Improving Productivity Through Effective Soil, Water And Nutrient Management In Liberia

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Abstract: Research on soil amendment and phosphorus fertilizer to increase crop productivity in Liberia has been limited to cereals with less emphasis on rice. A field experiment was therefore carried out at the Central Agricultural Research Institute, Suakoko, Liberia to improve rice productivity through effective soil, water and nutrient management. The experiment consisted of a factorial arrangement of five levels of mineral fertilizer (MF), five levels of a combination of MF and cattle manure (CM) and five levels of a combination of MF and poultry manure (PM), arranged in a randomized complete block design with four (4) replications. The mineral fertilizer consisted of a combination of NPK. The poultry or cattle manure were applied at the rate of 40 kg. Different combinations of N, P, K at three levels of 90, 60 and 120 kg/ha were used to form sub-treatments. An improved rice cultivar (Arica 2) was used as the planting material. At harvest the tallest plant (96.66 cm), leaf length (13.050cm), maximum grain yield (3.98 tons/ha), above ground biomass (13.516 tons/ha) fresh grain plus straw weight (9.001) was recorded from PM + MF1. Number of effective tillers per hill (13.52), the longest panicle (23.11 cm) and panicle weight were found in plot supplied with PM+MF4. CM+MF3 produced the highest weight of 1000 seeds (31.93 g), ha-1). Although the highest biological yield was recorded from PM + MF1 treatment, but statistically similar result were found from PM+MF2, PM+MF4 and PM+MF5 treatments. It was obvious that yield of rice can be increased substantially with the judicious application of organic manure with chemical fertilizer.

Key words: Poultry manure, Cow dung Mineral fertilizer and Arica 2.

INTRODUCTION

Farmers in Liberia generally achieve production levels that are far below what would be possible under favourable conditions. The vast majority of farmers hardly use external inputs and they are therefore strongly dependent on natural soil fertility. Soil fertility, defined as a mixture of soil chemical, physical and biological factors that affect land potential, is inherently low in sub-Saharan Africa (Smith et al., 2004). Uncultivated soils have a natural fertility determined by soil forming factors such as parent material, climate, and hydrology. For soils under natural vegetation, there is a virtual equilibrium; but as soon as the land is altered through clearing of the natural forest or savanna, this equilibrium is broken and soil fertility declines at a rate depending on the intensity of cropping and replacement of nutrient loss in the systems (Lehmann et al., 2006), or other factors such as erosion. Where nutrient-impoverished granites, basement sediments and sands cover about 90% of the land surface the establishment of soil nutrient up take by crop becomes difficult (Smaling, 2005). Most soils of Africa are poor compared to most other parts of the world. Lack of volcanic rejuvenation has caused the continent to undergo various cycles of weathering, erosion and leaching, leaving soils poor in nutrients (Ch'ng et al., 2004). Low soil fertility and the often unfavourable climate create intense pressure on land, even at relatively low population densities. Since the early 1980s there has been growing concern about the fertility of soils and, consequently, the sustainability of land use for crop production in Liberia and Africa at large (Arcelor et al., 2010). Many studies suggest that soils are rapidly degrading. For example, Sanchez et al. (1997) stated that 'soil fertility depletion in smallholder farms is the fundamental biophysical cause for declining per capita food production in sub-Saharan Africa (Adman 2003). Soil degradation seems to be more important in Liberia and West Africa and in some parts of the world. The nutrient balances include, on one hand, major nutrient inflows from rainfall, organic manure, mineral fertilizers, symbiotic N-fixation and sedimentation; and, on the other hand, nutrient outflows through harvested produce and losses due to erosion, leaching, (Franken et al., 1985) etc. Liberia is a country in West Africa that is gifted with abundant low land resources that have the potential to produce sufficient rice for local consumption and possible export. The country still produces less than 40% of its rice requirements, and requirements, over 80% of rice produce are produced by resource-poor farmers. Current yields are about 1.2 t/ha paddy which is among the lowest in the West African sub region. The main production ecology is the upland with its attendant negative environmental consequences. The country aims to obtain mean paddy yields of about 4 mt/ha by the year 2020; an improved and sustainable production technologies, notably cost effective soil and water management options (identified as major constraints) are introduced as against the current system of no water control and poor soil management with majority of rice farmers being poorly resourced farmers managed schemes which are cost effective and easy to adopt are therefore being introduce to build the capacity of the farmer with a high potential for increased lowland productivity in and around the country (CARI 1985). The current studies were undertaken to establish an integrated soil water and nutrient management system to increase lowland productivity. To encourage and promote the use of effective, affordable and sustainable local materials for soil fertility management in lowland rice production. This new technology will benefit Liberian farmers to maximum production to increase yield.

