STUDIA UNIVERSITATIS BABEȘ-BOLYAI
Engineering 66(1) 2021 DOI:10.24193/subbeng.2021.1.3

An assessment of physical properties and water holding capacity of soil under different fertilizer applications

Adeniyi Afolabi Rodiya*, Dauda Aluyah Okodugha,
Emmanuel Aleonolu Adoga, Samuel Olaiya, Michael Okafor

Abstract. *This study was carried out at the Teaching and Research Farm of the Department of Agricultural and Bio-Environmental Engineering, School of Engineering, The Federal Polytechnic, Ado-Ekiti to evaluate the water holding capacities of soil under different fertilizers. The experiment was laid out in randomized complete block design (RCBD). The treatments: control, poultry waste, biochar and urea fertilizer replicated four times were incorporated into the soil and maize seed planted. Data collected were subjected to statistical analysis. Soil samples were analyzed for moisture contents, bulk densities, particle densities and water holding capacities. Maize yield was also analyzed. The result obtained showed a significant ($p < 0.05$) changes in maize yield for the different fertilizers. It also shows a non-significant ($p < 0.05$) effect on water holding capacities of the soils incorporated with different fertilizers. The study concluded that fertilizers has no effect on the water holding capacity of the soil and that poultry waste amended soil will produce higher yield.*

Keywords*: water holding capacity, biochar, poultry waste, urea fertilizer*

1. Introduction

Water holding capacity designates the ability of a soil to hold water. It is useful information for irrigation scheduling, crop selection, groundwater contamination considerations, estimating runoff and determining when plants will become stressed [1, 2, 3]. Understanding some physical characteristics of the soil is useful to determine the strengths and weaknesses of different soil types. Soil moisture limits forage production potential the mostly in semiarid regions [4, 5, 6]. Estimated water use efficiency for irrigated and dry-land crop production systems is 50 percent, and available soil water has a large impact on management decisions producers make throughout the year (Hatfield and Dold, 2019*)* Fertilizers are mainly applied in form of farmyard manure and crop residues. Nevertheless, a study on soil fertility management on smallholder farms in western Kenya [7, 8, 9] showed that many of the farmers are using fertilizers but the application rates are low and differ between farm types.

Within that study, the farm types were classified by wealth; production orientation (self-consumption or market-oriented); constraints to land, labor and capital; family structure and main source of income. Mineral fertilizers are mainly applied as di ammonium phosphate and calcium ammonium nitrate and urea for top dressing. Small sized farms are less self-sufficient in food production and relay more on off-farm jobs, but dispose over a higher capital for mineral fertilizer purchase (Tisdale *et al.,* 1997).

However, decreasing soil fertility, the parasitic weed Striga spp is a major problem for agricultural productivity in SSA [10, 11]. Maize, which is one of the most important food crops in rural areas of Nigeria is greatly affected by this weed. Due to the land pressure and intensification of agricultural practices, the fallow periods tend to be shorter and the diversity of the crops lower (Mertz, 2002). This and the decline in soil fertility create an ideal environment for Striga and other weeds. Farmers have little knowledge about Striga control [12, 13]. Soil moisture available for plant growth makes up approximately 0.01 percent of the world's stored water [14]. Soil texture and structure greatly influence water infiltration, permeability, and water-holding capacity [15].

Soil texture refers to the composition of the soil in terms of the proportion of small, medium, and large particles (clay, silt, and sand, respectively) in a specific soil mass [16]. For example, a coarse soil is sand or loamy sand, a medium soil is a loam, silt loam, or silt, and a fine soil is a sandy clay, silt clay, or clay. Water holding capacity varies by soil texture. Permeability refers to the movement of air and water through the soil, which is important because it affects the supply of root-zone air, moisture, and nutrients available for plant uptake. A soil's permeability is determined by the relative rate of moisture and air movement through the most restrictive layer within the upper 40 inches of the effective root zone. Water-holding capacity is controlled primarily by soil texture and organic matter. Soils with smaller particles (silt and clay) have a larger surface area than those with larger sand particles, and a large surface area allows a soil to hold more water.

