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RESEARCH ARTICLE

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THE USE OF MICROBE PLUS TO IMPROVE PHOSPHORUS AVAILABILITY FROM ROCK PHOSPHATE UNDER OIL PALM (*Elaesis guineensis,* Jacq.) NURSERY

***[1]Oppong, E., [1]Opoku, A., [1]Ewusi-Mensah, N., [2]Danso, F., [1]Tuffour, H. O. and [1]Abubakari, A.**

[1]Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[2]Council for scientific and Industrial Research (CSIR)-Oil Palm Research Institute (OPRI), Kusi-Kade, Ghana

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****Corresponding author: Oppong, E.,***
Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

ABSTRACT

The need to improve phosphorus availability from rock phosphate with readily available product is of prime importance in crop production. The overall objective of the research was to improve P availability from RP using MP and the subsequent effect on biomass nutrient concentration and P uptake. The research was conducted at OPRI of Ghana, Kade-Kusi in the semi-deciduous zone of the country. Soil available P, seedlings frond nutrient content and P uptake was evaluated on oil palm seedlings at the nursery. The study was a 4 × 4 factorial experiment arranged in RCBD with 3 replications. P fertilizers; Po, TSP, SRP, TRP and Microbe Plus at rates of 0, 50, 100, 150 % were applied. Data obtained were subjected to analysis of variance (ANOVA) using Genstat statistical package (12.1 ed.). The results showed significant ($p<0.05$) influence of the applied inputs on the parameters determined. TSPMP150 and TSPMP100 complementary applications produced the highest soil available P and P uptake in seedling fronds by 285 and 161 % significant ($p<0.05$) increase over the control respectively at 10 MAT. Deficient K and Ca contents in frond biomass were recorded at the end of the trial. Field experiments are therefore recommended to validate the effects of MP and the P fertilizers on soil microbial dynamics and seedlings growth performance.

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INTRODUCTION

Phosphorus has been found to be a major limiting factor in crop production with an average consumption of about 1.5 kg of P_2O_5 per hectare (IAEA, 2002). The efficiency of P fertilizers throughout the world is around 10 – 25 % (Isherword, 1998), and concentration of bioavailable P in the soil is very low reaching the level of 1.0 mg kg^{-1} (Goldstein, 1994). Soil P dynamics is characterized by physicochemical (sorption – desorption) and biological (immobilization – mineralization) processes. Large amount of P applied as fertilizer enters into the immobile pools through precipitation reaction with highly reactive Al^{3+} and Fe^{3+} in acidic, and Ca^{2+} in calcareous or normal soils (Gyaneshwar *et al*., 2002; Hao *et al*., 2002). As stated by Grimme and Hardter (1991), Al toxicity is widespread in the humid tropics where soils are acidic and highly weathered which reduces root growth and formation in young palms, but can be corrected by RP application. To Asomaning *et al*. (2006), the usefulness of these RP's to farmers will depend on their dissolution patterns and availability of the released P.

The search for alternative ways to enhancing the breakdown of RP to plant-available P forms has resulted in several modification techniques. Numerous studies have been conducted amending RP's to increase their immediate phosphorus availability and also to enhance their rate of dissolution after application to soil (Akande *et al*., 2003; Akande *et al*., 2005). Inorganic forms of P are solubilized by a group of heterotrophic microorganisms excreting organic acids that dissolve phosphatic minerals and/or chelate cationic partners of the P ion (PO_4^{3-}) directly, releasing P into solution (He *et al*., 2002). Richardson (2001) reported that soil microorganisms play a key role in soil P dynamics and subsequent availability of phosphate to plants. Inference made by Khan *et al*. (2009) also suggested that PSB inoculants/biofertilizers hold great prospects for sustaining crop production with optimized P fertilization. Identifying and using such products which save farmers time and resources from the costly RP modification techniques is of prime importance. Microbe plus, a fusion of biological and conventional NPK fertilizers with compressive suit of bacteria and fungi on the Ghanaian market was identified. The study was therefore aimed at improving P availability from RP using MP and the subsequent effect on biomass nutrient concentration and P uptake.

