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Determination of the Influence of Texture and Organic Matter on Soil Water Holding Capacity in and Around Tomas Irrigation Scheme, Dambatta Local Government Kano State

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Abstract: This research was conducted in Dambatta local government with aim of determining the influence of texture and organic matter content on soil water holding capacity. Three sites were chosen based on land uses-cultivated area (Jama'a village), uncultivated site (shantake) and Tomas irrigation site. Fifteen composite samples were randomly collected from the top (0-15 cm) in the sites. The samples were analyzed for some soil parameters such as particle size distribution, organic carbon and water holding capacity using standard routine laboratory tests. In addition, statistical graphs and tables were employed to analyze the data. Mean values of soil organic carbon was computed to compare the results with the previous findings. The mean soil organic carbon of shantake, Tomas and Jama'a fields were found to be 2.57, 1.37 and 1.27%, respectively. The textures of the soil samples were found to be Sand and Loamy sand. The soil water holding capacity ranged from 5 to 25%. The results showed that soil organic matter was found to be higher in uncultivated fields than in irrigation fields and continuous cultivation fields. It was concluded that soil organic matter and texture had influence on water holding capacity and the effect was more pronounced when fine texture was coupled with appreciable amount of soil organic matter. It was recommended that higher levels of organic matter should be incorporated to the soils with aim of improving soil water holding capacity and further research should be done in order to fully understand the moisture characteristics of different soil samples in the study area and sudano-sahelian zone at large.

Keywords: Soil organic matter, soil texture, soil water holding capacity

INTRODUCTION

Soil has been called "the skin of the earth" it is dynamic natural body capable of supporting vegetative cover. It contains chemical solution, gases, organic refuse, flora and fauna (Gabler *et al*., 2009). According to Yusuf (2010) soil is the loose material that covers the land surfaces of the earth and supports the growth of plants. The most widely accepted scientific definition of soil is that by Waugh (1995) who stated that:

> *"Soil is the natural body of animal, mineral and organic constituents differentiated into horizons of variable depth, which differ from the material below in morphology, physical make up, chemical properties and composition and biological characteristics"*

Soil responds to climatic condition (especially temperature and moisture), to the land surface configuration, to vegetative cover and composition and to animal activity. Being dynamic entity, soil possesses physical, chemical and biological properties. Physical properties such as available water holding capacity is controlled by texture of the soil, amount of organic matter content and structure of the soil.

Available water holding capacity can be defined as the amount of water (moisture) the soil can hold for the use of plants root for certain period of time (Yusuf, 2010). An important indicator of soil physical fertility is the capacity to store and supply water and air for plant growth. The water holding capacity is a very important agronomic characteristic. Soils that hold generous amounts of water are less subject to leaching losses of nutrients. This is true because soil with a limited water holding capacity (i.e., sandy loam) reaches the saturation point sooner than a soil with higher water holding capacity (i.e., clay loam).

Soil texture refers to the sizes (or distribution of sizes) that make up the soil. In other words the proportion of particle sizes determines a soil's texture (Gabler *et al*., 2009). According to Waugh (1995) soil texture refers to the degree of coarseness or fineness of mineral matter in the soil. The physical and chemical weathering of rocks and animals results in a wide range in size of particles from stone, to gravel, to sand, to silt and to very small clay particles. The particle size distribution determines the degree of coarseness or fineness of the soil or the soil texture. Specifically texture is relative proportion of sand, silt and clay in a

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soil (Foth, 1990). Clayey soils have diameter of less than 0.002 mm; silty soils have diameter between 0.002-0.05 mm and sandy soils have diameter of between 0.05-2 mm.

Soil organic matter is the term that has been used to describe the organic constituents of soil. In this study, soil organic matter is used as defined by Baldock and Skjemstad (1999) "as all organic material found in the soils irrespective of origin or decomposition" since soil organic matter content consists of carbon, hydrogen, nitrogen oxygen, phosphorus and sulphur, it is difficult to actually measure the soil organic matter content and analytical methods determine the soil organic carbon content and estimate soil organic matter through a conversion factor (Krull *et al*., 2011). Changes made to the natural status of soil system (e.g., conversion to agriculture, deforestation and plantation) will result in different condition under which soil organic carbon enters or exits the system. Humus supplies nutrients to the soil and improves its ability to retain moisture. This study intends to investigate the influence of texture and organic matter on soil water holding capacity at Shantake, Tomas and Jama'a sites of Dambatta Local Government, Kano State. Shantake is uncultivated area, Tomas is irrigation site and Jama'a is rain-fed crop field.