2. Materials and Methods

2.1. Site description

The experiment was carried out at the Teaching and Research Farm of the Department of Agricultural and Bio Environmental Engineering, School of Engineering, The Federal Polytechnic, Ado-Ekiti, Ekiti State. The area lies on longitude 5° 13’ 17.0004” E and latitude 7° 37’ 15.9996” N in the derived tropical rainfall of southwestern Nigeria [14]. The climate of the area is classified as tropical. The average annual temperature of the area is 25.1°C and rainfall average is 1334 mm. The relative humidity of the area is between 60 – 80% [15]. The major materials used for the experiment are plastic buckets, (perforated) container of the same size, biochar, urea fertilizer and poultry waste. The biochar was purchased at Ado-Ekiti market and the urea fertilizer was obtained from Ondo state Agricultural Development Programme (OSADP) Ikare Akoko. The poultry waste was obtained from the poultry farms of the Department of Agricultural and Bio Environmental Engineering and Department of Agricultural Technology, The Federal Polytechnic Ado-Ekiti, Ekiti state. Other materials are Axe, tractor, motor saw, digger, cutlass, and shovel, hoe, and rake for land preparation. Mortal and sieve were used for the preparation of the biochar. Weighing balance, core sampler and mason jar were used to take measurement and the soil bulk density. While soil textural triangle was used to determine the soil structural classes. The water holding capacity was determined using plastic buckets which have been perforated.

2.2. Land preparation

The experimental site measured 19 x19 m (0.0361ha) was on a flat terrain which had been fallow for more than three (3) years. The vegetation on the area (trees and grasses) was removed using Axe, cutlass, hoe, and motor saw. The area was tilled mechanically using plough and harrow. While the marking out (the division into treatment plots) was done using measuring tape and pegs.

2.3. Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with four replications and four treatments. A total at sixteen (16) plots each measured 4 m x 4 m (16 m^2) were used for the experiment, the replicate was 1 m apart. The treatments were control, biochar, urea fertilizer and poultry waste. Treatments were uniformly incorporated to the plots after making the bed using plough and harrow [4, 9, 10]. Few weeks later, the soil samples from those treatment plots was collected at the same quantity and was put into the perforated buckets to determine their water holding capacity and other physical properties.

2.4. Soil sampling

2.4.1. Water holding capacity

A 10 kg soil sample was collected from each of the treatment's plots, 2500 ml of water was added into it and was left for 24 hours. The water that infiltrate into the containers was collected and was turn into measuring cylinder and measured. These were done for four times per treatment plot and the average was estimated.

2.4.2. Bulk density

The soil sample was collected using core sampler and it was measured to be 0.1433 kg/m^3 before taking to the laboratory to determine the volume and the cross-sectional area of the core sampler. It was done for four times per treatment plots.

2.4.3. Moisture content

This method is used to determine the percentage of water in a sample by drying the sample to a constant weight. The water content is expressed as the percentage by weight of the sample as shown in equation (1):

$$\%W = \frac{Wwet - Wdry}{Wdry} \times 100 \tag{1}$$

where: *%W* - Percentage of moisture in the sample
Wwet - weight of wet samples in grams (g)
Wdry - weight of dry sample grams (g)

2.4.4. Yield test

Five cobs were harvested at random from those treatment plots and weighed to determine the yield. This procedure was replicated four time per treatment.

2.4.5. ANOVA

Analysis of Variance (ANOVA) will be used to test for variation in water holding capacity of the soil under different fertilizer application as well as variation in physical properties of the soil (bulk density and particle density).

3. Results and discussion

3.1. Physical properties

Results of the treatment plots based on physical properties are as shown in Tables 1, 2, 3, and 4. Table 5 and 4.6 shows the effect of biochar, poultry waste and urea fertilizer on physical properties of the soil. The results show that the application of fertilizers causes significant difference in the soil's physical properties (moisture content, bulk density, and particle density). The significant value is less than the α value of 0.05. This shows that all the fertilizers incorporated into the soil will change the physical properties of the soil as seen in the multiple comparison test in Table 6. The findings agree with [15].

3.2 Water holding capacity

The effect of those soil on water holding capacity is shown in Tables 7 and 8. The application of biochar, poultry waste, and urea fertilizer has no significant difference in water holding capacity according to the analysis of variance (ANOVA) shown in Table 8.

3.3. Yield

The result of the effect of those treatments on crops planted into that treatment plot is shown in Tables 9 and 10. While Table 9 shows the raw data are collected on yield. Table 10 shows the analysis of variance of yield and 11 shows the multiple comparisons for yield. The tables show that there is a significant difference between those treatments and maize yield. The plot at which poultry waste and urea fertilizer was added has a highly significant.

