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RESPONSE OF NERICA AND SATIVA RICE LINES TO NITROGEN AND PHOSPHORUS RATES BY NUMBER OF TILLERS AND SHOOT BIOMASS YIELD

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ABSTRACT

An experiment was conducted at the Savanna Agricultural Research Institute on a Euteric Gleisol on latitude 9-25-41” N longitude O-58’ 42”W in the Guinea Savanna Zone of West Africa, Ghana. The objective was to establish the responses of the lowland “New Rice for Africa” (NERICA) and Sativa varieties for recommendation of optimum N and P rates. Six lowland NERICAs, three *Oryza sativa* and one *Oryza glaberima* lines were used. Number of tillers/m^2 quadrant and shoot dry biomass /15cm^2 was used to evaluate the P/N response of crop performance. For the dry biomass weight, destructive sampling was done at the 50% flowering stage. The Phosphorus and Nitrogen fertilizers rates were 0, 13, 26 kg P/ha and 0, 30, 60, 120 kg N/ha respectively. Potassium was applied at a uniform rate of 30 kg K_2O/ha to all plots before planting. The average days of 50% flowering and 80 % maturity of all varieties used, counting from seedling emergence, were 73 to 82 days and 104 to 113 days respectively. There were significant differences on the effect of P and N-levels on shoot –biomass/15 cm^2 quadrant ($p< 0.05$) but number of tillers/ m^2 quadrant were not ($p > 0.05$). The interaction of P/N fertilizer levels by variety was highly significant ($p < 0.001$). Increasing N levels increased biomass and tillers more markedly than increasing P-levels. It was noted that P may have been fixed because available Bray 1 P was not appreciably higher in the 26 kg P/ha plots than 0 kg P/ha. It could have been due to the oxidation of Iron (II) to Iron (III) resulting in insoluble Iron (III) Phosphate complexes or by formation of complex insoluble Aluminium (III) phosphates. Varieties such as V1, V2, V3, V8 and V9 were responsive to lower P and N inputs such as P0/N0 or P0/N30 and also to moderate inputs such as P13/N30, P26/N30 or P13/N60. Varieties such as, V4, V5 and V6 are not responsive to lower inputs but were very responsive to the higher inputs outlined above. Phosphorus and Nitrogen main plots pool for two years at high input rate, (P26/N60 and P26/N120), has no significant advantage over the lower (P0/N0 or P0/N30, P13/N0, P13/N30) and moderate combinations, (P13/N60, P13/120) as regards biomass yields ($p .> 0.05$).

Key words: NERICA, Phosphorous, Nitrogen, Shoot, biomass

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INTRODUCTION

The New Rice for Africa (NERICA) cultivars are crosses between *Oryza sativa* and *oryza glaberima* and have been widely used in Africa because of their high yielding traits and resistance to tropical diseases, erratic rainfall and low fertility soil of the African environment [1]. Both upland and low land varieties have been developed. However cultivars such as *Oryza sativas* and *Oryza glaberrima* are still being used by many farmers in West Africa and Research Stations through conventional breeding and selection [2]. Though the response of fertilizers to the upland varieties may be known in Ghana, that to the lowland cultivars may not be known especially in the Savanna Zone where rainfall is often erratic.

Africa is the continent that has been the most severely affected by climate change, and it is already having difficulty feeding its population [3]. The Africa Rice Center formerly known as, West Africa Rice Development Association (WARDA) has developed a hybrid species of rice known as NERICA – New Rice for Africa – by crossing African and Asian rice varieties. The African variety is a robust plant that adapts well to local conditions. As for the Asian variety, it has a much higher yield [4]. The NERICAs are products of the crossing of these two varieties. There is no exaggeration to say that in order to reduce poverty and hunger in sub-Saharan Africa, it is essential for Africa to realize a Green Revolution of its own. Needless to say, we do not recommend direct transfer of the "existing technology" in Asia to Africa without taking into account Africa-specific production environments [5].

New Rice for Africa (NERICA) rice combines the robustness of the African rice with the higher yield of the Asian rice. NERICA varieties adapt well to the difficult production environments and low levels of farming inputs. In Africa's sub-Saharan rice-growing environments where small producers do not have the means to irrigate their fields and apply chemical fertilizers, different varieties of NERICA can be grown. This is the case both on the inland valleys in the rainy season where the rainfall pattern is unpredictable and irregular, and also in upland areas where maize could have been grown [6].

The NERICA varieties are richer in protein than rice imported into Africa [7]. In general, all varieties of NERICA taste good and have a very good aroma when cooked. In some countries, some varieties of NERICA are still in the testing phase. However, other countries have reached the seed multiplication phase. Elsewhere, different varieties of NERICA are already produced on a large scale especially the upland varieties. This promotes the consumption of rice. As for the marketing of this rice, traders generally purchase the rice directly from producers to sell on the markets in major urban centers. In Togo, for example, NERICA rice can be found in supermarkets with very attractive packaging [8].