MATERIALS AND METHODS

Study area: The study was conducted at Shantake, Tomas and Jama'a sites of Dambatta Local Government, Kano State between December, 2011 and April, 2012. The sites were chosen based on the land use after a reconnaissance survey. Dambatta is situated in northern part of Kano State. It is enclosed between latitude 12° 25'59''N and longitude 08^0 30'55''E with area of 732 km^2 (282.6 mi^2). Figure 1 shows sampling points in the study area.

Climate: The climate of Kano State (Dambatta inclusive) is the tropical wet and dry type denoted as Aw by Koppen. The temperature is averagely warm to hot throughout the year at about 25°C+/-7°C (Olofin and Tanko, 2002). The monthly rainfall distribution over the Kano region is characterized by one peak (single maximum) which is usually attained in August (Buba, 2009).

Vegetation: The Sudan savanna can be said to be the natural vegetation of Kano State (the study area inclusive). It is composed of a variety of trees scattered over the expanse of grassland.

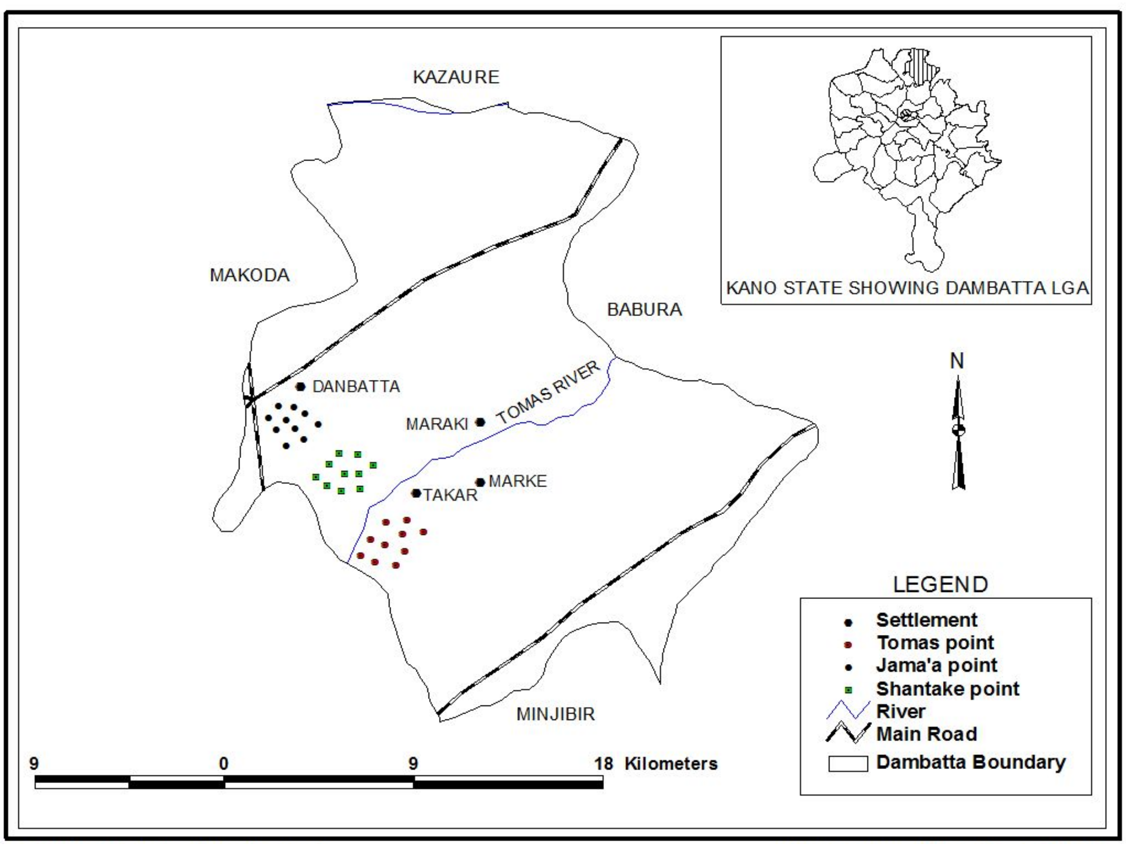

Fig. 1: Shows sampling points in the study area (Field work, 2011)

Soil: FAO/UNESCO genetic classification classified the soil of extreme part of northern Nigeria (the study area inclusive) as ferruginous tropical soils. These are Kaolinitic and iron dominated tropical soils. They are well matured red and brown soils of the savanna (Yusuf, 2010).

