Effect of organic and sulphur fertilization on productivity and quality of cauliflower in saline calcareous soil

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ABSTRACT

An experiment was carried out to investigate the effects of organic manure and sulphur fertilizer on cauliflower (Toobi cultivar) grown in saline calcareous soil at Ras Sudr, Egypt during 2013/2014 and 2014/2015. Sheep manure at the rate of 48 and 60 m³ ha⁻¹ and poultry manure at the rate of 36 and 48 m³ ha⁻¹ were compared with zero organic as the control. Sulphur at rates of 0, 360, 720 and 1080 kg ha⁻¹ were also investigated. The results indicated that both organic manure and sulphur treatments significantly increased vegetative growth (leaf number, fresh and dry weight), leaf chlorophyll content, leaf nutrients content (N, P, K and S), curd fresh weight, total yield and curds quality (protein, carbohydrate and vitamin C). The poultry manure at the rate of 48 m³ ha⁻¹ was more effective than the other organic manure treatments. Also, the application of 1080 kg sulphur ha⁻¹ gave the highest values of the vegetative growth, yield and quality. The best results of most plant growth characteristics, leaf nutrients content, yield and quality of cauliflower plants were found with application of 48 m³ poultry manure ha⁻¹ in combination with 1080 kg sulphur ha⁻¹.

Key words: Poultry manure, sheep manure, Brassica oleracea L. var. botrytis, growth, yield.

INTRODUCTION

Cauliflower (Brassica oleracea L. var. botrytis) is a kale belonging to the Cruciferae family and it is one of the most widely cultivated Cole crop in Egypt. The edible part contains significant amount of protein, mineral and vitamins along with isothiocyanates and S methylcysteine sulfoxide which have prominent anti carcinogenic properties (Hazra et al., 2011). Cauliflower is sensitive to soil pH, as best growth and yield were obtained with 6.0 - 6.8 pH (Knott, 1962), and moderately salt tolerant (Bernstein, 1959).

As a strategy to mitigate the effects of soil stress and calcareous conditions on plants, organic manure was used which showed several benefits (El-Dardiry, 2007; El-Maghraby and Shaaban, 2011). Organic matter improved soil aeration and permeability and enhanced water movement (El-Dardiry, 2007), as well as release of humic substances that act to mitigate the effects of salinity (Aydin et al., 2012), decreases soil pH and improves the structure of the calcareous soil (Beheiry and Soliman, 2005). Sheep manure and poultry manure are very good sources of organic matter that play a vital role in soil fertility improvement, as well as in the supply of primary, secondary and micronutrients for crop production (Reddy and Reddi, 1992). The use of sheep and poultry manure improved the growth and yield of onion (Moradi, 2015), cauliflower (Abdel-Razzak et al., 2008), garlic (Abou El-Maged et al., 2012), lettuce (Masarirambi et al., 2012), tomato (Appiah, 2015) and radish (Zeid et al., 2015).

Sulphur is an essential nutrient for plant growth as it helps in the synthesis of peptides, which contain cysteine such as glutathione, various secondary metabolites (Abdallah et al., 2010) vitamins (B, biotine and thiamine) and chlorophyll in the cell (Marschner, 1995; Kacar and Katkat, 2007). It now viewed as the fourth major plant...
nutrient as it is absorbed in amounts comparable to that of phosphorus. Sulphur is considered an amendment used for reclaiming saline and calcareous soils (Marschner, 1996; Ahmed et al., 2016). The application of sulphur in salt affected soils is a viable procedure to counteract uptake of unnecessary toxic elements (Na⁺ and Cl⁻), which encourage selectivity of K⁺/Na⁺ and ability of calcium ion to decrease the harmful impacts of sodium ions in plants (Wilson et al., 2000). The biochemical oxidation of sulphur produces H₂SO₄, which decreases soil pH and solubilizes CaCO₃ in alkaline calcareous soils, making soil conditions more favourable for plant growth, including better availability of plant nutrients, especially P (Ramadan, 2012). The beneficial effects of sulphur application, expressed as an increase in growth, yield and an improvement of crop quality were reported in many vegetable plants such as broccoli (Jasim, 2015; Slosar et al., 2016), cabbage (Ramadan, 2012), onion (Kandil, 2016; Tripathy et al., 2016). Therefore, the objective of the present study was to determine the influence of different soil amendments (sheep manure, poultry manure and sulphur) on productivity and quality of cauliflower plants under saline calcareous soil conditions.

