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CHANGES IN PHYSICAL PROPERTIES OF AN ULTISOL AS INFLUENCED BY COMPOSTED EMPTY OIL PALM BUNCHES AND CHEMICAL FERTILIZER UNDER WATER STRESS CONDITIONS

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ABSTRACT
A greenhouse study was conducted at the University of Nigeria, Nsukka to evaluate and compare the effects of sole and complimentary use of composted empty oil palm bunch and chemical fertilizer for improvement of soil physical properties under water stress conditions. The experiment was a 3x3x4 factorial in a completely randomized design with three replications. It consisted of 3 factors–irrigation intervals, NPKMg compound fertilizer and composted empty oil palm fruit bunch. Water stress was imposed by observing irrigation intervals of 7days, 14days and 21days after irrigating the soil to field capacity. NPKMg fertilizer was applied at 0g, 28g, 42g per/polybag. While the composted empty fruit bunch (EFB) was applied 0g, 100g, 200g and 300g per/polybag

Result showed that every 14 day intervals of irrigation significant ($P<0.05$) gave the lowest bulk density as well as highest total porosity, hydraulic conductivity, aggregate stability and mean weight diameter compared to 7 and 21 day intervals of irrigation. However, a non significant increase in bulk density and significant ($P<0.05$) decrease in total porosity, hydraulic conductivity, aggregate stability and mean weight diameter were mostly observed with increasing rates of the chemical fertilizer. Similarly, lowest significant bulk density as well as highest total porosity, hydraulic conductivity, aggregate stability and mean weight diameter values were observed with the highest rates of 300gcompost/polybag. Also, result showed that, combined application of 0gNPKMg and 300gcompost under 14 day intervals of irrigation had the lowest ($P>0.05$) effect on bulk density but showed highest ($P<0.05$) effects on total porosity, hydraulic conductivity, aggregate stability and mean weight diameter. Generally, the application of 300g compost/polybag was most effective in improving the physical properties of the ultisol under 14 day intervals of irrigation.

INTRODUCTION
Tropical soils are highly susceptible to degradation under continuous cultivation without putting conservation measures in place. This practice usually results in low yield and nutrient depletion coupled with soil degradation. The structural quality of many soils in the tropical region needs to be

improved with good and sustainable management practices. Ultisols, a prominent soil order within the tropics are subject of to low productivity and soil degradation and exhibits characteristics that makes its management important. These characteristics include low water holding capacity, poor surface soil stability and relatively high bulk density (Babalola and Obi, 1981).

Each year African's finite capacity to grow food and fiber progressively decreased largely because of the decline in soil fertility. As human populations are increasing more lands are being brought under cultivation, including marginal lands that are practically vulnerable to degradation by such processes as erosion, depletion in soil organic matter and nutrient (Owino *et al.*, 2006). To increase soil productivity and crop yields farmers now apply mineral fertilizer. However, continuous usage of these mineral fertilizers has been found to decrease base saturation, increasing acidification and physical degradation (Isherwood, 2008). Lombin and Ayotade (1991) reported that the combination of organic and inorganic fertilizer gives better result. Omueti et al. (2002) reported that integrated application of organic and inorganic sources improved bulk density, water retention and soil structure of a degraded soil.

Water resources have become meager due to climate change and competition from other water users (Farahani *et al.,* 2007). Climate changes constitute one of the heightened global concerns today; it can impact agricultural productivity via changes in rainfall distribution, drought and temperature influences, as most planning and timing of farming operations are tied to the onset and duration of rainfall especially in Africa. Drought is a major factor limiting productivity in agriculture and have caused a collapse in food production by reducing uptake of water, nutrient and increase in soil physical deterioration (Du and Wang, 2011). However, there is dearth of information on the impact of integrated nutrient management on soil physical properties under water deficit condition.

Therefore the objective of this study was to compare the effects of sole and integrated use of empty oil palm bunch compost and chemical fertilizer for improvement of soil physical properties under soil water stress conditions

MATERIALS AND METHODS

Description of study area: This study was conducted in the greenhouse of the Department of Soil Science, University of Nigeria Nsukka. Nsukka, is located in Enugu State in the Southern-agro ecological zone of Nigeria. The area lies at latitude 06^o52^1N and longitude 07^o24^1E; with a mean elevation 419 meters above sea level. The vegetation of the area can be described as derived savanna. The study is within the humid tropical climate and has an annual rainfall of 1700-1800mm.The rainfall pattern is bimodal and falls between April and October while the dry season is between November and March. The area is characterized with mean annual maximum (day) and minimum (night) temperatures of 31^oC and 21^oC respectively, while the average relative humidity is rarely below 60% (Asadu, 2002). The soil used for this study is deep; porous has been classified as Typic Kandiustult, derived from a false bedded sand stone (Akamigbo and Igwe, 1990).

Green House Study

Preparation of composted empty oil palm bunch waste: Oil palm bunch refuse was shredded into smaller particle. The shredded bits were packed in windrows (aerated compartment) and mixed with poultry droppings in a ratio of 4:1(bunch refuse: poultry droppings) and palm oil effluent to increase microbial activity and to reduce the Carbon: Nitrogen. The heap was turned weekly and moistened with the effluent for proper decomposition. The composting process was within 10 weeks after which the compost was analyzed and used as soil amendments. The overall procedure was the method adopted by Hang, (1980) and Catton, (1983)

Chemical analysis of the uncomposted and composted materials used for the study: Samples of the empty oil palm fruit bunch, palm oil mill effluent, poultry manure and the final compost were crushed and passed through a 2mm sieve and chemical properties such as pH, total N, Avail P, Exchangeable bases, organic carbon were determined.

Experimental design and treatment application: The experiment was laid out as 4x3x3 factorial in a completely randomized design with three replications. It consists of 3 factors–composted empty oil palm fruit bunch, NKPMg compound fertilizer and watering intervals. Composted EFB was applied at 4 levels (0g, 100g, 200g and 300g/polybag). NPKMg (12:12:17:2) fertilizer was applied at 0g, 28g, 42g per polybag. 28g was applied in two equal doses of 14g each at 1 and 3 months after incorporation of the composted EFB while 42g were applied in three equal doses of 14g each at 1, 3 and 5months after incorporation of the composted EFB. Water stress was imposed by observing irrigation intervals of 7days, 14days and 21days after irrigating the soil in the polybag to field capacity water content.