Geology and hydrology: Geologically, the northeastern extremes of Kano State (the study area inclusive) are areas of Chad formation. The formation consists of largely unconsolidated and unfolded sedimentary rocks of marine and terrestrial origin (Olofin and Tanko, 2002).

Due to the nature of the geology (unconsolidated sediments of Chad formation), the area varies in terms of the amount of water that can be found both on surface and underground. The surface water is minimal because the nature of the geology permits easy percolation of water down the ground; hence the area is characterized by high amount of underground water but minimal surface water.

Relief and drainage: Physiographically, the elevation of Kano region above mean sea level ranges from about 400 m at northeastern margin (the study area inclusive) to over 1200 m at the southern tips. Therefore, the elevations decrease both northwards and northeastwards (Olofin, 1987). This indicated that Dambatta falls within the lowest relief unit of Kano and consists of plains developed essentially on sedimentary structure known as Chad formation.

The surface drainage consists of disappearing flows. This type of drainage is made up of individual streams such as Gari and Tomas which drain the northeast and north of Kano eastwards.

Sample collection: The samples were collected from designated sites. The sampling procedure used was composite sampling. In this case, representative samples were collected randomly from the top (0-15 cm) in the sites using soil auger and trowel. Five samples were collected from each field and taken to the laboratory for preparation and analyses.

Laboratory analysis: Five samples of each field were mixed vigorously to form composite samples or sub-samples. Each composite sample was aired and sieved through a two millimeter mesh sieve. Fifteen composite samples were made. A half of kilogram of each composite sample was taken for laboratory analyses.

Standard laboratory methods for determining texture and organic carbon content of soils were employed. The organic carbon was determined using (Walkley and Black, 1934) which involves dichromate oxidation technique. The texture was determined using (Bouyouscos, 1962) method, popularly known as hydrometer method. The water holding capacity was determined using rudimentary method.

Statistical analysis: Statistical graphs and tables were used to analyze the data. Statistical graphs were drawn using Origin 6.0 professional software to ascertain the influence of organic matter on soil water holding capacity. Mean values of soil organic carbon were computed and employed to compare the results with relevant findings. Rating of soil organic carbon as low, medium and high was adopted from Adamu (1997).

RESULTS AND DISCUSSION

This chapter presented and discussed the results obtained from various soil analyses such as particle size distribution, organic carbon and water holding capacity. In addition, comparison between the results was also done. The mean values of analyzed soil parameters at the investigated area are shown in Table 1.

Soil organic carbon: The results of soil organic carbon determination showed that uncultivated soils had high amount of organic matter in all fields under study at Shantake except field one (Table 2). This is not surprising, because in uncultivated soils of Shantake area, litter is very abundant due to the presence of large number of trees, herbs and shrubs. The litter decays as a result of microbial activities and mixes with soil mineral matter. The mean soil organic carbon at Shantake was found to be 1.55%. This was in accord with what Hao *et al*. (1998) found. They found average soil organic carbon of 1.86% at three uncultivated plots in Ohio.

The finding of soil of soil organic carbon determination also showed that in Tomas irrigation site, fields four and five had high amount of organic matter; fields one and three had medium amount; and field two had low amount (Table 2). The high amount of soil organic carbon in fields four and five might be as a result of plant residues because the area is being

Table 1: Mean values of soil parameters determined for the study area

	Parameters							
Location	Texture clay%	Texture silt%	Texture sand%	Texture textural class	SOC%	SOM%	WHC%	N
Shantake	3.48	6.80	89.7	Sand	1.55	2.57	16	5
Tomas	3.20	7.16	89.7	Sand	0.79	1.37	9	5
Jama'a	3.32	8.75	88.05	Sand	0.74	1.27	8	5

Lab. analytical data (2011)

Table 2: Rating of soil organic matter at Shantake Tomas and Jama'a crop fields

Sample (0-15 cm)	Organic carbon (%)	Organic matter (%)	Rating
Shantake F_1	0.56	0.97	Medium
Shantake F_2	1.80	3.11	High
Shantake F_3	1.50	2.59	High
Shantake F_4	1.60	2.77	High
Shantake F_5	2.30	3.40	High
Tomas I_1	0.60	1.04	Medium
Tomas I_2	0.26	0.45	Low
Tomas I_3	0.68	1.20	Medium
Tomas I_4	1.20	2.70	High
Tomas I_5	1.20	2.70	High
Jama'a C_1	0.92	1.59	Medium
Jama'a C_2	0.14	0.24	Low
Jama'a C_3	1.74	3.00	High
Jama'a C_4	0.38	0.66	Low
Jama'a C_5	0.50	0.86	Low