**MATERIALS AND METHODS**

**Growth Conditions**

A field study was conducted during 2013/2014 and 2014/2015 seasons at the Experimental Farm of the Desert Research Center, Ras Sudr Region that is located in South Sinai Governorate, Egypt (30° 34′ N, 31° 34′ E) and characterized with semi-arid climate conditions. The farm soil was sandy loam in texture with pH value (1:1 water) of 7.7, electrical conductivity (EC) value with the extracting ratio of 1:5 (soil/water) of 8.65 mS·cm⁻¹ and CaCO₃ 53.90%. Cauliflower (Toobi cultivar) seeds were sowed in nursery on July 3 and 5 in first and second season, respectively. 45 days old seedlings were transplanted on row 75 cm apart and 60 cm between plants with drip irrigation (pH 8.6 and ECₑ 7.03 mS·cm⁻¹).

<table>
<thead>
<tr>
<th>Chemical content</th>
<th>Sheep manure</th>
<th>Poultry manure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Kg/20m³</td>
<td>Kg/25m³</td>
</tr>
<tr>
<td>N</td>
<td>2.26</td>
<td>244.9</td>
</tr>
<tr>
<td>P</td>
<td>0.92</td>
<td>99.7</td>
</tr>
<tr>
<td>K</td>
<td>0.90</td>
<td>121.9</td>
</tr>
<tr>
<td>Ash</td>
<td>9.61</td>
<td>1302</td>
</tr>
<tr>
<td>Curd fiber</td>
<td>20.01</td>
<td>2711</td>
</tr>
<tr>
<td>Density</td>
<td>542 kg/m³</td>
<td></td>
</tr>
</tbody>
</table>

**Experimental setup**

Factorial experiment within split plot design with three replicates was used, the main plots devoted to organic fertilizer (0, 48 and 60 m³ sheep manure ha⁻¹, 36 and 48 m³ poultry manure ha⁻¹), while the sub-plots were occupied with the sulphur (0, 360, 720 and 1080 kg ha⁻¹). The experimental unit area was 10.6 m² and it included 4 rows (3.6 m long and 75 cm width). The organic manure and sulphur treatments were applied during soil preparation. The chemical analysis of sheep and poultry manures is shown in Table 1. All agricultural practices were carried out according to the recommendations of the Egyptian Ministry of Agriculture for cauliflower production.

**Data collection**

Data were recorded during the harvest stage (six plants were taken from each experimental unit), which included leaf number per plant, fresh and dry weights per plant, leaf chlorophyll content which was determined by Spad meter (Inada, 1985), curd fresh weight, and total yield per hectare. The leaf and curd samples were collected at the time of harvest and dried in an electric oven (60-70°C) till a constant weight were reached. They were milled to a fine powder material and digested for the estimation of nutrients, that is, N, P, K and S in leaves, as well as protein and total carbohydrate in curds. Nitrogen was determined using the Micro-Kjeldahl method (Piper, 1947), potassium was determined using flame photometry (Jackson, 1967), phosphorus was determined according to Olsen et al. (1954) method using spectrophotometry, sulphur was determined as described by Rowell (1993), protein content was determined according to A.O.A.C. (1995) and total carbohydrate as described by Montgomery (1961). Vitamin C was determined in fresh curds according to Kumar et al. (2013).

