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Soil Quality Indicators Effects on Alfalfa Productivity under Egyptian Soil Conditions

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Abstract: This study was carried out in El-Sadat center, Menoufia governorate during 2013/2015 seasons, to study the relationship between physical and chemical soil quality indicators on alfalfa. Eight soil samples of six locations have been sampling to a depth of 30 cm. All samples collected for each region separately, and analyzed for fourteen physical indicators viz. CS, FS, S and clay, BD, real density, hydraulic conductivity, field capacity, wilting coefficient, slowly drainable porosity, quickly drainable porosity, mean Wight diameter, water holding porosity and total porosity; as well as, seven chemical indicators viz. pH, electric conductivity, organic matter, cation exchange capacity, calcium carbonate, available potassium and total nitrogen. Results showed that, the soil planted (alfalfa crop) were more affected (significant correlation) on the production of four indicators namely: pH (0.68^*) > TN (0.65^*) > OM (0.52) > clay (0.50). Results also, clear that there is insignificant relationship among physical parameters and alfalfa equivalent yield. Results added that, insignificant linear relationship correlation was observed between alfalfa productivity and most of chemical parameters under study such as (EC, $CaCO_3$, CEC, and Av. k) (r = -0.021, 0.490, -0.470, and 0.000) respectively, On the opposite, both of pH, OM and T.N indicators showing a significant positive linear relationship correlation ($P < 0.05$, r = 0.680, 0.520, 0.650) respectively.

Keywords: Physical SQI, Alfalfa, El-Sadat Center, OM, Productivity

1. Introduction

Soil is considered as the main source in providing essential plant nutrients, water reserves and a medium for plant growth. The definition of soil quality is the ability of a soil to perform within an ecosystem and soil use, to preserve both of biological activities, and environmental quality, as well as encourage plants, animals, and human health (Doran and Parkin, 1994). Soil quality (SQ) depends in part on the natural composition of the soil.

The definition of SQ discovered in the early 1990s (Wienhold et al., 2004) and defined as the ability of a soil to perform within an ecosystem and soil use, to preserve both of biological activities, and environmental quality, as well as encourage plants production (Karlen et al., 1997). Soil quality is considered one of the best methods for soil quality determination due to ease of use, flexibility and quantification. These indices represent the cumulative effects of different soil properties (physical, chemical and ecological) as an index from the role of each indicator in soil quality (Drury et al., 2003; Singh and Khera, 2009).

Soil physical quality is measured by soil indicators such as available water holding capacity (AWHC), relative field capacity to water saturation (RFC), macro porosity, bulk density (BD), and many others (Reynolds et al., 2009). Chemical Indicators of soil quality the purposed include on cation exchange capacity (CEC), contaminant presence (CP), (EC) exchangeable sodium, pH, Av. k, and Av. P…. etc.

Many researchers have proposed various SQ parameters (Larson and Pierce, 1994; Doran and Parkin, 1994; Karlen et al., 1998) that can be easily measured and they are sensitive to change of soil condition and therefore, they must be able to identify appropriated sustainable soil conditions (Gomez et al., 1996; Aparicio and Costa, 2007), Liu et al. (2013)

established SQ index depending on twenty-six soil physical, chemical and microbiological properties in a paddy soil of china by using both TDS and MDS methods.

In general, most researchers used a set of predefined soil indicators suggested by Gomez et al. (1996) and Shukla et al. (2004) to determine SQ and sustainability of agricultural land. The process of degradation in Egypt has intensified due to low farmers' information of agricultural soil conditions, and decrees of proper equipment's. Under these conditions, the soil quality is often influenced by limiting factors such as high temperature, poor soil fertility, low available holding capacity of water (AWHC), organic carbon of soil (SOC) and high concentrations of salt and pH.

When soil quality indicators are in the optimum range, crop yield response would be optimal (maximum obtainable yield) with reduced soil degradation (Reynolds et al., 2009).

A character's soil physical affect crop productivity by many ways. Development and growth of plant are heavily evaluated by the soil's texture, BD, porosity, WHC, and the presence or absence of hard pans. These characters are all improved by adding of organic matter to soils. Also, the previous characters impress relationships of soil and plant water. The distribution of water at the soil surface is important because it determines both SQ of surface and groundwater, in addition the amount of water that will be available for plant growth.

Therefore, aim of the present study is to study the relationship among physical and chemical SQ indicators as affected on alfalfa productivity under El-Sadat center soil conditions.

2. Materials and Methods

The current investigation was carried out in El-Sadat center, Menoufia governorate during period of 2013-2015 to study the relationship among physical and chemical SQ indicators with alfalfa productivity.

The materials and methods of this investigation are presented as follows: -

In this study, measuring physical and chemical SQ as for, physical indicators include the following; Texture (T), bulk density (BD), total porosity (TP), available water (AW), aggregates stability (AS), (HC), field capacity (FC), wilting coefficient (WC).

