ORIGINAL ARTICLES

CO₂ evolution and chemical constituents of leaves and tubers of potato plants as influenced by organic compost and mineral N-fertilizers applied individually or in different combination rates along with seaweed extract

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ABSTRACT

In field trials carried out during the two successive summer growing seasons of 2008 and 2009 at the experimental farm of the Fac. Agric., Shebin El-Kome, Minoufiya Univ., Egypt. Potato plants of the cv. Nieta were grown under several N-fertilization regimes, which used at the recommended dose of 120 kg N/fed. as soil addition. N-fertilizers were applied as zoological or botanical compost comparing to inorganic N-fertilizer either individually or in different combination rates along with foliar spray with seaweed extract to examine their effects on CO₂ production in the rhizospheric root zone and chemical constituents of leaves and tubers of potato plants. Carbon dioxide production, which is a direct indicator of microbial communities and activities as well as soil enzyme activities, plays an important role in maintaining soil fertility. The results indicated that fertilization with any of the used organic fertilizers namely zoological or botanical compost either each alone or in different combination rates with chemical fertilizer increased significantly CO₂ production with more effectiveness for the application of fertilizer mixture of 25 % mineral N + 75 % zoological compost + foliar spray of seaweed extract followed by 50 % mineral N + 50 % zoological compost + foliar spray of seaweed extract then 50 % mineral N + 50 % botanical compost + foliar spray of seaweed extract comparing with unfertilized control and mineral fertilized treatment. All investigated treatments significantly enhanced chlorophyll a, b and total chlorophyll content comparing with check treatment, however the three above-named treatments in descending order gave the highest content of chlorophyll pigments in potato leaves. NPK uptake by potato plants and total carbohydrates accumulation tended to increase significantly as a sequence of the tested organic and inorganic N fertilizers either in individual form or in different combination rates from each compared to the unfertilized treatment control. The greatest values of NPK and total carbohydrates were occurred also in leaves of potato plants fertilized with the above-said treatments. It is worthy to mention that unfertilized control, both organic fertilizers, each of them as a sole source of N, namely 100 % zoological compost and 100 % botanical compost as well as foliar spray with seaweed extract recorded the lowest nitrate accumulation in leaves and tubers of potato plants comparing with mineral fertilization treatment (100 % mineral N), which exerted the highest values of it. The less nitrate content was detected due to using 25 % mineral N + 75 % zoological compost + foliar spray of seaweed extract followed by 50 % mineral N + 50 % zoological compost + foliar spray of seaweed extract then 50 % mineral N + 50 % botanical compost + foliar spray of seaweed extract. Tubers of the plants fed only with organic compost either as zoological or botanical form (100 % zoological compost and (100 % botanical compost), respectively contain the lowest levels of reducing sugars, whereas unfertilized control followed by foliar spray with seaweed extract exerted the highest values, respectively. Concerning to non-reducing and total sugars content in potato tubers, the application 25 % mineral N + 75 % zoological compost + foliar spray of seaweed extract followed by 50 % mineral N + 50 % zoological compost + foliar spray of seaweed extract then 50 % mineral N + 50 % botanical compost + foliar spray of seaweed extract exhibited the highest values of the above-cited compounds, however the lowest ones were occurred in tubers of unfertilized control plants. Starch and total crude protein contents increased significantly by the application of the all studied fertilization treatments compared with the unfertilized control, whereas the greatest values from starch and total protein were recorded in tubers of plants received the fertilization mixture of 25 % mineral N + 75 % zoological compost + foliar spray of seaweed extract followed by 50 % mineral N + 50 % zoological compost + foliar spray of seaweed extract then 50 % mineral N + 50 % botanical compost + foliar spray of seaweed extract.

Kew words: Potato, CO₂ evolution, organic compost , mineral N-fertilizers, seaweed extract, chemical constituents.

Introduction

Potato (Solanum tuberosum, L.) is one of the most important world food crops, after rice, wheat and maize (Spooner and Bamberg, 1994). It is also considered a very important crop among the vegetable crops in Egypt for exportation as well as for local consumption.
Potato, nutritionally, is considered to be a well balanced major plant with a good ratio between protein and calories, and it has substantial amounts of vitamins, minerals and trace elements (Horton and Sawyer, 1985).

The production of potatoes shows an increasing tendency in all regions of the world, but the increase in rapid in the arid and semiarid regions such as in Egypt, especially in the newly reclaimed lands, which are sandy in structure and infertile. Therefore, soil improvement and/or manipulating its nutrient environment would be the most important attempts toward solving this problem (Horton and Fano, 1985). It is well known that, potato plant has high nutrients requirements, especially N-fertilizers, largely due to its shallow root system and short growth duration (Acland, 1980). The liberal application of mineral N-fertilizers to maintain adequate level of N in the rhizosphere, leads to accumulation of excessive levels of NO$_3^-$-N in the plant (Maynard et al., 1976) as well as contribute to high NO$_3^-$-N content of ground water (Viets and Hageman, 1971). Nitrates per se are relatively non-toxic constituent in foods, but may be considered as a potential hazard, as they are the precursor of nitrates. Nitrates inhibit oxygen transport by blood (Sohar and Domoki, 1980), besides in the human body, nitrates can react with amines and be converted to nitrosamines, which cause cancer Whitney et al. (1990).

In the near future, most of exported vegetables will be from the safety production. Therefore, there is an increasing interest in the using of organic N sources as fertilizers for production of “organic grown” vegetables in order to produce safe food for human health and exportation, especially to European markets, where the consumer is willing to pay higher price for healthy and safe product.

Seaweed extract nowadays, has applied to soil or sprayed on plants as fertilizer, which contain many growth regulators such as cytokinins, auxins, gibberellins and betaines besides most of macro and micro elements that necessary for the development, growth and productivity of plant as well as enhance plant defense against pest and diseases (Khan et al., 2009 and Jayaraman et al., 2010).

Conventional horticulture cropping due to continuous soil removal and intensive use of pesticides and fertilizers, is a main activity leading to deterioration of soil physical, chemical and biological properties (Albiach et al., 2000). Organic matter inputs through organic amendment, in addition to supplying nutrients, improve soil aggregation and stimulate microbial diversity and activity (Lee et al., 2004).