**Statistical analysis**

Data were statistically assessed by one-way analysis of
Table 2: Effect of organic and sulphur fertilization on leaf number, fresh and dry weight and leaf chlorophyll content of cauliflower plant during 2013/2014 and 2014/2015 seasons.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>O.F (m² ha⁻¹)</td>
<td>0</td>
<td>360</td>
</tr>
<tr>
<td>Without</td>
<td>19.33</td>
<td>22.00</td>
</tr>
<tr>
<td>48 S.M</td>
<td>21.00</td>
<td>23.00</td>
</tr>
<tr>
<td>60 S.M</td>
<td>21.33</td>
<td>24.67</td>
</tr>
<tr>
<td>48 P.M</td>
<td>23.00</td>
<td>26.33</td>
</tr>
<tr>
<td>mean</td>
<td>21.20</td>
<td>23.93</td>
</tr>
</tbody>
</table>

LSD _P_ = 0.05 for: O.F = 1.62, S = 1.10, interaction = n.s

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Fresh weight per plant (kg)</th>
<th>Dry weight per plant (g)</th>
<th>Leaf chlorophyll content (SPAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O.F (m² ha⁻¹)</td>
<td>Mean</td>
<td>Fresh weight per plant</td>
<td>Dry weight per plant</td>
</tr>
<tr>
<td>Without</td>
<td>1.02</td>
<td>148.61</td>
<td>166.75</td>
</tr>
<tr>
<td>48 S.M</td>
<td>1.24</td>
<td>157.11</td>
<td>168.32</td>
</tr>
<tr>
<td>60 S.M</td>
<td>1.37</td>
<td>164.36</td>
<td>183.48</td>
</tr>
<tr>
<td>36 P.M</td>
<td>1.31</td>
<td>160.77</td>
<td>173.45</td>
</tr>
<tr>
<td>48 P.M</td>
<td>1.40</td>
<td>168.97</td>
<td>181.57</td>
</tr>
<tr>
<td>mean</td>
<td>1.27</td>
<td>152.89</td>
<td>165.87</td>
</tr>
</tbody>
</table>

LSD _P_ = 0.05 for: O.F = 0.04, S = 0.03, interaction = n.s

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>O.F (m² ha⁻¹)</td>
<td>Mean</td>
<td>Leaf chlorophyll content</td>
</tr>
<tr>
<td>Without</td>
<td>59.60</td>
<td>64.93</td>
</tr>
<tr>
<td>48 S.M</td>
<td>62.77</td>
<td>66.43</td>
</tr>
<tr>
<td>60 S.M</td>
<td>66.63</td>
<td>69.83</td>
</tr>
<tr>
<td>36 P.M</td>
<td>64.43</td>
<td>68.63</td>
</tr>
<tr>
<td>48 P.M</td>
<td>69.50</td>
<td>75.60</td>
</tr>
<tr>
<td>Mean</td>
<td>64.59</td>
<td>69.09</td>
</tr>
</tbody>
</table>

LSD _P_ = 0.05 for: O.F = 1.10, S = 0.94, interaction = n.s

RESULTS AND DISCUSSION

Growth and chlorophyll content

The effects of organic manure and sulphur treatment on plant growth parameters (leaf number, fresh and dry weight) and leaf chlorophyll content of cauliflower plants are shown in Table 2. The application of organic manure significantly increased all plant growth parameters and leaf chlorophyll content in both investigated seasons.

Poultry manure at the rate of 48 m³ ha⁻¹ gave the highest values of growth parameters and leaf chlorophyll content followed by sheep manure at the rate of 60 m³ ha⁻¹. These results are in line with the results of Amara and Mourad (2013) and Zeid et al. (2015). This result might be due to the role of organic manure in the improvement of soil aeration, permeability and enhancement of water movement (El-Dardiry, 2007). This activates numerous species of living organisms, which release phytohormones and may stimulate plant growth (Arisha et al., 2003). The poultry manure, which performed better than the sheep manure could be attributed to the fact that poultry manure supplies more nutrients than sheep manure (Table 1). Solieman et al. (2006) they stated that chicken manure can offer quantity of N for soil micro-organisms activation, which are effective in nutrients availability through