MATERIALS AND METHODS

Experimental site: The experiment was carried out at the Agronomy Nursery of Oil Palm Research Institute, Ghana (OPRI), Kade–Kusi, in the Eastern Region (latitude 0.6^{o} 00' N and longitude 0.01^{o} 45' W). The area falls within the semi deciduous forest zone and is characterized by bi-modal rainfall with mean annual rainfall of 1600 mm. Day temperatures range from a mean minimum of 20 ^{o}C to a mean maximum of 31 ^{o}C with relative humidity ranging from 95 % in the rainy season to 40 % in the dry season.

Experimental design and treatments

The experiment was a 4 × 4 factorial arrangement in Randomized Complete Block Design with three replicates. Each treatment had 20 seedlings planted in a 70 × 70 × 70 cm triangular planting design. The treatments were 4 levels of phosphorus and 4 levels of microbe plus as follows:

- Phosphorus sources were: No P fertilizer (Po), Triple superphosphate (TSP), Togo Rock Phosphate (TRP), and Senegal Rock Phosphate (SRP)
- Microbe Plus (MP) rates were: Zero % MP ($MP_{\mathbf{0}}$), 50 % MP ($MP_{\mathbf{50}}$), 100 % ($MP_{\mathbf{100}}$) and 150 % MP ($MP_{\mathbf{150}}$)

All plants received a basal dressing of 6 g Urea (N) and 6 g Muriate of Potash (MOP) mixture/palm/month.

Pre-nursery: Mini polybags of dimensions 10 × 19 cm were filled with top soil. The soil used was Ferric PlinthicAcrisol (FAO, 1990). The lower third of the bags were perforated to enhance drainage of excess water. Germinated oil palm seed nuts of Dura × Pisifera (D × P) were sown singly in the black polybags for four months.

Main nursery: Maxi polybags of dimension 35 × 45 cm were filled with 10 kg topsoil and arranged in triangular planting design of distance 70 × 70× 70 cm. Pre-nursery seedlings at four month were transplanted into each of the maxi polybags and mulched with palm kernel shells.

Agronomic Practices: Watering of seedlings was done as and when necessary using the drip irrigation system after 3 days of no rain. Fertilizers were applied monthly as specified in the various treatments (table 1). Weeding (hoeing in-between polybags and hand picking within the polybags) was carried out manually as and when necessary. Prophylactic fungicide (diathane) and insecticide (actellic) were sprayed every two weeks and monthly respectively when necessary in controlling pest and diseases. Data collection on soil was done 6 MAT, 8 MAT and 10 MAT.

Physico-Chemical properties of medium used: Soil samples for the physical and chemical analysis were air dried and passed through a 2 mm mesh sieve. Soil pH was determined using a HI 9017 microprocessor pH meter.

Table 1. Treatments description and application rates

Treatment	Amount applied/palm/month
T1	Absolute control (PoMPo)
T2	TSP was applied at 6 g/palm/month. The standard practice recommended by OPRI of CSIR, Ghana.
T3	*SRP was applied at 8.2 g/palm/month
T4	*TRP was applied at 7.5 g/palm/month.
T5	MP_{50}. 25 ml of MP was dissolved in 1 liter of water and 50 ml of the mixture was applied.
T6	$TSPMP_{50}$. 6 g of TSP and 50 ml ofMP_{50}
T7	$SRPMP_{50}$. 8.2 g of SRP and 50 mlofMP_{50}
T8	$TRPMP_{50}$. 7.5 g of TRP and 50 ml ofMP_{50}
T9	MP_{100}. 50 ml of MP was dissolved in 1 liter of water and 50 ml of the mixture was applied.
T10	$TSPMP_{100}$. 6 g of TSP and 50 ml ofMP_{100}
T11	$SRPMP_{100}$. 8.2 g of SRP and 50 mlof MP_{100}
T12	$TRPMP_{100}$. 7.5 g of TRP and 50 ml of MP_{100}
T13	MP_{150}. 75.5 ml of MP was dissolved in 1 liter of water and 50 ml of the mixture was applied.
T14	$TSPMP_{150}$. 6 g of TSP and 50 ml of MP_{150}
T15	$SRPMP_{150}$. 8.2 g of SRP and 50 mlMP_{150}
T16	$TRPMP_{150}$. 7.5 g of TRP and 50 mlof MP_{150}

