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Evaluation of Co-compost of Oil Palm Empty Fruit Bunch and Cow Dung as Fertilizer in Oil Palm Nurseries

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Abstract · Oil palm empty fruit bunch (EFB) is one of the readily available crop residues that can serve as cheap organic fertilizer source for crop. EFB-cow dung composts (EFB: cow dung ratios of 100:0, 80:20, 60:40, and 0:100) pre-treated by soaking in water, unsoaked and sole cow dung (all on dry weight basis) were incubated in an Alfisol under laboratory conditions for 10 months. These treatments were also used to raise oil palm seedlings in the nursery. Nutrient release pattern of unsoaked EFB: cow dung (60:40) was significantly ($p<0.05$) better than other EFB compost treatments. Correlation coefficient (r) between phosphorus released and ECEC with time of incubation were 1.00 and 0.98 ($p<0.01$) respectively. Unsoaked EFB cow dung (60:40) was as effective as mineral NPKMg fertilizer in enhancing plant dry matter accumulation and nutrient uptake.

Keywords · Oil palm · Incubation · Organic fertilizers

Evaluation du Fumier de Régimes Sans Fruit de l'Huile de Palme et de la Bouse comme Fertilisant dans les Pépinières de l'Huile de Palme · Résumé · *Le Régime Sans Fruit (RSF) de l'huile de palme est une des plantes résiduelles très disponibles qui peuvent servir de source du fertilisant organique a moindre cout. Les fumiers de RSF-bouse (taux RSF : bouse de 100 :0, 60 :40, et 0 :100) traités au préalable par un trempage dans l'eau, sans trempage, et finalement seule la bouse (en poids net) ont été incubés dans l'Alfisol dans les conditions de laboratoires pour 10 mois. Ces traitements ont été utilises pour élever l'huile de palme dans les pépinières. Le relai de nutritifs du fumier sans trempage RSF : bouse (60 :40) était significativement mieux qu'autres fumiers RSF de traitements (p<0.05). Le coefficient de corrélation (r) entre le phosphore produit et l'ECEC avec le temps d'incubation étaient de 1.00 et 0.98 (p<0.01) respectivement. Le taux du fumier RSF sans trempage : bouse (60 :40) était aussi effectif que le fertilisant minéral N-P-K-Mg en renforçant l'accumulation de matières sèches dans la plante et la valeur nutritive.* ***Mots Clé ·*** *Huile de Palme · Incubation · Fertilisants organiques*

Introduction

Inorganic fertilizers are becoming too expensive for majority of farmers in many parts of the tropics. This situation has triggered the problems of insufficient fertilization and soil nutrient mining in many farms owned by poor resource farmers. Production in many farms has been on the decline due to the inability of the agricultural soils to meet up with crops' demand for essential nutrients. The desire of the Government of many countries is to revitalize agricultural productivity

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of their countries. Nigerian government for example believes that once again, major foreign income would be earned through agriculture in the future. For this target to be realised, agricultural production should be backed up with provision of cheap and readily available fertilizers to sustain crop production.

Oil palm (*Elaeis guineensis* L Jacq.) is one of the crops of national economic importance in Nigeria (AdeOluwa and Adeoye, 2008). This plant is reported the most productive oil producing plant in the world, with one hectare of oil palm producing between 10 and 35 tonnes of fresh fruit bunch (FFB) per year (von Uexkull, 1992). The crop produces an average of about 6 t oil ha^{-1} yr^{-1} (Mutert and Fairhurst, 1999). Though, fossil and historical evidence suggested that Africa, probably, West Africa is the original home of the oil palm (Gray, 1969), this crop is fast being identified with Malaysia (Kajisa *et al*., 1997), due to better environmental conditions for oil palm in that part of the world. Although the crop takes a long time to manifest responses to fertilizers as well as other agronomic treatments, it shows good responses at the early growth stage (Hartley, 1988).