Romero et al. (2000) demonstrated that increasing N level from both organic and inorganic fertilizers increased NPK contents in plant foliage as well as crude protein, reducing and total sugars besides starch in tubers. Also, Roinila et al. (2003) investigated the effect of different organic fertilizers such as compost, FYM and aerated slurry at 15, 30 and 60 t/ha., respectively combined with mineral N fertilization at different dose on chemical compositions of potato plants. They found that in contrast to FYM, the high application rate of the mineral fertilizer raised the concentration of nitrogenous compounds e.g. ascorbic acid, nitrate and free amino acids in potato tubers, whereas slurry fertilization caused a similar effect but smaller reaction. Barmaki et al. (2008) declared that nitrate contents in tubers of plants fed with 40 Mg/ha. composted dairy manure and/or 20 Mg/ha. dairy manure + 125 kg N/ha. were less than in the plants received only chemical fertilizers, however, no significant difference were detected between 40 Mg/ha. composted dairy manure and 20 Mg/ha. dairy manure + 125 kg N/ha. Recently, Agbede (2010) showed that using of mineral fertilizer at a rate of 125 kg N/ha. + 5 t/ha. poultry manure induced more NPK accumulation in sweet potato leaves over the control. Therefore, the purpose of this work was undertaken to examine the influence of the compost and mineral N fertilizers applied individually or in different combination rates along with seaweed extract on CO$_2$ production in the rhizospheric root zone and chemical constituents of leaves and tubers of potato plants.

**Materials and methods**

This work was carried out at the Experimental Farm of the Fac. Agric., Shebin El-Kom, Minoufiya Univ., Egypt, during the two successive summer growing seasons of 2008 and 2009 to investigate the influence of three kinds of organic fertilizers e.g. zoological and botanical compost as soil addition and aqueous seaweed extract as foliar application on CO$_2$ production in the rhizospheric root zone and chemical constituents of leaves and tubers of potato plants cv. Nieta. The physical and chemical properties of the soil are shown in Table (1).

The experimental design was a complete randomized blocks with 3 replicates. The experimental unit occupied 12m$^2$ in area and included four rows, each of 5 m long and 0.6 m wide.

The Experiment included 20 treatments as follows: Unfertilized control (T$_1$); foliar spray with seaweed extract (T$_2$); 100 % mineral nitrogen (T$_3$); 100 % mineral nitrogen + foliar spray with seaweed extract (T$_4$); 75 % mineral nitrogen + 25 % zoological compost (T$_5$); 75 % mineral nitrogen + 25 % zoological compost + foliar spray with seaweed extract (T$_6$); 50 % mineral nitrogen + 50 % zoological compost (T$_7$); 50 % mineral nitrogen + 50 % zoological compost + foliar spray with seaweed extract (T$_8$); 25 % mineral nitrogen + 75 % zoological compost + foliar spray with seaweed extract (T$_9$); 100 % zoological compost (T$_10$); 100 % zoological compost + foliar spray with seaweed extract (T$_11$); 75 % mineral nitrogen + 25 % botanical compost (T$_12$); 75 % mineral nitrogen + 25 % botanical compost + foliar spray with seaweed extract (T$_13$); 50 % mineral nitrogen + 50 % botanical compost (T$_14$); 50 % mineral nitrogen + 50 % botanical compost + foliar spray with seaweed extract (T$_15$); 25 % mineral nitrogen + 75 % botanical compost (T$_16$); 25 % mineral nitrogen + 75 % botanical compost + foliar spray with seaweed extract (T$_17$); 100 % botanical compost (T$_18$) and 100 % botanical compost + foliar spray with seaweed extract (T$_19$).
Table 1: The physical and chemical analysis of experimental soil pre-conducting the experiment (Depth 0-60 cm).

(a) Physical properties

<table>
<thead>
<tr>
<th>Fraction percentage</th>
<th>Texture class</th>
<th>Organic matter %</th>
<th>Field capacity %</th>
<th>Bulk density gm/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silt %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.89</td>
<td>23.93</td>
<td>41.29</td>
<td>1.73</td>
<td>36.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.55</td>
</tr>
</tbody>
</table>

(b) Chemical properties

<table>
<thead>
<tr>
<th>E.C* mhos/cm at 25 °C</th>
<th>pH**</th>
<th>C.E.C mg/100 g soil</th>
<th>Total N mg/100 g soil</th>
<th>Total P mg/100 g soil</th>
<th>Total K mg/100 g soil</th>
<th>Soluble ions meq/100 g soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.42</td>
<td>0.75</td>
<td>0.55</td>
<td>50.12</td>
<td>15.27</td>
<td>41.16</td>
<td>0.60</td>
</tr>
</tbody>
</table>

* E.C. Electrical conductivity in 1:5 soil water extract.
** In 1:2.5 Soil / water suspension.

The recommended dose of nitrogen fertilizer of 120 kg N/fed was chosen and was applied as N fertilization treatment. This treatment was added either as mineral fertilizer or as zoological and botanical compost one, based on the total nitrogen percentage in each compost beside combination treatments between mineral and both organic fertilizers as replacement rate with or without seaweed extract as foliar application, untreated plants with seaweed extract were sprayed with distilled water. Some chemical properties of the both organic compost and seaweed extract used are shown in Table (2 and 3).

Ammonium sulphate (20.5%) was used as a source of inorganic nitrogen, which was applied 120 kg N/fed. Inorganic-N fertilizer was applied in four equal doses. The first dose was preplanting added at the time of soil preparation, whereas, the second one was applied after tuber seeds emergence. The remaining two doses were added with 10 day intervals; i.e., 45 and 55 days after sowing. Organic nitrogen; i.e., zoological and botanical compost was preplanting (preriding). Seaweed extract was applied at a concentration of 2-3 cm³ dissolved in one liter of distilled water, sprayed as a fine mist to all exposed plants till run off. Foliar applications were applied for three times at 10 days intervals beginning at tuberization period; i.e., 6 weeks from sowing.

Table 2: Some chemical constituents of zoological and botanical compost.