*based on P_2O_5 content equivalent to TSP

Table 2. Initial physical and chemical properties of the soil used

Property	Value
pH (1:2.5, H_2O)	5.1
Organic carbon (%)	0.76
Total nitrogen (%)	0.08
Exchangeable cations ($cmol_c$/kg)	
Ca	1.87
Mg	0.53
K	0.17
Na	0.05
Exch. Acidity ($cmol_c$/kg)	0.45
Available P (mg/kg)	4.70
Sand (%)	46.76
Silt (%)	31.44
Clay (%)	21.80
Texture	Loam

The Walkley and Black procedure as modified by Nelson and Sommers (1982) was used to assess the organic C content in the soils. Total N was determined by Kjeldahl digestion method. The available P was extracted with a HCl:NH4F mixture method as described by Bray and Kurtz (1945) and determined colorimetrically using the molybdenum blue method at the wavelength of 636nm. Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined in 1.0 M ammonium acetate extract and exchangeable acidity (hydrogen and aluminium) was determined in 1.0 M KCl extract. The Effective Cation Exchange Capacity (ECEC) was calculated as the sum of exchangeable bases and exchangeable acidity (Table 2). Soil particle size was determined by using the hydrometer method (Bouyoucos, 1962). The P_2O_5content of the P fertilizers used for the trial was 46, 37 and 33.5 % for TSP, TRP and SRP respectively.

Parameters measured: Measurement was taken on soil available P, biomass nutrient concentration and Phosphorus uptake in biomass. Using an auger, random soil samples were taken at 6 MAT, 8 MAT and 10 MAT from the polybags, mixed together and a composite sample was taken for soil available P analysis. The readily acid-soluble forms of P were extracted with a $HCl:NH_4F$ mixture (Bray's No. 1 method) as described by Bray and Kurtz (1945) and Olsen and Sommers (1982). Phosphorus in the extract was determined on a spectrophotometer by the blue ammonium molybdate method with ascorbic acid as a reducing agent. Destructive sampling method was used to estimate the biomass nutrient concentration and P uptake. Five plants were sampled from each plot at the end of the experiment and each plant was divided into leaves, butt and roots. Dry weight of the fronds, butt and roots were recorded after oven drying at 70 ^oC to constant weight. Sub-samples of the leaves were milled to pass through 2 mm sieve. Nutrient concentrations (N, P, K, Mg and Ca) were then determined. Soil and plant nutrient analysis were determined in the laboratory of Soil Research Institute, Kwadaso – Kumasi.

Statistical analysis: All data obtained were subjected to analysis of variance (ANOVA) using Genstat statistical package (Genstat Discovery Edition, 12.1 ed) and separation of means was done by the use of least significant difference at $p < 0.05$.

RESULTS

Soil available phosphorus: The results showed that P fertilizers and microbe plus rates had significant ($p<0.05$) effect on P released into the soil (Table 3). The soil available P values recorded by TSP application increased steadily (156.5 – 180.4 mg kg^{-1}) from 6 to 10 MAT unlike the erratic available P values recorded by SRP and TRP. Available P of 180.4 mg kg^{-1} recorded by TSP at 10 MAT gave 85 % significant ($p<0.05$) increase over the Po, 11 % over SRP and 41 % over TRP. The magnitude of available P released upon microbe plus application fluctuated, however, MP_{100} treated medium significantly ($p<0.05$) recorded only 3 % increase over the MP_o at 10 MAT. The order of increasing P released into the soil was TSP > SRP > TRP > P_o for P fertilizers and MP_{100}>MP_o> MP_{50}> MP_{150} for microbe plus rates at 10 MAT. Notwithstanding, results presented in Table 4 showed that the combined application of P fertilizers and microbe plus rates significantly ($p<0.05$) had positive effect on P released into the soil. As presented, the conjoint application of TSP and microbe plus rates consistently increased P released into the soil throughout the sampling months contrary to the other combinations where fluctuated P values were observed. The highest available P of 180.9 mg kg^{-1} recorded by $TSPMP_{150}$ gave 285 % significant ($p<0.05$) increase over the control at 10 MAT. The best positive combination in terms of P release into the soil was TSP and microbe plus rates, whereas TRP and microbe plus rates combined recorded the lowest P released into the soil. Generally, there was a consistent decrease in available P recorded in the control from 6 to 10 MAT (Table 4).

