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CHANGES OF PHYSICAL PROPERTIES OF SANDY SOIL AND GROWTH OF PHYSIC NUT (*Jatropha curcas* L.) DUE TO ADDITION OF CLAY AND ORGANIC MATTER

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ABSTRACT

Agricultural sandy soil in Situbondo, East Java province, Indonesia which is used as a center garden for physic nut seed production has poor physical properties of soil indicated by low capacity to retain water. For plant growth of physic nut, the sandy soil physical properties need to be improved. In this study, the influence of addition of clay together with organic matter and intervals of irrigation to sandy soil on aggregate stability, bulk density, total soil porosity, water available content and plant growth of physic nut was investigated. The rates of clay and organic matter incorporated to top sandy soil were 5% clay + 0.8% organic matter and 10% clay + 1.6% organic matter. Two intervals of irrigation tested were 10 days and 20 days. The results showed that incorporation of clay together with organic matter increased aggregate stability, total soil porosity, available water content and plant growth of physic nut. Intervals of irrigation had no influence of soil physical properties and plant growth.

Keywords: agricultural, sandy soil, clay, organic matter, soil properties, physic nut

INTRODUCTION

Sandy soils characteristically consist of loose soil particles because the cohesion between them is weak (Shepherd *et al*., 2002). This natural property of sandy soil can cause problems in their use for agricultural production. The sandy soil of Asembagus Experimental Site, Situbondo which has been established as a center of physic nut seed production is one of examples. The soil is uniform in texture and contains more than 75% sand. The sandy soil is inherently low in all aspects of soil fertility and has a low capacity to retain water and applied nutrients (Farrington and Campbell, 1970). Further-more, sandy soils contain low proportions of clay and silt particles, hindering aggregation and they are associated with low levels of organic bonding formed during the decomposition of organic matter (Oades, 1993). In contrast, soils dominated by clay form fine granular aggregates because the clay particles are electrically charged and the oppositely charged surfaces provide the basis of a greater aggregation (Shepherd *et al*., 2001). For a range of soil analyses, the properties of sandy soils (especially soil biomass C) are generally lower than those of clay soils.

One way to increase aggregation in sandy soil may be to increase both clay and organic matter levels (Edwards and Bremner, 1967; Tisdall and Oades, 1982). Clay has the potential to stabilise soil organic matter by providing a protective coating on soil particles that inhibits or retards microbial decomposition (Bronick and Lal, 2005). Addition of clay and organic matter to sandy soil may change soil physical properties (such as soil aggregation, soil water content, and soil porosity) through cementation, cohesion and replacement of soil particles. Improved soil physical properties result in greater root distribution, penetration and hence greater nutrient and water uptake, and may result in increasing plant growth.

Soil aggregation and its stability are dynamic processes because both are affected by many factors, such as soil management practices, soil properties and the soil environment (such as soil water content) (Tisdall and Oades, 1982; Bronick and Lal, 2005). Aggregate stability is a vital property of soils used for agriculture because it is often related to soil fertility and agronomic productivity (Bronick and Lal, 2005).

In this study, sandy soil used for physic nut seeding production was amended with clay soil and organic matter. The soil at the site received irrigation regularly with intervals of 10 days. Unfortunately, due to its friable soil texture and low water holding capacity, the water supply to this soil was not enough to support the growth of physic nut. By adding clay and organic matter to the sandy soil, it was expected that aggregation and soil porosity would be increased, where, in turn, they would increase soil water holding capacity. Therefore, the research had an objective to quantify the effect of addition of clay and organic matter, and frequency of watering on aggregate stability, porosity, soil water holding capacity of sandy soil planted with physic nut.

MATERIALS AND METHODS

Land Preparation

A field trial was conducted at an Experimental Site of Indonesia Research Institute for Tobacco and Fiber Crops which is located at Situbondo, East Java from April to November 2009. The soil contained 89% sand, 3 % silt and 8% clay. The site was chosen because it has been established as a seeding production area for physic nut.

Experimental Design

The treatments consisted of two factors: (1) Three kinds of plant growth media (a. Sandy soil as a control, b. Sandy soil + 5 % clay soil + 0.8% organic matter, c. Sandy soil + 10% clay soil + 1.6% organic matter and (2) Two interval of irrigation (a. 10 days interval, b. 20 days interval). There were four replications of each treatment. The arrangement of treatments was as a Factorial Randomized Block design with four replications and each plot size was 9 m^2.

Addition of Clay Soil and Organic Matter

Clay soil (67% clay) was collected from sub soil of a land located about 2 km from experimental site. The clay soil was added with the rates as treatments, i.e 5% (equivalent to 538.6 kg/plot or 96 tones/ha) and 10% (equivalent to 1077.3 kg or 192 tones/ha). *Crotalaria juncea* was used as a source of organic matter which was planted on another plot 45 days before it was added to the sandy soil. The organic matter was added at rates of 0.8% (equivalent to 123.4 kg/plot or 22 tones/ha) and 1.6% (equivalent to 246.8 kg/plot or 44 tones/ha).