Irrigation procedure: The composted empty fruit bunch was mixed with 7kg of the sieved soil samples in polybags of 40cm X 45cm sizes perforated at the bottom. The polybags were uniformly watered for a period of one week for proper incubation after which they were weighed 48 hr later so as to determine their weight at field capacity by assuming free gravitational water must have stopped draining (Richard and Weaver, 1944). Furthermore, soil water deficit was now imposed by observing watering intervals at every 7, 14 and 21days respectively. The poly bags were also weighed at the different watering intervals so as to determine the level of soil water depletion. The deficit in soil water at the different watering intervals and that at field capacity was ascribed to be the approximate water loss by evaporation. The deficits soil water was estimated and the calculated amount of irrigation water (volume) was added in order to raise the soil water deficit to the predetermined field capacity. The general principle stated by Boutraa and Sanders (2001) was used for the water stress treatment.

Soil sampling: Core and surface soil samples were collected at 4 and 8 months after manure application (M.A.M.A) for the determination of some physical properties such as bulk density, total porosity, hydraulic conductivity, aggregate stability and mean weight diameter respectively.

Laboratory methods: Particle size distribution was determined by hydrometer method (Gee and Bander 1996) using sodium hexametaphosphate as dispersant. Bulk density was measured by the core method, as described by Blake and Hartge (1986). Total porosity (t) was calculated from bulk density (Bd) value assuming a particle density (Pd) of 2.65gcm^{-3}. Saturated Hydraulic Conductivity was determined using the Klute and Dirksen (1986) method. The distribution of water stable aggregate was estimated by the wet sieving technique described in detail by Kemper and Rosenau (1986). Mean weight diameter was calculated using the method of Van Bavel as modified by Kemper and Rosenau (1986). **Data Analysis:** The statistical analysis was performed using Genstat Statistical Package for the analysis of variance (ANOVA).Treatment means were compared by using the Fisher's Least Significant Difference (F-LSD) at 5% probability.

RESULTS

Table 1 shows the initial properties of the soil before treatment application. The soil was sandy loam with a high percentage of sand, low percentages of clay and silt. The soil is characterized with high bulk density value of 1.65g/cm^3, a low saturated hydraulic conductivity value of 10.61 cm/hr and low mean weight diameter values. These showed that the site was physically degraded. These soil properties may adversely affect plant growth by exhibiting low water and nutrient retention capacities. Table 2 shows the chemical properties of the raw materials used for composting EFB and composted EFB

Effects of treatments on soil physical properties

Bulk Density: Fig 1 showed the main effect of irrigation intervals on soil bulk density at 4 and 8 months after manure application (M.A.M.A). At 4 MAMA, lowest ($p<0.05$) value was obtained at irrigation intervals of 14 days. This value was lower than 7 and 21 days intervals of irrigation with 3.3% and 0.8% respectively. Similar trend was observed at 8MAMA (Fig 1). Fig 2 shows main effect of chemical fertilizer on bulk density at 4 and 8 MAMA. At 4MAMA, lowest ($P>0.05$) value was obtained at 0gNPKMg. Similar trend was observed at 8MAMA (Fig 2). Fig 3 shows main effect of composted EFB on bulk density at 4 and 8 MAMA. At 4MAMA, lowest ($P<0.05$) value was obtained at 300g composted EFB. Similar trend was observed at 8MAMA (Fig 3)

Table 3 shows the effects of compost and chemical fertilizer on bulk density under different irrigation intervals at 4 and 8 months after manure application. At 4MAMA, soil amended with 0gNPKMg+300gcompost and 42gNPKMg+300gcompost gave the lowest values respectively. Highest values were observed with 0gNPKMg+0gcompost, 28gNPKMg+0gcompost and 42gNPKMg+0gcompost. The interaction effect between compost, irrigation intervals and chemical fertilizer was not-significant ($p<0.05$). Similar trend was observed at 8MAMA (Table 3).

Total Porosity: Fig 4 shows main effect of irrigation intervals on total porosity at 4 and 8 MAMA. At 4MAMA highest ($P<0.05$) value was obtained at irrigation intervals of 14 days. This value was higher than 7 and 21 days irrigation intervals with 2.17% and 0.3% respectively. Similar trend was observed at 8MAMA (Fig 4). Fig 5 showed main effects of chemical fertilizer on bulk density at 4 and 8 MAMA. At 4MAMA, highest ($P<0.05$) value was obtained at 0gNPKMg. Similar trend was observed at 8MAMA. Fig 6 shows that at 4 and 8 MAMA, highest ($P<0.05$) values were obtained at 300gEFB relative to the control.

Table 4 shows the effects of compost and chemical fertilizer on total porosity under different irrigation intervals at 4 and 8 months after manure application. At 4MAMA, soil amended with 0gNPKMg+300gcompost and 42gNPKMg+3000g compost gave the highest values closely followed with 28g NPK Mg + 300g compost and 28g NPK Mg + 200g compost respectively. Lowest values were obtained with 0g NPK Mg + 0g compost, 28g NPK Mg + 0g compost and 42g NPK Mg + 0g compost respectively. The interaction effect between compost, irrigation intervals and chemical fertilizer was significant and the highest value was found when 0g NPK Mg + 300g compost was applied under 14days irrigation intervals and the lowest value was recorded under 28g NPK Mg + 0g compost amendments. A Similar trend was observed at 8MAMA (Table 4).

Hydraulic conductivity: Fig 7 shows main effect of irrigation intervals on hydraulic conductivity at 4 and 8 MAMA. At 4MAMA highest ($P<0.05$) value was obtained at irrigation intervals of 14 days. This value was higher than 7 and 21 days irrigation intervals with 7.72% and 6.03% respectively. Similar trend was observed at 8MAMA (Fig 7). Fig 8 shows main effects of NPKMg fertilizer on hydraulic conductivity at 4 and 8 MAMA. At 4MAMA highest ($P<0.05$) value was obtained at 0gNPK relative to 28gNPK and 42gNPK respectively. Similar trend was observed at 8MAMA (Fig 8). Fig 9 shows main effect of composted EFB on hydraulic conductivity at 4 and 8 MAMA. At 4MAMA highest ($P<0.05$)

value was obtained at 300gEFB. Similar trend was observed at 8MAMA (Fig 9).