Nitrogen and phosphorus are the most limiting nutrients in most soils in Ghana. Studies have shown that K is usually only a problem in successive cropping seasons.

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It is thus possible that by giving annually a minimal amount of K, the deficiencies of K in intensive lowland rice production systems can easily be overcome.

The fertilizer issue, which is not given sufficient attention, is certainly a topic that deserves further in-depth research [9].

Okonje et al. [10] studied the responses of upland NERICAS to nitrogen and phosphorus in Savanna moist West Africa and found low P and N levels in the soil showed low yields. The rice field of the Savanna Agricultural Research Institute (SARI) found in Northern Ghana which consist of a uni-modal modal rainfall pattern but rather moist from late July to early October, could be used to grow rice. The soils are moderately acidic because the bases are leached by excessive rainfall especially in August and September.

In Northern, there is a high variability in soil N and P in the various soils of the rice growing areas. The efficiency of fertilizer-use in lowland rice production is a function of water supply and management [11]. The improved lowland rice varieties particularly lowland NERICA lines may demand different nutrient requirements than the traditional lowland varieties (*Oryza sativa* and *oryza glaberima)* to optimize production under rain fed systems. With the current wide range of lowland rice varieties (*Oryza sativa* and *oryza glaberima),* it may be necessary to give recommendations for adequate fertilizer rates of P and N.

In the Northern Region, the rainy season begins in April and end in late October or early November. The wet months are usually from late July to early September. Rainfall pattern can sometimes be erratic with spells of droughts in between the wet months.

The development of the "New Rice for Africa (NERICA)" will increase rice production in Ghana but farmers need to know how much N and P fertilizer to apply and which varieties will do well in low input fertilizer rates. A majority of farmers are in the low input bracket but there may be a few farmers who could afford more chemical fertilizers.

The following were the selected rice cultivars coded for experimental purposes.

Varieties areV1 = NERICA L-19 (FKR 2N), V2 = NERICA L-20 (FKR 60N), V3 = NERICA L-41, V4 = NERICA L-42, V5 = NERICA L-60 (FKR 58N), V6 = Jasmine 85 FKR 19 (TOX 728-1), V7 = IR 12979-24-2-1FKR 54 (WABIR 12979), V8 = NERICA L-X (WAB 1159-4-10-15-1-3), V9 = WITA 4 and V10 = Kpukpla (local variety)

It has often been hypothesized that lowland NERICAS may not be as responsive to the Nitrogen (N) and Phosphorus (P) application in the Guinea Savanna zone as the normal local or Sativa lines grown. These varieties were selected based on their historical yield potentials in West Africa.

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The objective of this paper is to assess the response of the Lowland NERICAS, some selected Sativa lines (*Oryza sativa)* and a local (*oryza glaberima)* using the yield components of the number of maximum tillering and shoot-biomass yield at flowering to Nitrogen and Phosphorus fertilizer rates.

MATERIALS AND METHODS

Location

The experiment was carried out at the Savanna Agricultural Research Institute (SARI) experimental lowland rice fields for two years to assess the optimum fertilizer rate for the New Rice for Africa (NERICA) and some Sativas lines. The soil series was locally known as the Volta series and classified as a Euteric Gleisol [12]. The Savanna Agricultural Research Institute (SARI) is located 10 km West of Tamale the capital city of Northern Region, Ghana. The area lies at latitude 9-25-41" N longitude O-58' 42"W altitude 183M (msl) in the interior savanna zone and has a generally average annual rainfall of about 1000mm and mean annual temperature of 29 ^{o} C [13]. The plots used in year 2007 was different from 2006 but at the same lowland area. In year 2007 only the top soil to a depth of 0-20 cm layer was analyzed.

Field preparation

The field was ploughed with a disc plough to a depth of 30cm and then bounds made after the field layout. The design was the split-split- plot model [14]. The main plots were P- levels, sub-plots were N-levels and sub-sub-plots were the ten varieties. The field layout was as shown in figure (1) for only one replicate. The layout was replicated three (3) times.

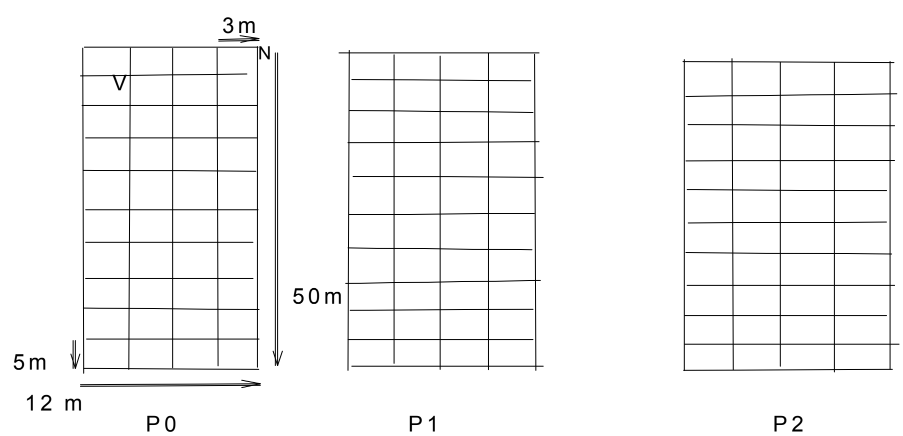

Figure 1: The field layout of the experimental field. P0, P1 and P2 are main plots replicated 3 times. The sub-plots N0, N1, N2 and N3 where 50 m x 3 m labeled N on every P-level plot (50 x 12m) and variety was sub-sub-plot measuring 5m x 3 m labeled V