Materials and methods

Location

The study consisted of three (3) field experiments, conducted at a lowland site along route of the Central Agricultural Research Institute (CARI), which is located in Suakoko Bong County, Central Liberia, about 153 km from the capital Monrovia. CARI has an altitude of about 163 m above sea level and lies between 6° 58'N and 9° 30' W. The total rain fall ranges from 2500 to 3000 mm per annum, and the total monthly sunshine is between 150 to 180 h (Owens CB 2000). The soil in the study area is fine sandy loam (FAO/CARI, 2002).

Experimental design and treatments

The experiment consisted of a factorial arrangement of five levels of mineral fertilizer (MF), five levels of a combination of MF and cattle manure (CM) and five levels of a combination of MF and poultry manure (PM) (Table 1), arranged in a randomized complete block design with four (4) replications. Each of these soil amendments were applied to plots measuring 15 m^2, and each plot was separated by a 0.5 m high bund, measuring 0.5 m wide in order to prevent inter-plot seepage. A soil analysis was carried out before imposition of treatments to experimental plot. Thus soil samples were obtained from 0 -20 cm depth of each plot, air dried, processed and analysed to determine the nutrient content of the experimental field before and at the end of the trial. This procedure was done to determine the limiting nutrient. An improved rice cultivar (Arica 2) was used as the plant materials. The mineral fertilizer consisted of a combination of NPK (Table 1). The poultry or cattle manure were applied at the rate of 40 kg. Different combinations of N, P, K at three levels of 90, 60 and 120 kg/ha were use to form sub-treatments. Plants were spaced at 20 cm x 20 cm and established by transplanting 3 seedlings per hill. The CM and PM were applied two weeks before transplanting of seedling, and all the P and K and 50% N were applied one week after transplanting. Twenty-five percent of the remaining N was applied as topdressing at maximum tiller formation and the rest applied at the panicle initiation stage of growth. Single/straight fertilizers (Urea, Triple super phosphate (TSP) and Murite of potash (MoP) were used. All plots were fully bunded for effective water control.

Data and statistical analysis

Analysis of variance (ANOVA) procedure was performed using the GENSTAT statistical package (12th edition 2009). Treatment means were separated using the least significant difference (LSD) method at 5% probability level.

