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Research Paper

EFFECT OF DIFFERENT NITROGEN APPLICATION RATES ON YIELD AND GROWTH CHARATERISTICS OF SOME RICE (*Oryza sativa* L.) GERMPLASM MATERIALS

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Abstract

Field studies were conducted during the 2014 cropping season to evaluate the effect of three nitrogen rates (30, 60 and 90kgN/ha) on yield and growth characteristics of twelve adapted rice germplasm materials. In each of the two growing ecologies (irrigated and rainfed) where the studies were conducted, the experiment was laid out in a randomized complete block design with split plot arrangement involving six germplasm materials as the main plot and the 3 N rates as the sub-plots with 3 replications per site. The objective was to investigate the influence of the rice germplasm (genotype) and N rate on yield and the other agronomic traits. At Tono (irrigated ecology), the greatest panicle weight (5.68 t/ha) was recorded with the application of 90kgN/ha followed by 60 kgN/ha (4.88 t/ha) and 30 kgN/ha (4.36 t/ha). At Nyangua (rainfed ecology), the greatest grain yield (3.063t/ha) was recorded with the application of 90kgN/ha followed by 60 kgN/ha (2.697t/ha) and 30 kgN/ha(1.012t/ha). Generally, an increasing trend on measured traits including grain yield were observed for increasing rates of N application, while genotype by N rate interaction was insignificant for the traits measured.

Key words: N rate, germplasm, rice, agronomic traits.

INTRODUCTION

Rice (*Oryza sativa* L.) is a major staple food crop for many developing countries and not only a main source of calories but also an important source of income and employment for many farmers, particularly poor households. In Ghana rice accounts for about 15% of agricultural Gross Domestic Product (GDP), and represents nearly 45% of total area planted to cereal grains. To achieve food security and foreign exchange savings, increased production of highly competitive domestic rice should be the utmost priority of Ghana's agriculture.

Identification and use of high yielding potential cultivars, though ensures higher yields, requires appropriate agronomic management including nitrogen application. Among macronutrients usually applied as commercial fertilizers, nitrogen has the quickest and most pronounced effect on cereal production. It increases size and number of grains per panicle and protein percentage. It also improves the utilization of phosphorus and potassium to an appreciable extent (Brady, 1999) [3].

According to Raun and Johnson (1991) [9], inadequate nutrition, especially limitation of nitrogen, is one of the major bottlenecks of rice production in the world where about one third of the total N applied to crops is used for rice. Rice is very responsive to N fertilization and high yield potential of modern varieties cannot be realized without N supply to the plant during the entire growing season. Application of nitrogen fertilizer either in excess or less than optimum rate affects both yield and quality of rice to a remarkable extent. Thus proper management of crop nutrition is of immense importance.

Within the Sudan savannah zones of Ghana, identification of location specific cultivars and optimum nitrogen dose are essential for increasing the productivity of rice. Such information is lacking for the newly developed rice germplasm materials, i.e Anyofula, Basmati 123, Good and New, GR 18, Perfume (ST) and GR 1837 recommended for irrigated ecologies and Matigey, Basmati 113, Sabota 36, Sebota 68, Sebota 87 and IR 72 (Ph) recommended for rice producing rainfed ecologies. The current shift in agricultural production strategies towards low external input sustainable agricultural (LEISA) practices has further emphasized the importance of selecting and promoting crop varieties that will fit into the subsistence farmers' practice of exploitative agriculture. Keeping these points in view, the present study was initiated during 2014 cropping season to investigate the effect of three different nitrogen levels (30, 60 and 90 kgN/ha) on the 12 rice germplasm materials and to determine the appropriate level of nitrogen that could help in achieving suitable paddy yield.