There is a need to explore soil fertility opportunities derivable from nutrient recycling through incorporation of plant residues to the soil and use less of mineral fertilizers. It has been discovered that N sources of fertilizers (urea and ammonium sulphate) mostly used in the tropics result to an increase in yield for some years but in the long run could lead to decreasing base saturation, acidification, thus reducing the soil fertility (Phicot *et al*, 1981). One of the major degradable wastes of oil palm plantations is oil palm empty fruit bunch (EFB). Oil palm EFB is the remnant of the harvested ripe female inflorescence with the fruits removed for oil extraction. EFB is a suitable raw material for recycling because it is produced in large quantities in localized areas. In the past, it was often used as fuel to generate steam at the mills, but now, open burning is becoming more prohibited globally to prevent air pollution (Ma *et al.* 1993). The ash, with a potassium content of about 30%, (Zaharah and Lim, 2000) was used as fertilizer. The EFB is now used mainly as mulch (Hamdan *et al.* 1998). Placed around young palms, EFB helps to control weeds, prevent erosion and maintain soil moisture. However, due to the current labour shortage, the transportation and distribution of EFB in the field is getting more expensive. There is a growing interest in composting EFB, in order to add to its value, and also to reduce the volume; making application easier (Yusri *et al*. 1995, Thambirajah *et al*. 1995; Danmanhuri 1998). Aisueni and Omoti (1999) reported that oil palm industry is one of the best sources of agricultural wastes that can be used as organic fertilizers. According to the authors, the palm industry in Nigeria produces 40 million metric tonnes FFB (fresh fruit bunch) annually, of which about 16 million tonnes of empty bunch refuse can be composted into organic fertilizer. Though oil palm EFB is very fibrous and not easily *compostable*, cow dung could be used to improve its *compost ability*. This research effort was directed at studying the rates of release of nutrients by different EFB compost treatments as affected by time, their influence on soil pH and nutrient uptake by oil palm seedlings.

Methodology

Experimental Site

Incubation and planting were carried out in the Department of Agronomy, University of Ibadan, Ibadan, Nigeria (located approximately between latitudes 3^0 48′ and 4^0 0′ E and longitude 7^0 25′ and 7^0 30′ E) between February 2001 and November 2003. The experimental soil can be regarded as being poor in fertility (especially for oil palm production) due to its low content of macro nutrients (Table 2). The soil was rain washed and originally meant to produce a “sand culture” that can easily allow the manifestation of plants’ responses to applied fertilizer treatments. The soil was passed through 2 mm sieve. The total N content (0.1 g kg^{-1}) was very low (Sobulo *et al*, 1975, Fed. Min. of Agric. and Nat. Res., 1989). The Mechlich’s III available soil P content (14 mg kg^{-1}) is on a medium level for soils of South-western Nigeria (Agboola and Corey, 1972; Agboola and Obigbesan, 1974). Also, the extractable K (Mechlich III) was low (Fed. Min. of Agric. and Nat.

Res., 1989). The neutral pH of the soil was within a safe range for most crops (Helyar *et al.,* 1990), though oil palm is tolerant to low pH soils (Hartley, 1988; von Uexkull, 1992).

Compost Treatments
The following were used as fertilizer treatments;

1. Control (no application)
2. 100% unsoaked oil palm empty fruit bunch (UEFB)
3. 80 % UEFB+ 20 % cow dung
4. 60 % UEFB + 40 % cow dung
5. 100% soaked oil palm empty fruit bunch (SEFB)
6. 80 % SEFB + 20 % cow dung
7. 60 % SEFB + 40 % cow dung
8. Cow dung
9. Mineral fertilizer (N:P:K:Mg - 12:12:17:2)

EFB and cow dung ratios were based on dry constant weight in oven at 70^0c. The composts were milled to pass through 2mm sieve before applying to the soils of the treatments.