<table>
<thead>
<tr>
<th>Compost</th>
<th>Organic C %</th>
<th>Organic matter %</th>
<th>C/N ratio %</th>
<th>E.C dS/m</th>
<th>pH (1:10 Soil / water suspension)</th>
<th>Chemical properties</th>
<th>Micro-nutrient %</th>
<th>Micro-nutrient Ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoological</td>
<td>17.07</td>
<td>29.44</td>
<td>11.15</td>
<td>1.76</td>
<td>7.2</td>
<td></td>
<td>Total-N</td>
<td>Total-P</td>
</tr>
<tr>
<td>Botanical</td>
<td>25.95</td>
<td>37.00</td>
<td>20.83</td>
<td>1.33</td>
<td>5.6</td>
<td></td>
<td>1.0</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table 3: Some chemical constituents of seaweed extract.

<table>
<thead>
<tr>
<th>Growth regulators</th>
<th>Micro-nutrient Ppm</th>
<th>Some chemical constituents %</th>
<th>Micro-nutrient %</th>
<th>Ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>35</td>
<td>7</td>
<td>20</td>
<td>0.04</td>
</tr>
<tr>
<td>Mannitol</td>
<td>35</td>
<td>7</td>
<td>20</td>
<td>0.03</td>
</tr>
<tr>
<td>Indole acetic acid</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<td>Indole acetic acid</td>
<td>100</td>
<td>100</td>
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</table>

Seed tubers ranging from 35-55 mm in size with 2-3 sprouts were sown on 2nd of February and 24th of January in 2008 and 2009 growing seasons, respectively. Potato seed pieces were set at 20cm between each other, on rows and in depth of about 15cm in rows. All field plots were fertilized with calcium superphosphate (15.5% P₂O₅) and potassium sulphate (48% K₂O) at rates of 75 kg P₂O₅ and 96 kg K₂O/fed. Superphosphate was added during soil preparation, while potassium sulfate was divided into two equal doses applied during soil preparation and at tuberization stage; i.e., 6 weeks from planting. The harvesting time was done after 120 days from planting for both growing seasons of study, since the cultivated variety is semi late maturated.

Estimating of CO₂ in the rhizospheric root zone:

After 30,60 and 90 days from sowing in the two growing seasons, CO₂ as an indicator of beneficial microbial activity was evaluated in the rhizospheric soil of all treatments. The rate of CO₂ production was determined in the rhizosphere soil according to the methods described by Promer and Schmid, (1964) and modified by (Alef and Nannipieri, 1995).

Some chemical constituents of leaves and tubers:

Leaves:

Photosynthesis pigments; i.e., Chlorophyll a and b were determined in the fifth upper leaves from the growing tip of three plants from each plot at one week after the final spray with seaweed extract as described by
the adopted method of A.O.A.C (2005). A sub-sample from the dried leaves was taken from the three plant samples to determine N, P, K and Total carbohydrate. The dried fine powder (0.2 g) was digested by using 5 cm$^3$ sulphuric acid and 1 cm$^{-3}$ perchloric acid according to Piper (1947). Total N content was determined using the microkjeldahl apparatus as described by method of A.O.A.C. (2005). Phosphorus (P) was determined according to the method of Jakson (1973). Potassium (K) was measured by the using of Flamephotometer (Model 149) as described by the adopted method of A.O.A.C. (2005). Total carbohydrates were determined according to the method of Somogy (1952). Meanwhile, nitrate content was determined according to the method described by Singh (1988).

Tubers:

At harvest time, a sub sample of 200g was taken from four representatives freshly grated tubers of each experimental unit and dried in a hot air oven until a constant weight at 70 °C under ventilation. These dried samples were ground and wet digested as described previously under mineral elements concentration of leaves. Chemical analysis of crude protein (N x 5.7) was determined according to the method described in A.O.A.C. (2005). Reducing and non-reducing sugars were determined by the method of Somogy (1952) and Dogras et al. (1991), respectively. Starch was performed according to the method described by Dogras et al. (1991), whereas nitrate content was determined according to the method described by Singh (1988).

All collected data were subjected to statistical analysis using the normal F-test means were compared by the LSD at 5% level of probability Snedecor and Cochran (1980).

Results And Discussions

1. Estimating of CO2 in the rhizospheric root zone:

Active living cells need a constant supply of energy, which for heterotrophic microflora derives from the transformation of organic matter such as cellulose, proteins, nucleotides and humified compound. Energy-supplying reactions in the cell are redox reactions based on the transfer of electrons from a donor to an acceptor. By respiration, that is the oxidation of organic matter by aerobic microorganisms, oxygen functions as the end acceptor of the electrons. The end products of the process are carbon dioxide and water. The metabolic activities of soil microorganisms can therefore be quantified by measuring the CO2 production or O2 consumption (Nannipieri et al. 1990).

Soil respiration is one of the oldest and still the most frequently used parameter for quantifying microbial activities in soil (Kieft and Rosacker, 1991). Nevertheless, the soil microbial community plays an important role in maintaining soil fertility. It performs functions such as residue decomposition, nitrogen fixation, nutrient cycling and carbon sequestration (Giller et al., 1997) and plays a major role in the suppression of diseases (Janvier et al., 2007). Therefore, from the aforesaid physiological viewpoint, CO2 determination can be successfully used to identify microbial activity in the growing media of plants root.

Also, it is well-know that N2- release bacteria in the used organic fertilizers share to a large extent in CO2 evolution in the rhizospheric root zone. Data of the influence of organic and inorganic N-fertilizers either each alone or in different combination rates alone with or without seaweed extract over CO2 rate are listed in Table (4) and Fig. (1).

It is clearly evident from the results in the above-named table that carbon dioxide production, which is a direct indicator of microbial activity, and indirectly reflects the availability of organic material significantly increased by all treatments used comparing with, unfertilized or inorganic treatment. Also, it is noteworthy to mention that T10 (25 % mineral nitrogen + 75 % zoological compost + foliar spray with seaweed extract) recorded the highest value of CO2 followed by those of T8 (50 % mineral nitrogen + 50 % zoological compost + foliar spray with seaweed extract) and T9.