For the purposes of experimental labeling the treatments were coded P0, P1, P2 for the P fertilizers and N0, N1, N2 and N3 for the N fertilizers. The varieties were coded as already outlined above. The sub-sub-plot were 15m^2 and bounded all round to retain water. The bounds were constructed on the 12/7/06 and 13/7/06 for the year 2006, but for 2007 this was done by 18/6/2007 22/6/2007. Seeds were drill sown at 20cm x 20cm within and between rows.

Soil sampling
Soil samples were taken from each plot for field physico-chemical properties of the experimental area. Only main plots and sub-plots were sampled and 72 soil samples were taken at the 0-20 cm and 20-40 cm depths and later bulked according to treatments into 36 samples for laboratory analysis. In 2007 soil sampling was only done at the 0-20cm depth.

After the broadcast of P fertilizer, soil samples were taken at depths of 0-20 cm of all P and N-level plots to analyze for initial available Bray1 P. A two week-period was allowed for the P fertilizer to react with soil. The moisture content of soil in the field was 20%. These plots were all main plots treated with 0, 13 and 26 kg P/ha. There were 36 samples from the 3 replicates. Samples were bulked according to their P-levels treatment and 3 composite samples were taken from each (0, 13 and 26 kg P/ha) plot. Nine samples were analyzed for Bray 1 P [15]. The Bray 1 P values were averaged per treatment and the graph Bray 1 P versus kg P/ha graph plotted (fig 1).

Planting
Planting was done by seed drilling 20 cm between rows and 20 cm within rows on 24/7/06 and 25/7/06. In 2007, planting was done on 26/6/2007.

Fertilizer application was done before planting by broadcasting the P-levels and basal application of K (30 kg K_2O/ha) to all plots. The nitrogen (N) levels application were split into two and the first split was applied at first tiller initiation after germination and the second at the panicle initiation stage. For bounding, planting, transplanting, fertilizer, herbicide application, weeding, thinning, refilling and harvesting activities, the time and number of people needed to do the work per plot was recorded for future economic evaluation of the experiment. Thinning and refilling of plants was done a week after full germination. The first hand weeding was done two weeks after germination and the second hand weeding was done when weeds were observed to be present in the plots.

Herbicide application was done using six liters of propanil added to one liter Weedone (trade name) per hectare. Weedone is a 2,4, D based located 1.5 km from the rice field.

Crop Evaluation
Crop evaluation at maturity was done by taking a sample of the shoot at the 80 % flowering stage. A quadrant (15cm m x 15 m) was thrown at random using the inner rows of the 15 m^2 and all shoots were cut at 5 cm above ground level. The shoots

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were weighed herbicide. Herbicide was applied when hand weeding failed to effectively control weeds. It was used as a post-emergent herbicide.

Weather records of rainfall, temperature and humidity were accessed from a weather record station at the Savanna Agricultural Research Institute (SARIfresh in the laboratory using a Satorious balance of sensitivity 0.01g. The shoot was dried in a Memmert air-circulated oven for 36 hours at 80^{o} C until a constant weight was achieved (when two consecutive weights at intermittent drying and weighing maintained the same weight).

The counting of the number of tillers started when the first tillers were noticed, and counting was done every other day until three consecutive counts maintained the same number of tillers. A wooden quadrant (1m x 1m) was used in the middle of the plot by ignoring the border plants. All plants within quadrant were counted for total number of tillers.

Statistical Analyses
The design was the split-plot design model as outlined by Genstat 11^{th} edition [14]. The main plots were P-levels, sub-plots were N- levels, sub-sub-plots were the varieties. The effect of PN-level on the pooled means of the varieties was evaluated after an ANOVA analysis to determine statistical significance.
The interaction of PN-level by variety was assessed.

RESULTS

From soil samples taken for characterization of the area two depths were taken in 2006. The pH was an average 4.3 in 1: 2.5 soil to water ratio for depth 0-20cm and 4.9 in the same soil to water ratio at depth 20-40 cm soil. The lower depth was less acidic. Only the top soil 0-20cm was taken in 2007. The average pH, 5.2 was rated moderately acidic. The organic matter was an average 3.0 g/kg soil for 2006 and 2.5 g/kg for 2007 also rated low. Total nitrogen was 0.47 gN/kg soil in 2006 and 0.40 gN/kg soil in 2007 rated low. Available Bray 1 was 6.5 mg P/kg soil. This is regarded as low according to Adepetu *et al*. [15]. Cation exchange capacity (CEC) was 6.0 $cmol^{(+)}$/kg soil and 5.4 $cmol^{(+)}$/kg soil in respective years. The CEC was rated low. Exchangeable K, the averaged was 40 mg K/kg soil, was rated sufficient for both years. The soils were sandy loams. Only the top soils 0-20cm depth were used for the characterization except pH for year 2006. Generally, the fertility of the soil in plant available nutrients were considered poor except for K and this was in line with the general perception that K was usually adequate in these soils (personal communication with Savanna Agric. Research Institute, Ghana Scientist [16].