Result and discussion

Effect of soil, water and nutrient management on yield of rice

From table 1.0, the significant impact of poultry manure was observed on plots containing poultry manure combined with mineral phosphorus and potassium fertilizer for grain yield, fresh grain plus straw weight, above ground biomass, panicle length and panicle weight. There was a significant ($p \leq 0.05$) increase in rice yield from 2.071 tons/ha to 3.983 tons/ha under the control and poultry manure combined with phosphorus and potassium fertilizer (MF5 and PM+MF1) respectively. The best growth revealed by plants in plots fertilized by poultry manure only and mineral phosphorus was possibly due to the adequate supply and availability of phosphorus which apparently increased yield in such amended plots. Astonishingly, reduction in yield was observed when phosphorus and potassium fertilizer were sorely applied to each experimental plot but later increased above the control when all three essential elements (NPK) were applied sorely. This result indicates that yield can never be successful when one of the essential elements is omitted. But to also give the importance of mineral phosphorus in rice production in iron toxic environments, mineral phosphorus and nitrogen had higher yield than that of mineral phosphorus and potassium. This result also reveals that in Liberian soils, potassium is not really a limiting factor to crop growth than that of nitrogen and phosphorus. On the other hand cow dung applied plot (CM+MF2) caused a serious reduction (1.966 ton/ha) below the control plot's yield (MF5). This could probably be due to immobilization of nitrogen by the cow dung. And since there were no mineral nitrogen applied to compensate for the nitrogen being immobilized by the cow dung, yield therefore took a reduction trend. But it was also observed that plots applied with cow dung and nitrogen and phosphorus fertilizer (CM+MF3) gave a significant yield (3.248 tons/ha) over the control plots' yield (MF5). This scenario agrees with that cow dung performance in an iron toxic field depends on the presence of nitrogen and phosphorus fertilizer (Feb 14, 20 07). Cow dung sorely applied plots increased grain yield from 26.10 kg to 31.97 kg under MF5 and CM+MF5 respectfully. Followed by cow dung combined with nitrogen and potassium fertilizer (CM+MF2) that delivered the second highest grain weight (30.30 kg). Interestingly, all poultry manure plots produced higher results in terms of grain yield, fresh grain plus straw weight, above ground biomass and panicle weight, but it was latter to grain weight when comparism is being made between the poultry manure and cow dung applied plots. And also grain weight obtained from cow dung plus nitrogen and potassium (CM+MF2) plots were comparative to the highest grain weight obtained in this experiment. Weight loss could be due to vigorous growth caused by the presence of all the essential nutrients in the poultry manure. And since P is being considered as the most limiting nutrient in this study, the presence of P readily antagonized the iron and made all the nutrients available to the plant. As it is clearly seen and compared in table 1.0, that the weight of a rice grain is not positively affected by the increase in plant nutrient.

2.0 Effect of soil, water and nutrient management on vegetative growth of rice

The application of poultry manure significantly ($p \leq 0.05$) influenced the growth of rice. Plant height, leaf length and number of tillers increased with poultry manure integratedly applied with phosphorus and potassium fertilizer (PM+MF1). The best growth exhibited by plants in plots fertilized by poultry manure only and mineral phosphorus and potassium was probably due to the adequate supply and availability of phosphorus which obviously stimulated rapid crop growth in such amended plots. This observation is consistent with the result of IFA (2000) and that of Shiyam et al.; JALSI (2017) in which optimal plant growth was similarly attributed to adequate nutrient supply in poultry manure plots particularly phosphorus and potassium which promoted crop performance. For leaf length and plant height, reduction in growth was seen in plots without any amendment which proves that application of organic materials or even mineral fertilizers plays an essential role in crop growth and development. But interestingly, poultry manure solely amended plots showed no significant difference with plots integratedly supplied with mineral fertilizer (PM+MF2, PM+MF3, PM+MF4 and PM+MF5). But increase in leaf length and plant height was rather observed in plots applied with poultry manure combined with mineral phosphorus and potassium (PM+MF1). This indicates that elemental phosphorus was the most limiting nutrient either in the soil or in the poultry manure and that further application of mineral N would cause reduction in leaf length and plant height instead. On the other hand mineral phosphorus is readily being made available to rice plant in an iron toxic environment. Thus further addition of mineral phosphorus might increase leaf length and plant height further. The scenario was slightly different with number of successfully developed tillers in that number of tillers increased when all the three essential elements were deliberately applied with poultry manure.