Regarding, the chemical indicators include the following; pH, electric conductivity (EC), organic matter (OM), cation exchange capacity (CEC), total calcium carbonate (TC), total nitrogen (TN), available potassium (AV-K) were determined according to page et al. (1982).

2.1. Maps and Location of Samples

The study sites are located within El-Sadat center, Menoufia governorate. Before beginning sampling, process was brought one Map Survey for the study area for Al-Menoufia governorate, the samples were signed on map and took samples from six locations.

Table 1. *The soil properties of studied sites.*

No.	Study site	Location	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	BD	EC	pH
1	Albarka basin and Almadaor.	30° 23' 58"N 30° 50' 8"E	0 -30	31	34	35	1	0.85	7.14
2	Khatatba village	31° 45' 10"E 31° 25' 8"N	0-30	53.5	22.8	23.7	1.31	0.69	7.36
3	Abu Nashaba.v	31° 50' 12'E 31° 31' 10"N	0-30	48.62	17.8	33.59	1.34	0.26	7.6
4	Alakhmas west	30° 59' 15"E 30° 26' 20"N	0-30	48.48	22.4	29.76	1.29	0.29	7.5
5	Alakhmas east	30° 50' 9" E 30° 25' 61"N	0-30	49.11	22.1	26.4	1.25	0.26	7.26
6	Altranh west	30° 40' 13"E 30° 22' 50"N	0-30	51.5	19.2	24.2	1.35	0.37	7.3

2.2. Data of Location

Eight samples of six locations have been sampling to a depth of 30 cm and collected all the data for each region separately, from the various management processes of the plant (crop), for example tillage and land preparation for agriculture, the process of application fertilizers mineral or Organic, the irrigation system and his condition (source), The drainage system and his condition, the high level of ground water, topographic, and all the data about the area under investigation. Crop has been planted (alfalfa). Whereas was the follow-up crop from planting to harvest, and follow up the root system and taken plants from each area and measure the root length and spread into the soil body, and taking photographic images to the length of the plant root (at a rate of twice each field, after one month and two months from planting). At harvest stage, the crop productivity per feddan for each location was calculated separately and compares it to similar crop grown in another location field with different soil texture. Whereas productivity is the basic factor in determining soil quality using parameters or soil quality indicators.

2.3. Laboratory Analysis: Determination of the Physical and Chemical Properties

2.3.1. Soil Physical Analysis

$$N = (Y^s - Y^d/Y^s) \times 100 \quad (1)$$

$$K = (QL / HAT) \quad (2)$$

Where:

K = Hydraulic Conductivity coefficient cm/h

Q = volume the filtrate (cm^3).

L = length of the soil column (cm).

H = length of the water column (cm).

A = area of the tube (cm^2).

T = Time (Sec).

$$AWC = FC - PWP \quad (3)$$

Where: (FC) is Field capacity, (PWP) is permanent wilting point.

$$MWD = \sum Xi\ Wi \quad (4)$$

Where: I = 1, X = mean diameter of the considered fraction mm, W = weight of the dry sieving fraction g.

2.3.2. Soil Chemical Analysis

Soil Chemical Analysis was determined according to (Page et al., 1982).

2.4. Statistical Analyses

Statistical analysis for data was don using SPSS V. 21 (2014).

3. Results and Discussion

3.1. Soil Physical Indicators

3.1.1. Soil Texture

Table (2) showed that the studied soil samples have different soil textural classes i.e. a relatively fine texture (clay loam soil samples 8), a relatively medium (loam, sandy clay loam and sandy clay soil samples 4, 12, 20, 21, 22, 24, 13. these widely variations are more relative to the soil origin, intensity of geo-chemical weathering, vertical or horizontal depositional pattern, nature of both depositional media and mechanism of transportation.

3.1.2. Soil Bulk Density (BD)

Data of Table 2 shows the studied samples have different soil physical properties. Soil bulk density is the important parameter to evaluate soil physical indicators such as total porosity and void percentages. It is role different factors including organic matter, total porosity, biological activity, particle packing density, carbonate and soil moisture contents.

Results in the same Table showed that studied soil samples was ranged from 1.20 to 1.46 g/m^3 for bulk density. The lowest value (1.20 g/m^3) was obtained in the soil sample 4, on the other hand, the highest value (1.46 g/m^3) was recorded in sample 20.

The general trend of change in bulk density with different studied sample was an increase with legumes crops. This may indicate an increase in secondary carbonates that would enhance the formation of the soil aggregates. However, soil bulk density values of soil samples tend to increase with depth that resulting from the deepening legumes (alfalfa) roots. This is probably to the increase of clay fraction and soil compaction with legumes roots.

