Nigerian
Journal of Soil and
Environmental Research

Nig. J. Soil & Env. Res. Vol. 22: 2023 47 - 52
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Determination of Alternative Fertilizer Recommendation for Rice (*Oryza Sativa*) in the Nigerian Northern Guinea and Sudan Savannas

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ABSTRACT

Rice (*Oryza sativa*) is the primary staple food for about 50% of the world's population and its consumption is growing faster than any other crop in Africa. A major threat to rice production is incorrect fertilizer application, which majority of the farmers assumes to be constant over time and over large areas. The fertilizer recommendation for rice in Nigeria consists of one predetermined rate of nitrogen (N), phosphorus (P), and potassium (K) for vast areas of crop lands. This study employed field data to develop alternative fertilizer recommendation (AFR) for rice (*Oryza sativa* L.) in Northern Guinea and Sudan savannas. Field trials were conducted for two years (2010 and 2011) in the rainy season at Samaru and Kadawa Research Farms (irrigation section) of Ahmadu Bello University Zaria, representing the two locations. Seventeen (17) NPK fertilizers treatments combinations were formulated and laid out in a randomized complete block design, replicated 4 times, giving a total of 68 plots in each location. The results showed that the soils of the study sites were slightly acid (pH 6-7) with low total nitrogen, available phosphorus, exchangeable bases, organic carbon and moderate in CEC. This confirmed the soils to be low in inherent soil fertility status, indicating need for additional nutrient inputs to increase their productivity. Application of 120 kg N ha^{-1}, 50 kg P ha^{-1} and 50 kg K ha^{-1} fertilizer NPK rates gave the highest yield of 3490.3 kg ha^{-1} and 3798.6 kg paddy ha^{-1} at Samaru and Kadawa, respectively.

Keyword: fertilizer recommendation, rice, northern guinea savanna, sudan savanna

INTRODUCTION

Rice (*Oryza sativa*) is the primary staple food of about three billion people, which is about 50% of the world's population. Rice consumption is growing faster than the consumption of any other crop in Africa; unfortunately, its yields are generally declining in many parts of the region (Haefele *et al*., 2000). Prior to 2016, rice production in Nigeria is very low and the country imports about $3 billion rice per year, making it one of the largest rice importing countries in the world (Chukwuka, 2016). In 2014, rice demand was estimated at 5.9 million metric tonnes, while only 2.7 million Mt was locally produced, leaving a supply gap of 3.2 Million MT (Kwabena *et al.,* 2016). Although the trend in rice production increases to 5.5m tons in 2015 and 5.8 m tons in 2017 from a population of 12 million rice producers (FAO, 2015), there is still need to improve its yield to meet with current population. Therefore practices such as proper fertilizer application should be employed to increase its yield.

Cropping systems for rice in the Nigerian savanna zones are characterized by improper and long-term use of inorganic fertilizers with little or no organic inputs. This practice result to mis-match between applied fertilizers, soil resources and plant needs and consequently, contribute to poor soil resource management; resulting in gradual decline in soil fertility which translates to low yields obtained in intensive and non-intensive rice-based systems (Haefele *et al*., 2003). Even though, rice crop has a critical need for fertilizers, especially nitrogenous in the Northern Guinea and Sudan Savanna zones, most rice farmers have no technical expertise in fertilizers use, in terms of type, rate, grade, when and how to apply (Kebbeh, 2003). This cropping practice results in gradual decline in soil fertility over time which manifest as decline in grain yield per unit area. Therefore, the management of nutrients for rice in Nigeria requires new approaches that will enable adjustments in applying N, P, and K to accommodate field-specific needs of the crop for supplemental nutrients. Hence, this study is aimed at providing the type and quantities of mineral fertilizers which should be applied by farmers to adjusted to the soil conditions of different rice domains and their rice yield potentials.

MATERIAL AND METHODS

Study Locations

Field trials were conducted in two different locations to determine alternative fertilizer recommendations for rice. The field experiment locations were Teaching and Research Farms of the Institute for Agricultural Research, Samaru (11° 11' N and 07°38' E) in the Northern Guinea Savanna and Kadawa out station (11°30' N and 8° 30' E) in the Sudan Savanna ecological zone of Nigeria. The experiments conducted in the wet seasons of 2010 and 2011 and the same fields were used in all the two years of study.