variance (ANOVA) using COSTAT software package. Proper mean separation procedure, least significant differences (LSD) test at p = 0.05 probability level was used (Steel and Torrie, 1981).
conversion of the nutrients from unavailable to available form for growing plants, which in turn, can give vigorous growth of plants. The results of the present study showed that application of sulphur up to 1080 kg ha\(^{-1}\) had significant effect on growth parameters and leaf chlorophyll content (Table 2). In general, plant leaf number, plant fresh and dry weight and leaf chlorophyll content were increased with increasing sulphur levels. The application of 1080 kg fed\(^{-1}\) gave the highest values, while the lowest values were recorded with control treatment in both growing seasons. These results confirmed findings of previous studies on broccoli (Jasim, 2015) and onion (Kandil, 2016; Tripathy et al., 2016). These results may be due to the role of sulphur in the mitigation of salt stress on plants (Ahmed et al., 2016), also it decreases soil pH value and solubilizes CaCO\(_3\) in calcareous soils to make soil conditions more favorable for plant growth, including the availability of plant nutrients (Ramadan, 2012), which as a result, improves plant growth.

The interaction effect between organic manure and sulphur application had a significant effect on plant fresh and dry weight and non-significant effect on leaf number per plant and leaf chlorophyll content (Table 2). Addition of 48 m\(^3\) poultry manure ha\(^{-1}\) in combination with 1080 kg S ha\(^{-1}\) gave the highest values of growth parameters and leaf chlorophyll content, while the lowest values recorded with plants received no organic and sulphur fertilizers in the two growing seasons.

### Leaf nutrients content

The application of organic manures resulted in significant increase in cauliflower leaf N, P, K and S contents at all fertilized treatments in contrast to the control treatment (Table 3). Application of poultry manure at the rate 48 m\(^3\) ha\(^{-1}\) gave the highest values of N (2.06 and 2.00%), P (0.59 and 0.61%), K (3.44 and 3.51%) and S (1.61 and 1.66%), while the control treatment recorded the lowest values of N (1.48 and 1.40%), P (0.45 and 0.43%), K (2.72 and 2.90) and S (1.40 and 1.50%) in the first and second seasons, respectively. The results are in agreement with the findings of Zeid et al. (2015) and Mahmutovic et al. (2014). These results might be due to the fact that the addition of organic manure to soil stimulates the activity of bacteria which promotes the availability of nutrients in the soil and enhances nutrients absorption by plant roots and its translocation to upper parts of plants (Kandil and Gad, 2009). In the present study, poultry manure performed better than sheep manure which could be attributed to the fact that poultry manure supplies more nutrients (N, P and K) than sheep manure as shown in Table 1.

The results of two seasons on leaf nutrients content as influenced by different levels of sulphur showed significant variations among them (Table 3). The application of all sulphur levels increased N, P, K and S contents in leaves as compared with the control treatment, with biggest increases in sulphur being 1080 kg ha\(^{-1}\) treatment in the two seasons. Similar results have been obtained by Motior et al. (2011). The considerable increase in the release of soil nutrients with great difference between rates of sulphur, which could be attributed to decrease in soil pH, resulted from the acidifying effect of sulphur and the release of plant nutrients from unavailable pools to soil solution (Aulakh, 2003; Karimizarchi et al., 2014).

Significant organic manure × sulphur interactions for N content were observed in both seasons, while the organic manure × sulphur interaction for K content was found to be significant only in the first season. No significant interaction effects between organic manure and sulphur were detected for P and S contents in both years. The highest values of N, P, K and S contents were recorded with plots that received 48 m\(^3\) poultry manure ha\(^{-1}\) combined with 1080 kg sulphur ha\(^{-1}\) in both seasons.