MATERIALS AND METHODS

Location/sites of Experiments

From a parallel study conducted (by the same authors) in the Sudan savannah zone during the 2013 cropping season during which some thirty rice germplasm materials were evaluated for grain yield stability and adaptability, six materials including Anyofula, Basmati 123, GH1837, GR 18, Good and New and Perfume (ST) were identified as specifically adapted to the higher yielding irrigated sites. Further, Sebota 87, Matigey, Basmati 113, Sebota 68, IR 72 (Ph) and Sebota 36 were also identified and recommended for rice producing rainfed ecologies. Based on these recommendations, two experimental fields were set up during the 2014 cropping season on the 15th July (Nyangua, rainfed site) and 4th September (Tono, irrigated site). They were each laid out in a randomized complete block design with split plot design with 18 treatments and three replications (54 plots) using a plot size of 5x3m^2. The18-treatment combination consisted of the six selected materials assigned to main plots and three levels of nitrogen (30, 60 and 90 kg N/ha) assigned to sub-plots at plant spacing of 20cm x 20cm. The 60Kg N/ha was the recommended rate for rice in the production area while the 30 and 90kgN/ha were the lower and higher rates respectively. The plots were separated by a bund of 0.75 m for main plot, 0.5m for sub-plot and 1m for replication. Each plot was thus separated from the others by bunds to prevent drifting of fertiliser between and among plots. Nitrogen fertilizer in the form of urea (46% N) was applied at the different levels in two equal doses to maximize N use efficiency. In all trials, 60 kg P_2O_5/ha as Triple Superphosphate (TSP) and 30 kg K_2O as muriate of potash were applied at planting. All other rrecommended agronomic practices and plant protection measures were followed.

Data collection

Soil chemical analyses of the trial sites within the 0-20cm depth were carried out prior to planting. Soil samples were collected, air-dried in the laboratory, ground and sieved through a 2mm sieve. Soil pH was measured using the pH meter at 1:1 soil to water ratio. Macro-nutrients including nitrogen, phosphorus and potassium were analysed. Percentage total nitrogen was determined by the micro kjeldahl-technique Jackson (1962) [5]. The available phosphorus wasS extracted by the Bray method and determined colorimetrically (Bray and Kurtz, 1945) [4].
Data were taken on number of tillers per hill 3 and 6 weeks after planting (or sowing), days to 50% flowering, plant height at maturity, days to maturity, number of panicles per hill, panicle weight, grain length, 1000 grain weight, straw yield and grain yield which was the major character measured for the analysis. Moisture content of the grain (paddy) yield was adjusted

appropriately. The data were collected by first selecting at random two-hill × two-hill sampling units from the test area (excluding borders) of each plot making sure these sample hills were not hills that were replanted or that were adjacent to a missing hill.

Data analysis

Data collected were subjected to analysis of variance (ANOVA) to establish treatment and the interaction effect on grain yield and other traits. All statistical analyses were conducted using the GenStat Statistical program (GenStat 12th). Treatment means were compared using the Least Significant Difference (LSD) at 5% level of significance. The effects of the genotypes, N rates and their interactions were determined from the ANOVA analysis. Main effects and interaction effects were considered significant when $P \leq 0.05$.

RESULTS AND DISCUSSION

Responses of rice grain yield and other agronomic traits to fertilizer N application

Main effects of Genotypes and N rates on some agronomic traits

Tables 1 to 2 show results of some agronomic traits of 6 rice germplasm materials during the 2014 trial season at Tono and Nyangua sites as affected by genotype and N levels. At Tono, the greatest panicle weight (5.68 t/ha) was recorded with the application of 90kgN/ha followed by 60 kgN/ha (4.88 t/ha) and 30 kgN/ha (4.36 t/ha). Thus, the application of N at enhanced rate led to the production of the greatest panicle weight which contributed significantly to final grain yield. In addition, application of fertilizer N probably facilitated better partitioning of dry matter to generative organs at the expense of vegetative components. At lower nitrogen levels, insufficient nutrients for filling of grains led to diminished grain numbers per panicle and hence lower panicle weight. In the present study, inadequate levels of N probably enhanced floral abortion and reduced final panicle weight.

Table 1: Some yield and yield components of 6 rice germplasm materials as affected by genotype and N level (t/ha) during the 2014 cropping season at irrigated (Tono) site in northern Ghana.

