Organic Farming by Using Different Desert Soils; Could it be an Alternative to Fertilizers?

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Abstract

It is shown that Saharan soil has the potential of producing bioavailable iron when illuminated with visible light and also it contains some essential macronutrient and micronutrient elements. In this study, these properties of the desert soil were tested on the certified wheat cultivars (Triticum aestivum L. var. gonen 98) using Hewitt nutrient solution, illuminated and non-illuminated soil solutions from Saharan desert and Ankara city and Zabol. Deionized water was used as a control solution. Wheat cultivar, displayed comparable results when grown in illuminated Saharan dust solutions and Hewitt solution. Results showed that dust from Saharan desert could act as a source of natural fertilizer under specific conditions and could be utilized in “true” organic farming.

Keywords: Saharan dust, Wheat, Mineral elements

1. Introduction

Desert regions cover a significant part of the earth surface. From these regions intense amounts of the desert dust is transported far distances. Sahara as being one of the biggest desert regions, transports huge amounts of dust over Mediterranean to the North Atlantic Ocean (Moulin et al., 1997).

Desert dust is a source of mineral aerosols with known geological and biogeochemical impacts (Gao et al., 1997). The climatic role of desert dust (Tegen et al. 1996) is an important question in the critical discussion on global climate change. The biogeochemical impact of desert dust also remains a matter of discussion regarding its contribution for different macro and micronutrient elements to terrestrial and marine systems, and especially its potential fertilizing role for remote oceanic areas by supplying micronutrients as phosphorus and iron (Jickells and Spokes, 2001).

Saydam and Senyuva (2002) have shown that under specific conditions, desert dust may enhance the production of bioavailable iron. The authors have shown that the temporal and spatial variability of the bioavailable iron, originated from dust desert and delivered to the ocean, might be controlled by cloud photochemical reduction and facilitated by the impact of oxalate released by fungil present within the desert soil. The basic process in the photochemical reduction of bioavailable iron through
Decarboxylation reaction involves simultaneous action of oxalate released by the fungi upon wetting the soil samples, within the cloud droplet above some threshold solar radiation. Therefore, the diurnal and latitudinal variations in the solar irradiation and the sporadic nature of the rain events along the path of the synoptic scale atmospheric depressions are the governing factors that determine spatial and temporal distribution of phytoplankton growth over the ocean surface. This natural source of bioavailable iron is very essential. Iron deficiency has been a limiting factor in oceanic micronutrient in some oceanic regions, away from lands for many years (Martin et al., 1989, 1990).

It has been further shown that besides the photochemical production of Fe (II), the production of other micronutrient elements, such as Zn and Mn, iron is released along with phosphate. Therefore, desert origin dust may support the view that desert soil has the potential of supplying some essential micronutrient elements to the nature (Saydam and Senyuva, 2002, Binnacleh 2006).

The production of reduced iron is a light intensity dependent reaction and due to its rather unstable nature under dark conditions, it is oxidized back to stable iron. It has been further shown that, amongst the soil samples studied, this property was only specific to Saharan desert soils, obtained from southern Tunisia. Other available the desert soil samples from Riyadh, (Saudi Arabia) and five different, so called fertile soil samples from different locations of Anatolia did not yield any bioavailable iron (Saydam and Senyuva, 2002).

Iron is essential for the synthesis of chlorophyll and heme. Lime-induced chlorosis in calcareous soil (high pH) is a major agricultural problem resulting in reduced crop yields. About 30% of the world’s cultivated soils are calcareous. For example, plants demand $\sim 10^{-4}-10^{-8}$ M Fe(III) ions for normal growth, but, theroretically, only 10-17 M are soluble at pH 7 (Mori, 1999, Kacar, 2003).

Pigments are integrally related to the physiological function of leaves. Chlorophylls and Carotenoids (yellow pigments) absorb light energy and transfer it into the photosynthetic apparatus. Because of the importance of pigments for leaf function, variations in pigment content may provide information concerning the physiological state of leaves. Chlorophyll tends to decline more rapidly than carotenoids when plants are under stress or during leaf senecence (Daniel et. al, 2002).