Figure 2 below shows the available P in the soil two weeks after applying P at various levels. Bray 1 P extracted [17] was rising on increasing P-levels applied. This shows that Bray1 extraction is a good extraction method for assessing available P in these soils. A much higher available Bray 1 P especially for 13 kg P/ha and 26 kg P/ha rates after two weeks was expected. However, they were not significantly different

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from the 0 kg P /ha rate (*p >0.05*). It is possible that the soil could be fixing P especially at the planting time when fields were not flooded. Flooding would have caused anaerobic conditions that will favour Iron (II) formation. Iron (II) phosphates are much more soluble than Iron (III) and Al (III) phosphate complexes. Iron (III) is more favoured in dryer conditions when Iron (II) is oxidized in aerobic environments [18]. This hypothesis could be more rigorously tested in another experiment. Analyses of soil for initial N and P in 2006/2007 showed insufficient initial N and P in the soil solution for plant uptake (0.04-0.07 %N, 3.5-9 mg P/kg in 2006 and 0.027-0.035%N and 2.0-6.0 mgP/kg in 2007.). The initial N and P levels were quite variable from plot to plot.

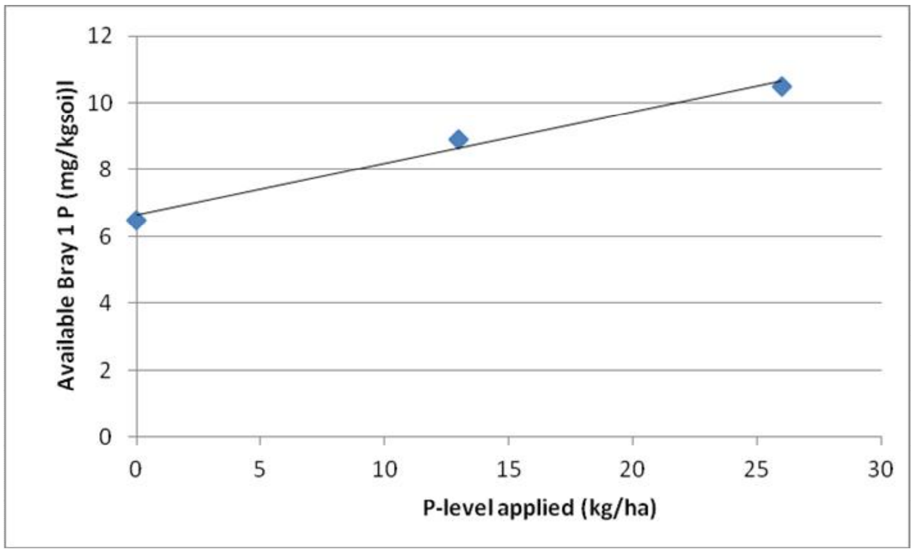

Figure 2: Available P measured as Bray 1 P upon application of P fertilizer (soils taken at 0-20cm two weeks after application at soil water capacity of 20% W/V)

It was observed that during the vegetative growth period, some varieties such as V10 and V7 had blast disease infestation in 2006 which was not observed in 2007. In 2006, V10 was 100 % infested with leaf blast. The NERICA varieties were not affected by blast unlike the Gambiaka local variety. Thus, in 2006, V10 biomass records were low while in 2007 V10 biomass records were high (field and laboratory observation). It is one of the problems to solve that necessitated the crosses of *Oryza sativa lines* to the *Oryza glaberama* local varieties by the African Rice Centre. In normal wet years such as in 2007, the local varieties could as well yield well.

Total lodging of plants was noticed to occur mostly in the V10 plots in 2006 but not in 2007. No symptoms of minor nutrient deficiency were observed. The variety V10 was the local variety and grows fairly tall and generally lodges in windy environments. In year 2007, there was no wind at plant flowering and maturity. There was severe drought in the flowering stage in 2006 while in 2007 there was no drought.

No destructive insect pest was observed despite the presence of some grasshoppers; no major harm was noticed (personal field observation).

The total rainfall for the year 2006 was 814 mm which was a dryer year than 2007 with a total rainfall of 1010 mm. There was more rain in the months of July and August in 2007 (415 mm), about 42% more than 2006 (240 mm). These are the months when flowering, panicle initiation and grain filling of the rice plants are starting. Generally, plant performance was affected by lack of sufficient water. For the year 2006 during the mini drought, plant scorching was observed and grain filling was poor. This effect was not observed in 2007, which had better rainfall distribution at the flowering and maturing stage of the rice plants.