Treatment	**Grain yield (t/ha) @14%MC**	**Panicle weight (t/ha)**	**Grain length (mm)**
Genotype			
Anyofula	4.74	5.85	9.60
Basmati 123	4.82	6.05	8.87
GH 1837	4.20	5.43	10.00
Good and New	4.14	5.07	9.00
GR 18	3.21	5.85	9.60
Perfume (ST)	4.33	5.55	8.87
Lsd (5%)	**0.27**	**0.33**	NS
N Level (kgN/ha)			
30	2.018	4.36	9.80
60	4.246	4.88	9.13
90	4.760	5.68	9.03
Lsd (5%)	**1.7**	**0.29**	NS
CV(5%)	**5.9**	**1.1**	3.0

Table 2: Some yield and yield components of 6 rice germplasm materials as affected by genotype and N level during the 2014 cropping season at Nyangua (rainfed) site in northern Ghana

Treatment	Grain yield (t/ha) @14%MC	Panicle weight (t/ha)	Grain length (mm)
Genotype			
Sebota 87	2.932	3.47	9.50
Matigey	3.361	4.19	8.78
Basmati 113	2.884	3.99	9.90
Sebota 68	3.307	4.67	8.91
IR 72 (Ph)	2.244	3.47	9.50
Sebota 36	**3.018**	4.19	8.78
Lsd (5%)	**0.181**	**0.029**	**NS**
N Level(kgN/ha)			
30	1.012	3.92	9.70
60	2.697	3.79	9.04
90	3.063	4.77	8.94
Lsd (5%)	**1.13**	**0.026**	**NS**
CV(5%)	**5.6**	**1.10**	**5.0**

Differences in genotype and N levels were significant (p<5%) at both sites (Tono and Nyangua) in affecting grain yield, straw yield, plant height at maturity and panicle weight. These traits increased with increase in N rates for all the materials, indicating that either the materials were efficient in their capture and use of fertilizer N or the soils are low in plant available nutrients or both. However, the two factors did not interact to influence these traits. In the environments where these studies were carried out, the soils were low in plant available nutrients (Appendix 1) with average pH of 5.50. Adamtey *et al.,*(2010) [2] reported low maize yields for soils that received no fertilizer and attributed it to reduced plant growth as a consequence of low nutrient, particularly N supply and uptake. This could be applicable to rice as well.

At Tono, the greatest grain yield (4.760t/ha) was recorded with the application of 90kgN/ha followed by 60kgN/ha (4.246t/ha) and 30 kgN/ha (2.018t/ha). Thus, the application of N at enhanced rate (90KgN/ha) led to the production of the greatest grain yield. Comparison of the grain yield showed that the enhanced rate of 90kgN/ha resulted in 135.9% more than the lower rate (30 KgN/ha). At Nyangua, the highest grain yield (3.063t/ha) was recorded with the application of 90kgN/ha followed by 60 kgN/ha (2.697t/ha) and 30 kgN/ha(1.012t/ha). Thus, the application of N at enhanced rate led to the production of the highest grain yield. Comparison showed that the enhanced rate of 90kgN/ha resulted in 202.6% more than the lower rate. At both locations, higher application rate generally, showed better trend for higher grain yield and yield components than lower fertilizer treatment. This could be attributed to more availability and better utilization of plant growth resources such as water, nutrients and solar radiation in the enhanced treatment thereby resulting in taller plants. Neil (2009) [6] reported that a greater yield response was obtained for maize with increasing N application under adequate soil water condition. Inhibition of photosynthesis during the grain filling period due to environmental stresses such as shading or water deficit can result in a major reduction in grain dry matter in rice (Abou-Khalifa 2012) [1].

Nitrogen fertilizer application rate significantly (p≤5%) influenced panicle weight per unit area, straw yield, plant height at maturity and SPAD reading (Tables 3 and 4). Leaf chlorophyll concentration was generally higher at enhanced rates of N but lower at lower fertilizer treatments. Chlorophyll concentration reduction and leaf yellowing are good indicators of N remobilization. Generally, N deficiency accelerated senescence as revealed in the present study by the decrease in chlorophyll concentration under lower fertilizer N treatment as compared with non-stressed conditions. In maize production, leaf N decrease has a direct effect on photosynthesis, resulting in greater floral abortion (Pearson and Jacob, 1987) [8] and lower kernel number (Uhart and Andrade, 1995) [10]. Enhanced leaf chlorophyll concentration could also lead to better capture of solar radiation and conversion to dry matter as depicted in the superior grain and straw yields produced under these treatments. Interactions between the yields (grain and straw) and N rate were not significant at the locations.