3.1.3. Soil Porosity

Total porosity is an index of the relative volume of pores in soil and is used to evaluate soil structure. Results of Table 2 indicated that, soil samples was ranged between 44% and 55.22% for total soil porosity. The lowest value was recorded in soil sample 20, within crop total porosity tends to be higher in the soil sample S4 (54.72%), results added that total soil porosity increases with increasing clay and organic matter content, but it decreases with increasing of soil compaction in the deeper roots comparing with surface roots, these results indicated that total porosity is mainly affected by soil physical properties and partly be both organic matter content and soil compaction.

Table 2. *Soil texture, BD, TP, HC, WP and FC of soil samples under study.*

Crops	Sample	Particle size distribution (%)				Textural class	B.D g/cm^3	T.P%	H.C Cm/h	Soil moisture constants	
		C.S	F.S	Silt	Clay					W.P%	F.C%
Alfalfa	S4	6.5	32.5	37	24	L	1.2	54.72	4.7	12.9	28.30
	S12	4.5	41.5	20	34	SCL	1.37	49.6	4.1	12.8	26.50
	S13	5.3	41.7	17	36	SC	1.24	48.15	4.2	12.15	26.25
	S20	7.2	38.4	20.4	34	SCL	1.46	44.00	0.83	8.5	19.10
	S21	7.9	42.7	19.8	29.6	SCL	1.30	52.3	8.31	14	29.40
	S22	12.1	41.2	22.1	24.6	SCL	1.33	48.2	0.94	9.2	21.30
	S23	8.4	36.1	23.9	31.6	CL	1.35	49.4	4.4	11.3	22.00
	S24	8.3	39.3	19.4	33	SCL	1.30	51.8	5.82	12.7	27.00

Where: C.S = Cores Sand, F.S = Fine Sand, T.C = Texture class, F.C = field capacity, B.D = Soil bulk density, R.D = Real density (particle phase density), H.C = Hydraulic conductivity, Por = porosity, CL: Clay loam, SCL: Sandy Clay Loam, L: Loam, SL: Sandy Loam, SC = Sand clay.

3.1.4. Soil Hydraulics Conductivity (HC)

Soil hydraulics conductivity is an important parameter in the planning of water use, irrigation, drainage as well as in leaching of salt affected soils in soil reclamation. It measures the rate of water conduction, water movements in the saturated flow principally through macrospores. The determined values of hydraulics conductivity of the studied soil samples are presented in Table 2. The obtained values of Soil hydraulics conductivity ranged between 0.83 Cm/h and 12.5 Cm/h, the lowest was obtained in sample S20 (0.83 Cm/h). On the opposite, the highest value was obtained in sample S21 (8.31 Cm/h). In general, the variations in the soil hydraulic conductivity can be attributed to the influence of soil quality and porosity.

3.1.5. Soil Moisture Parameters (FC, WP)

Soil moisture characteristics are very important parameter to determine the irrigation requirements of the cultivated crop in arid and semi-arid regions as well as selection of the cultivated crops. FC and WP were affected by many factors such as soil mineralogical composition, total soluble salts and the exchangeable Cations, the results of samples are shown in Table 2, declare that field capacity and wilting point differ from one physiographic unit to another value of moisture content at field capacity ranged between 19.10 and 39.79%. The lowest value was recorded in S16 (21.29%). on the other side, the highest value was found in S21 (29.40%). Values of moisture content at field capacity tends to increase with deeper and have an irregular distribution in the other soil samples.

Values of wilting point for soil samples in different area, were ranged between 8.5 and 15.2%. The lowest value was recorded in S20 (8.5%), while the highest value was found in S4 (12.9%).

Values of FC and WP tends to increase with deeper and have an irregular distribution in the other soil samples. These results may be suggested that they are positively related to soil fine particles (clay content).

3.2. Soil Chemical Indicators

3.2.1. Soil PH

According the values of pH for soil samples under study are recorded in Table 3. The obtained values of Soil pH ranged between 7.12 and 8.10, the lowest was obtained in sample S12 (7.12), while, the highest value was obtained in samples S4 (8.10) for alfalfa crop.

Considering the change in pH values, data revealed that a slightly increase with S4, S20, and S23 but a decrease was noticed in S12, S19 and S21 and no certain trend can be observed in some other soil samples (S22). Soil pH values may be indicated that these studied soils are base saturated since all their pH values are over 7.0.

3.2.2. Soil Salinity and Sodicity (EC)

Data of soil salinity, recorded in Table 3, showed that EC values were 0.16 to 0.88 (ds/m). So, the grade of soil salinity varies from "non-saline" to "strongly saline"

The soil can be classified in to the three categories according to the USDA salinity laboratory USDA, 1954 as follows:

1. Non-saline soils (less than 4 ds m^{-1}) involve all studied soil samples
2. Moderately saline soils (4-8 ds m^{-1}).
3. Strongly saline soils (8-16 ds m^{-1}).