Table 3. Effect of P fertilizers and microbe plus rates on soil available P

	Available P (mg/kg)		
P fertilizers	6 MAT	8 MAT	10 MAT
Po	55.83	81.65	97.53
TSP	156.48	173.98	180.36
SRP	156.37	113.12	161.34
TRP	149.59	61.13	107.25
Pr	<.001	<.001	<.001
Lsd (0.05)	1.201	1.044	1.116
Microbe plus			
MP_0	142.39	120.60	138.56
MP_{50}	138.50	96.80	136.45
MP_{100}	125.71	101.65	142.55
MP_{150}	167.49	110.82	128.92
Pr	<.001	<.001	<.001
Lsd (0.05)	1.201	1.044	1.116
Pr P fert.* MP	<.001	<.001	<.001
CV (%)	1.0	1.2	1.0

Table 4. Interaction effect of P fertilizers and microbe plus rates on soil available P

	Available P (mg/kg)		
P fert. + MP	6 MAT	8 MAT	10 MAT
$PoMP_0$	66.81	95.50	47.04
$PoMP_{50}$	112.40	115.80	144.38
$PoMP_{100}$	48.71	45.20	105.32
$PoMP_{150}$	151.90	70.10	93.36
$TSPMP_0$	105.56	173.80	180.18
$TSPMP_{50}$	173.49	173.80	180.18
$TSPMP_{100}$	173.49	173.80	180.18
$TSPMP_{150}$	173.49	174.50	180.90
$SRPMP_0$	166.87	107.70	157.14
$SRPMP_{50}$	173.49	79.50	164.87
$SRPMP_{100}$	111.62	140.90	163.12
$SRPMP_{150}$	173.49	124.40	160.25
$TRPMP_0$	163.60	105.40	169.90
$TRPMP_{50}$	94.64	18.10	56.37
$TRPMP_{100}$	169.02	46.70	121.58
$TRPMP_{150}$	171.09	74.30	81.16
Pr	<.001	<.001	<.001
Lsd (0.05)	2.402	2.089	2.233
CV (%)	1.0	1.2	1.0

Biomass nutrient concentrations: Based on the optimum nutrient levels (2.6 – 3.0 % N, 0.16 – 0.25 % P, 1.10 – 1.80 % K, 0.50 – 1.70 % Ca, 0.30 – 0.70 % Mg) and deficient nutrient levels (as % N < 2.50, % P < 0.15, % K < 1.00, % Ca < 0.30, % Mg < 0.20) in oil palm seedlings fronds reported by von Uexkull and Fairhurst (1999); the percentage of nutrient concentrations in seedlings fronds at 12 MAT was significantly ($p<0.05$) influenced by the applications of P fertilizers and microbe plus, as well as, their interactions (Table 5a and 5b). In the case of P fertilizers, the P_o treated palms recorded significantly ($p<0.05$) higher and optimum N content (2.53 %) and TSP recorded optimum P content (0.23 %). Microbe plus also recorded significantly ($p<0.05$) higher

K and Ca contents (0.47 and 0.36 % respectively) in MP_o treated palms and higher Mg content (0.37 %) in MP_{150} treated palms (Table 5a). N concentrations were optimum only in control (P_oMP_o) and $TSPMP_o$ treated palms; P concentrations were in excess only in $TSPMP_{100}$ treated palms; Mg levels were optimum in $SRPMP_{150}$, $TRPMP_o$, $TSPMP_{100}$, $TSPMP_{150}$ and P_oMP_{150} treated palms.P deficient contents were recorded in P_oMP_{50}, $TSPMP_{150}$, $SRPMP_{100}$, $TRPMP_o$ and $TRPMP_{50}$ treated palms. On the contrary, K and Ca contents were deficient in all the combinations at the end of the experiment (Table 5b).

Table 5a. Effect of P fertilizers and microbe plus rates on frond nutrient content

	Nutrient concentration (%)				
P fertilizers	N	P	K	Ca	Mg
Po	2.53	0.16	0.42	0.28	0.28
TSP	2.29	0.23	0.41	0.23	0.35
SRP	2.10	0.20	0.41	0.31	0.27
TRP	2.30	0.15	0.40	0.26	0.28
Pr	<.001	<.001	0.068	<.001	<.001
Lsd (0.05)	0.017	0.011	0.015	0.009	0.014
Microbe plus					
MP_0	2.48	0.16	0.47	0.36	0.27
MP_{50}	2.25	0.18	0.40	0.26	0.24
MP_{100}	2.26	0.21	0.39	0.24	0.29
MP_{150}	2.23	0.20	0.39	0.21	0.37
Pr	<.001	<.001	<.001	<.001	<.001
Lsd (0.05)	0.017	0.011	0.015	0.009	0.014
Pr P fert.* MP	<.001	<.001	<.001	<.001	<.001
CV (%)	0.9	7.1	4.2	4.3	5.8