Laboratory Incubation Study
The study was conducted as a laboratory-based work using the method described by Wieder and Lang (1982). The compost treatments listed above were applied to soil at the rate of 20 t ha^{-1} (i.e. 0.8 g compost per plastic cup with 40 g soil each) and incubated for a period of 10 months to mimic the behaviour of the treatments in experimental soils. The cups with soils were placed in an incubation chamber, covered and kept at field capacity throughout the experimental period of 10 months. Average temperature during incubation was 29 ^{0}C. Treatments were terminated at 3, 6 and 10 months interval for analysis of the released essential nutrients and the soils pH.

Oil palm Nursery
'Tenera' oil palm germinated seeds from Nigerian Institute for Oil Palm Research (NIFOR) were planted in black polythene bags. The number of treatments was 9, replicated three times, hence a total of 27 samples, arranged in a randomised complete block design. The volume of the soil was 5 kg per bag and the plants were exposed to prevailing environmental factors like rain and erosion. All the compost treatments and urea (mineral fertilizer) treatments were applied at the on-set of the pre-nursery stage (0 – 3 months old) of the seedlings. Only mineral N-P-K-Mg: 12-12-17-2 compound fertilizer treatment at a rate of 14g per plant (NIFOR, 1972; NIFOR 1973; Onwubuya, 1982) was applied twice (2nd and 8th months) in the observed nursery period. Plants were watered regularly to field capacity and manual weeding was done when due. Physical-chemical analyses

The physical and chemical analysis of the experimental soils was carried out before the treatments were added to the soils to determine the nutrient status of the soils. The soil was air-dried and sieved using a 2mm sieve. Particle size distribution was determined by hydrometer method (Bouyoucus, 1962). Soils pH was determined using 1: 1.25 soil: $CaCl_2$ solution with pH meter. Plants were digested using the dry ash method. Nitrogen was determined by Dumas method (Simonne *et al*, 1995). Mehlich's III method (Mehlich, 1984) was used to extract phosphorus, potassium, calcium, magnesium, copper, zinc, iron and manganese. The P concentration was determined using a spectrophotometer with vanadium-molybdate solution as the indicator. Potassium and calcium were measured with a Flame-Photometer, magnesium, copper; zinc, iron and manganese were measured with an Atomic-Absorption Spectrophotometer. Statistical analysis

Correlations of nutrient concentrations released with time and corresponding pH values were carried out with the aid of Microsoft Excel 2000. Level of significance of the correlation values was done with the aid of correlation table and means of nutrient uptake were separated with Duncan Multiple Range Test (DMRT) and standard error at 5% probability level.

Table 1: Nutrients Composition of Compost Treatments on Dry Matter Basis

Nutrients	Compost materials						
	100 % UEFB	80% UEFB + 20% cow dung	60% UEFB + 40% cow dung	100% SEFB	80% SEFB + 20% cow dung	60% SEFB + 40% cow dung	Cow dung
$g\ kg^{-1}$							
N	8.70	11.30	11.90	11.40	12.80	15.00	26.80
C	451.50	420.00	444.50	433.00	457.00	437.50	303.00
C:N	519.00	371.70	378.90	381.90	360.60	304.50	113.30
P	0.90	1.00	1.10	0.60	0.60	1.30	3.20
K	10.80	11.70	11.90	6.60	6.30	11.00	37.70
Ca	3.20	4.30	4.70	4.00	2.70	4.40	15.60
Mg	3.40	3.50	4.00	3.40	2.30	3.70	9.40
S	1.70	2.00	2.10	2.00	1.20	2.10	4.80
$mg\ kg^{-1}$							
Zn	84	64	99	71	72	85	135
Cu	21	18	19	14	13	18	24
Mn	152	132	144	157	105	153	365
Fe	618	471	650	668	551	644	2847

UEFB is unsoaked empty fruit bunch and SEFB is the soaked empty fruit bunch

Table 2: Physicochemical Properties of Experimental Soil

Parameters	Value
pH ($CaCl_2$)	7.00
Org. C ($g\ kg^{-1}$)	4.80
Total N ($g\ kg^{-1}$)	0.20
P ($mg\ kg^{-1}$)	14
Exchangeable bases (c mol kg^{-1})	
K	0.1
Mg	0.2
Ca	1.1
CEC	1.6
Extractable micronutrients (mg kg^{-1})	
Mn	41
Fe	55
Cu	1
Zn	8
Mechanical composition (g kg^{-1})	
Sand	930
Silt	50
Clay	20
Textural Class	Sand