Table 3: Some agronomic traits of 6 rice germplasm materials as affected by genotype and N level during the 2014 cropping season at irrigated (Tono) site in northern Ghana.

Treatment	**DFF (days)**	**Plant height @ Maturity (cm)**	**SPAD reading**	**Straw yield (t/ha)**
Genotype				
Anyofula	88.33	150.27	42.10	7.09
Basmati 123	71.67	89.38	40.03	7.37
GH 1837	88.00	152.82	37.51	7.49
Good and New	72.00	91.80	33.77	7.80
GR 18	88.33	150.27	37.50	8.46
Perfume (ST)	**71.70**	89.40	33.60	8.79
Lsd (5%)	**NS**	**7.443**	**NS**	**1.65**
N Level(kgN/ha)				
30	88.17	127.76	33.12	6.85
60	80.67	103.24	37.94	7.94
90	71.17	130.95	41.20	8.70
Lsd (5%)	**NS**	**2.824**	**2.121**	**0.09**
CV(5%)	**5.0**	**3.4**	**17.80**	**8.20**

DFF=Days to 50% flowering;

On average, all the materials responded similarly to increased N application at both sites as evidenced by the lack of significant genotype x N level interactions for most traits except for plant height at maturity. Differences among the materials were not significant for days to 50% flowering, SPAD reading and grain length at both sites.

Table 4: Some agronomic traits of 6 rice germplasm materials as affected by genotype and N level during the 2014 cropping season at Nyangua (rainfed) site in northern Ghana.

Treatment	DFF (days)	Plant height @ Maturity (cm)	SPAD reading	Straw yield (t/ha)
Genotype				
Sebota 87	88.30	135.24	39.12	4.11
Matigey	69.67	80.44	44.10	4.27
Basmati 113	86.00	137.54	36.24	4.34
Sebota 68	70.00	82.62	40.90	4.52
IR 72 (Ph)	86.33	136.27	41.33	4.91
Sebota 36	**67.68**	80.44	46.63	5.10
Lsd (5%)	**NS**	**6.699**	**NS**	**NS**
N Level(kgN/ha)				
30	86.17	114.98	38.19	3.97
60	78.67	92.92	41.23	4.60
90	69.17	117.85	44.73	5.05
Lsd (5%)	**NS**	**2.542**	**0.241**	**0.052**
CV(5%)	**3.0**	**3.4**	**11.60**	**5.60**

Tables 5 and 6 show the interaction effects of rice materials by N rate on plant height at maturity at Tono and Nyangua sites. Even though, the main effects of genotype and N rates were statistically significant (p<5%) at both sites for plant height at maturity, the interaction effects of genotype x N rate were also significant (p<5%) at both sites for the same trait. At Tono site, Anyofula accounted for the tallest plant height at maturity (182.47cm) at the lower N rate (30kg/ha) followed by Perfume (ST) (110cm), Basmati 123 (103cm) and Good and New (101cm) at the recommended N rate (60kg/ha). Perfume (ST) at the lower N rate (30kg/ha) accounted for the shortest plant height at maturity (72.78cm)

Table 5: Interaction effect of rice materials by N rate on plant height (cm) at maturity at the Tono site

Variety	N Rate (Kg N/ha)		
	30	**60**	**90**
Anyofula	182.47	99.97	168.36
Basmati 123	72.78	103.96	91.39
GH1837	182.47	101.20	174.80
Good and New	73.60	110.40	91.39
GR 18	182.47	99.97	168.36
Perfume (ST)	72.78	103.96	91.39
Lsd (5%)	**8.922**		
Cv (%)	**3.4**		

Averaged across the materials, plant height at maturity decreased with the recommended N rate (60kg/ha) at the Nyangua site (Table 4). The 30kgN/ha treatment produced significantly taller plant heights than the other rates, with Basmati 113 material accounting for the tallest plant (164.22cm) while Sebota 36 was the shortest (65cm) at that rate.