Table 1. Control experimentation

Trails	Moisture content (%)	Bulk density (kg/cm^3)	Particle density (kg/cm^3)
Trial1	22.22	0.0018	3.5
Trial 2	16.66	0.0018	5.0
Trial 3	17.88	0.0018	4.6
Trial 4	15.56	0.0018	5.4
Average	18.08	0.0018	4.6

Table 2. Treatment with poultry waste

Trials	Moisture content (%)	Bulk density (kg/cm^3)	Particle density (kg/cm^3)
Trial 1	13.33	0.0018	6.5
Trial 2	15.55	0.0018	5.4
Trial 3	14.44	0.0018	5.9
Trial 4	16.66	0.0018	5.0
Average	15.00	0.0018	5.7

Table 3. Treatment with biochar

Trials	Moisture (%)	Bulk density (kg/cm^3)	Particle density kg/cm^3
Trial 1	20.00	0.0018	4.0
Trial 2	17.77	0.0018	4.6
Trial 3	15.56	0.0018	5.4
Trial 4	17.78	0.0018	4.6
Average	17.78	0.0018	4.7

Table 4. Treatment with Urea

Trials	Moisture %	Bulk density kg/cm^3	Particle density kg/cm^3
Trial 1	14.44	0.0018	5.9
Trial 2	16.66	0.0018	5
Trial 3	18.88	0.0018	4.3
Trial 4	15.55	0.0018	5.4
Average	16.38	0.0018	5.2

Table 5. Variation in Physical Properties

Source	Type III Sum of Squares	Df	Mean Square	F
Corrected Model	595.499a	5	119.1	120.746
Intercept	636.96	1		
Fertilizer	0.816	3		
Physical Properties	594.683	2		
Error	5.918	6		
Total	1238.376	12		
Corrected Total	601.417	11		

a. R Squared = .990 (Adjusted R Squared = .982)

Table 7. Variation in Water Holding Capacity

Trials	Control (ml)	Poultry waste (ml)	Biochar (ml)	Urea(ml)
Trial 1	420	320	450	795
Trial 2	420	253	320	225
Trial 3	210	300	250	200
Trial 4	285	426	350	275
Mean average	334	325	343	374

Table 8. Water holding capacity. Dependent Variable: Observation

Source	Type III Sum of Squares	Df
Corrected Model	9411.687a	3
Intercept	1838058.063	1
Fertilizer	9411.687	3
Error	297739.25	12
Total	2145209	16
Corrected Total	307150.937	15

a. R Squared = .031 (Adjusted R Squared = -.21)

Table 9.

TRIALS	Poultry Waste (kg)	Biochar (kg)	Urea (kg)	Control (kg)
Trial 1	0.40	0.25	0.15	0.25
Trial 2	0.20	0.22	0.15	0.10
Trial 3	0.35	0.24	0.20	0.15
Trial 4	0.25	0.20	0.17	0.10
Mean average	0.30	0.23	0.17	0.15

Table 10. Multiple Comparisons for yield

(I) Fertilizer	(J) Fertilizer	Mean Difference(I-J)	Std. Error	Sig.
Control	Poultry Waste	-.1500*	0.0424	0.004
	Biochar	-0.0775	0.0424	0.093
	Urea	-0.0175	0.0424	0.687
Poultry Waste	Control	.1500*	0.0424	0.004
	Biochar	0.0725	0.0424	0.113
	Urea	.1325*	0.0424	0.009
Biochar	Control	0.0775	0.0424	0.093
	Poultry Waste	-0.0725	0.0424	0.113
	Urea	0.06	0.0424	0.182
Urea	Control	0.0175	0.0424	0.687
	Poultry Waste	-.1325*	0.0424	0.009
	Biochar	-0.06	0.0424	0.182

The error term is Mean Square (Error) = .004.
*. The mean difference is significant at the 0.05 level.

4. Conclusion

It is concluded that the different fertilizers incorporated into the soil has no effect on the water-holding capacity of the soil but have an effect on the physical properties of the soil and yield of maize. According to results obtained from the experiment, farmers are advised to use any fertilizer at any point in time because there is no effect at all on the water holding capacity of the soil. Fertilizers should also be applied to the soil to increase yield and the physical properties of the soil when the need arises.