Results of these experiments complemented to those of Arancon et al. (2005) and Ferreras et al. (2006) in which they concluded that most of the soils fertilized with zoological or botanical compost had significantly more microbial biomass N (P≤ 0.5) than soil fertilized with inorganic fertilizers only. In the same trend also, many investigators proved that, there was a trend for greater activity of dehydrogenase and β-glucosaminidase to occur in soils fertilized with organic compost compared to that in soils fertilized with inorganic fertilizers only.

Microbial activity in soils has been suggested by many authors as a result of organic fertilizers addition, where most of the carbon supplied by this amendment comprises partially decomposed material, easily degradable to be used as energy and nutrient source for soil microorganisms, resulting in an increase in soil microbial respiration (Bulluck et al., 2002 on tomato; Koga and Tsuji, 2009; Moeskops et al., 2010 and Heinze et al., 2011 on potato).
meter readings are usually normalized to an adequately N fertilized reference (Denuit et al., 2003) in potato. Consequently, chlorophyll meter readings are usually normalized to an adequately N fertilized reference (Denuit et al., 2002). Data illustrated in Table (5) imply the distinct effect of organic and inorganic N fertilizer each alone or in different combination rates from both with or without foliar spray of seaweed extract on chlorophyll content in potato plant leaves, which are recorded at one week after the final spray with seaweed extract.

Generally, it could be concluded from these results that all investigated treatments significantly increased chlorophyll a, b, and total chlorophyll content comparing with check treatment (T1). Moreover, it is important to point out that T10 (which 25 % mineral-N +75 % zoological compost + foliar spray with seaweed extract were applied) achieved the highest values of chlorophyll pigment followed by those of 50 % mineral-N + 50 % zoological compost + seaweed extract (T9) and 50 % mineral-N + 50 % botanical compost + seaweed extract (T16), respectively, with a significant differences between them. These results are true at both growing seasons.

A glimpse cursory on the above-named results, it could be concluded that N element was involved in the aforementioned treatment either in organic or inorganic form and the relationship between nitrogen and chlorophyll synthesis is well known.

The superiority of chlorophyll content in leaf tissues by using N fertilizers may be explained that synthesis of chlorophyll is known to be highly dependent on N availability as it is the main constituent of all the amino acids and hence of proteins and lipids like glactolipids which acting as a structural component of the chloroplasts (Marschner, 1995), whereas Fe is thought to be involved in chloroplast formation via protein synthesis (Pascual et al., 2008). It is clear also from the data illustrate in Table (5) that chlorophyll pigment in leaf tissues tended to increase significantly as a sequence of foliar spray with seaweed extract.

So it may suggest that this increment in chlorophyll content was depended on the summation of the role of each fertilizer involved. The increment in chlorophyll content could be interpreted in a way that seaweed extract contains high level of macro and micro elements such as N, K, Fe, Mn and Zn, which in some way are necessary in the synthesis of chlorophyll molecule itself or have a structural role in chloroplasts.

### Table 4: CO₂ estimation (mg/SW/t)** in the rhizospheric root zone as affected by organic compost and mineral N-fertilizers individually or in different combination rates from both along with foliar application with seaweed extract during 2008 and 2009 growing seasons.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>CO₂ production 30 days after sowing</th>
<th>CO₂ production 60 days after sowing</th>
<th>CO₂ production 90 days after sowing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2008</td>
<td>2009</td>
<td>2008</td>
</tr>
<tr>
<td>T1</td>
<td>14.7</td>
<td>14.9</td>
<td>15.9</td>
</tr>
<tr>
<td>T2</td>
<td>18.2</td>
<td>15.3</td>
<td>20.4</td>
</tr>
<tr>
<td>T3</td>
<td>19.7</td>
<td>17.4</td>
<td>22.2</td>
</tr>
<tr>
<td>T4</td>
<td>20.1</td>
<td>18.1</td>
<td>22.3</td>
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<tr>
<td>T5</td>
<td>62.1</td>
<td>61.7</td>
<td>62.1</td>
</tr>
<tr>
<td>T6</td>
<td>67.2</td>
<td>58.1</td>
<td>73.9</td>
</tr>
<tr>
<td>T7</td>
<td>62.1</td>
<td>56.1</td>
<td>71.7</td>
</tr>
<tr>
<td>T8</td>
<td>67.7</td>
<td>58.2</td>
<td>73.9</td>
</tr>
<tr>
<td>T9</td>
<td>57.1</td>
<td>49.9</td>
<td>64.7</td>
</tr>
<tr>
<td>T10</td>
<td>74.0</td>
<td>64.8</td>
<td>80.9</td>
</tr>
<tr>
<td>T11</td>
<td>31.5</td>
<td>29.2</td>
<td>40.3</td>
</tr>
<tr>
<td>T12</td>
<td>32.1</td>
<td>31.8</td>
<td>46.9</td>
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<td>T13</td>
<td>35.3</td>
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<td>40.1</td>
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<tr>
<td>T14</td>
<td>37.7</td>
<td>35.1</td>
<td>41.1</td>
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<td>T15</td>
<td>44.6</td>
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<td>T16</td>
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<tr>
<td>T17</td>
<td>46.9</td>
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<td>51.6</td>
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<tr>
<td>T18</td>
<td>47.1</td>
<td>42.9</td>
<td>52.9</td>
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<tr>
<td>T19</td>
<td>28.4</td>
<td>25.7</td>
<td>41.1</td>
</tr>
<tr>
<td>T20</td>
<td>31.2</td>
<td>28.6</td>
<td>48.4</td>
</tr>
</tbody>
</table>

LSD at 5% 14.2 9.3 5.3 9.8 6.1 6.3

T1: Unfertilized check; T2: Foliar spray of seaweed extract (SE); T3: 100% Mineral Nitrogen (MN); T4: 75% MN + 25% Zoological compost (ZC); T5: 75% MN + 25% ZC + SE; T6: 50% MN + 50% ZC + SE; T7: 50% MN + 50% ZC + SE; T8: 25% MN + 75% ZC; T9: 25% MN + 75% ZC + SE; T10: 25% MN + 50% BC; T11: 100% BC; T12: 100% BC + SE; T13: 75% MN + 25% Botanical Compost (BC); T14: 75% MN + 25% BC + SE; T15: 50% MN + 50% BC; T16: 100% BC + SE; T17: 100% BC; T18: 100% BC + SE.