Results added that EC values trend to decrease with alfalfa in S13, while, they trend to increase with alfalfa in S4, S19. However, EC values of the other soil samples show an irregular trend throughout the soil samples S12, S21 and S23 for alfalfa, which may be attributed to intensive surface irrigation or active upward movement of saline soil solution with drawn as a result of the relatively high saline water table.

With the respect of, soil sodicity, sodium adsorption ratio (SAR) for the saturation extract has been recommended for the sodic soil characterization. Values of SAR have been calculated according to formula introduced by the USDA, (1954).

These are given in Table 3. According to SAR, soil could be grouped in to the following categories according to Ghabbour (1988).

1. Slightly sodic soils (SAR < 20) representing soils of samples
2. Moderately sodic soils (SAR 20-50) involve all studied soils studied, with exception of soil samples
3. Strongly sodic soils (SAR > 50).

In general, the moderately sodic soils are mainly located near Birket Qarun and most of the studied area is moderately sodic soils.

Table 3. *Chemical indicators of the studied soil samples.*

Crop	Sample	pH 1:2.5	E.C (ds/m)	T.N (Mg/kg)	Av-k (Mg/kg)	CEC (C, mol/kg)	$CaCO_3$%	O.M%
Alfalfa	S19	7.30	0.37	14	35.1	20	0.57	1.98
	S4	8.10	0.42	21	111.15	38	2.56	2.3
	S12	7.12	0.27	17.5	87.75	39	1.0	2.1
	S13	8.10	0.21	28	60.45	40	2.0	1.6
	S20	7.72	0.25	22.4	70.2	36	2.11	1.9
	S21	7.38	0.27	15.4	54.6	39	0.49	2.0
	S22	7.65	0.25	21	46.8	42	1.48	2.16
	S23	7.71	0.27	22.4	42.9	34.7	1.12	1.98

3.2.3. Soil Calcium Carbonate Content ($CaCO_3$)

The total carbonate content of the studied soil samples have been measured as calcium carbonate content. Data of Table 3 shows the total carbonate content for studied soil samples was ranged from 0.42% and 3.65%. Soil sample S21 (0.49%) for alfalfa scored the lowest value. On opposite of, the highest value was obtained in soil sample S4 (2.56%). Regarding the distribution of carbonate within the soil samples under study, data showed that it tends to increase with alfalfa in S4 and S20, but decrease with alfalfa in S19 and S21, while in the some other soil samples, it exhibited an irregular distribution throughout the soil samples.

3.2.4. Organic Matter (OM)

Data of Table 3 cleared organic matter was generally low (ranged between 0.16 and 2.30%) throughout the different soil samples in different area under study. This is a natural characteristic of semi-arid and arid soils, due to the high temperature and dry climate that encourage the decomposition of organic matter. The highest OM was attained for alfalfa in S4 (2.30%), however, the lowest OM was recorded in S13 (alfalfa).

In general, organic matter trended to be high in the surface layer of soil and low in the deepest ones, this pattern of organic matter distribution related to the continuous additions manure and plant residues such as legumes crops to the soil surface.

3.2.5. Total Nitrogen (T. N) (Mg/kg)

Results showing in Table 3 concluded that the total nitrogen content of the studied soil samples ranged between 14 and 49 (Mg/kg). The lowest value was recorded in soil sample S19 (14 mg/kg) for alfalfa. On contrary, the highest value was obtained in soil sample S13 (28 mg/kg) for alfalfa. It can be noticed that, total nitrogen content tends to increase it with alfalfa crop (legumes fixed nitrogen) that variations in content and microorganism's activity in the different soil samples under study.

3.2.6. Available Potassium (Mg/kg)

Regard available potassium content (Table 3), data revealed that available potassium content ranged from 17.55 to 195 (Mg/kg). The lowest value was recorded in soil sample S19 (35.1 Mg/kg) for alfalfa. On the other hand, the highest value was obtained in soil sample S4 (111.15 Mg/kg) for alfalfa.

3.3. Chemical Analysis of the Soil Study Area Samples

3.3.1. Exchangeable Cations

Data of exchangeable Cations (Table 4) showed that calcium and magnesium were generally the principle exchangeable Cations in the studied soils. Exchangeable calcium content ranged between 1.30 and 4.40 (meq/L) soil. Whereas exchangeable magnesium content varied from 0.20 and 2.60 (meq/L) soil. On the opposite of the monovalent Cations sodium and potassium, which were generally ranged between 14.5 and 54.20 (meq/L) soil (for Na^+) and from 0.09 and 1.30 (meq/L) soil (for k+). Exchangeable potassium was the least abundant of the four Cations. Data showed that exhalable Cations were $Na^+ > Ca^{++} > Mg^{++} > k^+$ most of samples.

Data revealed that exchangeable sodium percent (ESP), in most studied soil samples, therefore based on the ESP criteria most soils were classified as non-sodic in some other soils, ESP values were more than 15%, thus being sodic. ESP values tend to increase with soil samples S19, S20, and S21, while the decrease with soil samples S23, but they showed an irregular distribution in the other soil samples.