Results and Discussion

The summary of results of the quantities of nutrients released due to the compost treatments used is shown in Table 3. During the 10 months incubation period, relationship between the amount of N released and incubation period was least ($r = 0.07$) with the control and best ($r = 0.90$) with unsoaked EFB/ cow dung combination at 60: 40 ratio (Table 4). The amount of phosphorus released with time was least in the 100% unsoaked empty fruit bunch treatment ($r = 0.12$) and highest ($r = 1.00$) with the unsoaked EFB: cow dung – 60: 40%. Quantity of potassium released with time was lowest ($r = 0.17$) with the 100% soaked oil palm empty fruit bunch and highest ($r = 1.00$) with the soaked EFB/ cow dung treatment at the ratio of 60: 40 as well as the cow dung treatment. The quantity of calcium released with time was least ($r = 0.04$) with the 100% oil palm empty fruit bunch and highest ($r = 1.00$) with the unsoaked EFB/ cow dung at the ratio of 80: 20 treatments. The relationship between amount of magnesium released with the period of incubation was least (r = 0.12) with 100% soaked empty fruit bunch and highest (r = 1.00) with both soaked EFB/ cow dung (ratio 60: 40) and the cow dung treatments. The relationship of quantities of manganese released with period of incubation was least (r = 0.04) in 100% soaked empty fruit bunch and highest (r = 1.00) in soaked EFB: cow dung (80: 20) treated soils respectively. The lowest relationship (r = 0.19) of Zinc released with time was recorded in the 100% unsoaked empty fruit bunch and highest (r = 1.00) in cow dung treated soils. The quantity of iron released with time was least (r = 0.22) in the cow dung and highest (r = 0.99) in unsoaked EFB: cow dung (80: 20) and both soaked and unsoaked EFB: cow dung (60: 40) treatments respectively.

The relationship between N released and soil pH changes within the time of incubation was least (r = 0.52) in control (no additive) and highest (r = 1.00) in unsoaked EFB: cow dung (80: 20) soils respectively. In the case of P, the least relationship (r = 0.26) resulted from the unsoaked EFB: cow dung (60: 40) soil and highest (r = 1.00) in the 100% soaked EFB treated soils. The relationship between K released and soil pH changes within the time of incubation was least (r = 0.17) in unsoaked EFB: cow dung (80: 20) and highest (r = 0.96) in soaked EFB: cow dung (60: 40) soils. The relationship was lowest (r = -0.56) in Ca with cow dung treated soil and highest (1.00) in soaked EFB: cow dung (60: 40) treated soil. This relationship with respect to Mg was lowest (r = 0.02) in the control soil and highest (r = 0.94) in soaked EFB: cow dung (60: 40) soil. The relationship between Mn released and soil pH changes within the time of incubation was lowest (r = -0.06) in unsoaked EFB: cow dung (60: 40) and highest (r = 0.99) in both 100% unsoaked EFB and cow dung soils respectively. The relationship was lowest (r = -0.11) in Zn with control and highest (r = 0.19) in 100% soaked EFB soils respectively. In term of Fe released with time and soil pH changes, the relationship was least (r = 0.36) in soaked EFB: cow dung (80: 20) and highest (r = 0.98) in the both soaked and unsoaked EFB: cow dung (60: 40) treated soils respectively. These results are shown on Table 5.