Apart from NERICA L-42 which germinated poorly (15% germination), germination for the rest of the varieties ranged from 80 to 90 % in 2006, while it was 100% in 2007 in all varieties.

The average days of 50 % flowering and 80 % maturity of all varieties used counting from the date of seed emergence, were 73 to 82 days and 104 to 113 days, respectively. The varieties were all early maturing. Kukpla (V10), the local variety was the most early maturing whereas NERICAL-42 the most late of all. All the NERICAs were more closely related in maturity date than the sativas. From the field observation, plots that had N application were delayed a day or two in maturity and flowering (personal field observation).

Analyses of variance in tables 1 and 3 for the two years showed PN-level had a highly significant effect on shoot biomass (*$p < 0.002$ and 0.014* respectively). The PN-level by variety interaction was significant in both shoot-biomass for both years (*$p < 0.001$ and 0.00,* respectively).

The number of tillers in year 2006 and 2007 showed that no significant difference in the PN-level treatments (tables 2 and 4).

The PN-level by variety interaction was highly significant (*$p < 0.001$ in both years)*. The varieties differed in their number of tillers on different levels of PN-levels applied, thus PN-level by variety interaction was significant.

In figure 3 are the average yields of all varieties for the two years pooled against PN-levels. On every P-level, increased N increased shoot biomass, whereas increasing P-levels with N constant hardly increased yields. In a comparison of P0/N0 with P13/N0, P26/N0, the yields were respectively 0.8, 0.9 and 0.93 kg. The Least Significant Difference (LSD) was 0.156 kg from the statistical analyses; which meant that there were no differences in the yield for that treatment combination. There were also no significant differences between P0/N120, P13/N60, P26/N60 and P26/N120 treated biomass yields. In fact, P26/N120, a high fertilizer combination has no advantage over the lower combinations P13/N60, P13/120 and P26/N60 yields. In comparing P0/N120 and P26/N120, treatment of N influences yield more than P

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treatment. The P13/N60 treatment is more economical for shoot biomas yield. It was observed that anytime there was an increase in P-level, increasing N beyond 60 kg/ha resulted in a diminishing return of biomass yields. For example comparison of P13/N0,P13/N30, P13/N60 P13/N120 to P26/N0, P26/N30, P26/N60, P26/N120showed diminishing return on further increases of N from N6O to N120 level**.** A farmer with low fertilizer inputs may be advised to apply at least nitrogen fertilizers as a single application if he found compound fertilizers more costly.

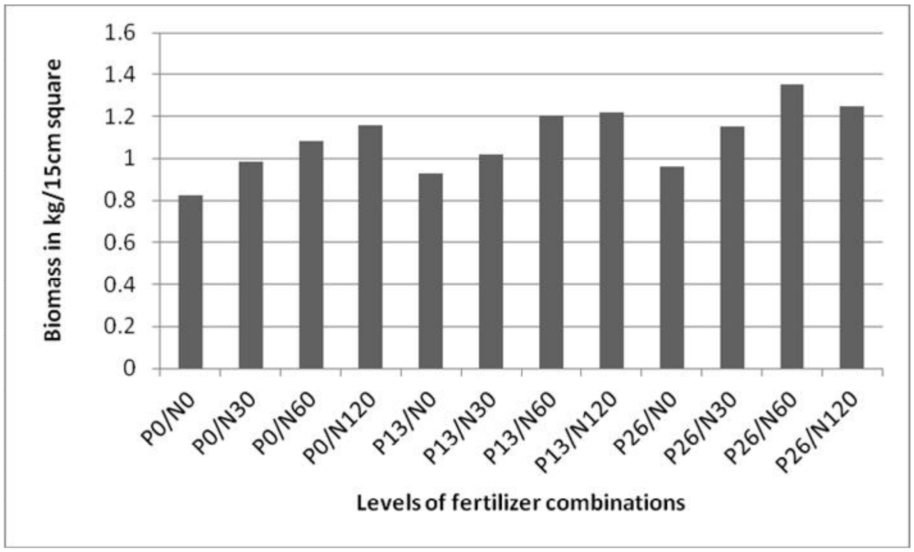

Figure 3: Means of all varieties on P and N fertilizer combination of dry shoot biomass yield/15 cm^2 quadrant for two years (L.S.D. = 0.156 and df of 119).

Figure 4 is the average means of the number of tillers per square meter of all varieties pooled over two years of all fertilizer P and N combinations. Here the trend is that as level of N increases, the number of tillers increases. However, the differences were not significant. An increase in P-level does not have an effect on tiller number. A comparison of P0/N0 with P13/N0 and P26/N0 showed the trend when there is more P higher rice yields are realized. A comparison of P0/N120 to P26/N120 showed that the rice responded more to the effect of N-levels than P-levels. Lower fertilizer combination such as P13/N120 could be as advantageous as a higher combination such as P26/N120. The insignificance of the number of tillers to explain yield could be due to counting mistakes or even counting mal—formed tillers. Tillers were counted every other day and for every plot, technicians could have made counting errors. The number of tillers may not be a good measure of fertilizer response trends especially for field experiments with a large number of plots. To evaluate the response of P and N to rice tillering, more closely, pot experiments could be tried. Plant grain yield was observed to be a better parameter for measuring NERICA and sativa response to P and N application Plant height used for fertilizer response studies was more related to the variety than to fertilizer combinations. Rice panicle weights by

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field observation were more related to grain yield and biomass to P/N treatments than tillering counts.