3.3.2. Exchangeable Anions

According to data of exchangeable anions (Table 4), cleared that HCO_3^-, Cl^- and SO_4 were generally the principle exchangeable anions in the studied soils. Exchangeable HCO_3^- content ranged between 0.60 and 1.40 (meq/L) soil in all the studied soil samples. Whereas the exchangeable Cl^- content varied from 0.60 and 3.85 (meq/L) soil. On the other hand the divalent anion SO_4, which was generally ranged between 16.58 and 55.20 (meq/L) soil. Exchangeable HCO_3^- was the least abundant of the three anions. Data showed that exhalable Cations were in the order of $SO_4^{++} > Cl^- > HCO_3^-$.

Table 4. *Chemical analysis of soil samples.*

No. of sample	Cations (meq/L)				Anions (meq/L)				SAR	ESP%
	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{++}	(Meq/L)	
S_4	3.00	0.80	36.00	0.57	----	1.60	1.80	40.37	26.27	27.26
S_{12}	1.80	0.20	36.30	0.45	----	1.00	1.00	36.75	36.30	34.33
S_{13}	1.80	0.20	29.60	0.31	----	1.40	0.70	29.81	29.60	29.77
S_{19}	1.30	0.70	37.20	0.28	-----	0.74	3.00	35.80	37.20	34.90
S_{20}	2.33	0.80	37.20	0.48	----	0.88	3.19	36.82	29.76	29.89
S_{21}	1.33	0.60	35.20	1.00	----	0.80	1.80	35.53	35.91	34.08
S_{22}	1.70	0.50	28.40	0.47	----	1.25	2.00	27.20	27.30	28.06
S_{23}	2.00	2.20	33.30	0.49	----	1.00	1.22	35.80	23.12	24.72

3.4. Chemical Analysis of the Water Samples

3.4.1. Water PH

The values of pH for water samples under study (Table 5), obtained ranged between 7.16 and 8.10, the change in pH values, data revealed that a slightly increase with gas factory area and Abu Nashaba village, Soil pH values may be indicated that these studied water are base- saturated since all their pH values are over 7.0.

3.4.2. Water Salinity and Sodicity (EC)

Data of water salinity, as expressed in terms of water paste (Table 5), showed values EC from 0.26 to 0.82 (ds/m). So, the grade of water salinity varies from "Low salinity or high quality water "to" Very high salinity or very low quality"

The water can be classified in to the three categories according to the USDA salinity laboratory USDA, 1954 as follows:

1. Low salinity or high quality water (less than 0.25 ds m^{-1})
2. Medium salinity or quality water (0.25-0.75 ds m^{-1}). involve all studied water samples with the exception water sample (Albarka basin and Al madaor sample)
3. High salinity or low quality water (0.75–2.25 ds m^{-1}), representing water samples of (Albarka basin and Al madaor sample) only.
4. Very high salinity or very low quality (more than 2.25 ds $m^{-1)}$

3.4.3. Exchangeable Cations

Table 5 showed that exchangeable Cations calcium and magnesium were generally the principle exchangeable cations in the chemical analysis water. Exchangeable calcium content ranged between 3.6 (meq/L) water at Al barka basin and Al madaor location and 9.40 (meq/L) water at gas factory area in all the studied water samples. Whereas the exchangeable magnesium content varied from 1.00 (meq/L) and 4.20 (meq/L) water at the same previous locations. On contrary, the monovalent cations sodium and potassium, which were generally ranged between 1.87 (meq/L) at Al barka basin and Al madaor location and 6.40 (meq/L) water at Abu Nashaba village location (for Na+) and 0.44 (meq/L) water at Alkhvoj village (for k+). Exchangeable potassium was the least abundant of the four Cations. Data showed that exhalable cations were $Ca^{++} > Na^{+} > Mg^{++} > k^{+}$ in most of water samples.

Table 5. *The chemical analysis water samples.*

Location No. Samples	pH	EC	Cations (meq/L)				Anions (meq/ L)				SAR
	(1:2.5)	(ds/m)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^{--}	HCo_3^{-}	CL^{+}	So_4^{++}	
Albarka basin and Almadaor.	7.55	0.82	3.6	1.00	1.87	0.25	-----	2.00	0.80	3.92	1.10
Khatatba village	7.25	0.32	4.75	2.66	3.42	0.44	-----	2.50	2.55	6.22	1.78
Abu Nashaba. v	7.55	0.82	3.6	1.00	1.87	0.25	-----	2.00	0.80	3.92	1.10
Alakhmas west	7.55	0.82	3.6	1.00	1.87	0.25	-----	2.00	0.80	3.92	1.10
Alakhmas east	8.10	0.73	4.50	3.40	6.40	0.39	-----	3.25	5.50	5.94	3.23
Altranh west	7.25	0.32	4.75	2.66	3.42	0.44	-----	2.50	2.55	6.22	1.78