Soil Sampling and analysis

Soil samples were collected to assess the nutrient status of the soils before cropping. Samples were collected at depth of 0-15cm by using the auger. Composite soil samples were collected during the wet season in 2010 after land preparation, before any fertilizer was applied or seed sown in both locations. Subsamples were taken and processed for physical and chemical properties using standard procedures (Anderson and Ingram, 1986).

Treatments and experimental design

Seventeen (17) fertilizer NPK treatment combinations were formulated and laid down in a randomized complete block design, replicated four (4) times, giving a total of 68 plots in each location. The fertilizer NPK combinations are shown in Table 3.1. The treatments were designed to allow for mutually exclusive assessment of soil indigenous nutrient supplies through incorporated nutrient omission treatments, and assessment of the responses of N, P and K by varying one element while keeping the other two constant. The experiment was set such that four (4) data sets: (i.) nutrient omission, (ii.) N response, (iii.) P response and (iv.) K response were obtained.

Nutrient omission plots and NPK response trials

The nutrient omission component of the field trials consisted of seven (7) incomplete factorial NPK treatments viz: NPK: 0:0:0, 120:0:0, 0:50:0, 0:0:50, 0:50:50, 120:0:50, 120:50:0 and 120:50:50, randomly assigned among the N, P and K response trial treatments and laid in a randomized complete block design.

Nitrogen response

The nitrogen response trial treatments were aimed at determining the yield response of the crop to N rates. This component trials consisted of five (5) incomplete factorial NPK treatments viz: NPK: 0:50:50, 40:50:50, 80:50:50, 120:50:50, and 160:50:50, randomly assigned among the nutrient omission, P and K response trial treatments and laid in a randomized complete block design

Phosphorus response

The phosphorus response trial treatments were aimed at determining the yield response of the crop to P rates. It consisted of five (5) incomplete factorial NPK treatments viz: NPK: 120:0:50, 120:25:50, 120:50:50, 120:75:50, and 120:100:50, randomly assigned among the nutrient omission, N and K response trial treatments and laid out in a randomized complete block design.

Potassium response

The potassium response trials treatment was aimed at determining the yield response of the crop to potassium rates. It consisted of five (5) incomplete factorial NPK treatments viz: NPK: 120:50:0, 120:50:25, 120:50:50, 120:50:75, and 120:50:100, randomly assigned among the nutrient omission, N and P response trial treatments and laid in a randomized complete block design.

Crop Husbandry Practices

The field was prepared at the beginning of the operations in June each year in 2010 and 2011. The two fields at Samaru and Kadawa were sprayed with glyphosate at the rate of 4 litres per hectare to control weeds. Two weeks after, the two fields at the two locations were harrowed and set into four blocks of 17 plots each measuring 4m x 2.4m (9.6m^2) with spacing of 1m between each block. Bunds between each plot were also raised and maintained using hoe to prevent loss of nutrients to neighboring plots The study was conducted on the same fields and the plots were maintained throughout the two years of the experiment. Hoe was used to break and level plots. FARO 44 (Sippi), a lowland rice variety of medium duration of 110-120 days maturity period was used. The seed was treated with Apron star (methylthiuram + metalaxyl + carboxin) at the rate of 3.0 kg seed per 10 g sachet of the chemical before sowing. Direct seeding was done by the dibbling method, where 5-8 seeds were planted per hole at spacing of 20 cm x 30 cm. Hoe weeding was carried out at 4 and 8 weeks after sowing (WAS). Phosphorus and potassium fertilizers were applied basally before sowing the rice crop according to the treatments. Nitrogen was applied in three splits, as shown in Table 1. Fertilizers used were Urea (46 percent N), Single Super phosphate (19 percent P_2O_5) and Muriate of potash (60 percent K_2O). The paddy rice was harvested differently according to location. The crop was harvested at maturity in both years. After harvest, the yield obtained was measured according to the treatments in kgha^{-1}

Statistical Analysis

All the plant data obtained from the experiment were sorted into 4 data sets: (i.) nutrient omission, (ii.) N response, (iii.) P response and (iv.) K response. Each data set was subjected to analysis of variance using the General Linear Model (GLM): The level of significance in the analysis of variance was set to a P-level of 0.05. (Gomez

Table 1. Fertilizer treatments and N splits at early tillering, panicle initiation and booting in the trial fields at Samaru and Kadawa during the wet seasons of 2010 and 2011.