Laboratory work (2011)

irrigated throughout the year. Omar (2011) attributed the high level of organic matter observed in some irrigated fields of Bauchi and Dass LGAs to high return of litter or agricultural residues to the soils. Similarly (Oriola, 2004) stated that high organic matter on the top layer of irrigated fields may be the result of the cultivation of legumes on rotational basis and plant residues after harvest. The low amount of soil organic matter in field two might be as a result of continuous tillage which helps in diminution soil organic matter and nutrients. Omar (2011) also stated that the low levels of organic carbon in some irrigated sites in Tafawa Balewa and Bogoro could be associated with rapid mineralization under high temperature and high moisture condition in the soils. The average soil organic carbon at Tomas irrigation site was found to be 0.788%. This agreed with what Mekonnen *et al*. (2008) found. They found mean soil organic carbon of 0.95% at three irrigated sites in Nile basin. Correspondingly, Usman *et al*. (2011) found 0.63% mean soil organic carbon at some irrigated fields along Jakara River (Magami).

In continuous cultivated crop fields at Jama'a village, the findings indicated that soil organic carbon was low in fields two, four and five; it was high and medium in fields three and one respectively (Table 2). This is because continuous tillage or ploughing contributes greatly in loosing soil organic matter. This finding agreed with what Shuraihu (2007) found. He found out that cultivation reduces soil organic matter by a variety of mechanisms. The first and most obvious is that cultivation removes plant residues from the soil, thereby restricting the natural recycling of materials in the system. This finding was also reinforced with what scientists found in Minnesota University. They found out that intensive tillage increases the loss of organic matter by speeding decomposition (Minnesota University Soil Report, 2002). Figure 2 is an illustration of soil organic matter losses and gains in response to tillage.

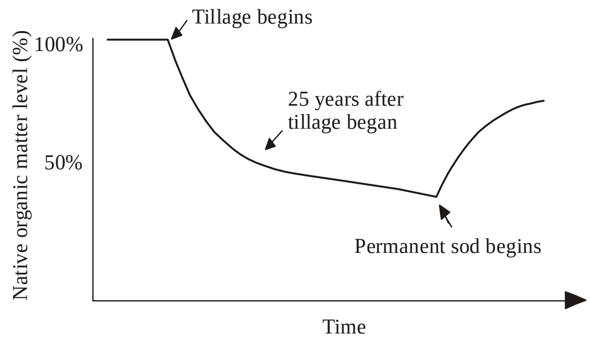

Fig. 2: Soil organic matter losses and gains in response to tillage Minnesota University Soil Report (2002)

Table 3: Soil texture at Shantake, Tomas and Jama'a crop fields

Sample (0-15 cm)	Clay (%)	Silt (%)	Sand (%)	Textural class
Shantake F_1	3.60	4.500	91.90	Sand
Shantake F_2	2.60	11.00	86.40	Loamy sand
Shantake F_3	4.00	4.100	91.90	Sand
Shantake F_4	3.60	4.400	91.90	Sand
Shantake F_5	3.60	10.00	86.40	Loamy sand
Tomas I_1	3.60	4.500	91.90	Sand
Tomas I_2	3.60	4.500	91.90	Sand
Tomas I_3	2.60	11.30	86.40	Loamy sand
Tomas I_4	2.60	5.500	91.90	Sand
Tomas I_5	3.60	10.00	86.40	Loamy sand
Jamaa C_1	3.60	1.060	86.40	Loamy sand
Jamaa C_2	2.60	0. 500	91.90	Sand
Jamaa C_3	3.60	7.250	89.15	Loamy sand
Jamaa C_4	3.60	10.00	86.40	Loamy sand
Jamaa C_5	3.20	10.40	86.40	Loamy sand

Laboratory work (2011)

Table 4: Surface texture of some soils in Sudano-sahelian zone of Nigeria

Site	Sand (%)	Silt (%)	Clay (%)	Texture
Kadawa	85.0	11.0	4.0	Loamy sand
Kano city	87.0	9.00	4.0	Loamy sand
Dambatta	92.0	4.00	4.0	Sand

Maduakor (1991)