### Curd fresh weight and total yield

The effects of organic manure and sulphur application on curd fresh weight and total yield are shown in Table 4. The curd fresh weight and total yield significantly increased with addition of organic manure. The application of 48 m\(^3\) poultry manure ha\(^{-1}\) resulted in highest curd fresh weight and total yield values as compared with other treatments in both growing seasons. The findings of the present study are in agreement with those of Abou El-Magd et al. (2012). This might be attributed to the stimulating effect of organic manure on plant growth, leaf chlorophyll content and uptake of nutrients and its accumulation in plant (Tables 2 and 3).

Sulphur addition significantly increased curd fresh weight and total yield as comparing with control in both seasons. The highest values of curd fresh weight and total yield were obtained in 1080 kg S ha\(^{-1}\) application in both seasons. These results are in line with the results of Slosar et al. (2016). The increase in curd weight and yield might owe better plant growth and chlorophyll content (Table 2) and can ascribed to larger uptake of nutrients from the soil (Table 3). The process of tissue differentiation from somatic to reproductive, meristematic activity and development of floral primordial might have increased with increasing sulphur supply and thus increasing the fruit weight and total yield (Singh and Verma, 1989). It is worthy of note that regression of cauliflower yield on applied sulphur treatments was polynomial type (second degree) as shown in Figure 1. Regression curve and regression equation indicated that total yield was increased with increasing sulphur level, however, the rate of increment was decreased as the sulphur level was increased particularly with the highest level (1080 kg S ha\(^{-1}\)). This was true in both investigated seasons.

Effects of interaction between organic manure and
Sulphur application were significant for curd fresh weight and total yield in first season (Table 4). The highest values were obtained in 48 m³ poultry manure ha⁻¹ in combination with 1080 kg S ha⁻¹ application in both seasons.

**Fruit quality**

All organic manure treatments led to significantly increased protein, carbohydrate and vitamin C content in cauliflower curds (Table 5). The highest values of protein, carbohydrate and vitamin C in the two seasons were obtained with 48 m³ poultry manure ha⁻¹ treatment as compared with the other treatments in the two seasons. These results are in agreement with the findings obtained in studies on tomato (Gad and Hassan, 2013) and on bell pepper (Abu-Zahra, 2011). The improvement in fruit quality might be due to improvement in soil physical properties, water holding capacity, structure, porosity,
Table 4: Effect of organic and sulphur fertilization on curd fresh weight total yield of cauliflower during 2013/2014 and 2014/2015 seasons.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>O.F (m³ ha⁻¹)</th>
<th>First season (2013/2014)</th>
<th>Second season (2014/2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>360</td>
<td>720</td>
</tr>
<tr>
<td>Curd fresh weight (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without</td>
<td>0.82</td>
<td>0.84</td>
<td>0.90</td>
</tr>
<tr>
<td>48 S.M</td>
<td>0.85</td>
<td>0.95</td>
<td>1.02</td>
</tr>
<tr>
<td>60 S.M</td>
<td>0.90</td>
<td>1.08</td>
<td>1.23</td>
</tr>
<tr>
<td>36 P.M</td>
<td>0.87</td>
<td>0.99</td>
<td>1.15</td>
</tr>
<tr>
<td>48 P.M</td>
<td>1.11</td>
<td>1.28</td>
<td>1.36</td>
</tr>
<tr>
<td>Mean</td>
<td>0.91</td>
<td>1.03</td>
<td>1.13</td>
</tr>
</tbody>
</table>

L.S.D p = 0.05 for O.F= 0.03, S= 0.02, interaction= 0.05
O.F= 0.05, S= 0.02, interaction= 0.05

Total yield (Mg ha⁻¹)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>O.F (m³ ha⁻¹)</th>
<th>First season (2013/2014)</th>
<th>Second season (2014/2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>360</td>
<td>720</td>
</tr>
<tr>
<td>Total yield (Mg ha⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 S.M</td>
<td>15.58</td>
<td>16.71</td>
<td>17.71</td>
</tr>
<tr>
<td>36 P.M</td>
<td>15.38</td>
<td>16.52</td>
<td>17.31</td>
</tr>
<tr>
<td>48 P.M</td>
<td>15.88</td>
<td>17.31</td>
<td>18.22</td>
</tr>
<tr>
<td>Mean</td>
<td>15.22</td>
<td>16.23</td>
<td>17.19</td>
</tr>
</tbody>
</table>

