ASPERGILLUS NIGER MEDIATED PHOSPHO-COMPOST AND MAIZE PRODUCTION IN A GREENHOUSE

ABSTRACT

Aims: Generally, soils in coastal savanna in Ghana are low in phosphorus (P) which affects crop growth and yield. Most phosphate rock deposits in West Africa are not reactive and therefore their direct applications do not promote readily P availability to crops. The new paradigm by scientists in response to P availability is Co-composting organic waste and phosphate rock and using phosphorus solubilizing micro-organisms (PSMs). The objectives of this study was to (1) evaluate the effectiveness of Aspergillus niger, a phosphorus solubilizing microbe, insolubilizing P in phosphate rock during co-composting with organic waste (citrus waste (CW) or rice straw (RS) and (2) to evaluate the growth, dry matter production and P uptake of maize to phospho-compost application.
Methodology: The phospho-compost was prospered at the University of Ghana Forest and Horticulture Research Center, Okumaning near Kade. The organic waste feedstocks used were: citrus waste and rice straw. The composition of each composting pile was in the ratio of 24:3:1 w/w of feedstock, Togo phosphate rock, and urea.
Results: The results showed that citrus waste feedstock was more effective than rice straw in solubilizing the P in rock phosphate. The phospho-composts produced were evaluated using maize (*Zea mays*) as test crop in a pot experiment.

***Keywords**: compost, dissolution, greenhouse, microbiological culture*

1. INTRODUCTION

Phosphorus (P) is an essential plant nutrient and its deficiency in soils severely restricts crop yields. In agricultural systems, P is needed for the accumulation and release of energy associated with cellular metabolism, seed and root formation, maturation of crops (especially cereals), crop quality, and strength of straw in cereals. In natural (i.e. non-agricultural) systems, P is recycled to the soil in the litter, plant residues and animal remains (Brogan et al, 2001; Sundara, 2002; Gilberto *et al*, 2015). Most soils in the tropics and subtropics show a widespread phosphorus (P) deficiency and high P sorption capacity. Some of the reasons adduced for the low P availability in these soils include; low inherent P status of the parent material, intensive weathering of soil minerals, and the reversion of soluble P into insoluble form through reactions with iron and aluminum oxides (Duncan et al 2012). According to Vitousek et al 2010, loss of inorganic and dissolved organic P via leaching, formation of soil layers that physically prevent/inhibit access by roots to potentially available P, slow release of P from mineral forms, relative to the supply of other resources, low inputs of P via weathering due to low concentrations of P in rock, sequestration of available P in an accumulating pool within ecosystems and enhanced supply of other resources (especially N) causes P limitation in most soils. Adequate quantity of inorganic P fertilizer is needed to maximize plant productivity (Sundara, 2002). African farmers may not be in a position to use fertilizer, or to use optimally, because they do not perceive the benefits, and/or they cannot afford to buy the fertilizer and/or fertilizer may not be physically available (Druilhe and Barreiro-Hurle 2012). Phosphate rock (PR) is a general term that describes naturally occurring mineral assemblages containing a high concentration of phosphate minerals. Phosphate is the component of agronomic interest in these rocks. The higher the phosphate (P_2O_5) contents as apatite, the greater the economic potential of the rock. Rock phosphate is a resource available to quite a number of developing countries that can be utilized for sustainable crop production (FAO/IAEA 2004). There is enough evidence to show that when insoluble rock phosphate is composted with organic waste, P availability is made easier compared to when applied directly. Phosphate rock application as fertilizer is known a long time ago. Phosphate rock is relatively slow to release soluble P, yet its low price appears to be very attractive as a phosphate fertilizer in comparison to the industrial P fertilizers (Hellal et al 2019). World resources of phosphate rock are more than 300 billion tons. There are no imminent shortages of phosphate rock (Sayma and Shaeba 2019). Togo rock phosphate is fluorapatite with a large reserve of P content (27% P). It can be easily accessed in Ghana as compared to the other RPs because of their location. Moreover, Togo RP is known to be un-reactive and therefore, does not dissolve sufficiently to increase crop yield (Tchangbedji et al., 2003; Agyin-Birikorang et al, 2007). It must be treated to improve its P release. It has also been established that incorporating microorganisms in the composting process is agronomically effective than composting with just organic waste and rock phosphate (Sadia et al., 2011).