Marine core sediments from west and east Africa have revealed air was substantially dustier and dust supply varied in 2.8, 1.7 and 1 million years ago in high latitude glacial regions (Mayewski et al., 1993). It is shown that untreated Saharan desert soil contains some essential macro and micronutrient elements (Avila et. al., 1997, Sluzberger and Laubscher, 1995). Thus, producing bioavailable iron from desert soil when illuminated with visible light is possible. As such, testing the impact of the end products of natural illumination process on various wheat cultivars grown in various desert dust mixtures (Saharan, Zabol and Ankara soil) was undertaken. It is expected to show the nutritional value of desert dust as fertilizer.

2. Material and Methods

2.1. Soil Solutions

In this research, Saharan desert, Zabol desert and Ankara raw soil samples taken in turn from southern Tunisia near Tozeur, southeast of Iran among of Iran, Afghanistan and pakistan border near Zabol city and Central Anatolia from Ankara capital of Turkey were used. In laboratory, the untreated soil samples were dried, sieved (30 mesh) and homogenized.

2.2. Wheat Seeds

In this research, bread wheat (Triticum aestivum L. var. gonen 98) winter type cultivar was used. Elit seeds of the cultivar were obtained from Central
Seeds were surface sterilized for 20 min in 4% sodium hypochlorite (NaOCl) solution, then rinsed with deionized water 2-3 times and were placed in deionized water at 23±1 °C for 5 h. Then, seeds were planted into pots (10x16 cm) containing perlit and were watered with relevant treatment solutions when required. Plants were grown at 25±2 °C day/night temperatures, 16/8 h light/dark periods and at 60% humidity in a controlled growth chamber for 30 days. Light intensity was 200 μmol. m⁻². sec⁻¹ near the top of the plants.

Ten different growth media, illuminated and non-illuminated Hewitt nutrient solution (Hewitt, 1966), illuminated and non-illuminated Saharan desert soil solutions and illuminated and non-illuminated Zabol soil solutions were utilized; For soil solutions, 400 g of dried, sieved (30 μ mesh) and homogenized Saharan soil, Zabol and Ankara samples were mixed with 8000 ml of deionize water and illuminated with 500-Watt halogen light with a wavelength spectrum of 380-800 nm, at constant temperature (20 °C) so as to simulate the encapsulated dust within a cloud droplet during the day time. During the course of the experiments no, in situ, Fe(II) measurements were made, however, since the system was illuminated with visible light for more than 3 hours, it was assumed that Fe(II)/Fe(III) ratio reached to a steady state level after two hours of irradiation as suggested by Saydam and Senyuva (2002).

Harvesting took place at 2 and 3 leaf stages of plants. Each pot contained 12 plants positioned randomly in the growth chamber. To avoid intermingling roots, only shoots of 6 plants were harvested at each stage. Shoot length was measured with Catiga CH-910 ruler (cm.seedling⁻¹).

2.3. Pigment Content

Photosynthetic pigments were extracted from six separate leaf samples in 100% acetone. The absorbance of the extracts was measured at 470, 644.8 and 661.6 nm using a Jen Wat 6105 UV/Vis Spectrophotometre. The concentration of chlorophyll a, b, a+b and carotenoid were determined and calculated using adjusted extinction coefficients (Lichtenthaler, 1987) and expressed on a fresh weight basis. The equations derived were (Eqs. (1)-(4)):

\[ k_{la} = (11.24 \times A_{661.6}) - (2.04 \times A_{648.8}) \]  
\[ k_{lb} = (20.13 \times A_{644.8}) - (4.19 \times A_{661.6}) \]  
\[ k_{la+b} = (7.05 \times A_{661.6}) - (18.09 \times A_{648.8}) \]  
\[ \text{karotenoid} = \frac{(1000 \times A_{470}) - (1.9 \times k_{la}) - (63.14 \times k_{lb})}{214} \]

Statistical variance analysis of the independent data with six replicates (n=6) was performed by using the statgraphics plus 5.1 packet program and the differences between the means were compared with least significant differences at the 5% level (LSD≤%5) (Garcia-SLADI)