Table 5 shows the effects between compost and chemical fertilizer on hydraulic conductivity under different irrigation intervals at 4 and 8MAMA. At 4MAMA, soil amended with 0g NPK Mg + 300g compost and 42g NPK Mg + 300g compost gave the highest values. Lowest values were obtained with 0g NPK Mg + 0g compost, 28g NPK Mg + 0g compost and 42g NPK Mg + 0g compost respectively. The interaction effect between compost, irrigation intervals and chemical fertilizer was significant on hydraulic conductivity and the highest value was found when 0gNPKMg+300gcompost were applied under 14days irrigation intervals. Lowest value was observed when 28gNPKMg+0gcompost were applied under 7days irrigation intervals. Similar trend was observed at 8MAMA (Table 5)

Aggregate stability: Fig 10 shows main effect of irrigation intervals on aggregate stability at 4 and 8 MAMA. At 4MAMA highest (P<0.05) value was obtained at irrigation intervals of 14 days. This value was higher than 7 and 21 days irrigation intervals with 3.4% and 6.1% respectively. Similar trend was observed at 8MAMA (Fig 10). Fig 11 shows main effects of NPKMg fertilizer on aggregate stability at 4 and 8 MAMA. At 4MAMA, highest (P<0.05) value was obtained with the control (0gNPK). Similar trend was observed at 8MAMA (Fig 11). Fig 12 shows main effect of composted EFB on aggregate stability at 4 and 8MAMA. At 4MAP highest (P<0.05) value was obtained at 300gEFB relative to the control (0gEFB). Similar trend was observed at 8MAP (Fig 12).

Table 6 shows the interaction effects between compost and chemical fertilizer on aggregate stability under different irrigation intervals at 4 and 8 months after manure application. At 4MAMA, soil amended with 0g NPK Mg + 300g compost and 42g NPK Mg + 300g Compost gave the highest values. Lowest values were obtained with 0g NPK Mg + 0g compost, 28g NPK Mg + 0g compost and 42g NPK Mg + 0g compost. The interaction effect between compost, irrigation intervals and chemical fertilizer was significant and the highest value was found when 0g NPK Mg + 300g compost were applied under 14days irrigation intervals. Lowest value was recorded when 28gNPKMg+0gcompot was applied under 21days irrigation intervals. Similar trend was observed at 8 MAMA (Table 6)

Mean Weight Diameter: Fig 13 shows main effect of irrigation intervals on mean weight diameter at 4 and 8 MAMA. At 6MAP highest (P<0.05) value was obtained at irrigation intervals of 14 days. This value was higher than 7 and 21 days irrigation intervals with 0.7% and 4.9% respectively. Similar trend was obtained at 8MAMA (Fig 13). Fig 14 shows main effects of chemical fertilizer on mean weight diameter at 4 and 8 MAMA. At 4MAMA, highest (P<0.05) value was obtained at 0gNPKMg. Similar trend was observed at 8MAMA (Fig 14). Fig 15 shows main effect of composted EFB on mean weight diameter at 4 and 8MAMA. At 4MAMA, highest (P<0.05) value was obtained at 300gEFB relative to the control (0gEFB). Similar trend was observed at 8MAMA (Fig 15).

Table 7 shows the effects of compost and chemical fertilizer on mean weight diameter under different irrigation intervals at 4 and 8 months after manure application. At 4 MAMA, soil amended with 0g NPK Mg + 300g compost, 28gNPKMg+300g compost and 42g NPK Mg + 300g compost gave highest values. Lowest values were detected with 0g NPK Mg + 0g compost, 28g NPK Mg + 0g compost and 42gNPKMg+0gcompost. The interaction effect between compost, irrigation intervals and chemical fertilizer was significant and the highest value was observed when 0gNPKMg+300gcompost were applied under 7days irrigation intervals (Table 7). Similar trend was observed at 8MAMA (Table 7).

DISCUSSION

The relative high sand content in the study area is the reflection of the effect of a sandy parent material. The parent materials of the soils of eastern Nigeria have been noted to influence the texture of the soils derived from them (Akamigbo and Asadu, 1983). A bulk density of 1.54g/cm^3 as observed in the initial soil physical properties showed a compacted soil and can create hindrances to root proliferation for nutrients (Ashrad *et al.,* 1996). Also, Brady and Weil (1999) stated that growth of roots into moist soil is generally limited by bulk densities ranging from 1.45Mg/cm^3 in clays to 1.85Mg/cm^3 in loamy sand. The observed improvements in nutrient composition of the composted EFB relative to the raw materials may be adduced to increase organic matter mineralization and humification brought about by the action of micro-organism. The composting makes the compost organic matter similar to soil organic matter (Senesi *et al.,* 1996). However, Brady and Weil (2002) reported that finished compost is generally more concentrated in nutrients than the initial combination of raw material used.

The noticeable improvements in soil physical properties under 14days relative to 7 and 21days intervals of irrigation may be due to an improved soil organic matter. Organic matter is known to ameliorate soil physical properties by reducing bulk density, increase porosities, saturated hydraulic conductivity, enhancing aggregation, and water holding capacity of soils (Mbagwu and Picolo, 1990; Adesodun *at al.,* 2005). The improved soil physical properties may result in greater root distribution and proliferation and hence greater nutrient and water uptake (Dexter, 1988) and may result in increasing plant growth.

The general decline in soil physical properties observed with sole application of NPK fertilizer relative to the control may be due to the damaging effects on soil organic matter which correlates with soil properties. This result is in line with the findings of Mahajan *et al.* (2008), Nottidge *et al.* (2005) who reported that continues use of inorganic fertilizer leads to deterioration in soil physical properties. Similarly, earlier workers had reported that sole use of chemical fertilizer brought about soil physical degradation (Isherwood, 2008).

The remarkable improvements in soil physical properties observed with increasing rates of composted EFB may be attributed to improved soil structure, brought about by the improved soil organic matter. The decreased in bulk density could be as a result of increased microbial activity which lead to the pulverization of the soil. This was associated with an increase in total porosity as was observed in this study. Previous studies (Kutu and Omueti, 2003; Aribe, 2003; Obe 2009) had established improvements of soil physical properties with the application of organic materials. Similarly, Lombin *et al.* (1991), Mbah *et al.* (2004) reported that organic materials improved soil fertility indices such as bulk density, porosity, aggregation, penetration resistance and cohesion force.

Under water stress condition, complementary use of compost and NPK fertilizer and those amended with compost alone showed excellent improvements in soil physical properties relative to sole use of chemical fertilizer and the control. The influence of organic amendments in improving soil physical properties had been widely reported (Mbagwu, 1989; Obi and Ebo, 1995; Nnabude and Mbagwu, 2001; Aluko and Oyeleke, 2005). The lowest bulk density obtained with the compost treated soil could be as a result of the improved soil organic matter. This improved soil granulation and soil porosity as well. Tejada *et al.* (2006) found that soil bulk density decrease with compost addition. Mbagwu (1992) reported that the decrease in bulk density obtained with different organic wastes treated soil was directly related to increase in organic matter which played a significant role in reducing compaction of soil. Similarly, Wanas (2002) reported that applying compost solely or in combination with inorganic fertilizer achieved significant impact on soil bulk density, total porosity, soil hydraulic conductivity and aggregation relative to the control.

