Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2014.19.1.1

Phosphorus Fertilization Under Different Land Preparation Methods and Performance of Groundnut (*Arachis hypogea* L.) in Rainforest Zone of Southern Nigeria

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Received 1 November 2013/Accepted 3 January 2014

ABSTRACT

A field experiment was conducted on an Arenic paleudult in the rainforest zone of Southern Nigeria to determine the response of an improved variety of peanut (*Arachis hypogea* L. var. Samnut 23) to phosphorus, under different land preparation methods. Selected land preparation methods were “slash and burn” (SB) and “slash and mulch” (SM), and the phosphate fertilizer rates were 0, 30, 60, 90 and 120 kg P ha^{-1}. The experiment was laid out as a randomized complete by block design. Each land preparation was divided into plots. Macro- and micro nutrient contents of peanut plants were determined, and the growth and yield components were also assessed. Results showed that the pre planting soil analysis for the SB management had a pH of 5.77, N (1.8 gkg^{-1}), P (2.05 mgkg^{-1}) and K (0.11cmol (+) kg^{-1}), while that of the SM had a pH of 5.95, N (0.9 g kg^{-1}), P (0.86 mg kg^{-1}) and K (0.07cmol(+)kg^{-1}). Plant height was not significantly different (pd” 0.05) in the land preparation methods, but leaf area was significantly different. However, plant height and leaf area responded better under the SB treatment with 90 kg P ha^{-1} rate of phosphorus fertilizer than the SM treatment under the same rate. Fresh pod weight of 908.6kg ha^{-1} and dry pod weight of 558.0kg ha^{-1} was obtained at 60 kg P ha^{-1} under the SB treatment and was significantly different from all other treatments including the SM. Significant differences were also observed in the nutrient concentrations of leaves and roots. Highest leaf phosphorus content (3.502 mg kg^{-1}) was recorded at 90kg P ha^{-1} in the SM treatment while the highest nutrient content of P in the roots (0.272 mg kg^{-1}) was recorded at 30 kg P ha^{-1} also in the SM treatment. However, the SB treatment recorded the highest peanut seed pods / shell at 60 kg P ha^{-1}. Generally, phosphorus fertilization under the SB management practice gave better results than the SM management practice.

Keywords: groundnut, land preparation, phosphorus fertilization, Slash and burn, slash and mulch

INTRODUCTION

Soil fertility is the first natural resource for food security, yet its depletion on small holder farms has led to stagnant or decreasing per capita food production all over Africa during the last two decades (Gladwin 2003). The management of the soil is of utmost importance for optimizing crop nutrition. The world’s most degraded soils can be found in Africa where about three-quarters of farm land are severely depleted of nutrients.

Traditionally, farmers have used fallows to maintain soil fertility by allowing fields to go back to bush for a number of years between cultivation cycles. The bush is cut and burn, leaving ashes for nutrients; few weed seeds, and a friable soil that is good for two or three years of cultivation. The International Centre for Soil Fertility and Agricultural Development estimates that loses of soil nutrients are up to 8 million metric tons of soil nutrients per year and over 95 million hectares of land have been degraded to the point of greatly reduced productivity (Henao and Baanante 2006). Some common farming practices, including burning crop residues and leaving soil bare unprotected from the sun and wind are parts of the problem. Excessive or insufficient use of fertilizers and improper crop rotations also lead to declining soil fertility. Avoidance of soil loss by improved management and the conservation of natural resources is therefore important to maintain the functions of the soil and contribute to food security today and for future generations (Ehui and Pender 2005). The main reason for land use intensification was and still is the increase in food production required to feed the rapidly growing population. Smallholder farming systems in Africa are faced with poor crop production and perennial food insecurity, especially in the semi-arid tropics where the majority of small holder farmers live

J Trop Soils, Vol. 19, No. 1 2014: 1-7
ISSN 0852-257X

(Ryan and Spencer 2001). Poor rainfall coupled with its concomitant pattern and poor soil fertility, inherently poor soil quality and inappropriate soil management practices are major constraints to crop production (Vanlauwe *et al.* 2003). Throughout Africa, negative nutrient balances for N and P have been in smallholder farming systems (Roy *et al.* 2003). In the smallholder farming systems of sub-Saharan Africa, these constraints are manifested in frequent crop failures and endemic food insecurity (Ncube *et al*. 2009). Traditional cropping systems vary, since they have evolved in response to prevailing soil and climatic conditions and social and ethnological preferences (Kang 1986). Traditional farmers often plant more than one crop species in a small patch of cleared and burnt land after several years of bush fallow.