Though was no significant ($p<0.05$) difference in the total dry weights of plants in all the oil palm empty fruit bunch treatments (Figure 1), but the unsoaked EFB: cow dung – 60: 40% compost treatment performed significantly better than the control treatment. Nutrients uptake in soil by the oil palm seedlings was not regular in pattern (Table 6). The highest mean uptake of Nitrogen was in the mineral fertilizer treatment (0.28 g $plant^{-1}$). Least N uptake was with soaked EFB: cow dung (80: 20) cow compost treatment. There was no significant difference in the P uptake by the plants in all the treatments, but ranged between 0.01 and 0.03 g $plant^{-1}$. The mean uptake of potassium by the plants was least (0.16 g $plant^{-1}$) in the control treatment and highest (0.31 g $plant^{-1}$) in unsoaked EFB: cow dung – 60: 40% compost treatment. Mean uptake of calcium (0.06 g $plant^{-1}$) was lowest in soaked EFB: cow dung (80: 20) compost treatment and highest (0.14 g $plant^{-1}$) in unsoaked EFB: cow dung (60: 40) compost treatment. In magnesium, mean uptake was least (0.02 g $plant^{-1}$) in soaked EFB: cow dung (80: 20) compost treatment and highest (0.07 g $plant^{-1}$) in unsoaked EFB: cow dung (60: 40) compost treatment. The least (0.01 g $plant^{-1}$) mean uptake of sulphur was recorded in soaked EFB: cow dung – 80: 20% and 60: 40% compost treatments and highest in the mineral, 100% unsoaked and unsoaked EFB: cow dung (60: 40) treatments. Marginal leaf necrosis, typical of manganese toxicity (Hochmuth *et al.,* 2004) was observed in the plants treated with cow dung. These plants died shortly after 3 months in the nursery.

Table 3: Release of Nutrient Element from Soils Treated to Different Treatments of Oil Palm Empty Fruit Bunch Composts in Soil during Laboratory Incubation

Treatments	Months of incubation	pH	TN	Av. P	K	Ca	Mg	ECEC	Mn	Zn	Cu	Fe
		$CaCl_2$	g kg^{-1}	mg kg^{-1}	c mol kg^{-1} soil				mg kg^{-1}			
Initial soil	0	7.0	0.2	14	0.1	1.1	0.2	16	41	8	1	55
Control (no additive)	3	7.3	0.1	34	0.1	1.6	0.2	24	27	10	1	47
100% UEFB	3	7.0	0.3	29	0.5	1.8	0.6	26	73	10	1	116
80% UEFB + 20% cow dung	3	7.0	0.4	45	0.8	2.2	0.9	43	83	12	1	151
60% UEFB + 40% cow dung	3	6.8	0.3	42	0.9	1.8	0.7	40	42	10	1	56
100% SEFB	3	7.1	0.3	33	0.5	2.3	0.8	40	74	15	1	121
80% SEFB + 20% cow dung	3	6.8	0.3	36	0.5	2.0	0.8	43	43	15	1	50
60% SEFB + 40% cow dung	3	7.0	0.4	57	0.8	2.4	0.9	36	71	12	1	99
Cow dung	3	7.1	0.4	130	1.6	2.3	0.8	73	29	7	1	43
Control (no additive)	6	7.1	0.1	27	0.1	1.7	0.3	32	40	31	1	40
100% UEFB	6	6.7	0.3	41	0.8	2.3	0.8	43	41	15	1	55
80% UEFB + 20% cow dung	6	6.7	0.3	42	0.9	1.9	0.9	47	64	13	1	113
60% UEFB + 40% cow dung	6	6.6	0.3	48	1.0	1.9	0.8	42	34	10	1	48
100% SEFB	6	6.8	0.4	28	0.5	1.9	0.6	38	49	10	1	78
80% SEFB + 20% cow dung	6	6.8	0.5	29	0.4	1.9	0.6	35	64	9	1	143
60% SEFB + 40% cow dung	6	6.7	0.3	55	0.7	2.2	0.8	44	48	12	1	76
Cow dung	6	7.0	0.3	155	1.8	3.0	1.0	65	63	10	1	63
Control (no additive)	10	7.2	0.2	28	0.1	1.6	0.3	24	28	8	1	42
100% UEFB	10	6.8	0.2	28	0.6	1.9	0.7	34	43	9	1	43
80% UEFB + 20% cow dung	10	6.7	0.3	30	0.7	1.6	0.7	39	30	8	1	30
60% UEFB + 40% cow dung	10	6.9	0.5	57	0.8	1.7	0.7	43	28	7	1	28
100% SEFB	10	6.8	0.3	29	0.5	2.3	0.8	36	73	11	1	94
80% SEFB + 20% cow dung	10	6.7	0.4	50	0.5	2.3	0.8	40	35	16	1	50
60% SEFB + 40% cow dung	10	6.6	0.3	42	0.6	2.0	0.6	35	57	11	1	57
Cow dung	10	7.1	0.4	205	2.0	3.6	1.3	61	49	15	1	49