CONCLUSION

The study has demonstrated the effectiveness of sole application of composted EFB for improvement of soil physical properties compared with its complimentary use with NPK Mg fertilizer, chemical fertilizer alone, and the control under water stress condition. However, result showed that irrigation intervals of 14days had the lowest significant effect on bulk density, dispersion ratio as well as highest on total porosity, hydraulic conductivity, aggregate stability and mean weight diameters respectively. However, increasing rates of the chemical fertilizer did not increase soil bulk density but significantly reduced total porosity, hydraulic conductivity, aggregate stability and mean weight diameter coupled with a significant increase in dispersion ratio throughout the sampling period. Similarly, lowest bulk density, dispersion ratio as well as highest total porosity, hydraulic conductivity, aggregate stability and mean weight diameter values were observed with the highest rates of 300gcompost/poly bag. Generally, the application of 300gcompost/polybag was most effective in improving the physical properties of the ultisol under 14 day intervals of irrigation and its therefore recommended.

Table 1: Initial physical properties of the soil used for the study

Characteristics	Values
F.S (%)	26
C.S (%)	50
Silt (%)	11
Clay (%)	13
Textural class Aggregate	Sandy Loam
stability (%) Mean weight	42.84
diameter (mm)	0.43
Hydraulic conductivity (cm/hr)	10.61
Bulk Density (g/cm^3)	1.56
Total Porosity (%)	41.29

F.S = Fine Sand, C.S = Coarse Sand

Table 2: Chemical properties of the materials used for composting EFB and composted EFB

Properties	Poultry Manure	POME	EFB	Composted EFB
pH (H_20)	5.8	3.3	7.3	8.2
EC (ds/m)	18.80	7.44	10.44	5.4
Total N (%)	1.62	0.44	0.36	2.24
Potassium (%)	1.06	0.49	1.30	9.81
Magnesium (%)	0.32	0.07	0.24	3.12
Calcium (%)	1.89	0.42	0.49	4.82
Phosphorus (%)	0.05	0.02	0.04	0.65
C/N ratio	0.39	7.00	35.47	17.85
Carbon (%)	0.64	3.08	12.77	40.00

POME = Palm Oil Mill Effluent, EFB = Empty Oil Palm Fruit Bunch, CN = Carbon/Nitrogen

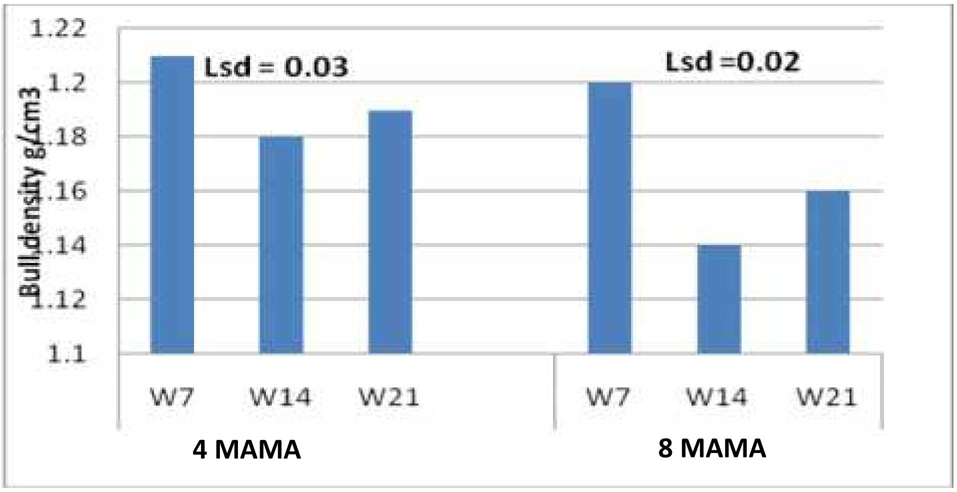

Fig. 1: Main effect of irrigation intervals on bulk density at 4 and 8 MAMA

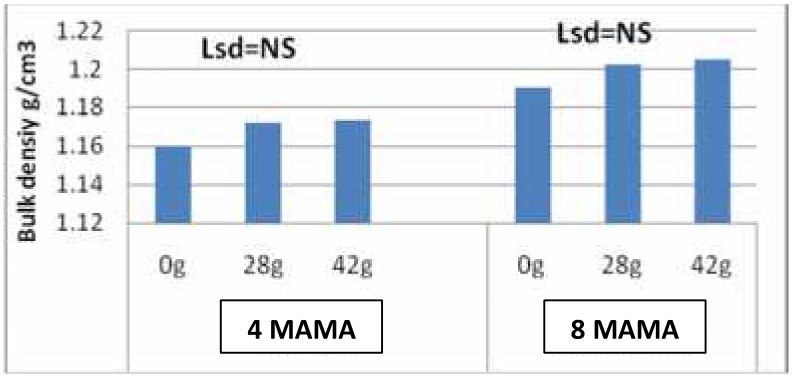

Fig. 2: Main effect of NPK fertilizer on bulk density at 4 and 8 MAMA

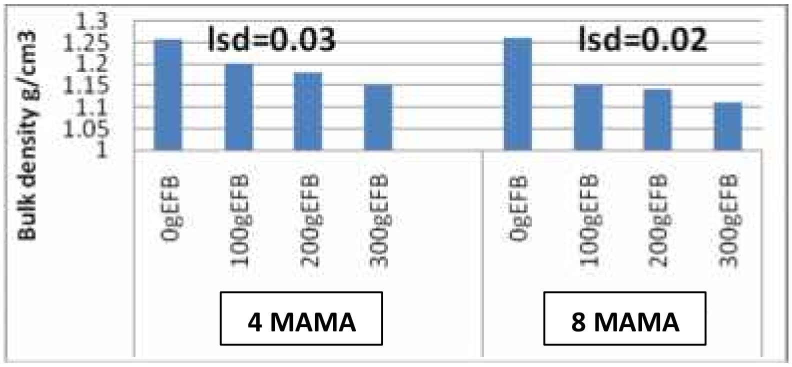

Fig. 3: Main effect of composted EFB on bulk density at 4 and 8 MAMA

Table 3: Effects of compost and chemical fertilizer on bulk density (gcm^{-3}) under different irrigation intervals at 4 and 8 months after manure application (MAMA)