After N, P is the second most frequently limiting macronutrient for plant growth in the tropics. Phosphorus deficiency is a major abiotic stress that limits plant growth and crop productivity throughout the world (Sanchez and Salinas 1981). That is why in most researches carried out the total amount of P in the soil maybe high, but it is often present in unavailable forms or in forms that are only available outside of the rhizosphere. Few unfertilized soils release P fast enough to support the high growth rates of crop plant species. In many agricultural systems in which the application of P to the soil is necessary to ensure plant productivity, the recovery of applied P by crop plants in a growing season is very low; because in the soil more than 80% of the P becomes immobile and unavailable for plant uptake because of adsorption, precipitation or conversion to the organic form (Holford 1997). Adding to the active P pool through fertilization will also increase the amount of P fixed. Depleting the active pool through crop uptake may cause some of the fixed P to slowly become active P. The conversion of available P to fixed P is partially the reason for the low efficiency of P fertilizers. Most of the P fertilizers applied to the soil will not be utilized by the crop in the first season. Continued application of more P than the crop can utilize increases the fertility of the soil, but much of the added P becomes fixed and unavailable. As a P source, single super phosphates appears to be the most suitable fertilizer for groundnuts in the Nigerian savannah at present partly because it also contains S and partly because of its solubility.

There is paucity of information on the use of Phosphorus fertilization in groundnut cultivation in the area of study hence the objective of the study is to investigate effect of soil management and phosphorus fertilizer on the growth and yield of groundnut in the rainforest zone of Southern Nigeria.

MATERIALS AND METHODS

The experiment was conducted at Otovwodo, Ughelli North Local Government Area, of Delta state, Southern Nigeria with coordinates Longitude 5^0 59' - 6^0 2' East, Latitude $5^0$30’ - 5^0 40’ North of the Equator.

The materials used for the experiment were groundnut seeds, cultivar ‘Samnut 23’ which was purchased from Institute of Agriculture Research (IAR), Ahmadu Bello University (ABU) Zaria and Single super phosphate fertilizer was purchased from Agricultural Development Programme.

Experimental Layout

The experiment was laid out in a randomized completely block design and replicated three times. The plot sizes were 4.5 × 4.5m with 1m alley. Each of the plots was ridged to a height of about 15cm.There were two treatments (soil management and phosphorus fertilizer). The soil management was: i) Slash and burn (SB) and ii) Slash and mulch (SM). In SB, the field was slashed and was allowed to dry and residue was then burned. In SM, the land was slashed, allowed to dry and the residue was used as mulch on the soil. Phosphorus fertilizer was at 0, 30, 60, 90 and 120 kg ha^{-1} of P_2O_5 as single superphosphate. Planting was done one week after the land preparation. Two seeds were planted per hole at a spacing of 10cm intra row and 60cm inter row. The P was applied to the various plots in the slash and burn and slash and mulch using the band placement method.

Field Maintenance and Harvest

Hoe weeding and hand weeding was carried out throughout the duration of the experiment.

At harvest the plants were taken from a 3m x 3m quadrant which was the net plot. The plants were uprooted and washed to remove all sand particles. The pods were separated from the roots, after which the pods were weighed to get the fresh pod weight. The pods were then dried to get the dry pod yield. The leaves were also separated from the roots and dried in the oven at 80^oC for 48 hours. After drying the roots and leaves were taken to the laboratory for analysis.

Plant Data Collection, Soil Sampling and Soil Analysis

Data were collected for plant height, leaf area, fresh pod and dry pod yield. The plant heights were measured with meter rule two weeks after germination. This was achieved by measuring the selected plants in the quadrant from the soil level to the topmost tip of the selected crop and the mean was computed for analysis. The leaf area was carried out by taking the length and breadth of three plants per plot using ruler and the mean was computed for analysis. The pod weight was taken using a measuring scale after harvest. Soil sampling was carried out before the experiment. Five composite soil samples at 0-15 cm soil depth from the experimental areas were collected by random sampling and later bulked to obtain a representative sample, air dried and sieved through a 2 mm mesh before being subjected to laboratory analysis.

