750</td>
<td>1664</td>
<td>1613</td>
<td>1673</td>
<td>1667</td>
<td>1713</td>
<td>1689</td>
</tr>
<tr>
<td>2020 season Total nitrogen (%)</td>
<td>1583</td>
<td>1637</td>
<td>1700</td>
<td>1770</td>
<td>1707</td>
<td>1673</td>
<td>1667</td>
<td>1713</td>
<td>1743</td>
<td>1689</td>
</tr>
<tr>
<td>16</td>
<td>1610</td>
<td>1703</td>
<td>1767</td>
<td>1813</td>
<td>1723</td>
<td>1643</td>
<td>1683</td>
<td>1737</td>
<td>1833</td>
<td>1724</td>
</tr>
<tr>
<td>32</td>
<td>1633</td>
<td>1717</td>
<td>1777</td>
<td>1837</td>
<td>1741</td>
<td>1670</td>
<td>1797</td>
<td>1817</td>
<td>1860</td>
<td>1786</td>
</tr>
<tr>
<td>Mean (N)</td>
<td>1590</td>
<td>1658</td>
<td>1739</td>
<td>1793</td>
<td>1640</td>
<td>1693</td>
<td>1723</td>
<td>1778</td>
<td></td>
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</tr>
<tr>
<td>LSD at 5%</td>
<td>(P)= 0.05 (N)= 0.03 (P×N)= 0.013 (P)= 0.009 (N)= 0.009 (P×N)= 0.018</td>
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</table>

<table>
<thead>
<tr>
<th>Phosphorus fertilization level (kg P₂O₅/fed.)</th>
<th>0.0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>Mean (P)</th>
<th>0.0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>Mean (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 season Total phosphorus (%)</td>
<td>0.523</td>
<td>0.532</td>
<td>0.533</td>
<td>0.540</td>
<td>0.532</td>
<td>0.540</td>
<td>0.543</td>
<td>0.550</td>
<td>0.580</td>
<td>0.553</td>
</tr>
<tr>
<td>2020 season Total phosphorus (%)</td>
<td>0.543</td>
<td>0.547</td>
<td>0.549</td>
<td>0.594</td>
<td>0.558</td>
<td>0.533</td>
<td>0.550</td>
<td>0.650</td>
<td>0.600</td>
<td>0.562</td>
</tr>
<tr>
<td>16</td>
<td>0.543</td>
<td>0.577</td>
<td>0.623</td>
<td>0.643</td>
<td>0.597</td>
<td>0.553</td>
<td>0.605</td>
<td>0.617</td>
<td>0.657</td>
<td>0.608</td>
</tr>
<tr>
<td>32</td>
<td>0.543</td>
<td>0.627</td>
<td>0.663</td>
<td>0.680</td>
<td>0.628</td>
<td>0.590</td>
<td>0.630</td>
<td>0.643</td>
<td>0.677</td>
<td>0.635</td>
</tr>
<tr>
<td>Mean (N)</td>
<td>0.538</td>
<td>0.571</td>
<td>0.592</td>
<td>0.614</td>
<td>0.554</td>
<td>0.582</td>
<td>0.593</td>
<td>0.629</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>(P)= 0.03 (N)= 0.013 (P×N)= 0.026 (P)= 0.008 (N)= 0.013 (P×N)= 0.023</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Phosphorus fertilization level (kg P₂O₅/fed.)</th>
<th>0.0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>Mean (P)</th>
<th>0.0</th>
<th>25</th>
<th>50</th>
<th>100</th>
<th>Mean (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 season Total potassium (%)</td>
<td>2.472</td>
<td>2.487</td>
<td>2.483</td>
<td>2.500</td>
<td>2.533</td>
<td>2.483</td>
<td>2.500</td>
<td>2.533</td>
<td>2.472</td>
<td></td>
</tr>
<tr>
<td>2020 season Total potassium (%)</td>
<td>2.520</td>
<td>2.547</td>
<td>2.570</td>
<td>2.607</td>
<td>2.561</td>
<td>2.517</td>
<td>2.527</td>
<td>2.613</td>
<td>2.623</td>
<td>2.570</td>
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<tr>
<td>16</td>
<td>2.567</td>
<td>2.620</td>
<td>2.690</td>
<td>2.703</td>
<td>2.645</td>
<td>2.550</td>
<td>2.560</td>
<td>2.690</td>
<td>2.710</td>
<td>2.528</td>
</tr>
<tr>
<td>48</td>
<td>2.587</td>
<td>2.637</td>
<td>2.707</td>
<td>2.733</td>
<td>2.666</td>
<td>2.603</td>
<td>2.673</td>
<td>2.720</td>
<td>2.753</td>
<td>2.688</td>
</tr>
<tr>
<td>Mean (N)</td>
<td>2.535</td>
<td>2.568</td>
<td>2.615</td>
<td>2.641</td>
<td>2.536</td>
<td>2.561</td>
<td>2.631</td>
<td>2.655</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5%</td>
<td>(P)= 0.012 (N)= 0.012 (P×N)= 0.023 (P)= 0.016 (N)= 0.013 (P×N)= 0.027</td>
<td></td>
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</tbody>
</table>

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Fig. 1. Effect on phosphorus fertilization level on total capsaicin content in fruits (mg/100g as dry weight) of hot pepper plant during 2019 and 2020 seasons.

Fig. 2. Effect of interaction between phosphorus fertilization level and nano-chitosan concentrations (0.0 and 1000 ppm) on total capsaicin content in fruits (mg/100g as dry weight) of hot pepper plant during 2019 and 2020 seasons.

CONCLUSION

From above mentioned results, it is preferable to spray Capsicum annuum cv. Hyffa plants with nano-chitosan at 100 ppm under phosphorus fertilization at 48 kg P₂O₅/feddan to enhance the plant growth, flower set percentage, fruit dimensions, yield components, total chlorophyll, and vitamin C content as well as total capsaicin content under Dakahlia Governorate conditions.

REFERENCES