2. METHODOLOGY

2.1 Research Design

Culturing of Aspergillus niger was carried out in the Pathology Laboratory at Crop Science department of the School of Agriculture, University of Ghana, Legon. Photo-composts were prepared at the University of Ghana Forest and Horticulture Research Centre, Okumaning near Kade (6º 05’ N; 0º 05’W), located in the humid forest ecology in the Eastern region of Ghana. The composting processes were carried out from November 2013 to January 2014. The second part of the study (pot experiment) was conducted in the greenhouse of the University of Ghana at the Sinnas garden of the Crop Science Department between March and April 2014.

2.2 Culturing of Aspergillus niger (Fungi)

A plate of Aspergillus niger spores was obtained from the Plant Pathology Laboratory of the Department of Crop Science, University of Ghana, Legon.

2.3 Preparation of Potato Dextrose Agar (PDA)

Two hundred (200) grams of peeled Irish potatoes were cut into 12 mm cubes and weighed into a beaker and then rinsed several times with distilled water. The washed potato cubes were placed in a beaker after which 1.0 L of distilled water was added and allowed to boil for an hour. The softened potato cubes were squeezed a little through a mutely cloth. The mixture was transferred into a one-liter conical flask and topped up to the mark with distilled water. Twenty grams of agar and dextrose was added, stirred, and boiled till it dissolved. Twenty (20) grams of dextrose were also added and stirred to dissolve. The mixture was then sterilized at 15 psi for an hour after which it was allowed to cool and stored.

3. RESULTS

3.1 Characterization of Feedstock Used in Compost Preparation

Chemical compositions of citrus waste and rice straw used in preparing the compost are shown in Table 4.2. Citrus waste, consisting mainly of peel and pulp contains soluble and insoluble carbohydrates, as well as digestible crude fiber and protein. The C/N ratio of the citrus waste feedstock was 27.8, which falls within the optimum range for composting (Verdonck, 1988), whiles that of rice straw feedstock was 48.1 and therefore was adjusted 32.4 by applying an N source (Urea). The C and N contents in rice straw are similar to those obtained by Kumari et al., (2008). The C: N for citrus waste was reported by Van Heerden et al. (1995) to be 28:1.

Table 1: Chemical composition of the feedstock.

Material	Total P	Total N	Organic C	C:N
Citru waste	**0.18**	**0.99**	**47.5**	**48.1**
Rice straw	**0.23**	**1.48**	**41.2**	**27.8**

3.2 Preliminary Study Outcome

The results of a preliminary study, involving the comparison of two substrates, citrus waste and rice straw on whether to use sterilizing agents before inoculating piles with Aspergillus niger, are presented in Table 4.3. Among the citrus waste (CW) compost, there was no significant difference in available P between CW with NaOHCl and CW without NaOHCl. A similar result was observed for the rice straw feedstock.

Table 2: Effect of NaOHCl on treatment as a sterilizing agent in week 2.

Treatments	Ph	Available P (%)
CW, RP, U, A. niger	3.5	0.64
CW,RP,U,A. niger, NaOHCl	3.6	0.61
RS, RP, U, A. niger	6.5	0.47
RS, RP,U, A. niger, NaOHCl	6.8	0.50