3.4.4. Exchangeable Anions

Data presented in (Table 5) clarified that exchangeable anions of HCO_3^-, Cl^- and SO_4 were generally the principle exchangeable anions in the studied of water samples. Exchangeable HCO_3^- content ranged between 2.00 (meq/L) water at Al barka basin and Al madaor location in all the studied water samples. Whereas the exchangeable Cl^- content varied from 0.80 (meq/L) water at Al barka basin and Al madaor location. On the other hand the monovalent anion SO_4. Exchangeable HCO_3^- was the least abundant of the three anions. Data revealed that exhalable Cations were $SO_4^{++} > Cl^- > HCO_3^-$ in most of water samples under study.

Regarding, sodium adsorption ratio (SAR) in most water samples of the study area. Values of SAR have been calculated according to formula introduced by the USDA, (1954).

3.5. General Descriptive Statistics of Soil Indicators Under Study

The data obtained in Table 6 show that mean data of 21 SQ indicators effects on Alfalfa productivity. Results concluded that, three physical SQ indicators (FS, TP, and FC) only were significantly different (39.17 ± 3.44), (49.77 ± 3.24), and (24.94 ± 3.69) respectively, compared with other physical SQI. Also, these three SQI were recorded the largest relative weighted and most effective on alfalfa productivity. Both FS, TP and FC had affected by (1.23%, 1.57%, and 0.79%) respectively, on alfalfa productivity.

Results also cleared that, CEC chemical SQI indicator had significant effect (37.58 ± 3.19) by relative weighted 1.18% on alfalfa yield comparing with other chemical SQ indicators which recorded the lowest relative weighted values and lowest effective on alfalfa productivity. This results in agreement with Bhardwaj *et al.* (2011) and Zornoza *et al.* (2007)

With regard to, regression coefficients obtained between SOC, AWHC, AC, RFC, pH, and EC showed significant relationships with soil physical and chemical indicators. These variables positively impacted the physical quality of soil by improving soil structural stability and biological properties as reported by many authors (Shukla et al., 2006; Liu et al., 2013). Because of SOC for soil, it was selected in this study.

Table 6. *Descriptive statistic of soil quality indicators under study (n = 21).*

Parameters	Descriptive Statistics			
	Mean	Std. Deviation	Weight	Sample No.
Alfalfa productivity	32.9389	1.85810	0.104	8
CS	7.5250	2.32056	0.024	8
FS	39.1750	3.44207	0.123	8
SILT	22.4500	6.21243	0.071	8
CLAY	30.8500	4.45774	0.097	8
R.D	2.6687	0.05592	0.008	8
B.D	1.3188	0.07990	0.004	8
T.P	49.7712	3.24196	0.157	8
Q.D.P	14.3500	2.67795	0.045	8
S.D.P	10.4375	1.26710	0.033	8
W.H.P	13.2875	1.93127	0.042	8
F.C	24.9813	3.69478	0.079	8
W.P	11.6938	1.91953	0.037	8
H.C	4.1625	2.44335	0.013	8
M.W.D	2.1262	0.77012	0.007	8
E.C	0.2738	0.06232	0.001	8
PH	7.6938	0.33088	0.024	8
OM	2.0125	0.20645	0.006	8
CaCO3	1.4850	.68694	0.005	8
CEC	37.5875	3.19662	0.118	8
Av-k	0.3362	0.11987	0.001	8
T.N	0.2987	.05357	0.001	8

3.5.1. Physical and Chemical SQI

Significant positive correlation ($P < 0.05$) was observed between physical and chemical parameters (Table 7). Among the highly correlated parameter, results notice that there was negative correlation between CS & RD (r = - 0.65), CS & SDP (r = - 0.65), FS & Silt (r = - 0.868), FS & EC (r = - 0.786) & FS, $CaCO_3$ (r = - 0.60), Silt & Clay (r = - 0.732), Clay & QDP (r = - 0.708), Clay & EC (r = - 0.678), Clay & OM (r = - 0.776), RD & QDP (r = - 0.67), B.D & T.P (r = - 0.771), B.D & WHP (r = - 0.765), B.D & FC (r = - 0.727), B. D & WP (r = - 0.63), QDP & SDP (r = - 0.69), HC & MWD (r = - 0.723).

In this study, both EC (r = 0.966), OM (r = 0.700), Av-k (r = 0.660), is also showing significant correlation (P<0.05) with Silt. While, FC (r = 0.757), WP (r = 0.871), HC (r = 0.845) representing high positive significant correlation (P < 0.01) with RD.

Results also concluded that, TP showing strong positive correlation (P < 0.01, 0.05) with FC (r = 0.837), WHP (r = 0.794), WP (r = 0.813), HC (r = 0.733), and EC (r = 0.670). While, QDP showing moderate positive correlation with OM (r = 0.640).