Nutrient combinations	4 MAMA Irrigation intervals (days)				8 MAMA Irrigation intervals (days)			
	7	14	21	Mean	7	14	21	Mean
T1 = 0gNPKMg+0g E.F.B.	1.32	1.20	1.33	1.28	1.29	1.23	1.31	1.28
T2 = 0gNPKMg+100g E.F.B.	1.21	1.18	1.18	1.19	1.18	1.14	1.15	1.16
T3 = 0gNPKMg+200g E.F.B.	1.19	1.16	1.19	1.18	1.16	1.10	1.16	1.14
T4 = 0gNPKMg+300g E.F.B.	1.07	1.08	1.21	1.12	1.14	1.02	1.14	1.10
T5 = 28gNPKMg+0g E.F.B.	1.31	1.31	1.31	1.31	1.25	1.30	1.21	1.25
T6 = 28gNPKMg+100g E.F.B.	1.22	1.19	1.13	1.18	1.25	1.09	1.14	1.16
T7 = 28gNPKMg+200g E.F.B.	1.20	1.15	1.18	1.17	1.19	1.13	1.09	1.13
T8 = 28gNPKMg+300g E.F.B	1.16	1.10	1.18	1.14	1.07	1.06	1.17	1.10
T9 = 42gNPKMg+0g E.F.B.	1.32	1.32	1.25	1.30	1.27	1.28	1.22	1.26
T10 = 42gNPKMg+100g E.F.B.	1.27	1.24	1.04	1.18	1.24	1.09	1.20	1.18
T11 = 42gNPKMg+200g E.F.B.	1.20	1.15	1.18	1.17	1.24	1.17	1.04	1.15
T12 = 42gNPKMg+300g E.F.B	1.14	1.13	1.13	1.13	1.13	1.09	1.16	1.12
Mean	1.22	1.18	1.19		1.20	1.14	1.16	
F-L.S.D 0.05		NS				NS		

EFB: composted empty oil palm fruit bunch

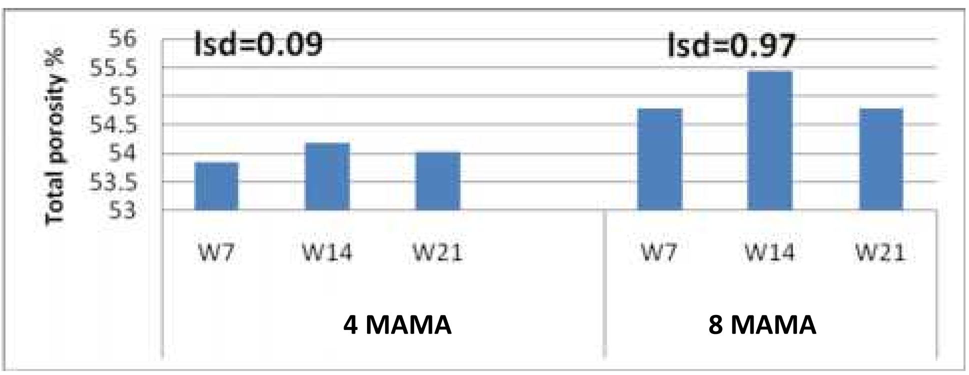

Fig. 4: Main effects of irrigation intervals on soil total porosity at 4 and 8 MAMA

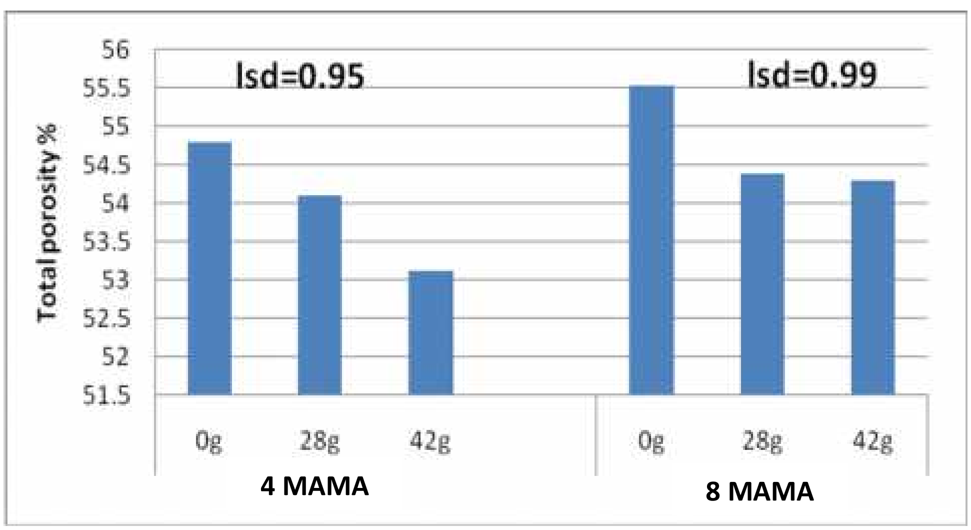

Fig. 5: Main effects of NPK fertilizer on soil total porosity at 4 and 8 MAMA

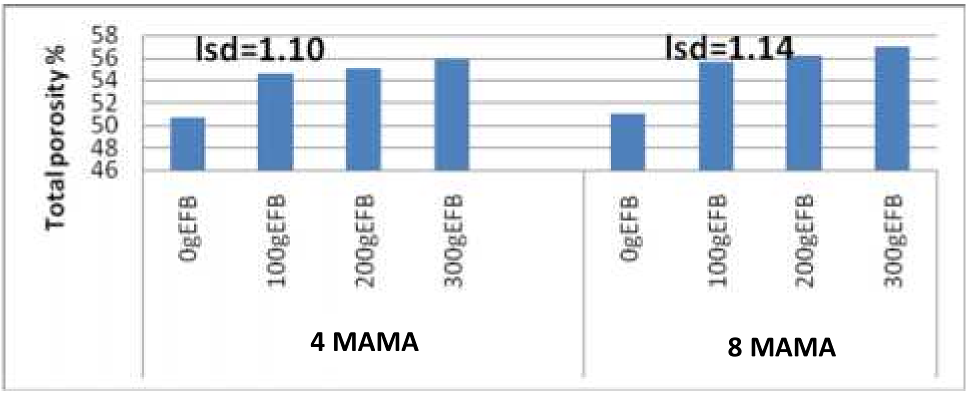

Fig. 6: Main effects of composted EFB on soil total porosity at 4 and 8 MAMA

Table 4: Effects of compost and chemical fertilizer on total porosity (%) under different irrigation intervals at 4 and 8 months after manure application (MAMA)