Acknowledgment. The authors equally contributed to this study. The also thank Engr.(Dr.) Olotu Yahaya for his technical contributions.

References

[1] Adediran J.A., Banjoko V.A., Response of maize to N, P, and K fertilizers in the savanna zone of Nigeria, *Commun. Soil Sci. Plant Anal.*, 26, 2012, pp. 593-606.
[2] Adu S.V., *Soils of the Kumasi Region, Ashanti Region, Ghana. Soil Research Institute* (Council for Scientific and Industrial Research). Memoir No. 8, 2014.
[3] Aggarwal P.K., Singh A.K., Chaturvedi G.S., Sinha S.K., Performance of wheat and triticale cultivars in a variable soil-water environment. II. Evapotranspiration, WUE, harvest index and grain yield. *Field Crops Research*, 13, 2009, pp. 301-315.
[4] Akande M.O., Adediran J.A., Oluwatoyinbo F.I., Effects of rock phosphate amended with poultry manure on soil available P and yield of maize and cowpea. *Afr. J. Biotechnol*. 4, 2008, pp.444-448.
[5] Black C.A., *Soil-Plant Relationships*, Department of Agronomy, Iowa State College, Ames, Iowa. Published by John Wiley & Sons, Inc, 1965.
[6] Baanante C.A., Thompson T., Acheampong K., Rhodes E.R., Pouzet D., Opoku S., *Fertilizer use and agricultural development in the Ashanti Region of Ghana. An analysis of farm survey data*, IFDC, Muscle Shoals A1. USA, 2010.
[7] Bationo A., Mokwunye A.U., Role of manures and crop residue in alleviating soil fertility constraints to crop production: With special reference to the Sahelian and Soudanian zones of West Africa, *Fertilizer Research*, 29, 2004, pp. 217-225.
[8] Bergmann W., *Nutritional disorders of plants*. 2nd ed. Gustav Fischer Verlag, Jena, Germany, 2009.
[9] Bray R.H., Kurtz L.T., Determination of total organic and available forms of phosphorus in soil, *Soil Science*, 599, 2011, pp. 39-45.
[10] Boateng, J.K., Oppong J., *Proceedings of Seminar on organic and sedentary agriculture held at the Science and Technology Policy Research Institute (C.S.I.R)* Accra. 1-3 Nov, 1995, p. 85.

[11] Buol S.W., Stokes M.L., Soil profile alteration under long-term high-inputagriculture. In: R. J. Buresh, P. A. Sanchez and F. Calhoun (eds.): Replenishing soil fertility in Africa. Special Publication No. 51. *Soil Sci. Soc. Am.,* Madison, WI, 1997.

[12] Cleaver K.M., Schreiber G.A., *Reserving the spiral; the population, agriculture and environment nexus in sub-Saharan Africa*, World Bank, Washington, DC, 2008.

[14] Chand S., Anwar M., Patra D.D., Influence of long-term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint mustard cropping sequence, *Communications in Soil Science and Plant Analysis*, 37, 2006.

[15] Chang C., Sommerfeldt T.G., Entz T., Rates of soil chemical changes with eleven annual applications of cattle feedlot manure, *Can. J. Soil Sci.*, 70, 1990, pp. 673 - 681.

[16] CAST.1996. *Integrated animal waste management. Task Force Report. No. 128.* Council for Agricultural Science and Technology. Ames. Iowa.

Addresses:

- Engr. Adeniyi Afolabi Rodiya, Department of Agricultural & Bio-Environmental Engineering, The Federal Polytechnic, Ado-Ekiti, Nigeria
  afolabrodiya@yahoo.com
  (*corresponding author)
- Engr. (Dr.) Daudua Aluyah Okodugha, Department of Civil Engineering, Auchi Polytechnic, Auchi, Edo State, Nigeria
  aluyahd@gmail.com
- Engr. Emmanuel Aleonolu Adoga, Department of Civil Engineering, Auchi Polytechnic, Auchi, Edo State, Nigeria
- Engr. Samuel Olaiya, Department of Civil Engineering, Auchi Polytechnic, Auchi, Edo State, Nigeria
- Engr. Michael Okafor, Department of Civil Engineering, Auchi Polytechnic, Auchi, Edo State, Nigeria