3.3 P uptake of shoot

The highest P uptake was recorded in CW phosphor-compost without *A. niger* at 120 kg P/ha and CW with *A. niger* at 60 kg P/ha (3.7 t/ha each) whiles the lowest P uptake was recorded in Control (0.5 t/ha). There was no significant difference in P uptake in shoot at 120 kg P/ha (2.7 t/ha) and 180 kg P/ha (2.6 t/ha) CW phospho-compost with *A. niger*. However, at 60 kg P/ha CW phosphor-compost without A. niger recorded higher P uptake (3.1 t/ha) than at 180 kg P/ha (2.3 t/ha). With regards to RS phosphor-compost without *A.niger*, the highest P uptake was recorded at 120 kg P/ha (3.3 t/ha), followed by 180 kg P/ha (2.8 t/ha) and finally 60 kg P/ha recorded 1.8 t/ha. Similarly, RW phosphor-compost with *A. niger* at 120 kg P/ha (3.1 t/ha), at 180 kg P/ha P uptake was 3.9 t/ha and that of 60 kg P/ha was 1.9 t/ha. Control and RP with *A. niger* gave same shoot P uptake (0.5 t/ha) and TSP recorded 1.5 t/ha. The order in shoot P uptake was: CW with A. niger = CW without A. niger> RS with A. niger = RS without A. niger = TSP > RP with A. niger = Control.

Table 3: Effect of compost type and application rate on P uptake of maize shoot at week 7.

Material	P uptake (t/ha)
CW, RP, U at 60kg P/ha	3.1
CW, RP, U at 120kg P/ha	3.7
CW, RP, U at 180kg P/ha	2.3
CW, RP,U, A. niger at 60kg P/ha	3.7
CW, RP, U, A.niger at 120kg P/ha	2.7

CW, RP, U, A.niger at 180kg P/ha	2.6
RS, RP, U at 60kg P/ha	1.8
RS, RP, U at120kg P/ha	3.3
RS, RP, U at 180kg P/ha	2.8
RS, RP, U, A. niger at 60kg P/ha	1.9
RS, RP, U, A. niger at 120kg P/ha	3.1
RS, RP, U, A. niger at 180kg P/ha	2.9
TSP	1.8
RP, A. niger	2.1
Control	0.5

4. DISCUSSION

The results revealed that the temperature of the compost piles consistently decreased from Day 20 -90 in both citrus and rice compost piles with or without A. niger addition. In general, higher temperatures were observed in the A. niger treated compost piles than the piles without A. niger. In all cases, temperatures stabilized in the compost piles between 21°C and 29°C on Day 90. An increase in temperature may be due to microbial activity. Citrus waste inoculated compost entered the thermophilic phase from the 6th - 10th day of composting indicating increased microbial activity in the compost pile.
Rice straw compost which had a high pH during the first week of composting also dropped from 7.5 to 5.2 for RS without A. niger by week 3 from 7.1 to 4.1 for RS with A. niger by week 4. By the end of week 6, all compost piles were within the ranges of 7.1 to 7.4. A similar observation was made by Motaal et al. (2005) who reported that the reduction in pH in the initial days of decomposition was due to fermentation. The pH tended to rise towards the end of the process. All compost with or without Aspergillus niger stabilized at pH between 7.1 and 7.4 which confirms De Bertoldi et al. (1983) report that the optimum pH values for matured compost were between 5.5 and 8.0.
The differences in the P dissolution by the CW and RS feedstocks were observed and seemed to be more feedstock based than A. niger inoculation. Results obtained in this study confirm earlier studies (Adu, 2006) that the dissolution of P from PR is dependent on the type of organic material or feedstock used in the composting process. Organic materials vary considerably in both chemical and physical qualities, and these qualities could influence the composting process and the subsequent release of decomposition products.

5. CONCLUSION

The study has confirmed the initial findings that the direct application of TPR does not release the P for plant uptake. Direct application of TPR with Aspergillus niger did not increase the solubilization of P from the TPR since TPR with Aspergillus niger produced similar dry matter yield and P uptake to that of control. Citrus waste and rice straw were effective in solubilizing P in the phosphate rock. Inoculation of the feedstock with A. niger was not very effective in the solubilization of P in the phosphate rock.

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