http://www.sisoft.ucm.es/Manuales/sgwin5.pdf

3. Results and Discussion

3.1. Morphological Parameters

The length of seedlings in both harvesting stages was greater in Non-Illuminated Saharan Desert Soil Solution (SDSS+NI), Illuminated Saharan Desert Soil Solution (SDSS+I), non-illuminated Zabol soil solution (ZSS+NI), illuminated Zabol soil solution (ZSS+I), non-illuminated Ankara soil solution (ASS+NI), illuminated Ankara soil solution (ASS+I) and non-illuminated Hewitt Nutrient Solution (HNS+NI) and illuminated Hewitt Nutrient solution (HNS+I) that with Deionized Water (DW) (Fig. 1). At H1, in B-1, Ç-86 and at H2 in D-81 and H-95 had the most closed seedling length to HNS within the cultivar. The seedling length in different growth media assumed as percentage of HNS (100),
SDSS+I (93%), SDSS+NI (89%) ZSS+I (63), ZSS+NI (60), ASS+I (53), ASS+NI (50), DW+I (46) and DW+NI (50).

The seedling length response to HNS increased while for SDSS+I decreased compared to DW in the cultivar. These results showed that there were similarity between SDSS+I and HNS but not between SDSS+NI, ZSS+I and ZSS+NI.

3.2. Chlorophyll- α Content

Chlorophyll-α content of second leaf of the cultivar was increased with SDSS+NI, ASS+NI, ASS+I, ZSS+NI, ZSS+I, SDSS+I, and HNS compared to DW, respectively (Figure 2). This effect was pronounced significantly with SDSS+I compared to DW, SDSS+I compared to SDSS+NI. SDSS+I (94.4%) and ZSS+I (91.4%) in SDSS+I displayed the closest value to HNS (100%) within the cultivars (Table 1 and 2). Chlorophyll-α content of second leaf of the cultivar was increased with HNS compared to DW about 46% and with SDSS+I compared to DW about 56%.

Table 1- Changes in various parameter of wheat plant by using different solution (10 days after germination)

<table>
<thead>
<tr>
<th>Solution</th>
<th>Seedling Length(cm)</th>
<th>Chlorophyll-a (mg/g. fw)</th>
<th>Chlorophyll-b (mg/g.fw)</th>
<th>Total chlorophyll (mg/g.fw)</th>
<th>Carotenoid (mg/g .fw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNS+I</td>
<td>20,00</td>
<td>2,04</td>
<td>0,56</td>
<td>1,90</td>
<td>0,16</td>
</tr>
<tr>
<td>HNS+NI</td>
<td>19,17</td>
<td>2,02</td>
<td>0,50</td>
<td>1,90</td>
<td>0,26</td>
</tr>
<tr>
<td>SDSS+I</td>
<td>19,33</td>
<td>1,99</td>
<td>0,53</td>
<td>1,91</td>
<td>0,38</td>
</tr>
<tr>
<td>SDSS+NI</td>
<td>11,33</td>
<td>1,45</td>
<td>0,39</td>
<td>1,67</td>
<td>0,11</td>
</tr>
<tr>
<td>ZSS+I</td>
<td>17,33</td>
<td>1,33</td>
<td>0,54</td>
<td>1,83</td>
<td>0,53</td>
</tr>
<tr>
<td>ZSS+NI</td>
<td>10,50</td>
<td>1,24</td>
<td>0,42</td>
<td>1,77</td>
<td>0,45</td>
</tr>
<tr>
<td>ASS+I</td>
<td>9,17</td>
<td>0,97</td>
<td>0,31</td>
<td>1,48</td>
<td>0,92</td>
</tr>
<tr>
<td>ASS+NI</td>
<td>9,33</td>
<td>0,92</td>
<td>0,30</td>
<td>1,39</td>
<td>0,71</td>
</tr>
<tr>
<td>DW+I</td>
<td>7,00</td>
<td>0,59</td>
<td>0,29</td>
<td>1,24</td>
<td>0,79</td>
</tr>
<tr>
<td>DW+NI</td>
<td>7,33</td>
<td>0,53</td>
<td>0,25</td>
<td>1,20</td>
<td>0,79</td>
</tr>
</tbody>
</table>

Table 2- Changes in various parameter of wheat plant by using different solutions (30 days after germination)