Determination of Aggregate Stability and Bulk Density

The mean-weight diameter of water-stable aSSregates (MWD) index (Kemper and Rosenau, 1986) was used to evaluate the stability of the aggregates. Higher values indicate the dominance of large aggregates in the soil'

Bulk density was measured in the field only for soil in the depth of 0-7.5 cm. A ring sampler with the diameter of 7.2 cm and height of 7 cm was used to collect samples. Surface soils were gently cleared to about 0.5 cm to remove plant debris and gravels before sampling. Bulk density was calculated by dividing the mass of the 105^oC oven dry soil by the volume of the soil. Six replication samples per plot were collected for bulk density measurements.

RESULTS AND DISCUSSION

Soil Aggregate Stability

Process of soil particle adhesiveness or aggregation and its stabilization was affected by clay particles and organic matter in soil. The increase in aggregate stability which occurred with addition of clay soil was probably due to the development of clay coatings on the sand particles and clay bridges between them during wetting and drying cycles. In another study, in which different levels of clay (10% and 20%) were mixed with silt particles, increased aggregate stability was related to increasing clay content and the development of silt-clay fabric (Attou *et al.,* 1998). In this present study, for all three times of observation (30, 60, and 90 days after treatment), aggregate stability of sandy soil was significantly influenced ($p<0.05$) by addition of clay and organic matter. However, the aggregate stability of the sandy soil did not significantly increase when the rate of added clay and organic matter was increased (Table 1). Aggregate stability was most pronounced when 10% clay and 1.6% organic matter were added to the sandy soil at 90 DAT. A combination of 10% clay and 1.6% organic matter markedly increased the DMR Index value from 0.67 up to 1.54%. The role of organic matter includes binding of clay particles so that clay dispersion is reduced. Lado *et al*. (2004) found that clay dispersion of a soil with higher organic matter content was lower than that of soil with lower organic matter content.

The source of organic matter added to the sandy soil in this study was chopped *Crotalaria* *juncea* which is categorized as particulate organic matter (POM) (Golchin *et al.,* 1994). This form of POM consisted of large particles of organic matter (250-2000 m), free POM light fractions (LF) or encrusted with soil particles, which would protect organic matter from decomposition (Plante and McGill, 2002). Commonly, the LF in soil is associated with clay and polyvalent cations to form aggregates (Jastrow, 1996). Fortun and Fortun, (2005) found that clay soil amended with organic materials had higher aggregate stability than did sandy soil with similar amendments because organic matter interacted with silt and clay particles primarily via cation bridges.

The factor which contributes to aggregate stability is wetting and drying cycles (Piccolo *et al.*, 1997). In this study, however, the 10 day interval of irrigation did not affect aggregate stability which may be due to the high intensity of drying cycle process occurring in the short period of time.

Soil Bulk Density

Addition of clay soil and organic matter to sandy soils significantly decreased ($p<0.05$) soil bulk density at 30.60 and 90 DAT, yet interval of irrigation did not affect on sandy soil bulk density (Table 2). The results are in agreement with Arvidson (1998) who observed several field soils with different texture and organic matter content and found that increasing clay and organic matter content of the soiy'decilased bulk density did not increase sand content and bulk density. Barzergar *et al*., (2002) also reported that addition of different organic matter types (farmyard manure, composted biogases and wheat straw) decreased bulk density of soil under growth of wheat.

Total Porosity of Soil

Total sandy soil porosity was significantly affected ($p<0.05$) by addition of clay and organic matter, even though increasing the rate of both soil amendments did not affect on soil porosity (Table 3). Total porosity of sandy soil increased with added clay and organic matter. The higher total porosity of the sandy soil after added with clay and or Sanic matter might be related to the lower bulk density of the soil. Arvidson (1998) also found that the decrease in bulk density for the soil with higher clay and organic matter content was mainly attributed to increasing soil porosity.

Soil Available Water Content

There was a significant ($p<0.05$) effect of addition of clay and organic matter on available water content, even though the interval of irrigation and its interaction with plant growth media did not affect on soil available water content (Table 4). In all observation times, addition of clay and organic matter to sandy soil increasing available water content, which might be due to higher soil porosity resulting in much water ,could be retained in the soil spores. Previous studies have also found that available water content was influenced by clay content (Ellis and Etherton, 2002) and organic matter content (Barzergar *et al.*, 2002).