Treatment	Total N dose	N at Early tillering	N at panicle initiation	N at booting	Total P dose	Total K dose
Missing elements	←		$Kgha^{-1}$			→
T1	0	0	0	0	0	0
T2	120	50	50	20	0	0
T3	0	0	0	0	50	0
T4	0	0	0	0	0	50
T5	0	0	0	0	50	50
T6	120	50	50	20	0	50
T7	120	50	50	20	50	0
N rate						
T8	40	10	20	10	50	50
T9	80	30	30	20	50	50
T10	120	50	50	20	50	50
T11	160	60	60	40	50	50
P rates						
T12	120	50	50	20	25	50
T13	120	50	50	20	75	50
T14	120	50	50	20	100	50
K rates						
T15	120	50	50	20	50	25
T16	120	50	50	20	50	75
T17	120	50	50	20	50	100

and Gomez, 1984). For comparison between treatment means, Duncan New Multiple Range Test with alpha < 0.05 was used (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Paddy yields from nutrient omission trials

Nutrient omission trials to determine the effect of the most limiting nutrient (N, P or K) on grain yield at Samaru and Kadawa during 2010, 2011 and the mean seasons are presented in Table 2. Results showed that paddy rice yield was consistently and significantly higher in NPK: 120:50:50 treatments (treatment containing full doses of N, P and K nutrients) in both Samaru and Kadawa soils, during 2010, 2011 and combined seasons. The highest paddy yield (5.83 tons ha^{-1}) was obtained with NPK: 120:50:50 in 2010 at Samaru. Lowest paddy yields were generally observed at the control treatment (NPK: 0:0:0) during 2010, 2011 and mean season in both Samaru and Kadawa soils. Omission of N P K from the fertilizer schedule reduced paddy yields by 72%, 73% and 72% during 2010, 2011 and mean season in Samaru location. Similarly, in Kadawa, paddy yields were reduced by 72%, 76% and 74% respectively during 2010, 2011 and mean seasons. Omission of P in Kadawa reduced yield of paddy by 20%, 40% and 30% respectively, during the same period. However higher yield response was shown on N and P as indicated from NPK: 120:50:0 treatments which produced the second highest yields during the two seasons. When K was Omitted (NPK: 120:50:0) from the fertilizer schedule, paddy yield also reduced by 31%, 15% and 27% during 2010, 2011 and mean season in Samaru respectively and 8%, 28% and 17% in Kadawa during the same season respectively. Nitrogen and phosphorus were observed to be the most limiting nutrients to paddy yield in both Samaru and Kadawa. Potassium was less limiting to paddy yields as shown in NPK: 120:50:0 treatment which was consistently next highest after NPK: 120:50:50 during the 2010, 2011 and combined season in Samaru and Kadawa soils. Nitrogen and phosphorus were observed to be the most limiting nutrients to paddy yield in both Samaru and Kadawa soil. Potassium was less limiting to paddy yields as shown in NPK: 120:50:0 treatment which was consistently next highest after NPK: 120:50:50 during.the 2010, 2011 and combined season in Samaru and Kadawa soils. The yield limitation by N, P and K were therefore, in the order of N> P> K. The significantly higher paddy yields obtained with NPK: 120:50:50 treatment consistently during the 2010, 2011 seasons and mean, at both Samaru and Kadawa soils showed both Samaru and Kadawa soils responded to N, P, and K fertilization. Omission of N from the fertilizer schedule (NPK: 0:50:50) reduced paddy yields by 42%, 30% and 39% in Samaru during 2010, 2011 and combined seasons respectively. In Kadawa during the same seasons, paddy yield was reduced by 33%, 47% and 39% respectively due to omission of N from the fertilizer schedule. Omission of P from the fertilizer schedule (NPK: 120:0:50) reduced paddy yields by 34%, 23% and

Table 2. Paddy yield as influenced by N, P and K omission and full dose application in Samaru and Kadawa soils during 2010, 2011 seasons.