Table 5b. Interaction effect of P fertilizers and Microbe plus rates on frond nutrient content

	Nutrient concentration (%)				
P fert. + MP	N	P	K	Ca	Mg
$PoMP_0$	3.17	0.16	0.47	0.32	0.23
$PoMP_{50}$	2.43	0.12	0.44	0.32	0.25
$PoMP_{100}$	2.39	0.19	0.40	0.32	0.25
$PoMP_{150}$	2.14	0.17	0.38	0.16	0.40
$TSPMP_0$	2.72	0.19	0.50	0.32	0.27
$TSPMP_{50}$	2.10	0.24	0.37	0.29	0.27
$TSPMP_{100}$	2.10	0.34	0.41	0.13	0.42
$TSPMP_{150}$	2.26	0.14	0.37	0.16	0.42
$SRPMP_0$	2.06	0.16	0.47	0.42	0.34
$SRPMP_{50}$	2.14	0.21	0.43	0.26	0.13
$SRPMP_{100}$	2.02	0.13	0.37	0.19	0.30
$SRPMP_{150}$	2.18	0.30	0.38	0.35	0.30
$TRPMP_0$	1.98	0.13	0.44	0.38	0.25
$TRPMP_{50}$	2.35	0.13	0.37	0.16	0.32
$TRPMP_{100}$	2.51	0.16	0.37	0.32	0.17
$TRPMP_{150}$	2.35	0.17	0.43	0.16	0.36
Pr	<.001	<.001	<.001	<.001	<.001
Lsd (0.05)	0.034	0.022	0.029	0.019	0.028
CV (%)	0.9	7.1	4.2	4.3	5.8

Phosphorus uptake in biomass: The use of TSP and SRP alone exerted more influence on P uptake in biomass where 62 and 32 % significant increase were recorded over the P_o respectively. In the case of the microbe plus rates, MP_{100} and MP_{150} also exerted 62 and 57 % increase in biomass P uptake respectively over the MP_o. The order of increasing P uptake in biomass was P_o< TRP < SRP < TSP for P fertilizers and MP_o< MP_{50}< MP_{150}< MP_{100} for microbe plus rates (Table 6). As shown by Figure 1, the combined applications significantly ($p<0.05$) influenced the uptake of P in the seedling biomass. $TSPMP_{100}$ treated seedlings recorded 161 % increase in P uptake over the control (P_oMP_o). This was followed by the application of $SRPMP_{150}$ where 94 % significant increase in P uptake over the control was also recorded.

Table 6. Effect of P fertilizers and microbe plus on frond P uptake

P fertilizers	P uptake (%)	Microbe plus	P uptake (%)
Po	29.2	MP_o	26.3
TSP	47.3	MP_{50}	30.7
SRP	38.9	MP_{100}	42.7
TRP	25.4	MP_{150}	41.2
Pr	<.001		<.001
Lsd (0.05)	7.45		7.45
Pr P fert. * MP	<.001		<.001`
CV (%)	25.4		25.4