<table>
<thead>
<tr>
<th>Solution</th>
<th>Seedling Length(cm)</th>
<th>Chlorophyll-a (mg/g. fw)</th>
<th>Chlorophyll-b (mg/g.fw)</th>
<th>Total chlorophyll (mg/g.fw)</th>
<th>Carotenoid (mg/g .fw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNS+I</td>
<td>30</td>
<td>2,24</td>
<td>1,03</td>
<td>2,02</td>
<td>0,10</td>
</tr>
<tr>
<td>HNS+NI</td>
<td>28</td>
<td>2,22</td>
<td>0,96</td>
<td>1,98</td>
<td>0,20</td>
</tr>
<tr>
<td>SDSS+I</td>
<td>28</td>
<td>2,19</td>
<td>0,99</td>
<td>2,02</td>
<td>0,32</td>
</tr>
<tr>
<td>SDSS+NI</td>
<td>19</td>
<td>1,65</td>
<td>0,86</td>
<td>1,76</td>
<td>0,05</td>
</tr>
<tr>
<td>ZSS+I</td>
<td>26</td>
<td>1,53</td>
<td>1,00</td>
<td>1,97</td>
<td>0,47</td>
</tr>
<tr>
<td>ZSS+NI</td>
<td>18</td>
<td>1,44</td>
<td>0,88</td>
<td>2,00</td>
<td>0,71</td>
</tr>
<tr>
<td>ASS+I</td>
<td>16</td>
<td>1,17</td>
<td>0,77</td>
<td>1,54</td>
<td>0,86</td>
</tr>
<tr>
<td>ASS+NI</td>
<td>15</td>
<td>1,12</td>
<td>0,76</td>
<td>1,66</td>
<td>0,65</td>
</tr>
<tr>
<td>DW+I</td>
<td>14</td>
<td>0,79</td>
<td>0,76</td>
<td>1,35</td>
<td>0,73</td>
</tr>
<tr>
<td>DW+NI</td>
<td>15</td>
<td>0,73</td>
<td>0,72</td>
<td>1,30</td>
<td>0,73</td>
</tr>
</tbody>
</table>
3.3. Chlorophyll-b Content

At H2, chlorophyll-b content of second leaf of the cultivar showed also a similar response to chlorophyll-a. This effect was pronounced significantly with SDSS+I compared to DW and SDSS+I compared to SDSS+NI. However, results of SDSS+I were not significantly different from that of HNS.

SDSS+I (94.6%) and ZSS+I (75.9%) in SDSS+I displayed the closest value to HNS within the cultivar. Chlorophyll-b content of second leaf of the cultivar increased with HNS (100%) compared to DW about 44% and with SDSS+I compared to DW about 47%.

3.4. Chlorophyll (a+b) Content

At H2, chlorophyll (a+b) content of second leaf of the cultivar also showed a similar trend to chlorophyll-a and chlorophyll-b; this effect was pronounced significantly with SDSS+I compared to DW, SDSS+I compared to SDSS+NI. However results of SDSS+I were not different from that of HNS.

SDSS+I (97.8%) and ZSS+I (88.3%) in SDSS+I displayed the closest value to HNS (100%) within the cultivar. Chlorophyll (a+b) content of second leaf of the cultivar increased with HNS compared to DW about 44.5% with SDSS+I compared to DW about 45.5%.

3.5. Carotenoids Content

At H2, a similar response to chlorophyll-a and chlorophyll-b was also obtained. Content of the carotenoids of the second leaf of the cultivars increased with SDSS+I, ASS+I, ASS+NI, ZSS+I, ZSS+NI SDSS+I and HNS compared to DW; respectively. This effect was pronounced significantly with SDSS+I compared to DW, SDSS+I compared to SDSS+NI. However SDSS+I were not significantly different from that of HNS.

ZSS+I (108%) and SDSS+I (128%) had the most closed value to HNS (100%) within the cultivar. Carotenoids content of the second leaf of the cultivars increased with HNS compared to DW about 54% and SDSS+I compared to DW about 20%.

4. Discussion

By using Saharan desert dust and Zabol dust there were no deficiencies, and no toxicity symptom were observed during the growth. The effect of SDSS+I on seedling length, Chlorophyll-a, Chlorophyll-b, Chlorophyll (a+b) and Carotenoids contents were very similar and not much different from that of HNS.

Saharan desert dust which transported by wind from different altitudes of earth, is deposited with rain. Structure, texture and chemical contents of SDS as well as Zabol desert dust affect and nutritionally enrich colloidal material in agricultural ecosystems and affect water content of soil. Therefore, by using natural desert dust instead of chemical fertilizer, ill impacts of chemical fertilizers on the environmental are more manageable.

A further step would be to extend this investigation to the marine ecosystem and growth of algae.

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