Soil texture: Using United States Department of Agriculture (USDA) textural triangle, sample F_1 and F_3 were found to be loamy sand while F_2, F_4 and F_5 were sand (Table 3). The findings have also shown that in Tomas irrigation site, samples I_1, I_2 and I_4 were sand while I_3 and I_5 were found to be loamy sand (Table 3). This was in conformity with what Jibrin *et al*. (2008) found. They stated that soils at Kano River Irrigation Project (KRIP) contain high amount of sand with little silt and clay. The Jama'a rain-fed crop fields were all loamy sand except sample C_2 which was found to be sand (Table 3). According to Maduakor (1991) most of the soils of sudano-sahelian zone (the study area inclusive) are sandy, the texture ranging from sandy to very fine sandy loam. Table 4 shows surface texture in some selected areas in sudaano-sahelian zone.

Table 5: Soil water holding capacity at Shantake, Tomas and Jama'a crop fields

Sample (0-15 cm)	$W_{1/g}$	$W_{2/g}$	$W_{3/g}$	WHC%	WHC mm/cm
Shantake F_1	10.0	11.0	1.0	10.0	1.0
Shantake F_2	10.0	12.0	2.0	20.0	2.0
Shantake F_3	10.0	11.0	1.0	10.0	1.0
Shantake F_4	10.0	11.5	1.5	15.0	1.5
Shantake F_5	10.0	12.5	2.5	25.0	2.5
Tomas I_1	10.0	11.0	1.0	10.0	1.0
Tomas I_2	10.0	10.5	0.5	5.00	0.5
Tomas I_3	10.0	11.0	1.0	10.0	1.0
Tomas I_4	10.0	11.0	1.0	10.0	1.0
Tomas I_5	10.0	11.0	1.0	10.0	1.0
Jamaa C_1	10.0	11.0	1.0	10.0	1.0
Jamaa C_2	10.0	10.5	0.5	5.00	0.5
Jamaa C_3	10.0	11.0	1.0	10.0	1.0
Jamaa C_4	10.0	10.5	0.5	5.00	0.5
Jamaa C_5	10.0	11.0	1.0	10.0	1.0

Laboratory work (2011)

Soil water holding capacity: The results of soil water holding capacity were found to be 10% (1.0 mm/cm), 10% (1.0 mm/cm), 20% (2.0 mm/cm), 15 % (1.5 mm/cm) and 25% (2.5 mm/cm) for F_1, F_2, F_3, F_4 and F_5, respectively at Shantake (Table 5). In Tomas irrigation site, the results showed that all the fields under investigation had water retention capacity of 10% (1.0 mm/cm) each except I_2 which had 5% (0.5 mm/cm) (Table 5). Samples C_1, C_3 and C_5 of Jama'a rain-fed crop fields had 10% (1.0 mm/cm) soil water holding capacity each (Table 5). On the other hand, sample C_2 and C_4 were found to have 5% (0.5 mm/cm) soil water keeping capacity each (Table 5). These findings were in accord with what Maduakor (1991) found. He found out that sand textured and loamy sand textured soil of sudano-sahelian region of Nigeria (the study area inclusive) retained moisture ranging from 1.3-2.5 and 2.3-3.0 mm/cm, respectively. According to Ball (2011), sand and loamy sand could hold soil water holding capacity ranging from 0.2-0.6 and 0.9-1.0 mm/cm, respectively.

Comparison between results: Despite that the soils of the study area were formed from the same parent material under the same climatic condition, they differ considerably in terms of water retention capacity. The results showed that soil water holding capacity is generally higher in uncultivated soils of Shantake than in soils of Tomas irrigation site and Jama'a crop fields. This clearly indicated that soil organic matter content influences the ability of soils to retain moisture. Ekwue (1990) asserted that addition of soil organic matter increases the amount of soil water holding capacity. In general soil water holding capacity increased with an increase in soil organic matter content. Figure 3 shows the gradual increase in soil water holding capacity with increase in soil organic matter at Shantake. When soil organic matter is 0.97%, the soil water holding capacity is 10%; when soil organic matter is 2.77%, the soil water holding capacity is 15%; when soil organic matter is 3.11%, the soil water holding capacity is 20%; and when soil organic matter is 3.40%, the soil water holding capacity is 25%.