	Paddy Yield (tons ha^{-1})					
	Samaru			Kadawa		
Treatment	2010	2011	Mean	2010	2011	Mean
0.0.0	1.65f	0.57g	1.11e	1.48f	1.08f	1.28g
0.0.50	3.02cd	1.32de	2.17cd	2.76d	2.22d	2.50e
0.50.0	2.76de	1.20e	1.98d	2.39de	2.19d	2.29e
0.50.50	3.35bcd	1.43d	2.39bcd	3.61c	2.43d	3.02d
120.0.0	2.03ef	0.77f	1.40e	2.11e	1.63e	1.87f
120.0.50	3.61bc	1.59c	2.60bc	4.28b	2.71c	3.49c
120.50.0	4.00b	1.74b	2.87b	4.94a	3.26b	4.10b
120.50.50	5.83a	2.06a	3.94a	5.38a	4.55a	4.96a
Mean	3.28	1.34	2.31	3.37	2.51	2.94
SE±	0.13	0.26	0.69	0.97	0.41	0.51

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. SE= Standard Error

34% respectively in Samaru during 2010, 2011 and the response of paddy to nutrients omission indicated nitrogen and phosphorus to be the most limiting to paddy yield in both Samaru and Kadawa. Potassium was less limiting to paddy yields as shown in NPK: 120:50:0 treatment, which was consistently next to NPK: 120:50:50 during the 2010, 2011 and combined season in Samaru and Kadawa soils. Yield limitation by N, P and K were in the order N> P> K. Similar result was obtained by Ezui *et al*., (2010) during their study on informed site-specific fertilizer recommendation for upland rice production in northern guinea savanna of Nigeria. The significantly higher paddy yields obtained with NPK: 120:50:50 treatment consistently during the 2010, 2011 seasons and mean, at both Samaru and Kadawa soils showed that both Samaru and Kadawa soils responded to N, P, and K fertilization. This is in line with the findings of Ezui *et al*., (2010).

Generally, the study showed that treatments with high N rates (NPK: 120:0:50, 120:50:0 and 120:50:50) produced significantly ($p<0.05$) higher grain yield than the rest of the treatments. This implies that nitrogen was vital for rice production in the study area. It was also observed that no fertilization of N, P and K from the fertilizer schedule reduced paddy yields by 75% and 74% respectively at both locations implying that the productive capacity of the soils from the two locations was very low to sustain rice yields without fertilizer application. This is in line with the findings of (Yoshida, 1981), that identified N, P and K as the most commonly deficient nutrients and in these nutrients promotes increase in crop production. Omission of N from the fertilizer schedule (NPK: 0:50:50) reduced paddy yields by 39% from the two locations, while the omission of P (NPK: 120:0:50) reduced paddy yields by 34% at Samaru 30% at Kadawa. Omission of K (NPK: 120:50:0) reduced paddy yields by 27% and 17% in Samaru and Kadawa during the same season respectively. Nitrogen and phosphorus were therefore, the most limiting nutrients to paddy yield in these soils. Potassium was not seen to be less limiting to paddy yields. The limitation to yield by the N, P and K nutrients were therefore seen in the order of N> P>K (Dobermann *et al.,* 2000). Studies conducted by Kebbeh *et al*., (2003) on challenges and opportunities for improving irrigated rice productivity in Nigeria also discovered low nitrogen and phosphorus fertility while potassium fertility was adequate. Similarly, Segda *et al*., (2004) while characterizing the soils of the Irrigation scheme of Borkina Faso discovered the deficiency of N, P and K in those soils to be in line with the trend obtained from this research. High temperatures of the Savanna region, results in high rate of weathering, which might have been responsible for the of the potassium abundance.

Paddy yields response (kg ha^{-1}) to NPK fertilizer rates

Effects of NPK fertilizer rates on paddy yield of rice are presented in Table 3. The results indicated a wide variation in paddy yields due to different N P K treatments combinations. In 2010 season at Samaru, paddy yields varied between 1.13 tons ha^{-1} paddy and 4.54 tons ha^{-1} paddy. Application of NPK at 120:50:75, 120:50:50 and 120:50:100kg ha^{-1} recorded statsically similar and the highest rice paddy yield of 4.54 tons ha^{-1}, was observed with 120:50:75, while 1.34 tons ha^{-1} for 120:50:50 and 120:50:100kg ha^{-1}. The lowest paddy yield of paddy was recorded from NPK: 0:0:0 (control). Although NPK 160:50:50, 120:50:50 and 120:25:50 kg ha^{-1} are statistically similar In 2011 season, the highest paddy yield of 2.81 tons ha^{-1} paddy was recorded from NPK: 160:50:50. The lowest paddy yield of 0.9375 tons ha^{-1} paddy was recorded NPK: 0:0:50, though statistically the same as NPK: 0:0:0 kg ha^{-1}. The mean analysis of two