Soil pH was determined at 1:1 soil to water ratio using glass electrode digital pH meter. Organic carbon was determined by chromic acid wet oxidation procedure as described by Jackson (1962). Available P was extracted using Bray-1 solution (Bray and Kurtz 1945). Exchangeable bases were extracted using 1*N* neutral ammonium acetate solution. Calcium and Mg content of the solution were determined volumetrically by Ethylene diamine tetra acetic acid (EDTA) titration procedure Black (1965). The level of Ca, K and Na were determined by flame photometry. The total N of the soil and the plant was determined by Micro-kjeldal procedure as described by Jackson (1962). Particle size distribution was determined by hydrometer method of Bouyoucos (1951) and the exchangeable acidity was determined by the KCl extraction and titration method of Mclean (1965).

Chemical analysis of plant tissue sample was carried out in the laboratory using standard procedures. The tissue samples were ashed in a muffle furnace at a temperature of 550^{o}C. The nutrients in the ash were extracted using 0.1*N* HCl. Phosphorus was determined colometrically by the vanadomolybdate (yellow) method. Potassium and Na were determined by flame photometry while Mg and Ca were determined by atomic absorption spectrophotometer.

Data Analysis

Data obtained on soil analysis and on growth parameters of the different management practices were subjected to statistical analysis using Genstat release 8.1 statistical package and measurable variables were tested for significance with analysis of variance (ANOVA) procedure in a randomized complete by block design.

RESULTS AND DISCUSSION

The physical and chemical properties of the soil used for the experiment are presented in Table 1. The result of the analysis showed out that the soils in experimental site were low in P with a value of 2.05 mg kg^{-1} in the slash and burn and 0.86 mg kg^{-1} in the slash and mulch. Soil organic carbon was also low with a value of 1.44 g kg^{-1} and 1.11 g kg^{-1} in the slash and burn, slash and mulch respectively. Total N was 1.8 g kg^{-1}and 0.9 g kg^{-1} in the slash and burn,

Table 1. Some physical and chemical properties of the soil before planting.

Soil parameter	Units	Slash and burn	Slash and mulch
pH(H_2O) 1:1		5.77	5.95
Electrical Conductivity (EC)	dSm^{-1}	23.88	29.77
Soil organic carbon	g kg^{-1}	1.44	1.11
Organic matter	g kg^{-1}	25	19.2
Total Nitrogen	g kg^{-1}	1.8	0.9
Available Phosphorus	mg kg^{-1}	2.05	0.86
Calcium	cmol (+)kg^{-1}	1.85	2.91
Magnesium	cmol (+)kg^{-1}	0.99	0.83
Sodium	cmol (+)kg^{-1}	0.31	0.18
Potassium	cmol (+)kg^{-1}	0.11	0.07
Effective Cation Exchange Capacity (ECEC)	cmol (+)kg^{-1}	4.51	4.92
Zinc	mg kg^{-1}	3.22	2.59
Manganese	mg kg^{-1}	0.18	0.04
Iron	mg kg^{-1}	10.01	9.97
Copper	mg kg^{-1}	0.94	0.18
Sand	g kg^{-1}	75	67
Silt	g kg^{-1}	67	85
Clay	g kg^{-1}	858	848

slash and mulch respectively. Exchangeable bases (K, Mg, Ca and Na) were also low compared to the critical levels established for these elements. The micronutrients (Mn, Cu, Zn and Fe) levels were sufficient when compared to the established critical levels. The soils were clay in nature and slightly acidic in both slash and burn and slash and mulch field. The higher values of P, OC, total N, Mg, K and micronutrients in slash and burn soil compared with slash and mulch were consistent with the general believe that farmers slash and burn in order to obtain nutrients for their crops from the ash produced by burning.

Nutrient Content of Leaf Sample in the Slash and Burn, and Slash and Mulch Management

The nutrient content of leaf sample in the SB and SM is shown in Table 2. The result indicated that there were significant difference in nutrient content in the groundnut leaf in the SB and SM and at all levels compared with control. Irrespective of level of applied P, leaf P, K, Mg, Ca, S, Cu, Fe and Mn was higher in SB than in SM except leaf N which was higher in SM. This was attributable to volatilization of N during burning. Increased availability of ash in the soil as a result of burning should have enhanced uptake of nutrients. Many studies have confirmed that ash is a source of macro and micronutrients (Nottidge *et al*. 2007; Ayeni *et al*. 2008).