2. Some chemical constituents of leaves:

a. Chlorophyll content:

Chlorophyll contents in vegetation depend on soil nitrogen availability and on crop nitrogen uptake, which are important management factors in arable farming. Crop nitrogen uptake is important, as nitrogen is needed for chlorophyll formation, which is essential for photosynthesis; i.e., the conversion of absorbed radiance into plant biomass (Jongschaap and Booij, 2004). Leaf chlorophyll content has been used in various crops as an indirect indicator of plant N status as proved by (Gianquinto et al., 2003) in potato. Consequently, chlorophyll meter readings are usually normalized to an adequately N fertilized reference (Denuit et al., 2002). Data illustrated in Table (5) imply the distinct effect of organic and inorganic N fertilizer each alone or in different combination rates from both with or without foliar spray of seaweed extract on chlorophyll content in potato plant leaves, which are recorded at one week after the final spray with seaweed extract.
SW is the soil dry weight in grams and t is the incubation time in hours.

T16 (50% mineral nitrogen + 50% botanical compost + foliar spray with seaweed extract), respectively compared with other treatments. These results are being true at the three sampling dates and in both growing seasons.

Fig. 1: CO₂ estimation (mg/sw/t)** in the rhizospheric root zone as affected by organic compost and mineral N-fertilizers individually or in different combination rates from both with or without foliar spray of seaweed extract during 2008 and 2009 growing seasons.

Besides, seaweed extracts have been found to contain significant amounts of cytokinins, auxins and betaines which enhance chlorophyll concentration in the leaves (Blunden et al., 1997). Moreover (Whapham et al., 1993) stated that increment in chlorophyll content may be due to a decrease in chlorophyll degradation,
which might be caused in a part by the role of betaines in the seaweed extract. These results confirmed with those of Whapham et al. (1992); Arisha and Bardisi, 1999 on potato; Schwab and Raab, 2004 on strawberry and Sivasankari et al. (2006) on peas.

Table 5: Chlorophyll content of potato fresh leaves as affected by organic compost and mineral N- fertilizers individually or in different combination rates from both with foliar application with seaweed extract during 2008 and 2009 growing seasons.

<table>
<thead>
<tr>
<th>Treatments*</th>
<th>Chlorophyll a mg/100g F W</th>
<th>Chlorophyll b mg/100g F W</th>
<th>Total chlorophyll mg/100g F W</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>96.1</td>
<td>92.8</td>
<td>36.1</td>
</tr>
<tr>
<td>T2</td>
<td>98.4</td>
<td>94.9</td>
<td>40.0</td>
</tr>
<tr>
<td>T3</td>
<td>108.8</td>
<td>100.1</td>
<td>43.9</td>
</tr>
<tr>
<td>T4</td>
<td>112.9</td>
<td>103.9</td>
<td>47.6</td>
</tr>
<tr>
<td>T5</td>
<td>113.3</td>
<td>105.9</td>
<td>44.1</td>
</tr>
<tr>
<td>T6</td>
<td>116.2</td>
<td>108.1</td>
<td>47.9</td>
</tr>
<tr>
<td>T7</td>
<td>116.7</td>
<td>109.9</td>
<td>45.6</td>
</tr>
<tr>
<td>T8</td>
<td>119.5</td>
<td>112.0</td>
<td>49.2</td>
</tr>
<tr>
<td>T9</td>
<td>114.6</td>
<td>110.3</td>
<td>45.3</td>
</tr>
<tr>
<td>T10</td>
<td>121.8</td>
<td>114.6</td>
<td>53.0</td>
</tr>
<tr>
<td>T11</td>
<td>109.8</td>
<td>105.8</td>
<td>45.0</td>
</tr>
<tr>
<td>T12</td>
<td>112.2</td>
<td>107.8</td>
<td>48.5</td>
</tr>
<tr>
<td>T13</td>
<td>108.8</td>
<td>102.3</td>
<td>43.5</td>
</tr>
<tr>
<td>T14</td>
<td>111.1</td>
<td>105.5</td>
<td>47.0</td>
</tr>
<tr>
<td>T15</td>
<td>113.4</td>
<td>106.2</td>
<td>43.8</td>
</tr>
<tr>
<td>T16</td>
<td>116.3</td>
<td>109.6</td>
<td>47.7</td>
</tr>
<tr>
<td>T17</td>
<td>113.2</td>
<td>109.9</td>
<td>42.5</td>
</tr>
<tr>
<td>T18</td>
<td>115.5</td>
<td>111.0</td>
<td>46.1</td>
</tr>
<tr>
<td>T19</td>
<td>106.0</td>
<td>98.6</td>
<td>43.6</td>
</tr>
<tr>
<td>T20</td>
<td>110.0</td>
<td>101.9</td>
<td>47.4</td>
</tr>
</tbody>
</table>

LSD at 5%: 2.2 1.9 3.4 1.5 5.6 3.5

* T1 till T20: The same footnote in Table (4).

b. NPK contents:

Data concerned with N, P and K contents of potato leaves as affected by organic and inorganic N fertilizers each alone or in different combination rates from both with or without seaweed extract are showed in Table (6). It is evident from such data that N, P and K uptake by potato plants tended to increase significantly as a sequence of the tested organic and inorganic N fertilizers either in individual form or in combination rates from each compared with the control treatment.

Results in the same table and fig. indicate that foliar spraying with seaweed extract in tries combination with organic and inorganic fertilizer was more effective comparing with the other ones. It is also worthy to mention that the highest values of N, P and K content in potato leaves were achieved via using the treatment of 25 % mineral-N + 75 % zoological compost + foliar spray with seaweed extract (T16) followed with those of 50 % mineral-N + 50 % zoological compost + seaweed extract (T8) and 50 % mineral-N + 50 % botanical compost + seaweed extract (T18). These increments in N, P and K contents owing to organic fertilizers were supported with those obtained by Sreenivas et al. (2000) on gourd who reported that compost provides all nutrients in readily available form and thus enhances nutrients uptake by plants.