Nutrient combinations	4 MAMA Irrigation intervals (days)				8 MAMA Irrigation intervals (days)			
	7	14	21	Mean	7	14	21	Mean
T1 = 0gNPKMg+0g E.F.B.	42.72	43.77	47.02	44.50	42.71	45.07	45.35	45.35
T2 = 0gNPKMg+100g E.F.B.	56.77	59.95	52.32	56.34	57.88	58.07	56.77	56.77
T3 = 0gNPKMg+200g E.F.B.	55.56	58.49	55.34	56.46	56.65	56.57	56.88	56.88
T4 = 0gNPKMg+300g E.F.B.	62.24	62.72	61.71	62.22	61.38	65.88	63.92	63.72
T5 = 28gNPKMg+0g E.F.B.	41.41	37.42	49.99	42.94	41.93	44.96	44.79	44.79
T6 = 28gNPKMg+100g E.F.B.	52.87	59.51	55.34	55.90	53.58	58.64	56.55	56.55
T7 = 28gNPKMg+200g E.F.B.	55.26	58.05	58.41	57.24	55.34	58.15	57.68	57.68
T8 = 28gNPKMg+300g E.F.B	57.68	54.98	54.64	55.76	58.73	58.05	56.56	57.78
T9 = 42gNPKMg+0g E.F.B.	40.20	40.45	50.35	43.66	45.72	43.63	44.41	44.41
T10 = 42gNPKMg+100g E.F.B.	56.09	57.11	53.42	55.54	53.41	59.13	56.93	56.93
T11 = 42gNPKMg+200g E.F.B.	54.39	59.02	53.21	55.55	57.19	58.23	57.63	57.63
T12 = 42gNPKMg+300g E.F.B	60.98	58.85	56.46	58.77	62.09	59.96	58.44	60.21
Mean	53.01	54.19	54.02		53.96	55.44	45.35	
F-L.S.D 0.05		3.32				3.41		

EFB: composted empty oil palm fruit bunch.

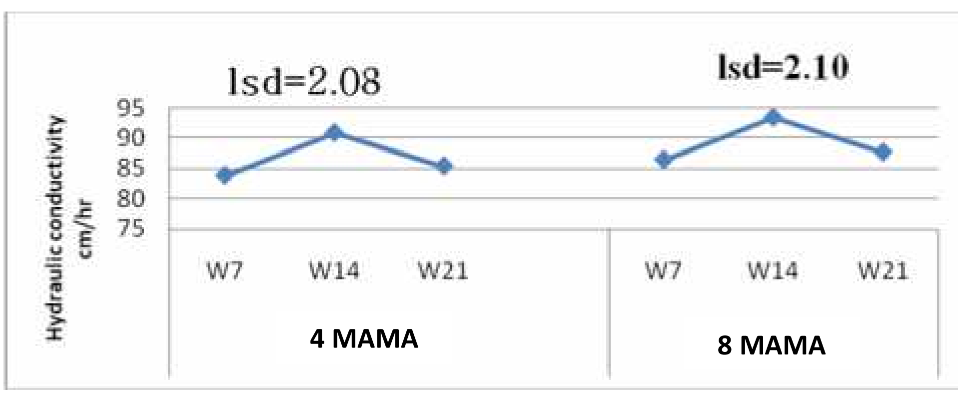

Fig. 7: Main effects of irrigation intervals on hydraulic conductivity at 4 and 8 MAMA

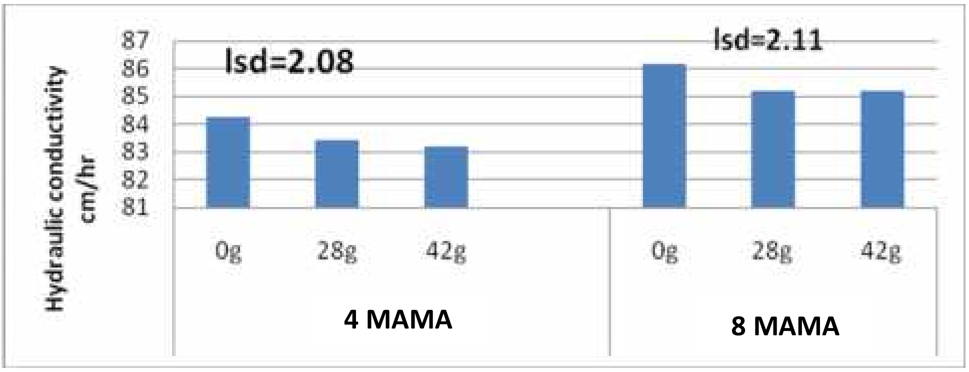

Fig. 8: Main effect of chemical fertilizer on hydraulic conductivity at 4 and 8 MAMA

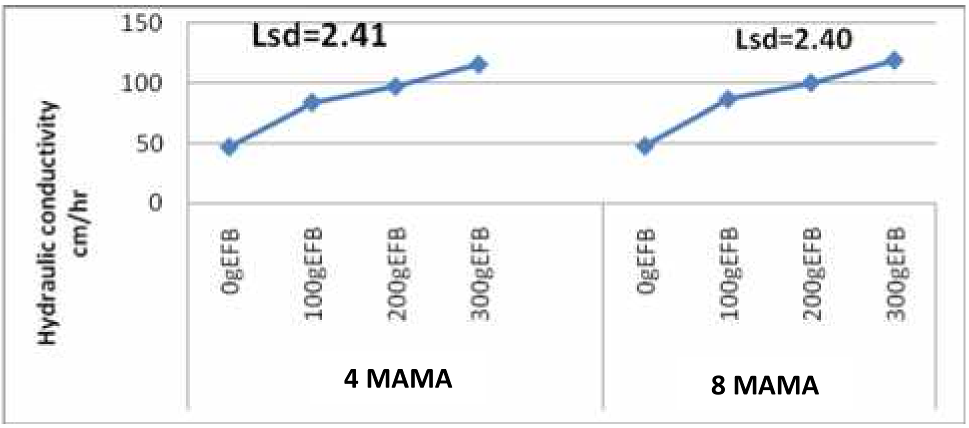

Fig. 9: Main effect of composted EFB on hydraulic conductivity at 4 and 8 MAMA

Table 5: Effects of compost and chemical fertilizer on hydraulic conductivity (cm/hr) under different irrigation intervals at 4 and 8 months after manure application (MAMA)