As for, WHP indicator, results cleared that it is showing highly positive correlation both FC (r = 0.960), WP (r = 0.841), and HC (r = 0.719).

Regarding FC showing highly correlation (P < 0.01) with WP (r = 0.959) and HC (r = 0.857), in addition, WP represented highly significant with HC (r = 0.926), Moreover, EC showing high correlation (P < 0.05) with OM (r = 0.735) and Av-k (r = 0.757), while PH gives high significant (P < 0.05) with $CaCO_3$ (r = 0.766) and TN (r = 0.755), Although, $CaCO_3$ showing moderate significant correlation (P < 0.05) with TN (r = 0.650) only.

Table 7. *Correlation relationship matrix between soil quality and alfalfa productivity.*

	productivity	**CS**	**FS**	**SILT**	**CLAY**	**R.D**	**B.D**	**T.P**	**Q.D.P**	**S.D.P**	**W.H.P**
productivity	1.00										
CS	-0.30	1.00									
FS	-0.15	0.04	1.00								
SILT	-0.17	0.02	-.868**	1.00							
CLAY	0.50	-0.58	0.41	-.732*	1.00						
R.D	0.07	-0.65*	0.29	-0.28	0.50	1.00					
B.D	-0.16	0.12	0.24	-0.45	0.38	-0.28	1.00				
T.P	-0.18	-0.08	-0.33	0.57	-0.50	0.44	-.771*	1.00			
Q.D.P	-0.34	.791*	-0.47	0.48	-.708*	-0.67*	0.19	0.08	1.00		
S.D.P	0.32	-0.65*	-0.06	-0.08	0.49	0.35	-0.25	-0.05	-0.69*	1.00	
W.H.P	0.04	-0.33	0.09	0.22	-0.21	0.58	-.765*	.794*	-0.37	0.02	1.00
F.C	-0.02	-0.42	0.08	0.18	-0.09	.757*	-.727*	.837**	-0.42	0.12	.960**
W.P	-0.08	-0.47	0.06	0.12	0.04	.871**	-0.63*	.813*	-0.44	0.20	.841**
H.C	-0.08	-0.28	0.11	0.00	0.06	.845**	-0.50	.733*	-0.27	-0.05	.719*
M.W.D	0.15	-0.13	0.01	0.04	0.01	-0.43	0.09	-0.35	-0.20	0.44	-0.16
E.C	-0.21	-0.12	-.786*	.966**	-0.68*	-0.09	-0.45	0.67*	0.37	-0.11	0.39
PH	0.68*	0.03	-0.54	0.40	-0.15	-0.30	-0.55	0.10	0.07	0.20	0.07
OM	0.52*	0.32	-0.46	0.70*	-.776*	-0.26	-0.11	0.55	0.64*	-0.40	0.19
$CaCO_3$	0.49	-0.18	-0.60*	0.53	-0.19	-0.51	-0.24	-0.14	0.05	0.24	-0.08
CEC	-0.47	0.08	0.39	0.00	-0.35	-0.24	-0.20	-0.09	-0.18	0.04	0.17
Av-k	0.00	-0.59	-0.49	0.66*	-0.24	0.06	-0.28	0.35	-0.17	0.23	0.42
T.N	0.65*	-0.12	-0.18	-0.07	0.30	-0.29	-0.17	-0.43	-0.27	0.57	-0.32

Table 7. *Continued.*

	F.C	**W.P**	**H.C**	**M.W.D**	**E.C**	**PH**	**OM**	**$CaCO_3$**	**CEC**	**Av-k**	**T.N**
productivity											
CS											
FS											
SILT											
CLAY											
R.D											
B.D											
T.P											
Q.D.P											
S.D.P											
W.H.P											
F.C	1.00										
W.P	.959**	1.00									
H.C	.857**	.926**	1.00								
M.W.D	-0.31	-0.43	-.723*	1.00							
E.C	0.36	0.30	0.17	-0.03	1.00						
PH	-0.03	-0.13	-0.15	0.08	0.25	1.00					
OM	0.15	0.10	0.02	0.08	.735*	-0.22	1.00				
$CaCO_3$	-0.24	-0.38	-0.53	0.52	0.42	.766*	-0.01	1.00			
CEC	0.04	-0.09	-0.23	0.36	-0.02	-0.11	-0.02	0.11	1.00		
Av-k	0.35	0.25	-0.02	0.39	.757*	0.12	0.42	0.56	0.15	1.00	
T.N	-0.38	-0.40	-0.46	0.36	-0.26	.755*	-0.63*	0.65*	0.07	-0.09	1.00

Aparicio and Costa (2007) who found there were correlation among OC and some indicators such as Bulk density, porosity, HC and MWD consider in this study for BD and porosity. A significant relationship with soil physical and chemical indicators. These variables positively impacted the physical quality of soil by improving soil structural stability and biological properties as reported by many authors (Shukla et al., 2006; Liu et al., 2013). Because of SOC for soil, it was selected in this study. Thus, it can be concluded that SOC is one of key indicators affecting the soil quality and sustainability in the studied area, which findings Govaerts et al. (2006), Lal, (2003), Gregorich et al. (1997). In addition, Lee et al., (2009) reported indices monitor soil sustainability changes instead of using the common definitions of SQI like physical and chemical properties and their processes.