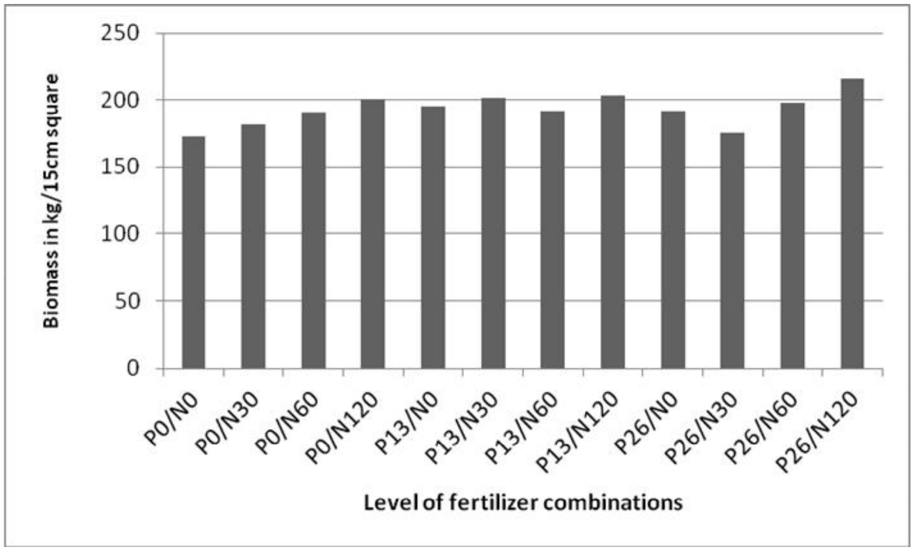

Figure 4: Means of all varieties on P and N combination of number of tillers/m^2 for two years. (L.S.D. = 23 and df of 119)

For the purpose of studying various varietal responses to P and N combinations, figures 5 and 6 were used. Varieties V7, V8, V9, V2 and V1 in order of increasing biomass yields were not significantly different from each other and their response to low inputs such as P0 and N0 were significantly higher than all the other varieties. The varieties V5, V4, V6 were less responsive to soil P0 and N0. The varieties V7, V8, V6, V2, V3 were responsive to P0/N30 fertilizer and showed the N-level influence. The effect of N-level fertilizer is clearly shown when there were significant increases of biomass yield in V9, V2, V6 at the P0/N60 combination. The yields of V9, V2, V6 were not significantly different at the combination P0/N60 and P0/N120. The variety V10 had higher biomass increase with higher P/N combinations. This is seen when a comparison of P26/N120, P13/N120, and P0/N120 combinations were made. The yields of P26/N120 > P13/N120 > P0/N120 were estimated at (2>1.6>0.9 kg), shoot biomass, respectively; this showed that the variety has a high biomass yield on increasing N-levels. The local variety (V10) was the very tall variety which easily lodged in a windy environment towards late August and early September, it was sensitive to drought spells; biomass and grain yields were good in a wet year such as 2007. The combination P13/N60 was good for almost all the varieties except V6 and V7.

From the graphs (figures 5 and 6) the varieties V1, V2, V3, V8, V9 respond well to low inputs of fertilizer; even with just nitrogen fertilizer alone, one could still have a relatively good response. Varieties V1, V2, V3, V8, V9 response was highly significant (*$p < 0.05$*) to high inputs of fertilizer such as P26/N60. There is no advantage of increasing nitrogen fertilizer beyond 60 kgN/ha for these varieties.

Inputs of P13/N30 may be sufficient for low resourced farmers. Low resourced farmers with similar soil chemical characteristics can grow the varieties without P application.