L.S.D p = 0.05 for O.F= 0.09, S= 0.09, interaction= 0.02
O.F= 0.24, S= 0.16, interaction= n.s


Figure 1: Regression of cauliflower yield (Mg/ha) on applied sulphur treatment (kg/ha) in 2013/2014 (A) and 2014/2015 (B).

bulk density, hardiness and the essential nutrients in organic manure that play significant role in improving the fruit quality (Joy and Paul, 2008).

Table 5 shows that curd contents of protein, carbohydrate and vitamin C increased significantly in all sulphur treatments, as compared with the control treatment. The highest protein and vitamin C were found when 1080 kg S ha⁻¹ was applied. The content of carbohydrate of cauliflower curds was highest in the 720 or 1080 kg S ha⁻¹ treatments, with no significant differences between them in both seasons. These results are in line with the opinion of Motior et al. (2011). This may be due to the role which sulphur play in protein synthesis and N assimilation, and it is a structural
Table 5: Effect of organic and sulphur fertilization on protein, carbohydrate and vitamin C contents of cauliflower curd during 2013/2014 and 2014/2015 seasons.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>O.F (m² ha⁻¹)</td>
<td>S (kg ha⁻¹)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protein (%)</td>
<td></td>
</tr>
<tr>
<td>Without</td>
<td>1.78</td>
<td>1.82</td>
</tr>
<tr>
<td>48 S.M</td>
<td>1.84</td>
<td>1.95</td>
</tr>
<tr>
<td>60 S.M</td>
<td>1.93</td>
<td>2.12</td>
</tr>
<tr>
<td>36 P.M</td>
<td>1.92</td>
<td>2.09</td>
</tr>
<tr>
<td>48 P.M</td>
<td>2.14</td>
<td>2.25</td>
</tr>
<tr>
<td>Mean</td>
<td>1.92</td>
<td>2.05</td>
</tr>
<tr>
<td>L.S.D p&lt;0.05 for O.F= 0.05, S= 0.03, interaction= 0.07</td>
<td>O.F= 0.08, S= 0.04, interaction= n.s</td>
<td></td>
</tr>
<tr>
<td>Total carbohydrate (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without</td>
<td>3.24</td>
<td>3.31</td>
</tr>
<tr>
<td>48 S.M</td>
<td>3.35</td>
<td>3.50</td>
</tr>
<tr>
<td>60 S.M</td>
<td>3.41</td>
<td>3.62</td>
</tr>
<tr>
<td>36 P.M</td>
<td>3.38</td>
<td>3.55</td>
</tr>
<tr>
<td>48 P.M</td>
<td>3.63</td>
<td>3.92</td>
</tr>
<tr>
<td>Mean</td>
<td>3.40</td>
<td>3.58</td>
</tr>
<tr>
<td>L.S.D p&lt;0.05 for O.F= 0.05, S= 0.04, interaction= 0.09</td>
<td>O.F= 0.05, S= 0.04, interaction= 0.10</td>
<td></td>
</tr>
<tr>
<td>Vitamin C (mg/100g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without</td>
<td>33.26</td>
<td>36.53</td>
</tr>
<tr>
<td>48 S.M</td>
<td>37.22</td>
<td>40.30</td>
</tr>
<tr>
<td>60 S.M</td>
<td>39.02</td>
<td>45.17</td>
</tr>
<tr>
<td>36 P.M</td>
<td>38.93</td>
<td>42.78</td>
</tr>
<tr>
<td>48 P.M</td>
<td>43.92</td>
<td>47.07</td>
</tr>
<tr>
<td>Mean</td>
<td>38.47</td>
<td>42.37</td>
</tr>
<tr>
<td>L.S.D p&lt;0.05 for O.F= 0.67, S= 0.57, interaction= 1.28</td>
<td>O.F= 0.81, S= 0.72, interaction= 1.60</td>
<td></td>
</tr>
</tbody>
</table>