Nutrient combinations	4 MAMA Irrigation intervals (days)				8 MAMA Irrigation intervals (days)			
	7	14	21	Mean	7	14	21	Mean
T1 = 0gNPKMg+0g E.F.B.	33.37	29.49	45.90	36.58	34.41	29.51	46.19	36.70
T2 = 0gNPKMg+100g E.F.B.	62.69	86.53	65.05	71.42	64.29	89.21	67.07	73.52
T3 = 0gNPKMg+200g E.F.B.	88.18	85.64	79.07	90.29	100.64	88.30	100.08	96.34
T4 = 0gNPKMg+300g E.F.B.	157.28	165.58	99.70	140.70	164.90	170.71	102.79	146.13
T5 = 28gNPKMg+0g E.F.B.	24.58	68.15	89.47	60.75	25.35	68.21	90.56	61.37
T6 = 28gNPKMg+100g E.F.B.	44.47	148.56	102.55	98.16	45.85	153.06	105.72	101.54
T7 = 28gNPKMg+200g E.F.B.	97.53	88.72	112.61	99.62	99.32	91.47	116.10	102.20
T8 = 28gNPKMg+300g E.F.B	85.24	166.07	98.81	106.70	76.64	171.21	101.08	116.60
T9 = 42gNPKMg+0g E.F.B.	58.41	37.51	58.40	51.44	60.22	38.23	59.12	53.52
T10 = 42gNPKMg+100g E.F.B.	92.02	49.42	67.42	69.62	94.87	50.95	68.83	71.55
T11 = 42gNPKMg+200g E.F.B.	111.99	43.91	92.21	82.71	115.46	45.07	85.09	85.54
T12 = 42gNPKMg+300g E.F.B	150.22	120.79	95.31	122.10	154.87	124.53	98.26	125.88
Mean	83.83	90.85	85.37		86.40	93.37	87.65	
F-L.S.D 0.05		7.23				7.03		

EFB: composted empty oil palm fruit bunch.

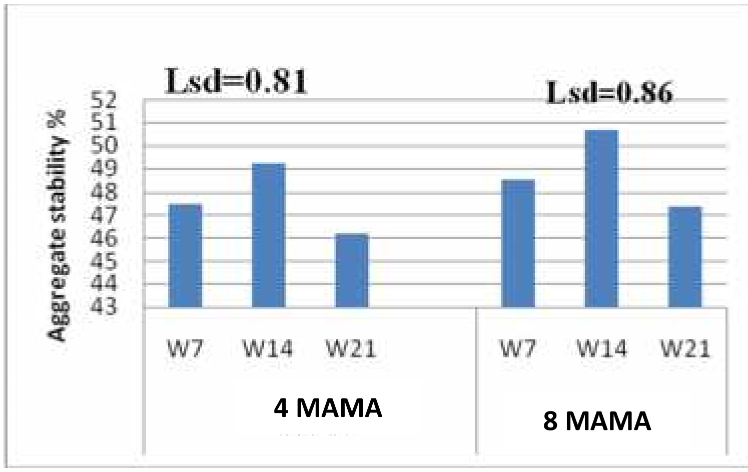

Fig. 10: Main effect of irrigation intervals on aggregate stability at 4 and 8 MAMA

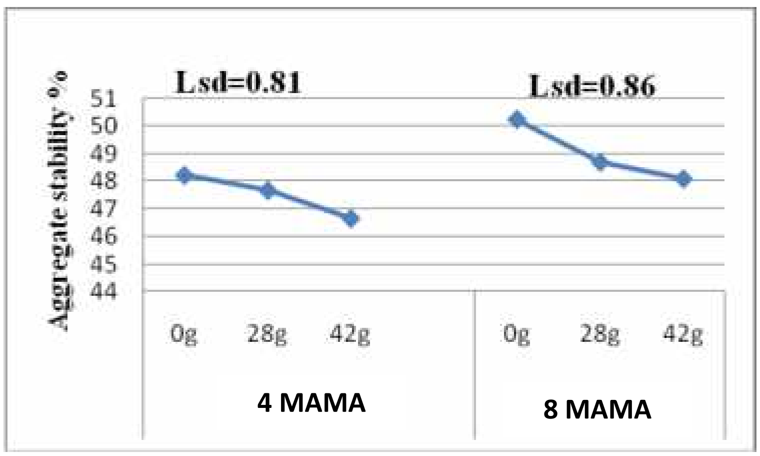

Fig. 11: Main effect of Chemical fertilizer on aggregate stability at 4 and 8 MAMA

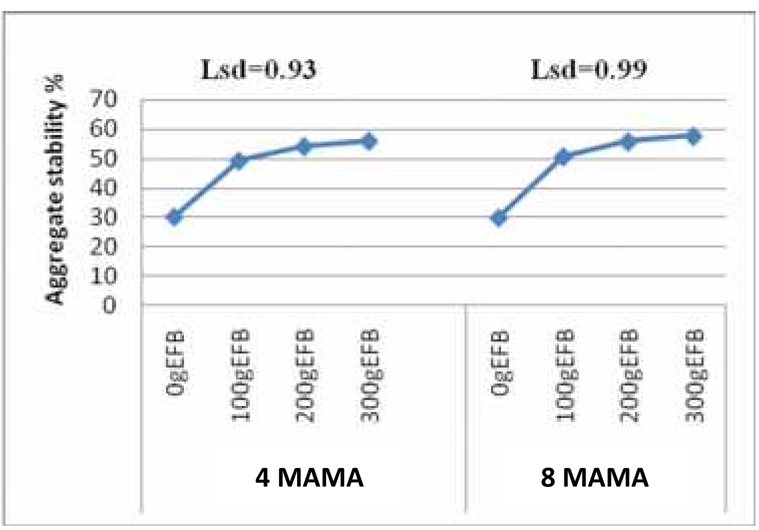

Fig. 12: Main effect of composted EFB on aggregate stability at 4 and 8 MAMA

Table 6: Effects of compost and chemical fertilizer on aggregate stability (%) under different irrigation intervals at 4 and 8 months after manure application