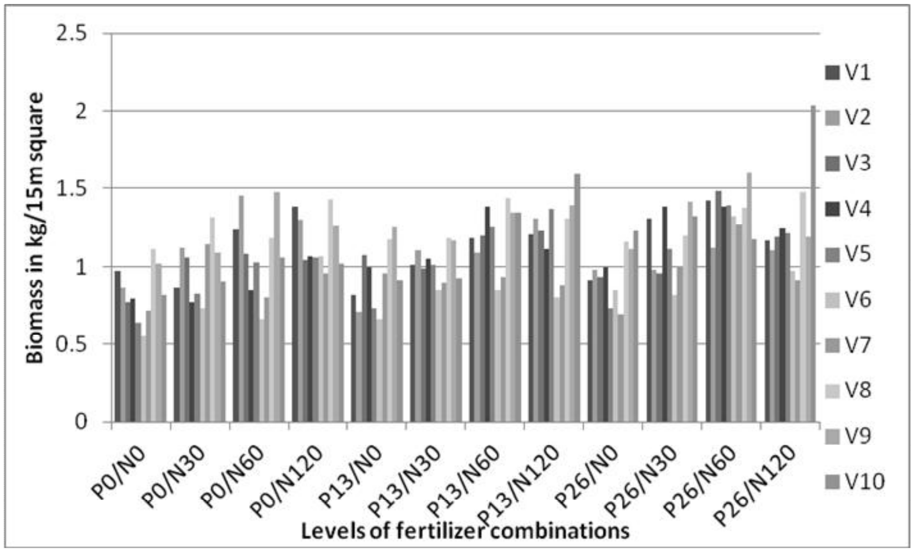

Figure 5: The effect of PN by Variety interaction of dry shoot biomass in kg/15 cm^2 quadrant plots (LSD =0.4926 df 119)

Figure 6 shows the number of tillers with respect to P/N fertilizer combination. Varieties V1, V6, V5 had higher number of tillers at P13/N30 but did not outperform P26/N120. From the graphs, varietal tillering was not as responsive as shoot biomass to differences in fertilizer levels. The trend was increasing tillers at moderate fertilizer combinations especially at moderate nitrogen levels. For example V1, V6 at the combination P13/N30 increased number of tillers by 133% with respect to P0/N0, but further combinations to P26/N120 at higher levels were not significantly higher than the P13/N30 levels even for V1 and V6. The local variety V10 did not appreciably increase in number of tiller at P26/N120 high fertilizer treatments. The P26/N60 and P26/N120 combinations did not increase tiller numbers significantly more than P13/N30 and the P13/N60 combinations for almost all the varieties used, except V10. It is possible to say that low to moderate P and N combinations can increase tillering in the NERICA and Sativa lines. This may translate into grain yield.

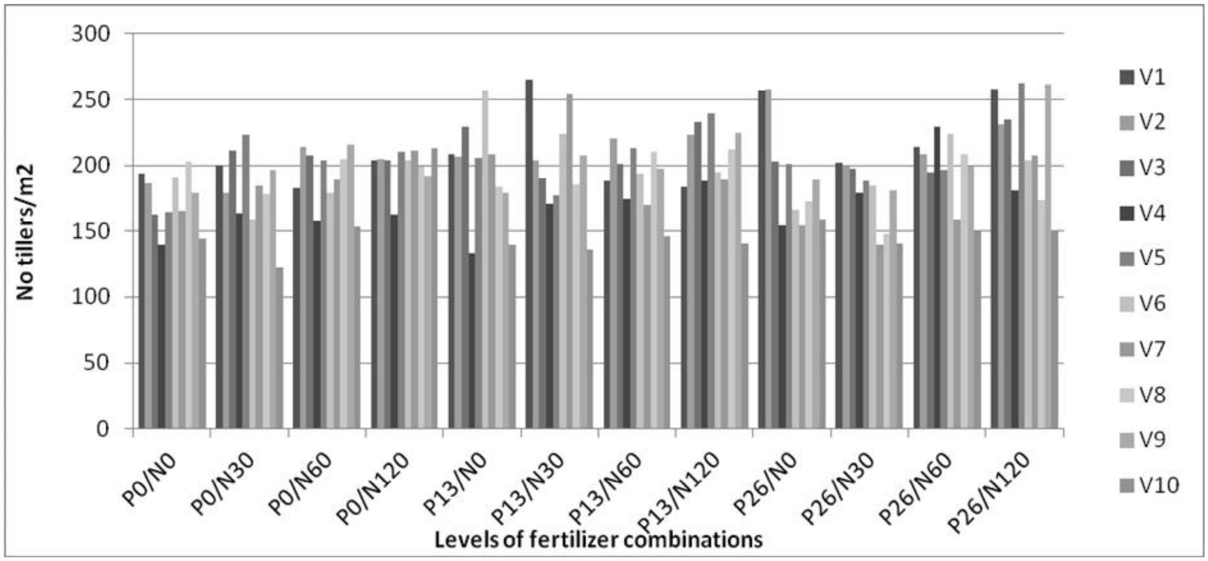

Figure 6: The effect of PN by Variety interaction number of maximum tillers /m^2 quadrant of plots.(L.S.D. = 74 and df of 119)

DISCUSSION

The available P values were quite variable implying non-uniform P content in the plots. The heterogeneity of the plots could influence plant response to P treatments and less so for the N treatments. However, the available P according to Bray1 extraction is low. Generally one would expect a highly significant P response with increasing levels of P. In figure 1, the highest application of P (26kg/ha of P) only yielded 10.20 mg P/kg soil with Bray 1 P extraction. This was slightly higher than the critical level to sufficiently supply adequate P in solution for plant uptake [15]. Thirteen kg P/ha (13kgP/ha) applied to the soil could increase Bray 1 extraction but was not sufficient to supply adequate P for the crop uptake beyond the critical level. This could imply P fixation in the soil by insoluble amorphous Iron (III) or Al (III) oxides [19].