Nutrient Content of Root Sample in the Slash and Burn, and Slash and Mulch Management

The nutrient content of root sample in the SB and SM is shown in Table 3. The result indicated that there were significant differences in nutrient content in the groundnut root in the SB and SM at control compared to all levels. N was highest in the slash and burn at 30 kg ha^{-1} with a value of 1.348 g kg^{-1} , P was highest in the slash and mulch at 90 kg P ha^{-1} with a value of 0.264 mg kg^{-1}, K was highest at 90 kg P ha^{-1} in the slash and burn with a value of

Table 2. Nutrient content of leaf in the slash and burn and slash and mulch management.

Treatment	N	P	K	Mg	Ca	S	Cu	Fe	Zn
	← g kg^{-1} →					← mg kg^{-1} →			
0 SB	0.19^{a}	0.21^{a}	0.64^{ab}	0.93^{b}	1.94^{ab}	0.06^{ab}	0.01^{b}	0.00^{b}	0.07^{bc}
0 SM	2.11^{b}	0.14^{a}	0.69^{ab}	0.62^{a}	1.46^{a}	0.03^{ab}	0.00^{a}	0.01^{a}	0.03^{a}
30 SB	0.27^{a}	0.28^{a}	0.72^{ab}	0.98^{bc}	2.54^{ab}	0.19^{c}	0.01^{a}	0.03^{b}	0.08^{c}
30 SM	1.51^{b}	0.19^{a}	0.62^{ab}	0.21^{a}	1.58^{a}	0.02^{a}	0.00^{a}	0.00^{a}	0.03^{a}
60 SB	0.23^{a}	0.27^{a}	0.63^{ab}	0.27^{bc}	1.93^{ab}	0.08^{ab}	0.01^{a}	0.03^{b}	0.07^{c}
60 SM	1.44^{b}	0.15^{a}	0.73^{ab}	0.10^{a}	1.73^{ab}	0.04^{ab}	0.00^{a}	0.01^{a}	0.04^{a}
90 SB	0.15^{a}	0.22^{a}	0.78^{ab}	1.11^{bc}	1.87^{ab}	0.13^{bc}	0.01^{b}	0.04^{b}	0.05^{ab}
90 SM	2.05^{b}	0.50^{a}	0.60^{a}	0.19^{a}	1.63^{a}	0.02^{a}	0.01^{a}	0.01^{a}	0.04^{a}
120 SB	0.29^{a}	0.27^{a}	0.80^{b}	1.43^{c}	1.45^{a}	0.07^{ab}	0.01^{b}	0.03^{b}	0.08^{bc}
120 SM	1.66^{b}	0.17^{a}	0.62^{ab}	0.21^{a}	1.73^{a}	0.03^{ab}	0.00^{a}	0.02^{a}	0.04^{a}

Means with the same letter in the same column are not significantly different at 0.05 probability.

Table 3. Nutrient content of root in the slash and burn and slash and mulch.

Treatment	N	P	K	Mg	Ca	S	Cu	Fe	Zn
	← g kg^{-1} →					← mg kg^{-1} →			
0 SB	0.925^{bc}	0.179^{abc}	0.739^{a}	0.249^{a}	1.443^{a}	0.021^{a}	0.003^{a}	0.011^{a}	0.032^{a}
0 SM	0.207^{ab}	0.249^{cd}	0.670^{a}	1.129^{b}	2.239^{b}	0.053^{ab}	0.013^{ab}	0.048^{c}	0.064^{bc}
30 SB	1.155^{c}	0.171^{ab}	0.746^{a}	0.150^{a}	1.726^{ab}	0.030^{a}	0.019^{b}	0.011^{a}	0.032^{a}
30 SM	0.613^{a}	0.272^{d}	0.726^{a}	0.875^{b}	2.228^{a}	0.116^{c}	0.013^{ab}	0.041^{bc}	0.076^{c}
60 SB	1.054^{c}	0.163^{a}	0.654^{a}	0.142^{a}	1.715^{ab}	0.018^{a}	0.003^{a}	0.012^{a}	0.027^{a}
60 SM	0.266^{ab}	0.219^{abcd}	0.726^{a}	1.309^{b}	1.806^{ab}	0.071^{abc}	0.015^{ab}	0.033^{b}	0.074^{c}
90 SB	1.348^{c}	0.179^{abc}	0.759^{a}	0.386^{a}	1.710^{ab}	0.036^{ab}	0.003^{a}	0.016^{a}	0.031^{a}
90 SM	0.324^{ab}	0.264^{d}	0.699^{a}	1.001^{b}	1.785^{ab}	0.087^{bc}	0.014^{ab}	0.04^{bc}	0.077^{c}
120 SB	1.340^{c}	0.169^{ab}	0.652^{a}	0.194^{a}	1.550^{a}	0.022^{a}	0.003^{a}	0.005^{a}	0.032^{a}
120 SM	0.155^{a}	0.245^{bcd}	0.727^{a}	0.846^{b}	1.892^{ab}	0.059^{ab}	0.013^{ab}	0.031^{b}	0.055^{b}