Table 4: Coefficients of Correlation Relating Nutrient Concentrations with Time of Nutrient Release by Different Treatments of Oil Palm Empty Fruit Bunch (EFB) Composts in Soils after 10 Months of Incubation

Treatments	N	P	K	Ca	Mg	ECEC	Mn	Zn	$Cu	Fe
	(mg kg^{-1})	(mg kg^{-1})	(c mol kg^{-1})					(mg kg^{-1})		
Control	0.07	0.54	0.63	0.71	0.91	0.56	-0.45	0.20	-	-0.84
100% UEFB§	-0.90	-0.12	0.43	0.06	0.34	0.43	-0.80	-0.19	-	-0.90
80% UEFB + 20% cow dung	-0.82	-0.97*	-0.70	-1.00**	-0.91	-0.54	-1.00**	-0.79	-	-0.99**
60% UEFB + 40% cow dung	0.90	1.00**	-0.55	-0.44	-0.59	0.98*	-0.99**	-0.91	-	-0.99**
100% SEFB§	-0.08	-0.74	0.17	0.04	0.12	-0.97*	0.04	-0.73	-	-0.54
80% SEFB + 20% cow dung	0.43	0.71	0.22	0.75	-0.29	-0.23	-0.32	0.17	-	-0.09
60% SEFB + 40% cow dung	-0.82	-0.95*	-1.00**	-0.97*	-1.00**	-0.13	-0.56	-0.90	-	-0.99**
Cow dung	0.08	0.99**	1.00**	0.99**	1.00**	-0.95*	0.52	1.00**	-	0.22

$ Concentration remained <1 mg kg^{-1} all through the incubation period.
§ UEFB=unsoaked EFB, SEFB=soaked EFB
*significant, P=0.05; ** highly significant, P=0.01

Table 5: Coefficients of Correlation Relating Nutrient Concentrations with pH of different Treatments of Oil Palm Empty Fruit Bunch (EFB) Composts in Soils after 10 Months of Incubation

Treatments	N	P	K	Ca	Mg	ECEC	Mn	Zn	Cu	Fe
	($g\ kg^{-1}$)	($mg\ kg^{-1}$)	($c\ mol\ kg^{-1}$)				($mg\ kg^{-1}$)			
Control	-0.52	0.96*	0.82	0.76	0.02	0.43	-0.90	-0.11	-0.54	0.48
100% UEFB§	0.31	-0.63	-0.95*	-0.77	-0.92	-0.95*	0.99**	-0.58	-0.47	0.94
80% UEFB + 20% cow dung	1.00**	0.65	0.17	0.85	0.52	-0.04	0.78	0.30	0.86	0.74
60% UEFB + 40% cow dung	0.62	0.26	-0.94	-0.97*	-0.92	0.03	-0.06	0.61	-0.76	-0.37
100% SEFB§	-0.55	1.00**	0.47	0.58	0.51	0.91	0.58	1.00**	0.85	0.94
80% SEFB + 20% cow dung	-0.16	-0.88	-0.48	-0.91	0.01	-0.06	0.57	-0.44	-0.79	0.36
60% SEFB + 40% cow dung	0.96*	0.79	0.96*	1.00**	0.94	-0.20	0.80	0.90	0.29	0.98**
Cow dung	0.87	-0.33	-0.43	-0.56	-0.34	0.68	-0.99**	0.35	-0.77	-0.98*