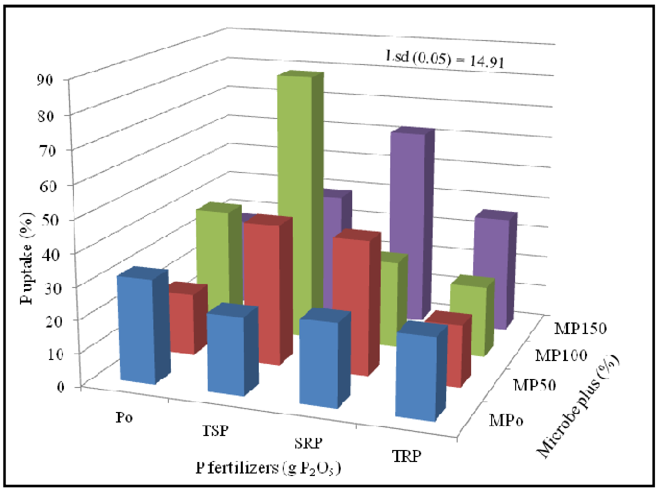

Figure 1. Interaction effect of P fertilizers and microbe plus rates on P uptake

DISCUSSION

Available P dynamics: Available P in TSP amended soils was consistently higher than the available P in the other P fertilizers amended soils (156.5 – 180.5 mg kg^{-1}) (Table 4). This observationsupports the findings of Diatta *et al.* (2017) due to high solubility potential of TSP which provides quick and high P supply to plants than RP with slow and low supply of P to plants. Earlier work by Khasawneh and Doll (1978) also reported that the residual effects of soluble P fertilizers were greater than those of rock phosphates in the first 3 or 4 years after application. MP_{100} recorded higher available P with an added advantage in relation to the other rates applied and could be the best rate in terms of P build-up. The variability in available P recorded was in agreement with the assertion of Roy *et al.* (2006) that the content of available nutrients and their degree of availability and accessibility was not a static condition but an ever-changing and very dynamic process due to the various inorganic and biochemical processes that took place. Studies have shown that decreasing soil pH increases RP effectiveness (Prochnow *et al.,* 2010).Soil available P recorded at 10 MAT showed that, TSP either solely applied or combined with MP rates gave significantly ($p<0.05$) higher available P. Clearly demonstrating the higher soluble nature of TSP and that more P was solubilized and made available in the rhizosphere. Besides, interactions between TRP and rates of MP yielded low available P. The observed antagonistic effect of MP on TRP could be due to immobilization. It was inferred therefore that interactions between SRP and any rate of MP would be superior (in terms of available P) to TRP. The superior effect of SRP was in line with Kaushik and Garg (2004) when RP emended with microbial inoculant improved soil available P; as resulted from the conversion of rock phosphate P to water-soluble form and greater efficiency of the dissolved P in terms of its availability to plants (Khanna *et al*., 1983). Studies have indicated increased P availability from RP with length of incubation period (Sinclair *et al.,* 1986; Rajan *et al.,* 1987), which contributed to the superior effect of TSP over the RPs in this study. Yet, slow dissolution rates may also be an advantage over soluble fertilizers in soils with very low P-fixing capabilities, as P is less likely to be lost to leaching (Sanyal and De Datta 1991). Roy *et al*. (2006) explained that the amount of nutrients estimated to be available was not a measure of the total available pool of nutrient, but the proportion that correlated significantly to crop response. The high available P observed in this study could be due to the fact that the study was conducted in polybags and therefore provided a concentrated environment which encouraged the build-up of P in the soil. This condition cannot be ruled out as there was a tendency for P to be fixed in the soil and reduce leaching losses.

Biomass nutrient concentrations and P uptake: The deficient N, K, and Ca contents recorded showed that the application of P fertilizers and microbe plus rates had no positive effect on the concentration of these nutrients in fronds (Table 5a), however, P uptake was significantly affected (Table 6 and Fig. 1). The optimum P and Mg contents recorded by TSP and MP_{150} treated seedlings (Table 5a) and higher P uptake (Table 6) indicated their positive influence on the uptake of these nutrients. This was in agreement with the findings of Lucas *et al*. (1979) and Menon and Chien (1990) who observed similar trend in oil palm seedlings treated with different P fertilizers. The complementary application of P fertilizers and microbe plus (Table 5b) showed optimum N levels only in the control and $TSPMP_0$ treated seedlings. This could be due to available native soil nutrients in the control medium, whereas, the TSP with its high solubilization ensured high N availability in the vicinity of plant roots which contributed to high N use efficiency and a corresponded higher N content in the fronds; as well as, higher P uptake in TSP treated seedlings (Table 6) and in the complementary applications of TSP with MP_{100} and MP_{150} (Fig. 2). According to Zin *et al*. (2007), P has synergetic effects on N and this might contribute to the higher N content recorded. Contrarily, Dwivedi (1985) reported that high N use efficiency of seedlings could maintain low level of nutrients in the tissues. The excess P content in $TSPMP_{100}$ and optimum Mg levels in TSP with MP_{100} and MP_{150} rates treated seedlings supported Huang and Schnitzer (1986) and Orlov (1995) that biofertilizers could enhance the uptake of P and Mg in plants. The deficient K and Ca levels recorded in the complimentary use of P fertilizers and microbe plus (Table 5b) supported the findings of Bah and Zaharah (2004) who observed antagonistic effects between K and Mg in the plants and explained that the absorption of these elements by roots depended on their relative concentrations in the medium. K deficiency level recorded agreed with the findings of Fairhurst and Mutert (1999) that high level of N when K was low resulted in K deficiency because the increased seedling growth required more K. Thus K^+ uptake increased as concentrations of Ca^{2+} and Mg^{2+} declined in the soil solution and vice versa (Havlin *et al*., 1999).