The superior effect of zoological than botanical compost on leaf mineral content could be explained as zoological compost is a very diverse product and the release of N, P and K is more effective comparing with the other ones. It is also worthy to mention that the highest values of N, P and K content in potato leaves were achieved via using the treatment of 25 % mineral-N + 75 % zoological compost + foliar spray with seaweed extract (T16) followed with those of 50 % mineral-N + 50 % zoological compost + seaweed extract (T8) and 50 % mineral-N + 50 % botanical compost + seaweed extract (T18). These increments in N, P and K contents owing to organic fertilizers were supported with those obtained by Sreenivas et al. (2000) on gourd who reported that compost provides all nutrients in readily available form and thus enhances nutrients uptake by plants.

A distinct increase in nutrient absorption due to the application of organic fertilizers, compared to mineral ones could be attributed to the release of available amount of such macronutrients in root zone due to the increasing activity of the microbial population, which stimulate the plant absorption of such nutrients and hence increase their content in plant foliage. These results are in accordance with those obtained by Abo-Sedera on potato (2006); Leroy et al. on maize (2007) as well as Kelly and Bateman on tomato and lettuce (2010).

Moreover, the additional promoting effect of seaweed extract in increasing N, P and K uptake was also recorded by Mancuso et al. (2006); Sivasankari et al. (2006) on cowpea and Rathore et al. (2009) on soybean who pointed out that, seaweed extract contains macro and micro element and the presence of marine bioactive substances in them improves stomata uptake efficiency in treated plants compared to non-treated plants.
c. Carbohydrate content:

Leaf total carbohydrates content (%), which largely reflect the efficiency of photosynthesis process, as affected by organic and inorganic N-fertilizers individually or in combination rates from both with or without foliar spraying with seaweed extract was listed in Fig. (2). These results reveal obviously that all the studied fertilization treatments, significantly increased carbohydrate content in comparison to unfertilized control, which recorded the lowest content of it.

Table 6: Content of N, P and K (% DM) in potato leaves as affected by organic compost and mineral N- fertilizers individually or in different combination rates from both with or without foliar spray of seaweed extract during 2008 and 2009 growing seasons.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Treatments</th>
<th>1st sample (0 day after sowing)</th>
<th>3rd sample (90 day after sowing)</th>
<th>2nd sample (45 day after sowing)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>K (%)</td>
<td>P (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td>T10</td>
<td>0.37</td>
<td>0.43</td>
<td>0.41</td>
<td>0.47</td>
</tr>
<tr>
<td>T11</td>
<td>0.38</td>
<td>0.44</td>
<td>0.42</td>
<td>0.48</td>
</tr>
<tr>
<td>T12</td>
<td>0.39</td>
<td>0.45</td>
<td>0.43</td>
<td>0.50</td>
</tr>
<tr>
<td>T13</td>
<td>0.40</td>
<td>0.45</td>
<td>0.44</td>
<td>0.51</td>
</tr>
<tr>
<td>T14</td>
<td>0.41</td>
<td>0.46</td>
<td>0.45</td>
<td>0.53</td>
</tr>
<tr>
<td>T15</td>
<td>0.42</td>
<td>0.47</td>
<td>0.46</td>
<td>0.55</td>
</tr>
<tr>
<td>T16</td>
<td>0.43</td>
<td>0.47</td>
<td>0.47</td>
<td>0.57</td>
</tr>
<tr>
<td>T17</td>
<td>0.44</td>
<td>0.48</td>
<td>0.48</td>
<td>0.59</td>
</tr>
<tr>
<td>T18</td>
<td>0.45</td>
<td>0.49</td>
<td>0.49</td>
<td>0.61</td>
</tr>
<tr>
<td>T19</td>
<td>0.46</td>
<td>0.50</td>
<td>0.50</td>
<td>0.63</td>
</tr>
<tr>
<td>T20</td>
<td>0.47</td>
<td>0.51</td>
<td>0.51</td>
<td>0.65</td>
</tr>
</tbody>
</table>

It is important to point out that application of organic and inorganic fertilizers in double combination rates from both was much better than applying each of them in a single form and the using of seaweed extract with them in tries combinations were the most effective treatments comparing with other ones. So, it may suggest that this increment in carbohydrate content of leaves was depended on the summation of the role of each fertilizer involved. Results at the same table indicate that, the greatest value of total carbohydrates content was occurred in leaves of potato plants fertilized with 25 % MN + 75 % ZC + SE (T10) followed by that of 50 % MN + 50 % ZC + SE (T8) and 50 % MN + 50 % BC + SE (T16), respectively and these results are true at the three sampling dates and in both growing seasons. These findings are supported with those obtained by Pascual et al. (2000) who reported that pepper plants fertilized with organic fertilizer exhibited photosynthetic rates that were up to 125 % higher than those of control plants. They also suggested that the photosynthetic surface area besides leaf chlorophyll content are the key factors that determine total carbohydrates production and chlorophyll content is considered an index of the metabolic efficiency of the plant regarding use of absorbed nutrients. In the present study, the application of the aforesaid three treatments (e.g. T10, T8 and T16) possessed the greatest values of each of leaf area (as found in the work of Gawish et al., 2012) and chlorophyll content (see Table 5) resulting in higher total carbohydrates content. The obtained results are in conformity with those of El-Motaiau and Abo-Scoud (2007).

Concerning the effect of seaweed extract, it is easily to conclude from the data illustrated in Fig. (2) that potato plants sprayed with it proved to be more superior in leaf carbohydrate content as compared to those fertilized with different combination rates from organic and inorganic fertilizers only. Increases in carbohydrate content in potato leaves resulted from foliar spray with seaweed extract may be explained that it contains major and minor nutrients (e.g. N, P, K, Fe, Mn, Mg, Ca and Cu), amino acids, vitamins, some growth promoting substances such as IAA, IBA, GA3 and cytokinins (Sivasankari et al., 2006 and Rathore et al., 2009), which all augmented plant growth, especially leaf area (Turan and Köse, 2004), leaf chlorophyll content (Blunden et al., 1997) as well as conductance and uptake efficiency of stomata owing to the presence of marine bioactive substances in seaweed extract, which in turn reflected in an increment in carbohydrate content of leaves.