Table 6: Interaction effect of rice materials by N rate on plant height at maturity (cm) at the Nyangua site

Variety	N Rate (Kg N/ha)		
	30	**60**	**90**
Sebota 87	160.22	89.98	151.52
Matigey	65.50	93.56	82.25
Basmati 113	164.22	91.08	157.32
Sebota 68	66.24	99.36	82.25
IR 72 (Ph)	162.22	89.98	151.52
Sebota 36	65.00	93.56	82.25
Lsd (5%)		**8.030**	
***CV* (%)**		**13**	

CONCLUSION

Rice materials performed differently in different environments and required optimum N rates for increased agronomic benefits. As opposed to the use of farmer varieties of rice which are typically noted to be of low agronomic efficiency, the use of adapted germplasm materials and optimum levels of N are crucial in influencing grain yield. The materials and N rate performed differently under the same conditions at Tono and Nyangua and hence the need to consider materials with consistent yield advantage cannot be ruled out if increased production and productivity is to be achieved. Basmati 123 supported the greatest grain yield while in Nyangua, Matigey accounted for the greatest grain yield.

RECOMMENDATIONS

Grain yield of rice obtained from the enhanced rate (90KgN/ha treatment) was greater than that for the other rates at both locations. Basmati123 was the ideal material for the irrigated ecologies while Matigey was the ideal for rainfed ecologies in the Guinea savanna zones. However, since this study was conducted under researcher's management, on-farm adaptive trials are required to validate these findings in order to arrive at conclusive recommendations for rice production within the Guinea and Sudan savannah zones.

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REFERENCES

1. Abou-Khalifa,A,A,B. 2012. Evaluation of same rice varieties under different nitrogen levels. Pelagia Research library(Advances in Applied Science Research). Vol3(2):1144-1149.

2. Adamtey, N., Cofie O., Ofosu-Badu, F.G. and Ofosu-Anim, J. 2010. Effect on N-enriched compost on transpiration efficiency and waste-use efficiency of maize (Zea mays L.) under controlled irrigation. *Agricultural Water Management* 97:995-1005

3. Brady, N. C. 1999. The nature and properties of soils. Prentice Hall of India Pvt. Ltd. Delhi.

4. Bray, R.H. and L.T., Kurtz, 1945. Determination of total organic and available forms P in soils. *Soil science* **39**:39-45

5. Jackson, M. L. 1962. Soil chemical analysis. Practice, Hall, Inc. New York.

6. Neil, A. A. (2009) Grain yield and rainfall use efficiency responses of maize and alternative rotating crops under marginal production conditions in the western Highveld of South Africa. *South Africa Journal of Plant Soil*, 26(3): 264-269

7. Normile, D. 2004. Yangtze seen as earliest rice site. Science 275: 309.

8. Pearson, C. J. and B. C. Jacob 1987. Yield components and nitrogen partitioning of maize in response to nitrogen before and after anthesis. Aust. J. Agric. Res. 38:1001-1009

9. Raun, W. R. and G. V. Johnson. 1991. Improving nitrogen use efficiency for cereal production. Ind. J. Agron. 91(3): 357 p.94

10. Uhart, S. A. and F. H. Andrade, 1995. Nitrogen deficiency in Maize: II. Carbon-Nitrogen interaction effects on kernel number and grain yield. Crop Sci. 35:1384-1389

APPENDIX

Appendix 1: Range (and mean) of various chemical attributes of the soils at sample points in the trial sites within the 0-20cm depth during the 2013 cropping season in northern Ghana

Soil variable	Tono	Libga	Nyangua	Largbani
Nitrogen (%)	0.030 – 0.040 (0.034)	0.021 – 0.030 (0.023)	0.033-0.040 (0.035)	0.050 – 0.64 (0.056)
Phosphorus (mg/kg)	4.00 – 4.52 (4.26)	3.02 – 4.90 (3.50)	5.03 – 5.28 (5.10)	4.23 – 6.9 (5.84)
Potassium (mg/kg)	64.0 – 70.0 (68.4)	9.0 – 20.0 (14.0)	39.0 – 48.0 (44.6)	24.0 – 55.0 (48.1)
pH	5.2 – 5.8 (5.50)	4.7 – 5.80 (5.25)	5.10 – 5.20 (5.15)	5.13 – 5.70 (5.60)