Means with the same letter in the same column are not significantly different at 0.05 probability.

0.759 cmol (+) kg^{-1} , Calcium (Ca) was highest at control in the slash and mulch with a value of 2.239 cmol (+) kg^{-1}, Mg was highest at 60 kg P ha^{-1} in the slash and mulch with a value of 1.309 cmol (+) kg^{-1}, S was highest at 30 kg P ha^{-1} in the slash and mulch with a value of 0.116 g kg^{-1}. There was a significant difference in the amount of Fe and Zn in the SB and SM except Cu. The result presented in this table revealed that SM did better than the SB except for N and K. The higher nutrients content of groundnut root in SM were attributable to gradual decomposition of the mulch, mineralization of nutrients and consequent leaching for the uptake and retention of root before possible uptake into the leaf system. The higher values of N and K in the root systems in SB might be due to the fact that these nutrients were more rapidly leached from ash to reach the root system, they were more mobile and soluble.

Effect of Slash and Burn, Slash and Mulch on Dry Pod Weight of Groundnut

Effect of SB and SM on dry pod weight of groundnut is presented in Table 4. There was significant difference ($P < 0.05$) in pod weight between the SB and SM. It was observed that the weights of pods in slash and burn treatments were higher than that of SM at the different time of measurement. This was consistent with higher concentrations of nutrients in leaf of plants grown on SB soil compared to SM soil. Unlike nutrients in roots, nutrients in leaves were more essential to formation of photosynthesis in leaves which were transferred to form the seed. However, N is essential for early development of vegetable (IITA, 1980) and N fixation requires large amount of P. No much difference were observed for groundnut yields regarding fertilizer levels, however the yields were greater when compared with treatments on which fertilizers were not applied. Some authors have described that in mulched fields, the fertilizing effect was observed only in a prolonged cropping period after the mulch had decomposed and the nutrients released, showing that fertilization is essential during the earlier part of the cropping period (Kato *et al.* 1999; Denich *et al.* 2005).

Table 4. Effect of slash and burn, and slash and mulch on dry pod weight of groundnut.

Weight	Slash and Burn	Slash and Mulch	LSD
Wet weight	702[b]	438.51[a]	255.6
Dry weight	429.62[b]	273.08[a]	100.0

Means with the same letter in the same row are not significantly different at 0.05 probability.

Effect of Different Levels of SSP under Slash and Burn, Slash and Mulch on Weight of Groundnut Pods

The result of the different levels of SSP applied under SB and SM on the weight of groundnut pods is shown in Table 5. Single Super Phosphate application had significant effect in SB and SM on the pod weight. The highest value of fresh pod weight was recorded at 60kg P ha^{-1} with a value of 908.6kg ha^{-1} under SB and a dry weight of 558kg ha^{-1} at the same level of added P and was significantly different than all other treatments. The SB burn was better than the SM. The weight of pod increased with the level of single super-phosphate for both SB and SM. The weights of pod for SB and SM were statistically significant at 5% level. This is in agreement with Tran (2003) who reported that P fertilizer significantly increased groundnut yield and yield components in both poor alluvial and sandy soils as compared to untreated control plots and also increase in grain yield of groundnuts with increase in P- levels up to 60 kg P ha^{-1} for poor alluvial soil and 90 kg P_2O_5 ha^{-1} for sandy soil