In this direction, Choular et al. (2009) demonstrated also that the increase of the all above- cited constants of plant as a result of seaweed extract spray have been shown to play a role in cell respiration, photosynthesis, various enzymatic reactions such as α amylase and β amylase activity, sugar translocation and consequently affected carbohydrate metabolism and accumulation in potato leaves. Our results partially agree with those previously reported.

d. Nitrate content:

Nitrites are naturally occurring compounds in vegetables, since their presence in the plants is connected with the nitrogen transformations to amino acids and proteins. Nitrate per se is relatively non-toxic constituents
in foods (Speijers, 1996), but approximately 5% of all ingested nitrate is converted in saliva and in the gastro-intestinal tract to the more toxic nitrite (Pannala et al., 2003). Nitrites inhibit oxygen transport by blood, leading to methaemoglobin formation, and producing a medical condition known as methaemoglobinemia, to which in infants are at a greater risk than adults because of the lower acidity in their stomachs. Also, in the human body, nitrites can react with amines and be converted to nitrosamines, which cause cancer (Maynard et al., 1976; Knobeloch et al., 2000 and Mensinga et al., 2003).

![Figure 2](image)

**Fig. 2:** Total carbohydrates % (% DM) in potato leaves as affected by organic compost and mineral N-fertilizers individually or in different combination rates from both with or without foliar spray of seaweed extract during 2008 and 2009 growing seasons.

NO₃⁻ content was determined in potato leaves to be used as an indicator of its status in tubers. It is quite evident from the data in Fig. (3) that N-application sources; i.e., mineral-and organic fertilizers (e.g. zoological and botanical compost) in individual form or in different combination rates from each along with or without seaweed extract foliar spray significantly influenced nitrate concentration in potato leaves. It is important to
mention that unfertilized control (T1), both organic fertilizers, each of them as a sole source of N, (T11 and T19) and foliar spray with seaweed extract (T2) recorded the lowest nitrate accumulation in potato leaves comparing with mineral fertilization treatment (T3), which exerted the highest values of it.

![2008 Nitrate Content Chart](image1)

![2009 Nitrate Content Chart](image2)

* T1 till T20: The same footnote in Fig. (1).

**Fig. 3:** Nitrate content (Ppm) in potato leaves as affected by organic compost and mineral N- fertilizers individually or in different combination rates from both with or without foliar spray of seaweed extract during 2008 and 2009 growing seasons.

Concerning the different combination rates from organic and inorganic fertilizers with or without foliar spray with seaweed extract, data in the same table indicate that less nitrate accumulation was detected due to T16, T8 and T16 treatments, respectively in comparison to mineral fertilization ones (T3). The reduction in nitrate accumulation owing to organic fertilization may be attributed to the slow - N-release and slow nitrification properties of zoological and botanical compost (Pavlou et al., 2007). They reported also that accumulation of nitrates results from an imbalance between the uptakes and translocation of nitrate by the xylem and the
reduction of these nitrates to ammonia which is subsequently rapidly incorporated into amino acids (Maynard et al., 1976). However, the internal nitrate concentration in the plant seems to be controlled by a self-regulatory mechanism exerted either by negative feedback control on the net nitrate uptake rate (Cardenas-Navarro et al., 1998) or by passive control on nitrate efflux (Scaife, 1989).

Regarding the effect of seaweed extract, there is no adequate information in the literature about the effects of it on the reduction of nitrate accumulation in plant leaves.

3. Some chemical constituents of tubers:

a- Nitrate content:

Vegetable are important components of a healthy diet since they are a good source of vitamins, minerals, fibers and other nutrients. Sufficient daily consumption of vegetables can help prevent major diseases, including cardiovascular diseases, cancers, obesity and diabetes (World Health Organization, 2003). Vegetables also contain nitrates (NO₃⁻), which are naturally occurring compounds in it, since their presence in the plants is connected with the nitrogen transformations to amino acids and proteins. The potential hazard of vegetable-borne nitrate is from its conversion to methaemoglobin- producing nitrite before and/or after ingestion (Greer and Shannon, 2005). Methaemoglobin cannot bind oxygen and produces a leftward shift in oxygen-dissociation curve, causing hypoxaemia (Chan, 2011).

Furthermore, the more toxic nitrite is also associate in the human bodies with gastric cancer (Pannala et al., 2003) to which infants are at a greater risk than adults, for several reasons (Greer and Shannon, 2005 and Savino et al., 2006). They have lower activity of red cell enzyme NADH-cytochrome b5 reductase, which converts methaemoglobin to haemoglobin. Their lower gastric pH results in proliferation of intestinal flora, which reduce the ingested nitrate to nitrite. Foetal haemoglobin is oxidized more readily by nitrite to methaemoglobin than adult haemoglobin (Chan, 2011).

Potato is classified among vegetables with low nitrate content (Schuddeboom, 1993 and Ierna, 2009). However, because of the large amounts consumed, it can contribute greatly to the daily intake of nitrate in the diet (Santamaria et al., 1999 and Santamaria, 2006). The European Community’s Scientific Committee for Food (SCF) set the acceptable daily intake (ADI) for NO₃⁻ at 3.65 mg.kg⁻¹ body weight.day⁻¹.

From the results recorded in Table (7) it can be noticed generally that, NO₃⁻ content in potato tubers was significantly influenced by both mineral- and organic fertilizers (e.g. zoological and botanical compost) either in individual form or in different combination rates from each with or without applying of seaweed extract. These results were insistently observed in both growing seasons. It is worthy to mention that fertilization treatments of 100 % ZC + SE (T12) followed by that of 100 % BC + SE (T20) resulted in less nitrate accumulation with a values of 181 and 186 mg/kg DW (average of the two growing seasons), respectively, whereas the use of T2 (foliar spray with seaweed extract) followed by both organic fertilizers, each of them as a sole source of N; i.e., T11 (100 % ZC) and T19 (100 % BC) recorded the lowest nitrate accumulation with values of 168, 176 and 178 mg/kg DW comparing with other N fertilization treatment.