Conclusion

The application of TSP alone and $TSPMP_{150}$ recorded the highest soil available phosphorus at 12 MAT. In terms of P uptake in fronds, MP_{100} and TSP applied alone and their complementary application proved to be the best options. Field experiments are therefore recommended to validate the effects of MP and the P fertilizers on soil microbial P dynamics and seedlings performance.

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REFERENCES

Akande, M. O., Adediran, J. A., Oluwatoyinbo, F. I. 2005. Effects of rock phosphate amended with poultry manure on soil available P and yield of maize and cowpea. *Afri. J. Biotechnol.* 4(5):444-448.

Akande, M. O., Oluwatoyinbo, F. I., Adediran, J. A., Buari, K. W. and Yusuf, I. O. 2003. Soil amendment affects the release of P from rock phosphate and the development of okra. *J.Veg. Crop Production*. 9(2): 3-9.

Asomaning, S. K., Abekoe, M. K. and Owusu-Bennoah, E. 2006. Phosphate rock dissolution and availability in some soilsof semi-deciduous rainforest zone of Ghana. West *African Journal of Applied Ecology*, vol. 10, no. 1.

Bah, A. R., Zaharah, A. R. 2004. Evaluating urea fertilizer formulations for oil palm seedlings using the 15N isotope dilution technique. *J. Oil Palm Res.* 16 (1):72-77

Bouyoucos, G. J. 1962. Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal* 53: 464-465.

Bray, R. H. and Kurtz, L. T. 1945. Determination of the total organic and available forms of phosphorus in soil. Soil Sci. 599: 39-45.

Diatta, J., Borowiak, K. and Szczepaniak, W. 2017. Evaluation of fertilizers solubility and phosphate release in slightly acidic arable soil. Archives of Agronomy and Soil Science, Volume 64, 2018 – Issue 8.

Dwivedi, R. S. 1985. Advances in mineral nutrition of groundnut. Bulletin, NRCG (ICAR), Junagadh, India. Pp 68.

Fairhurst, T. H. and Mutert, E. W. 1999. "Introduction to oil palm production" Better Crops International, Vol.13, Issue 1, May 1999 Special Edition.

FAO, 1990. Soil Map of the World- Revised Lengend, 4th Draft. FAO. Rome. Fertilizer research 36: 141 – 150.

GenStat. 2012. GenStat Release 12.1 ed. VSN International Ltd. UK.

Goldstein, A. H. 1995. Recent progress in understanding the molecular genetics and biochemistry of calcium phosphate solubilization by Gram-negative bacteria. Biol. Agri.Hort. 12:185-193.

Grimme, H. and Härdter, R. 1991. Cerealproduction on acid soils: The effect of the magnesium supply at high Al concentrations in the soil solution. In: Portch, S. (ed.) International Symposium on the Role of Sulphur, Magnesium and Micronutrients in Balanced Plant Nutrition. Hong Kong. PPI, pp.181–188.

Gyaneshwar, P., Kumar, G. N., Parekh, L. J. and Poole, P. S. 2002. Role of soil microorganisms in improving P nutritionof plants. Plant Soil 245:83-93.

Hao, X., Cho, C. M., Racz, G. J. and Chang, C. 2002. Chenical retardation of phosphate diffusion in an acid soil as affected by liming. Nutr. Cycl. Agroecosys. 64:213-214.

Havlin, J. L., Beaton, J. D., Tisdale, S. L. and Nelson, W. L. (1999). Soil fertility and fertilizers: An introduction to nutrient management (6thed.). Upper Saddle River, New Jersey: Prentice-Hill. Pp 1-94.

He, Z. L., Bian, W. and Zhu, J. 2002. Screening and identification of microorganisms capable of utilizing phosphate adsorbed by goethite. Comm. Soil Sci. Plant Anal. 33:647-663.