constituent of several co-enzymes and prosthetic groups (Marschner, 1995). Sulphur helps in the metabolism of carbohydrate and increases its content in plant (Kumar et al., 2015). It enhances the nutrients uptake ability of plant which is reflected on nutrient optimization, resulting in higher vitamin C content in plant (Ducsay and Varga, 2004).

As regards the organic manure and sulphur interaction, the highest protein and vitamin C contents in cauliflower curd were observed in the combination of 48 m²/poultry manure ha⁻¹ and 1080 kg S ha⁻¹, but the highest carbohydrate content in curd was observed in 48 m³/poultry manure ha⁻¹ and 720 kg S ha⁻¹. The differences among treatments were significant in both seasons, except protein content in the second season.

**Correlation analysis**

The relationship among the investigated traits revealed that either leaf number per plant or leaf chlorophyll content had high significant positive correlation with curd fresh weight (Figure 2). Correlation coefficients (r) were 0.96 and 0.97 in the first season and 0.91 and 0.97 in second season, respectively. The corresponding coefficient of determination (r²) were 0.91 and 0.94 in the first season and 0.83 and 0.93 in the second season indicating that about 83 to 91 and 93 to 94% of the variation in curd fresh weight was associated with the plant leaf number and leaf chlorophyll content, respectively. The regression coefficients (b) for the respective traits were 0.07 and 0.03 in the first season, 0.06 and 0.03 in the second season which indicated that curd fresh weight correspondingly increased by 0.07 and 0.03 kg in the first season, 0.06 and 0.03 kg in the second season, respectively for each increase of one unit of either leaf number per plant or leaf chlorophyll content.

Also, Figure 3 shows that there were significant positive relationship between total yield per feddan and either plant leaf number, leaf chlorophyll content or curd fresh weight. Correlation coefficients (r) were 0.97, 0.93 and 0.93 in the first season and 0.93, 0.93 and 0.90 in the second season, respectively, indicating dependency of total yield per hectare on plant leaf number, leaf chlorophyll content and curd fresh weight. The corresponding coefficients of determination (r²) were 0.94, 0.87 and 0.87 in the first season, and 0.86, 0.87 and 0.81 in the second season, indicating that about 94, 87 and 87% in the first
Figure 2: Regression lines, correlation coefficients ($r$), coefficients of determination ($r^2$) and regression coefficients ($b$) for both leaf number per plant or leaf chlorophyll content (Spad) and curd fresh weight in 2013/2014 (A, C) and 2014/2015 (B, D) seasons.

season, 86, 87 and 81% in the second season of the variation in total yield per hectare were associated with the plant leaf number and leaf chlorophyll content and curd fresh weight, respectively. On the other hand, the regression coefficients ($b$) were 0.47, 0.21 and 5.99 in the first season, and 0.40, 0.21 and 6.22 in the second season, respectively. This indicates that for each increase of one unit of plant leaf number, leaf chlorophyll content and curd
Figure 3: Regression lines, correlation coefficients (r), coefficients of determination (r²) and regression coefficients (b) for either leaf number per plant or leaf chlorophyll content or curd fresh weight and total yield per hectare in 2013/2014 (A, C, E) and 2014/2015 (B, D, F) seasons.

Conclusions

The addition of organic manure (sheep manure and...
poultry manure) and sulphur led to the increasing plant growth, leaf chlorophyll content, leaf mineral content (N, P, K and S), yield and quality of cauliflower. The highest yield and quality of cauliflower (Toobi cultivar) can be obtained under the application of poultry manure at the rate of 48 m$^3$ ha$^{-1}$ in combination with 1080 kg S ha$^{-1}$ under saline calcareous soil conditions.

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