On the other hand, the application of mineral fertilizer in separate form (T3) exerted the highest values of nitrate content in both growing seasons with an average of 251 mg/kg DW. However, this value is still less than the critical limits permitted for nitrate accumulation in potato tubers with a range from 57 to 1000 mg/kg FW (US National Academy of Science, 1981). The results of NO₃⁻ accumulation in potato tubers were similar to that occurring for potato leaves (see Fig. 3).

The reduction in NO₃⁻ accumulation in tubers of organic-fed plants found in this study may be due to its physiological effects which was found and discussed in the a forenamed part of nitrate contents in potato leaves.

Also, Montagu and Goh (1990) as well as Faller and Fialho (2009) demonstrated that nutrients from organic fertilizers are released more slowly and steadily to the plant, whereas synthetic chemical fertilizers offer more readily available sources of nitrogen, to accelerate plant growth and accumulate the excess N in the form of NO₃⁻. The obtained results coincide with those of Morsy, (2005) and Gawish et al., (2011).

b- Reducing- non-reducing- and total sugars:

The level of sugars in potato tubers is an important factor affecting quality in potatoes, especially colour of processed potato products. Of the many chemical constituents affecting the colour of processed potato products (Smith, 1987), sugar are generally considered to be the most important ones (Roe et al., 1990). Sugar levels in potato tuber are conditioned by several factors, which include genotype the environmental conditions and cultural practices during growth, and several post-harvest factors including storage.
Meanwhile increased non-reducing and total sugars contents compared with those of unfertilized check plants that all the used fertilization treatments decreased significantly the levels of reducing sugars in potato tubers, foliar spray on reducing, non-reducing and total sugars are shown in Table (7). It is evident from such results rates (between the mineral and one only from the organic compost) along with or without seaweed extract as and organic fertilizers namely, zoological and botanical compost either each alone or in different combination contain less than 1g / kg fresh weight of reducing sugars to minimize the acrylamide formation.

As for as browning development in fried potato products is concerned, the reducing sugars (glucose and fructose) which considered potentially carcinogenic, compound (Mottram, 2002 and Maggio, 2008). These higher sugar contents results from the rich photosynthetic activity and organic fertilizers either each alone or in different combination (Bruulsema, 2002 and Maggio, 2008). These also accumulated less reducing sugars during storage (Iritani and Weller, 1978). They added also, in adequate fertilized with N had tubers with lower reducing sugar concentration at harvest.

Regarding non-reducing and total sugars content in potato tubers, results presented in Table (7) showed that both chemical compounds increased significantly by the all tested fertilization treatments, whereas the application of fertilizers mixture of 25 % MN + 75 % ZC + SE (T10) followed by 50 % MN + 50 % BC + SE (T16) exhibited the highest values of the above-cited compounds, however the lowest ones were occurred in tubers of unfertilized control plants (T1). Many researchers state that organically grown crops contain less nitrates but higher concentration of important nutritive substances (Brulsem, 2002 and Maggio, 2008). These higher sugar contents results from the rich photosynthetic activity of these plants which previous were found and discussed in details in section 1.1. The obtained results coincide with those of Abou-Hussein et al. (2003a) and Gawish et al., (2011) on potato.

c- Starch and total crude protein:

Potato tubers are an excellent source of starch, which contributes to the textural properties of many foods and is widely used in food and industrial application as a thickener, colloidal stabilizer, gelling agent, bulking
agent and water holding agent (Singh et al., 2006). Also, protein is an essential compound in food, where its concentration in plants is highly dependent on N availability in soil at sowing time, N released during the growing seasons through mineralization of soil organic matter and N applied as organic or inorganic fertilizer (Wang et al., 2008).

Data listed in Table (7) illustrated the effect of mineral-and organic N fertilizers either in individual form or in different combination rates along with or without foliar application of seaweed extract on starch and total protein contents in potato tubers. It is easily to conclude from these data that the concentrations of the above-named constituents increased significantly by the application of the all studied fertilization treatments compared with the unfertilized control, whereas the greatest values from starch and total protein were recorded in tubers of plants received the fertilization mixture corresponding to 25 % MN + 75 % ZC + SE (T10) with a values of 76 and 15.0 % followed by 50 % MN + 50 % ZC + SE (T8) with 75 and 14.6 % then 50 % MN + 50 % BC + SE (T16) with 74 and 14.2 % (average of the two growing seasons) for starch and total protein, respectively. As appears from the aforesaid results, that the application of the combinations between mineral fertilizer, organic compost and foliar spray with seaweed extract was more effective in enhancing starch and protein contents in potato tubers than applied each of them individually.

Increasing each of starch and total protein contents may be account for the response of other growth parameters, which were previously mentioned and discussed. Increases in starch content (%) resulted from the using of organic compost (e.g. zoological and / or botanical) with a high rate from 50 % up to 75 % of the fertilizers mixture were attributed primarily to increment in photosynthetic apparatus (leaf area) of the plants received these fertilizers mixture (as found in the work of Gawish et al., 2012), since they possessed higher metabolites, where starch largely reflect the efficiency of photosynthesis process and subsequently enhances the sink activity of the tubers as well as the translocation of assimilated to tubers.

The promoting effect of organic compost in increasing protein content could be interpreted in a way, that the use of chemical fertilizers alone to sustain high crop yield has not been successful due to enhancement of soil acidity, nutrient leaching and degradation of soil physical and organic matter status (Ojeniyi, 2000 and Nottidge et al., 2005), which in turn decreased N uptake and led to finally to reduce total protein.

Moreover, the stimulatory effect of treating potato plants with seaweed extract on starch and protein contents was agreement with those mentioned by Mancuso et al. (2006); Rathore et al. (2009). They stated that the presence of marine bioactive substances in seaweed extract improves stomata uptake efficiency of N, P and K in treated plants compared to non-treated plants. Furthermore, biostimulants, even those containing minerals, are not able to supply all the essential nutrients in the quantities required by plants (Schmidt et al., 2003) but may enhance root growth of plant and subsequently nutrients uptake as well as nutrient utilization from soil (Frankenberger and Arshad, 1995) as reported in our study with increased uptake of nutrients in potato leaves (see Table (6) and Fig. (3)).

References