3.5.2. Influence of Physical SQ Indicator on Alfalfa Productivity

Data recorded in Table 7 revealed that, insignificant relationship was observed between soil physical parameters and yield of alfalfa.

3.5.3. Relationship Among Chemical SQI and Alfalfa Productivity

Results mentioned in Table 7 and figure (1, 2, 3), showed that, Correlation matrix between alfalfa yield and chemical soil quality indicators. Results concluded that, insignificant linear relationship correlation was observed between alfalfa productivity and most of chemical parameters under study such as (EC, $CaCO_3$, CEC, and Av. k) (r = -0.021, 0.490, -0.470, and 0.000) respectively, on the opposite, both of PH, OM and T. N indicators showing a significant positive linear relationship correlation ($P < 0.05$, r = 0.680, 0.520, 0.650) respectively.

Semi results confirmed by Mohanty et al., (2007), reported that accumulation OM can increasing SQ by reducing BD, surface sealing and crust formation as well as raise aggregate stability (Somasundaram et al., 2013), cation exchange capacity, nutrient cycling, and biological activity (Karlen and Andrews, 2004). Based on fertilizers and other input can be decreased by increasing biological nitrogen fixation (Lal, 2003). Also, Liborio Balota et al., (2004) found that, the applied variables range from those which are more common and discussed, like (OC) and (TN) components, to those which are related to biological activities and which are more recent, such as determining enzyme activity (EA). The latter are particularly useful for monitoring soil quality, since determining biochemical parameters is related to key microbial processes used to preserve its metabolic activity (Trasar-Cepeda et al., 2008). Eiza et al. (2005), Ferreras et al. (2009) and De Figueiredo et al. (2010) agree that most of the changes which occur during different soil managements take place in the OC's particulate fraction. Eiza et al. (2005) says it is an indicator which is more effective than the TOC for identifying the effects on the soil.

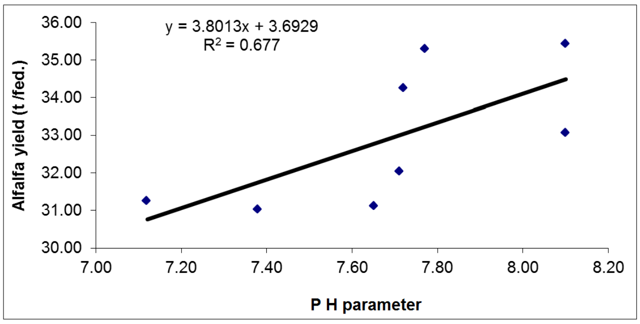

Figure 1. *The linear Relationship correlation between chemical pH SQI and alfalfa yield (t/fed.).*

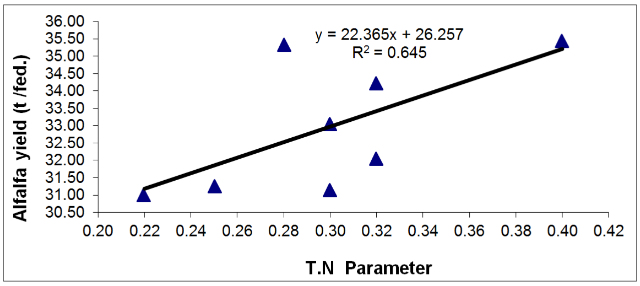

Figure 2. *The linear Relationship correlation between total nitrogen (T.N) and alfalfa yield (t/fed.).*

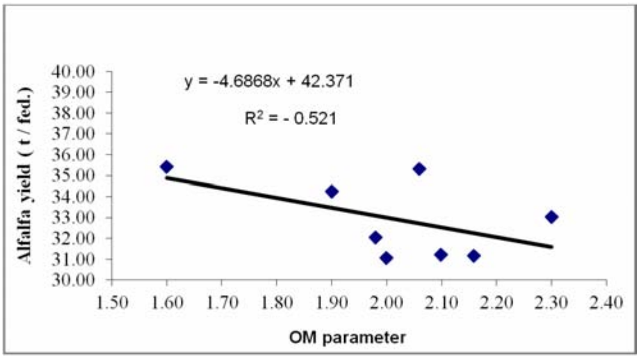

Figure 3. *The linear Relationship correlation between organic matter (OM) and alfalfa yield (t/fed.).*

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