1.0 *Effect of soil, water and nutrient management on yield of rice*

TMT.	1000 G WT	Grain yield	FGSWT	AGB	PL(cm)	PW(kg)
			Tons/ha			
MF1	25.57 e	1.481 e	2.869 e	4.802 cd	20.19 d	0.188 cd
MF2	25.60 e	1.695de	3.026 e	4.373 cd	20.48 cd	0.150 d
MF3	26.60 cde	2.164	4.229 de	6.021 cd	21.18 cd	0.214 abc
MF4	27.30 bcde	2.446	4.884 de	4.901 cd	21.10 cd	0.218 abc
MF5	26.10 de	2.071 cde	3.73 de	4.796 cd	20.59 cd	0.190 bcd
CM+MF1	29.20 abcd	2.307 cde	4.892 de	3.382 d	20.88 cd	0.198 abcd
CM+MF2	30.30 ab	1.966 cde	4.039de d	3.202 d	20.66 cd	0.179 cd
CM+MF3	29.95 abc	3.248 abc	6.112 cd	5.074 cd	20.95 cd	0.186 cd
CM+MF4	29.00 abcde	2.312 cde	4.321 de	2.913 d	21.13 cd	0.181 cd
CM+MF5	31.97 a	2.597 bcde	4.828 de	5.082 cd	20.51 cd	0.173 cd
PM+MF1	27.55 bcde	3.983 a	9.008 a	13.516	21.45 bcd	0.250 a
PM+MF2	27.50 bcde	3.832 ab	8.2 abc	13.067	22.53 ab	0.246 ab
PM+MF3	28.02 bcde	2.905 abcd	6.273 bcd	8.272 bc	21.79 abc	0.228 abc
PM+MF4	26.40 de	3.874 ab	8.748 ab	12.026 ab	23.11 a	0.250 a
PM+MF5	27.7 bcde	3.248 abc	8.237 abc	10.114 ab	21.63 bc	21.63 bc
CV (%)	3.7	8.7	5.9	17.6	1.4	7.0
LSD (5%)	3.55	1.32	2.58	3.96	1.33	0.06

TMT= Treatment, GWT= grain weight, DSSWT= Dry straw weight, FGSWT= Fresh grain + straw weight, AGB= above ground biomass, Panicle length, Panicle weight, above ground biomass

2.0 *Effect of soil, water and nutrient management on vegetative growth of rice*

TMT.	Leaf length(cm)	Plant height(cm)	Number of Tillers
MF1	25.14 bcd	81.27 abcd	7.760 cd
MF2	24.13 cd	79.90 bcd	7.840 cd
MF3	22.94 cd	75.77 d	7.930 cd
MF4	21.02 d	72.89 d	5.865 d
MF5	19.90 d	73.79 d	5.880 d
CM+MF1	21.96 d	78.26 cd	7.560 cd
CM+MF2	21.86 d	76.81 cd	7.560 cd
CM+MF3	23.00 cd	78.10 cd	6.560 cd
CM+MF4	22.06 d	79.59 bcd	6.950 cd
CM+MF5	24.02 cd	83.03 abcd	8.070 c
PM+MF1	31.60 a	96.66 a	12.420 ab
PM+MF2	29.76 ab	95.77 ab	11.250 ab
PM+MF3	27.39 abc	92.17 abc	10.260 b
PM+MF4	29.65 ab	96.58 a	13.050 a
PM+MF5	30.10 ab	96.61 a	11.730 ab
CV (%)	2.6	2.7	3.0
LSD (5%)	5.3048	9.125	2.1831

Conclusion and Recommendation

This study evaluated the effects of selected strategies of soil management on nutrient losses under iron toxicity and on crop yield. To conclude, the combination of an organic amendment with soil surfactant could be considered the best treatment for lowland areas with deeper soils less affected by soil erosion and setting the focus on increased crop yield. Further research should focus on long-term field trials to include a wider range of rainfall conditions and should test different rates of organic amendments. This study aimed to help smallholder subsistence farmers, so an evaluation of the cost-effectiveness of the selected technologies will be crucial in establishing sustainable options under lowland conditions and in determining their biophysical and socio-economic applicability at a wider scale. Since highest yield was observed in plots conditioned with poultry manure combined with phosphorus and potassium, it is therefore recommended that PM+MF1 be used for yield increment. Effective farmer involvement through the establishment of demonstration plots and farmer education and awareness of the need to prevent the degradation of soil fertility for sustainable lowland yields will be essential to foster the adoption and successful implementation of the selected strategies.

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