2010 and 2011 data showed that highest paddy yields of 3.65 tons ha^{-1} paddy was obtained when NPK: 160:50:50 kg ha^{-1} was applied and was however statistically similar with NPK: 80:50:50, 120:50:50 and 120:50:75 kg ha^{-1}. The lowest paddy yield of 1.18 tons ha^{-1} paddy was obtained when no NPK was applied. In 2011 season, the highest paddy yield of 2.81 tons ha^{-1} paddy was recorded from NPK: 160:50:50 which was statistically similar with NPK: 120:50:50 and 120:25:50 kg ha^{-1}. The lowest paddy yield of 0.9375 tons ha^{-1} paddy was recorded NPK: 0:0:50, though statistically the same as NPK: 0:0:0 kg ha^{-1}. The mean analysis of two 2010 and 2011 data showed that highest paddy yields of 3.65 tons ha^{-1} paddy was obtained when NPK: 160:50:50 kg ha^{-1} was applied and was however statistically similar with NPK: 80:50:50, 120:50:50 and 120:50:75 kg ha^{-1}. The lowest paddy yield of 1.18 tons ha^{-1} paddy was obtained when no NPK was applied. In 2010 season, paddy yields ranged between 2.24 to 4.19 tons ha^{-1} paddy. The highest yield of 4.19 tons ha^{-1} paddy was obtained when NPK was applied at the rate of NPK: 120:50:50 which was however, statistically similar with almost all other treatments under balance fertilization except NPK: 120:0:50, 120:50:0 and 120:50:100. The lowest paddy yield of 2236.4 kg ha^{-1} was obtained where NPK was not applied (control) which was however statistically similar with NPK: 120:0:0 and 80:50:50. However, in 2011 wet season the range of paddy yield was between 1.7361 to 3.6806 tons ha^{-1} paddy. The highest yield of 3.6806 tons ha^{-1} paddy was recorded when NPK was applied at the rate of NPK: 160:50:50 which was statistically similar to when NPK was applied at the rate of 120:50:100. The lowest yield of 1.7361 tons ha^{-1} paddy was recorded at NPK: 120:0:0 treatment. Values of combined analysis between 2010 and 2011 wet season on paddy yields showed that paddy yields vary between 2.0622 and 3.7986 t /ha paddy. The highest paddy yield of 3.7986 tons ha^{-1} paddy was obtained from NPK: 120:50:50 treatment. The lowest paddy yield of 2.0622 tons ha^{-1} paddy was obtained from NPK: 0:50:0 treatment. Generally, highest yields in the trial were achieved with NPK rates of120:50:50. It was observed that increase in doses of N from 0 to 120 kg N ha^{-1} resulted in significant yield improvement from 1.9234 to 4.0903 paddy yield (tons ha^{-1}) at Samaru, and 1.281 to 4.7014 paddy yield (tons ha^{-1}) at Kadawa. Further increase in N beyond 120 kg ha^{-1} did not result in significant yield improvement. Increase in P and K doses from 0 to 50 kg ha^{-1}had also improved grain yield significantly, whereas increase in P and K doses from 50 to 100 kg ha^{-1}resulted in reduced grain beyond the optimum of 50 kg ha^{-1} yield. Increased grain yield associated with added fertilizer N, P and K levels might be due to the increase in nutrient absorption by the crop and production of assimilates from photosynthesis and the cumulative effect of increased translocation of these assimilates from leaves to the rice panicles resulting in enhance performance of yield

Table 3. Effect of N P K fertilizer rates on paddy yield during 2010, 2011seansons and mean at Samaru and Kadawa.