Huang, P. M. and Schzitzer, M. 1986. Interaction of soil amendments, natural organics and microbes. SSSA Spec Publ. 17 SSSA, WI. Pp 77-101.

International Atomic Energy Agency, IAEA, 2002. Assessment of Soil Phosphorus Status and Management of Phosphatic Fertilisers to Optimise Crop Production. (IAEA-TECDOC-1272).

Isherword, K. F. (1998). Fertilizer use and management. In: N. Ahmed and A. Hamid (eds), Proc. Symp. Plant Nutrition Management for Sustainable Agricultural Growth. NFDC, Islamabad. Pp. 57-76.

Kaushik, P. and Garg, V. K. 2004. Dynamics of biological and chemical parameters during vermicomposting of solid textile mill sludge mixed with cow dung and agricultural residues. Bioresourcestechnology, 94(2): 203-209.

Khan, A. A., Jilani, G., Akhtar, M. S., Naqvi, S. M. S. and Rasheed, M. 2009. Phosphorus Solubilizing Bacteria: Occurrence, Mechanisms and their Role in Crop Production. *J. Agric. Biol. Sci. 1*(1): 48-58.

Khanna, S. S., Tomar, N. K. and Gupta, A. P. 1983. Efficiency of incubated phosphate fertilizers varying in water solubility with organic matter to wheat. Proc. Third International Congress on Phosphorus Compounds. *Brussels, Belgium.* Pp.567 580.

Khasawneh, F. E. and Doll, E. C. 1978. The use of phosphate rock for direct application to soils. *Adv. Agron.* 30:159-206.

Lucas, E. O., Ataga, D. O. and Thomas, G. O. 1979. Partitioning of dry matter and nutrient in oil palm seedlings grown in polybags. *Exp. Agric.,* 15: 361-368.

Menon, D. G. and Chien, S. H. 1990. Phosphate availability to maize from partially acidulated phosphate rock and phosphate rocks compared with triple superphosphate. *Plant and Soil,* 127:123-128.

Nelson, D. W. and Sommers, L. E. 1982. Total carbon, organic carbon and organic matter. In: Page, A.L., Miller, R.H.,Keeney, D. R. (Eds.), Methods of soil Analysis, Part 2. Chemical and Microbiological Properties, 2nd ed. (Agronomy series no. 9) ASA, SSSA, Madison, Wis. Pp.539-579.

Orlov, D. S. 1995. Humic substances of soil and general theory of humification. A.ABelkema Publishers, Rotterdam, the Netherlands. Pp 23-54.

Prochnow, L. I., Quespe, J. F. S., Francisco, E. A. B. and Braga, G. 2010. Effectiveness of phosphate fertilizers of different water solubilities in relation to soil phosphorus adsorption. ScientiaAgricola, vol. 63, no. 4.

Rajan, S. S. S., Gillingham, A. G., O'Connar, M. B., Percival, N. A. and Gray, M.G. 1987. Ground phosphate rocks as fertilizers for pastures. In: The use of reactive phosphate rocks and their derivatives as fertilizers. Ed. by White, R. E. and Currie, I. D. Occasional report No. 1, Massey University, PalmerstonNorth, New Zealand, pp. 78-83.

Richardson, A. E. 2001. Prospects for using microorganisms to improve the acquisition of phosphorus by plants. *Aust. J. Plant Physiol.* 28:897-906.

Roy, R. N., Finck, A., Blair, G. J. and Tandon, H. L. S. 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin 16:1-346.

Sanyal, S. K. and De Datta, S. K. 1991. Chemistry of phosphorus transformations in soil. Advances in Soil Science 16: 37-55.

Sinclair, A. G., Johnstone, P. O., Smith, L.C., Risk, W.H., O'connor, M.B., Roberts, A.H., Morton, J.D., Nguyen, L., and Shannon, P.W. 1986. Effect of reactive phosphate rock on the pH of soil under pasture. *N. Z. J. Agric. Res.,* 36, 381-384.

vonUexkull, H. R. and Fairhurst, T. H. 1991. Fertilizing for high yields and quality. The oil palm. IPI, Bern. p.79.

Zin, Z. Z., Zulkifli, H., and Tarmizi, A. M. 2007. Maximizing the potential of phosphate fertilizers for increasing mature oil palm yield. MPOB. *Information Series* No. 347. June 2007.

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