§ UEFB=unsoaked EFB, SEFB=soaked EFB
*significant, P=0.05; ** highly significant, P=0.01

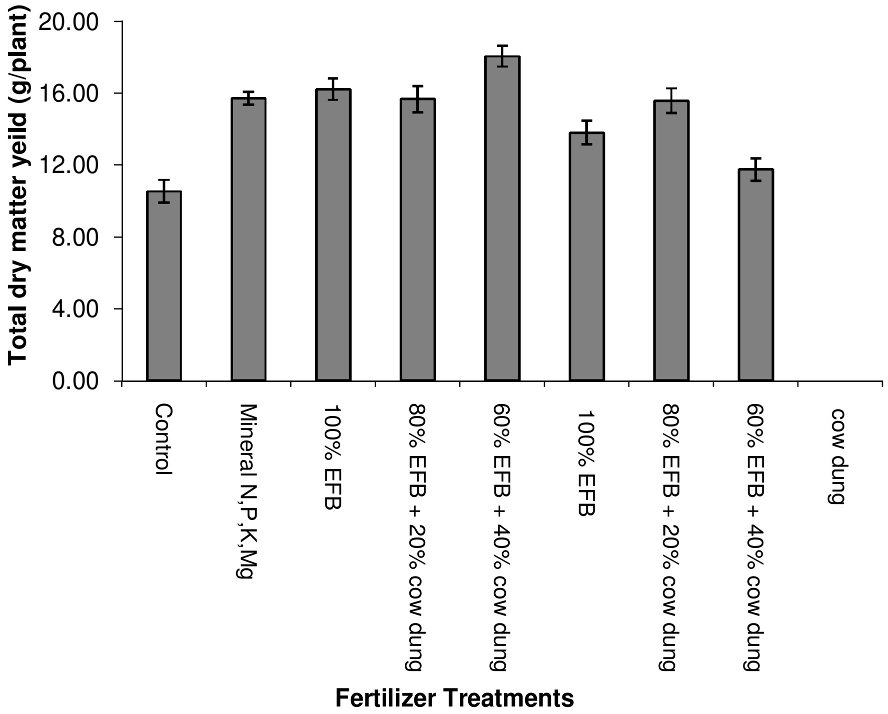

Figure 1: Effect of Oil Palm Empty Fruit Bunch (EFB) Compost on Oil Palm Dry Matter Yield at 10 Months in Nursery
Note: Bars indicate standard error ($p<0.05$)

Table 6: Effect of Oil Palm Empty Fruit Bunch (EFB) Treatments on Nutrient Uptake of Oil Palm after 10 Months of Growth in Nursery

Nutrients	Compost treatments								
	Control	Mineral fertilizer (NPKMg)	100 % UEFB	80% UEFB + 20% cow dung	60% UEFB + 40% cow dung	100% SEFB	80% SEFB + 20% cow dung	60% SEFB + 40% cow dung	Cow dung
g plant^{-1}									
N	0.13ns	0.28 ns	0.19 ns	0.18 ns	0.22 ns	0.17 ns	0.12 ns	0.15 ns	-
P	0.02bc	0.03a	0.02ab	0.03 a	0.03 a	0.03 a	0.01 a	0.02ab	-
K	0.16 a	0.24 a	0.29 a	0.22a	0.31 a	0.22 a	0.17 a	0.21a	-
Ca	0.07 b	0.08 ab	0.10 ab	0.10 ab	0.14 a	0.11 ab	0.06 ab	0.08 ab	-
Mg	0.03 bc	0.04 abc	0.05abc	0.06 ab	0.07 a	0.05 abc	0.02 abc	0.05 ab	-
S	0.02 ab	0.03 a	0.03 ab	0.02 ab	0.03 a	0.02ab	0.01 ab	0.01 b	-
mg plant^{-1}									
Zn	0.33bcd	0.87a	0.6ab	0.50bc	0.53abc	0.37bc	0.47bc	0.37bc	-
Cu	0.03bc	0.04ab	0.05ab	0.05ab	0.05ab	0.04b	0.05ab	0.04bc	-
Mn	3.31bc	18.92a	4.07b	3.38b	4.18b	2.90bc	3.10bc	2.48bc	-
Fe	16.67cde	40.00a	36.67ab	26.67abcd	33.33abc	23.33adcd	33.33abc	20.00bcd	-