Treatment (kg ha^{-1})	Paddy Yield (tons ha^{-1})					
	Samaru			**Kadawa**		
	2010	2011	Mean	2010	2011	Mean
Indigenous Soil N P K Conditions (Nutrient omission)						
$N_0.P_0.K_0$	1.3371h	1.0156hi	1.1763i	2.2364i	2.1181de	2.1772g
$N_0.P_0.K_{50}$	3.6719ef	0.9375i	2.3047f-h	3.5694cd	2.2222d	2.8958de
$N_0.P_{50}.K_0$	3.5833eg	1.7187ef	2.6510de	2.8264fg	2.3611d	2.5937f
$N_{120}.P_0.K_0$	3.0672g	1.2396g	2.1536h	2.3889hi	1.7361e	2.0625g
$N_0.P_{50}.K_{50}$	3.0676g	1.3542g	2.1901gh	2.6319g-i	2.1331de	2.3825fg
$N_{120}.P_0.K_{50}$	3.2657fg	1.1875gh	2.5365e-f	3.7291bc	2.8819c	3.4687bc
$N_{120}.P_{50}.K_0$	3.713.3ef	1.2500g	2.4818e-g	3.3889c-e	3.0556bc	3.2222cd
Improved Soil N P K Conditions (Balance fertilization)						
$N_{40}.P_{50}.K_{50}$	3.7500d-f	1.979.2cd	2.8645c	2.7986f-h	2.1528de	2.4757fg
$N_{80}.P_{50}.K_{50}$	4.2707b-d	2.0573c	3.1640ab	2.9444f-g	2.2915d	2.6179ef
$N_{120}.P_{50}.K_{50}$	4.5065a	2.4740ab	3.4903ab	4.1944a	3.4028b	3.7986a
$N_{160}.P_{50}.K_{50}$	4.2917b-d	2.8119a	3.6548a	3.4861cd	3.6806a	3.5833ab
$N_{120}.P_{25}.K_{50}$	3.8855c-e	2.4219ab	2.8437cd	4.0556ab	3.4375ab	3.5833ab
$N_{120}.P_{75}.K_{50}$	3.9115c-e	2.0833bc	2.9974bc	3.0069e-g	3.2431a-c	3.1250d
$N_{120}.P_{100}.K_{50}$	3.4479e-g	2.3032bc	3.2365b	3.1736d-f	2.4305d	2.8025d
$N_{120}.P_{50}.K_{25}$	4.2917b-d	1.9010c-e	3.0964c	4.1666a	3.0556bc	3.6111ab
$N_{120}.P_{50}.K_{75}$	4.5428a	2.1875b	3.3651a	4.0625ab	3.6528a	3.8576a
$N_{120}.P_{50}.K_{100}$	4.4968a	2.2272bc	3.3620b	2.8153f-h	3.1181bc	2.96678b
SE ±	**0.2699**	**0.1024**	**0.1474**	**0.2092**	**0.2091**	**0.2183**

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. SE= Standard Error components (Dobermann *et al*., 2002). Clear yield increases due to N and P application with little effects of K was observed repeatedly in several West African Savanna regions (Haefele, 2001 and Haefele *et al*., 2003b). The result showed that, the highest yields in the trial were achieved with NPK rates of 120:50:50 and increase in doses of N from 0 to 120 kg N ha^{-1} resulted in significant yield improvement from 1.92 to 4.09 paddy yield (tons ha^{-1}) at Samaru, and 1.281 to 4.7014 paddy yield(tons ha^{-1}) at Kadawa. Hence, further increase in N beyond 120 kg ha^{-1} did not result in significant yield improvement. Increase in P and K doses from 0 to 50 kg ha^{-1} had also improved grain yield significantly, whereas increase in P and K doses from 50 to 100 kg ha^{-1} resulted in reduced grain beyond the optimum of 50 kg ha^{-1} yield. Increased grain yield associated with added fertilizer N, P and K levels might be due to increase in nutrient absorption by the crop and production of assimilates from photosynthesis and the cumulative effect of increased translocation of these assimilates from leaves to the rice panicles resulting in enhance performance of yield components (Dobermann *et al*., 2002). Clear yield increases due to N and P application with little effects of K was observed repeatedly in several irrigation schemes in the West African Savanna regions (Wopereis *et al*., 1999; Haefele, 2001; Haefele *et al*., 2003b).

CONCLUSION

The application of 120 kg N ha^{-1}, 50 kg P ha^{-1} and 50 kg K ha^{-1} fertilizer NPK rates gave the best yield of 3490.3 kg paddy ha^{-1} at Samaru and 3798.6 kg paddy ha^{-1} at Kadawa. Yield targets of up to 6.2 tons of paddy ha^{-1} is achievable with NPK rates of 126.7 kg N ha^{-1}, 86.4 Kg P_2O_5 ha^{-1} and 132 kg K ha^{-1} at Samaru, while 6.7 tons of paddy ha^{-1} is achievable with NPK rates of 123.3 kg N ha^{-1}, 76.8 Kg P_2O_5 ha^{-1} and 105 kg K ha^{-1} at Kadawa.

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