In this study, it was observed that increasing P levels did not have significant impact on plant biomass yield (fig 4). This may be due to the fixing of the P by the soil. May and June were months the field was not flooded. From August to early October, the peak rainy period, the fields were flooded. Iron (III) could have been reduced to Iron (II) and Al (III) hydrolyzed to $Al(OH)^{++}$ or $Al(OH)_2{}^{+}$ thus releasing the fixed P back to the plant as available P [20]. This aspect of the experiment requires further research by a soil chemist.

The varieties V1, V2, V3, V8 and V9 respond to low (P0/N0 to P13/N30) to moderate (P26/N30) inputs. There could be an increase in yield of about 40% at P26/N60 or P26/N120 combinations over the P0/N0 combination. It was found [21, 22] that some upland NERICA varieties were responsive to low to moderate inputs (P0/N0/K0,

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P13/N30/K25 and P13/N60/K25) and high inputs (P26/N120/K25) in Benin. Okeih *et al*. [23, 24] made the following recommendation: P13/N60/K25 meaning, 13kg of P, 60kg N and 25kg K fertilizer combination. Therefore, it is possible to conclude that at low inputs, V1, V2, V3, V8 and V9 could be profitable. These varieties are also responsive to higher fertilizer inputs P26/N120 [20]. In all cases, 30 kg K_20 [22] should be applied alongside. At very low inputs, it is advised that farmers apply at least 30 kg N/ha even if there is no available P. The varieties V4, V5 and V6 are more responsive to high fertilizer inputs and may not be appropriate for low input farmers. Variety 10 does well in high inputs of nitrogen fertilizer but lodging and leaf spot disease may reduce yields. In a wet year, V10 is highly responsive to higher nitrogen levels in biomass yield from field observations made during the study in 2007. In 2006, which was a drier year; especially in early to mid-July V10 showed signs of wilting and biomass yield was affected.

CONCLUSION

From the study, it can be concluded that the soil of the study area may be fixing P because increasing levels of P application did not significantly increase Bray 1 extraction P ($p > 0.05$). It is recommended that an in-depth study be conducted on P fixation in these soils. It will appear essential to study the amorphous iron and aluminium oxides levels in these soils. Bray 1 P is the measure of the availability of soluble P to plants. The study showed that N increased rice plant performance more than P.

The NERICA rice and some Sativa varieties adapted to the Savanna zone in the Savanna Agricultural Research Institute are very responsive to P and N combinations. Varieties such as V1, V2, V3, V8 and V9 are responsive to lower P and N inputs such as P0/N0 or P0/N30 and also to moderate inputs such as P13/N30, P26/N30 or P13/N60. The varieties were also very responsive to higher P and N inputs such as P26/N60, P13/N120 and P26/N120 in biomass yield ($p < 0.001$). However, varieties such as,V4, V5 and V6 are not responsive to lower inputs but are very responsive to the higher inputs as outlined above. Using plant tillering to assess fertilizer responsiveness to P/N combinations did not show any significant differences ($p > 0.005$). Phosphorus and nitrogen combinations and varietal interaction was highly significant in tillering data ($p < 0.001$). Plant biomass yield is more responsive to P/N combination and was significant ($p < 0.05$) while P/N by varietal interaction was highly significant ($p < 0.001$). The translation of P, N, and V1 to V10 for actual rate or varieties has been outlined above.

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Table 1: Analysis of variance table for shoot dry weight in year 1

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	Probability
Replications x PN-level stratum	2	0.5662	0.28336	1.66	
PN-level	11	8.01054	0.72823	4.26	0.002
Residual	22	3.76451	0.17111	3.98	
PN-level x variety	108	881299	0.10483	2.44	<.001
Residual	207	8.89553	0.04297		
Total	350	32.01816			

Table 2: Analysis of variance table for number of tillers in year 1

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	Probability
Replications x PN-level stratum	**2**	55952	27976	2.32	
PN-level	**11**	118801	10800	0.90	0.559
Residual	22	265403	12064	2.58	
PN-level x variety	108	881299	8160	1.74	<.001
Residual	201	940644	4680		
Total	344	2162591			

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Table 3: Analysis of variance for shoot dry weight year 2

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	Probability
Replications x PN-level stratum	**2**	9.0715	4.5357	16.84	
PN-level	**11**	8.8817	0.8074	3.00	0.014
Residual	22	5.9242	0.2693	1.23	
PN-level x variety	108	35.3233	0.3271	1.49	0.007
Residual	216	47.3255	0.2191		
Total	359	106.5262			

Table 4: Analyses of variance for number of tillers in year 2

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	Probability
Replications x PN-level stratum	**2**	42935.3	21467.7	5.41	
PN-level	**11**	36133.03	3284.8	0.83	0.616
Residual	22	87371.4	3971.427	5.86	
PN-level x variety	108	130139.6	1205.0	1.78	<0.001
Residual	216	146332.6	677.4657		
Total	359	442911.9			

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