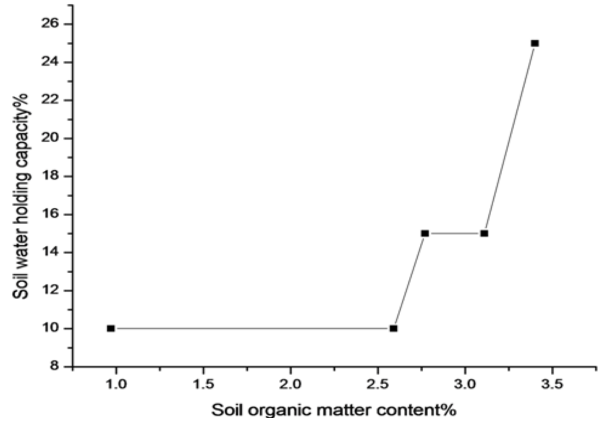

Fig. 3: Relationship between soil organic matter and soil water holding capacity at Shantake

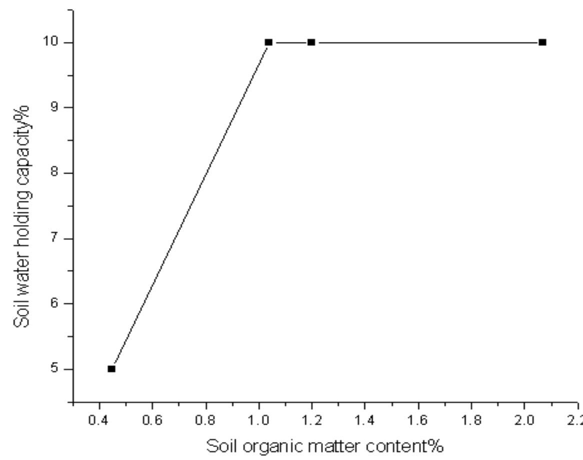

Fig. 4: Relationship between soil organic matter and soil water holding capacity of Tomas irrigation site

The Loamy sand texture coupled with high amount of soil organic matter content allowed samples F_2 and F_5 to retain more moisture than the rest of the samples. This is because fine texture and high amount of soil organic matter enhance soil water holding capacity (Minnesota University Soil Report, 2002).

Compared with Shantake site, soil water holding capacity was lower in Tomas irrigation site and Jama'a crop fields. This was due to differences in soil organic matter content. According to Brady and Weil (1999), it safe to generalize that cultivated lands contain much lower levels of organic matter when compared to areas under natural vegetation. Figure 4 and 5 show positive relationships between sol organic matter and soil water keeping capacity at Tomas irrigation site and Jama'a crop fields, respectively.

In Jama'a crop fields, soil organic matter was much lower when compared to Shantake and Tomas irrigation site, but soil water retention capacity is very close to

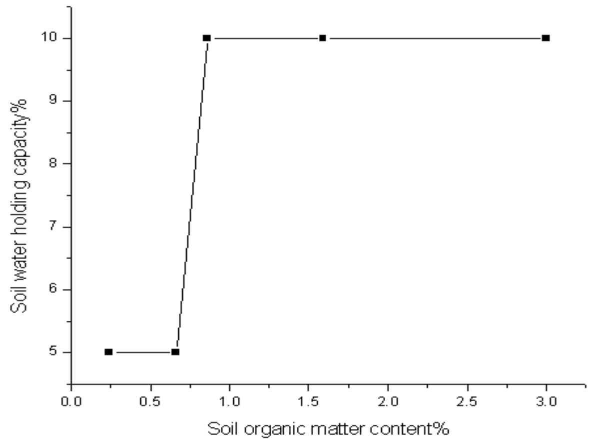

Fig. 5: Relationship between soil organic matter and soil water holding capacity of Jama'a crop fields

that of Tomas irrigation site. This clearly pointed out that loamy sand texture played a vital role in determining soil water retention capacity here. Finely-textured soils retain more water than coarsely-textured soils. Loamy sand has 10-20% clay to hold moisture and retain nutrients; sufficient sand 0-90% to prevent water logging; to be well aerated and to be light to work; and sufficient silt 0-20% to act as an adhesive holding the sand and clay together.

CONCLUSION

Conclusively, a strong relationship exists between soil organic matter, soil texture and soil water holding capacity. It was concluded that addition of soil organic matter could increase soil water holding capacity. Correspondingly, the degree of fineness or coarseness of soil affects its ability to retain moisture. Fine-textured soils retain more moisture than coarse-textured soils.

RECOMMENDATIONS

Since the effect of soil organic matter/carbon on water holding capacity is generally assumed to be positive, but type of the carbon responsible and synergistic behavior with other soil properties is not well understood; there is a need for further investigation. A non-tillage farming should be adopted where possible with aim of reducing loss of soil organic matter through continuous tillage.

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