Means with same letters in the rows are not significantly different (p<0.05) using DMRT
ns = means not significant at p< 0.05
¢ Plants died shortly after 3 months in the nursery

Nutrient Release Pattern of Different Treatments of Oil Palm Empty Fruit Bunch in Soil

Result of the correlation of amount of nutrients released (from the soil treated to the various composts) with time and pH are shown in Tables 4 and 5 respectively. The high significant correlation ($p<0.01$) in respect of available P released and time recorded in unsoaked EFB: cow dung 60:40 and cow dung treated soils indicates the constant rate of P mineralization by these treatments over the others. Generally, P fixation is influenced by pH value but since these two treatments had no significant correlation between P released and pH value, it can be concluded that they were better P sources than other than treatments used in this experiment.

The highly significant ($p<0.01$) negative correlation of extractable potassium released with time by the soaked EFB: cow dung 60:40 implies that K produced by this treatments was fixed by either clay or organic contents of the soil with time (Ogunremi, 1977; Adeoye, 1986) or there was a very high release in the early part and then a decrease with time. Also, this particular treatment of EFB compost revealed a significant positive correlation between K and pH ($p<0.01$). This means K released in this compost treated soil was pH dependent. Though Mengel and Kirkby (2001) reported that higher pH leads to increasing availability of basic cations like K, Ca and Mg, but the reality in most oil palm soils is reduction in pH with time. This means that soaked EFB: cow dung 60:40 having lower K content (Table 1) might not be a good source of K in this soil. Release pattern of extractable calcium and magnesium by the applied treatments was similar to that observed in K.

The high negative correlation ($p<0.001$) of manganese and iron released with time by unsoaked EFB: cow dung 80:20% and 60:40 composts is an indication that their Mn and Fe were probably chelated with time by the soil organic matter. This could be a good characteristic of these composts considering the susceptibility of oil palm soils under low pH (below 5.0) condition to Mn toxicity (Hartley, 1988; von Uexkull, 1992). The concentration of Cu in the soil did not vary within the 10-month period of this experiment (as shown in Table 2). This indicated that applied treatments did not improve extractable Cu concentration in the soil, which might be a result of low Cu concentration in the applied composts, as shown in Table 4. The marginal change in Cu concentration in leaves of oil palm nursery at 10 months resulting from the application of these treatments as shown in Table 6 is in support of the report by von Uexkull (1992) that Cu deficiency is common in highly leached sandy soils in high rainfall areas.

Nutrient uptake by oil palm in the nursery

Dry matter accumulation was better in the unsoaked EFB: cow dung 60:40 compost treatment than other treatments, Also, nutrient uptake of plants under this treatment was comparable to those under mineral fertilizer treatment (except in manganese). Again, this could be as a result of better nutrient release pattern of this EFB treatment among other EFB treatments under the prevailing environmental condition during the planting period. This is a good indication that the unsoaked EFB: cow dung 60: 40 compost performed better than other treatments used in this experiment.

Conclusion

Plant essential nutrients' release pattern of 40% inclusion of cow dung in unsoaked EFB compost seems to be better than those of the other EFB composts used in this investigation. This organic treatment could then be suggested as a cheaper source to fertilize oil palm soils, especially when the plant is in the nursery. Since oil palm EFB is readily available in oil palm plantations, this compost will be a good alternative to the conventional mineral fertilizer commonly used to grow oil palms. Thus, the use of 40% inclusion of cow dung in unsoaked EFB compost will go a long way to avoid the problem of unavailability and high costs associated with mineral fertilizers in the production of the crop.

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