	4MAMA				8 MAMA			
	Irrigation intervals (days)				Irrigation intervals (days)			
Nutrient combinations	**7**	**14**	**21**	**Mean**	**7**	**14**	**21**	**Mean**
T1 = 0gNPKMg+0g E.F.B	37.99	21.72	23.47	27.72	37.63	22.05	23.41	27.69
T2 = 0gNPKMg+100g E.F.B	52.79	44.61	43.41	46.93	53.70	42.85	44.71	47.08
T3= 0gNPKMg+200g E.F.B	46.93	55.66	56.94	53.17	52.33	57.32	53.49	54.38
T4= 0gNPKMg+300g E.F.B	56.12	70.64	69.93	65.56	54.19	51.28	72.02	62.36
T5 = 28gNPKMg+0g E.F.B	30.95	27.53	21.16	26.54	34.33	27.47	21.13	27.64
T6 = 28gNPKMg+100g E.F.B	51.63	60.27	49.14	53.68	53.17	62.07	51.27	55.45
T7 = 28gNPKMg+200g E.F.B	61.59	52.83	53.77	56.06	55.53	64.59	54.57	58.23
T8 = 28gNPKMg+300g E.F.B	55.09	49.79	55.71	53.53	56.74	75.51	57.38	63.21
T9 = 42gNPKMg+0g E.F.B	27.80	26.38	27.52	27.23	25.55	26.61	27.84	26.66
T10=42gNPKMg+100g E.F.B	50.33	53.31	46.59	50.07	51.83	54.90	47.84	52.18
T11=42gNPKMg+200g E.F.B	45.36	65.15	53.67	54.72	46.72	67.10	55.27	56.36
T12=42gNPKMg+300g E.F.B	53.92	62.71	52.99	56.54	58.71	56.36	62.38	59.15
Mean	47.55	49.21	46.19		48.54	50.67	47.36	
F- L.S.D 0.05		2.81					2.98	

EFB Composted empty oil palm fruit bunch. M.A.M.A. = Months after manure application

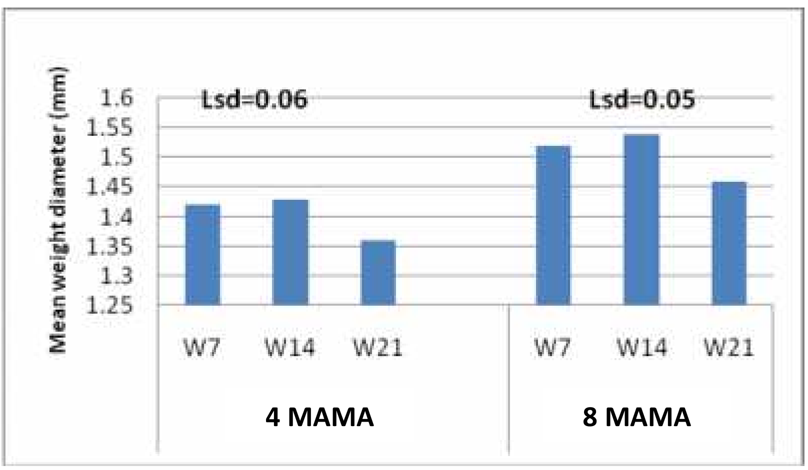

Fig. 13: Main effect of irrigation intervals on mean weight diameter at 4 and 8 MAMA

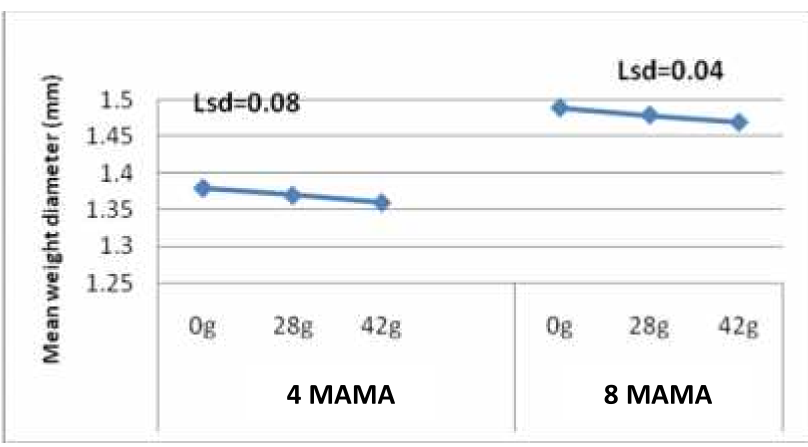

Fig. 14: Main effect of NPK fertilizer on mean weight diameter at 4 and 8 MAMA

Fig. 15: Main effect of composted EFB on mean weight diameter at 4 and 8 MAMA

Table 7: Effects of compost and chemical fertilizer on mean weight diameter under different irrigation intervals at 4 and 8 month after manure application

	4 MAMA Irrigation intervals (days)				8MAMA Irrigation intervals (days)			
Nutrient combinations	**7**	**14**	**21**	**Mean**	**7**	**14**	**21**	**Mean**
T1 = 0gNPKMg+0g E.F.B	0.82	0.77	1.66	0.92	0.76	0.81	1.16	0.91
T2 = 0gNPKMg+100g E.F.B	1.23	1.78	1.30	1.43	1.92	1.32	1.49	1.57
T3= 0gNPKMg+200g E.F.B	1.61	1.52	1.33	1.33	1.63	1.74	1.43	1.60
T4= 0gNPKMg+300g E.F.B	2.05	1.60	1.66	1.77	2.18	1.94	1.53	1.88
T5 = 28gNPKMg+0g E.F.B	0.80	0.76	1.11	0.89	0.70	0.83	1.10	0.87
T6 = 28gNPKMg+100g E.F.B	1.45	1.49	1.65	1.53	1.61	1.56	1.78	1.65
T7 = 28gNPKMg+200g E.F.B	1.85	1.54	1.45	1.61	1.79	1.90	1.56	1.75
T8 = 28gNPKMg+300g E.F.B	1.84	1.83	1.60	1.76	1.97	1.84	1.76	1.85
T9 = 42gNPKMg+0g E.F.B	0.79	0.75	0.98	0.84	0.60	0.97	0.88	0.79
T10=42gNPKMg+100g E.F.B	1.15	1.25	1.54	1.31	1.34	1.58	1.66	1.52
T11=42gNPKMg+200g E.F.B	1.86	1.62	1.18	1.55	1.95	2.01	1.28	1.75
T12=42gNPKMg+300g E.F.B	1.54	1.90	1.79	1.74	1.82	1.95	1.69	1.82
Mean	1.42	1.43	1.36		1.52	1.54	1.45	
F- L.S.D 0.05		0.32					0.16	

EFB composted empty oil palm fruit bunch

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