Effect of Different Levels of SSP, Slash and Burn, Slash and Mulch on Leaf Area and Plant Height

The effect of the different levels of the fertilizer applied on plant height and leaf area is shown in Table 6.There was no significant difference in the leaf area, plant height, the number of seeds counted from the small portion taken from the bulk of the harvest and also that of the shelled nut before the seeds were removed. The result indicated that there was a significant difference in leaf area at 0 level but none at the other levels of application. According to Bala *et al.* (2011) groundnut crop growth rate (CGR) responded inconsistently to application of NPK and that such an observation could be as a result of higher levels of leaf area index, leaf area duration and net assimilation rate under the increasing leaf area compared to the control. There was no significant difference for the plant height. It was also observed that Slash and Burn did better in all the levels.

It was also showed that the leaf area was significant and plant height was not significantly different under SB and under SM. This implied that SB and SM management practices showed no difference in the leaf area and seed of groundnut. However, there was significant difference for the plant height and the shelled groundnut. It was also

Table 5. Effect different levels of SSP in slash and burn, and slash and mulch on pod weight.

Weight	0	30	60	90	120	LSD
	←		$kg\ ha^{-1}$		→	
Wet wt SB	581.7[a]	675.0[ab]	908.6[b]	648.3[ab]	698.2[ab]	272.1
SM	384.1[a]	396.5[a]	444.9[a]	471.6[a]	495.3[a]	
Dry wt. SB	314.0[abc]	461.3[de]	558.0[e]	392.0[bcd]	422.2[cd]	100.0
SM	266.1[a]	221.7[a]	285.9[ab]	298.2[ab]	293.8[ab]	

Means with the same letter in the same column are not significantly different from one another at 0.05 probability.

Table 6. Effect different levels of SSP fertilizer on leaf area and plant height.

Levels of SSP	Management Practice	Plant Height (cm)	Leaf area (m^2)
0kg P ha^{-1}	SB	21.57[a]	10.32[a]
	SM	19.93[a]	18.74[b]
30kg P ha^{-1}	SB	25.40[a]	17.68[ab]
	SM	20.43[a]	13.27 [ab]
60kg P ha^{-1}	SB	22.60[a]	15.52 [ab]
	SM	17.60[a]	12.05 [ab]
90kg P ha^{-1}	SB	27.00[a]	17.27 [ab]
	SM	20.13[a]	10.39[a]
120kg P ha^{-1}	SB	19.83[a]	13.63 [ab]
	SM	17.23[a]	11.68 [ab]

Means with the same letter in the same column are not significantly different from one another at 0.05 probability.

observed that SB did better. The effect of SB was better on leaf area, plant height, seed and shelled groundnut as compared to that of SM. This could be attributed to the fact that a lot of nutrients were returned back to the soil in the SM than in SB through the ash. This is in line with Tran (2003) who reported that higher availability of plant nutrients consequently had higher growth parameters in the fertilized treatments and higher yield of groundnut. Responses of groundnut crop to fertilizer application was also observed in Vietnam (Tran 2003). However, studies by Awodun and Ojeniyi (2005) found that application of wood ash significantly increased seed yield in groundnut and leaf and seed N, P, K, Ca and Mg. Ash was also found to be effective as sources of nutrients and thereby increased nutrients availability and yield of vegetables, Maize, Cassava, Rice and Kola seedlings (Ezekiel *et al*. 2009; Ayeni *et al*. 2009).

CONCLUSIONS

In conclusion, the low level of P in the Ughelli environment required application of inorganic fertilizer to improve yield of groundnut a common crop in the area. A 60 kg ha^{-1} of P_2O_5 was found to produce optimum yield, lower and higher rates produced lower yield of groundnut.

The result showed that SB management system had a better result than that of SM. Slash and burn added more nutrients to the soil in the one year trial. There was reduced N due to volatilization a result of heat due to burning.

The burning produced nutrient in the ash form which was easily available for the crop absorption and so can be recommended though it should be done with caution because of its adverse effect on the soil. Farmers are advised to also incorporate SM management system with SB so that a balance can be experienced with a better outcome for the labour they put into farming. There is also the need to apply fertilizer especially P based ones due to the fact that the soils in the area where the experiment was conducted lack sufficient phosphorus.

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