Table 1. Effect of addition of clay soils and organic matter and interval of irrigation on soil water availability at 30, 60, and 90 DAT

Treatments	DMR Index (mm) [1)]		
	30 DAT[1)]	60 DAT	90 DAT
Plant growth media:			
Sandy soils (Control)	0.67 a	0.83 a	0.71 a
Sandy soils + 5% clay soils + 0.8% organic matter	0.95 b	1.17 b	1.38 b
Sandy soils + 10% clay soils + 1.6% organic matter	1.05 b	1.24 b	1.54 b
Interval of irrigation (day):			
10	0.96	1.08	1.29
20	0.82	1.08	1.26

Remarks = Numbers followed by the same letters on the same columns were not significantly different (LSD 5%). DAT: Day After Treatment

Table 2 Effect of addition of clay soils and organic matter and interval of irrigation on soil bulk density at 30, 60, and 90 DAT

Treatments	Bulk density (g cm^{-3}) [1)]		
	30 DAT[1)]	60 DAT	90 DAT
Plant growth media:			
Sandy soils (Control)	1.38 b	1.39 b	1.39 b
Sandy soils + 5% clay soils + 0.8% organic matter	1.30 a	1.25 a	1.24 a
Sandy soils + 10% clay soils + 1.6% organic matter	1.24 a	1.20 a	1.19 a
Interval of irrigation (day):			
10	1.30	1.27	1.27
20	1.31	1.27	1.28

Remarks= Numbers followed by the same letters on the same columns were not significantly different (LSD 5%
DAT= Day After Treatment

Table 3. Effect of addition of clay soils and organic matter and interval of irrigation on total porosity of soil at 30, 60, and 90 DAT

Treatments	Total porosity (%)[1)]		
	30 DAT[1)]	60 DAT	90 DAT
Plant growth media:			
Sandy soils (Control)	37.06 a	38.26 a	39.53 a
Sandy soils + 5% clay soils + 0.8% organic matter	43.20 b	42.77 b	40.83 b
Sandy soils + 10% clay soils + 1.6% organic matter	44.15 b	44.43 b	41.66 b
Interval of irrigation (day):			
10	40.36	40.51	39.80
20	40.58	42.46	41.55

Remarks= Numbers followed by the same letters on the same columns were not significantly different (LSD 5%
DAT= Day After Treatment

Table 4. Effect of addition of clay soils and organic matter and interval of irrigation on soil water content at 30, 60, and 90 DAT

Treatments	Total porosity (%)[1)]		
	30 DAT[1)]	60 DAT	90 DAT
Plant growth media:			
Sandy soils (Control)	12.84 a	8.31 a	9.21 a
Sandy soils + 5% clay soils + 0.8% organic matter	19.55 b	20.64 b	16.67 b
Sandy soils + 10% clay soils + 1.6% organic matter	20.21 b	21.17 b	22.31 b
Interval of irrigation (day):			
10	18.03	10.12	15.34
20	17.03	9.96	16.78

Remarks = Numbers followed by the same letters on the same columns were not significantly different (LSD 5%
DAT= Day After Treatment

Plant Growth

In this study, the significant effect of addition of clay and organic matter on sandy soil physical properties was followed by their significant effect of plant growth which was expressed by plant height and number of shoots. Addition of clay and organic matter to sandy soil increased plant height (Table 5) and number of shoots of physic nut (Table 6). The higher available water content in the plant growth media composed of sandy soil + clay + organic matter might support physic nut to have higher plant height and more number of shoots than that grown on sandy soil.

Table 5 Effect of addition of clay soils and organic matter and interval of irrigation on plant height on 20 and 80 DAT

Treatments	Plant height (cm) [1)]	
	20 DAT[1)]	80 DAT
Plant growth media:		
Sandy soils (Control)	14.15 a	57.68 a
Sandy soils + 5% clay soils + 0.8% organic matter	17.62 b	59.20 b
Sandy soils + 10% clay soils + 1.6% organic matter	20.85 b	62.28 b
Interval of irrigation (day):		
10	16.21	60.17
20	16.88	59.26

Remarks = Numbers followed by the same letters on the same columns were not significantly different (LSD 5%
DAT= Day After Treatment

Table 6 Effect of addition of clay soils and organic matter and interval of irrigation on shoot population at 10, 30, 40, 50, 60, 70, 80, and 90 DAT

Treatments	Number of shoot (DAT) [1)]							
	10	30	40	50	60	70	80	90
Plant growth media:								
Sandy soils (Control)	0.78a	1.26a	1.45a	1.57a	1.65a	1.94a	2.32	2.47a
Sandy soils + 5% clay soils + 0.8% organic matter	1.21b	1.90b	2.25b	2.43b	2.57b	3.10b	4.17b	4.69b
Sandy soils + 10% clay soils + 1.6% organic matter	1.18b	1.90b	2.24b	2.50b	2.69b	3.64b	4.79b	5.67b
Interval of irrigation (day):								
10	1.15	1.78	1.92	2.09	2.18	2.86	3.92	4.53
20	0.96	1.59	2.05	2.24	2.44	2.93	3.60	4.03

Remarks = Numbers followed by the same letters on the same columns were not significantly different (LSD 5%
DAT= Day After Treatment

CONCLUSIONS

Incorporation of clay together with organic matter to sandy soil increased aggregate stability, total soil porosity, available water content, and decreased soil bulk density. The response of physic nut growth in sandy soil added with clay and organic matter was indicated by increasing plant height and number of shoots. However, the difference of interval irrigation (10 days and 20 days) did not affect on soil physical properties and plant growth.

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