NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 41, 2024
www.incda-fundulea.ro; doi.org/10.59665/rar4139 First Online: February, 2024. DII 2067-5720 RAR 2024-73

Influence of Variety, Seedling Transplanting Age and Nitrogen Fertilizer Rates on Selected Chemical Composition of Rice Grains and Straws

Simon Nda and Erick Sebetha*

Food Security and Safety Niche Area, Faculty of Natural and Agricultural Sciences, North West University, Mmabatho, South Africa

*Corresponding author. E-mail: Erick.Sebetha@nwu.ac.za

ABSTRACT

The study was conducted under lowland ecological conditions at the Edozhigi and Badeggi National Cereal Research Institute (NCRI) farms in the Guinea savannah region of southern Nigeria during the 2015 and 2016 growing seasons. The objective was to determine the effect of seedling transplanting age and nitrogen fertilizer rates on nutrient content of two rice varieties. The trial was laid out in a split-split plot arrangement fitted into randomized complete block design (RBCD) and replicated three times. The treatments for the trial consisted of two rice varieties as the main factor (FARO 44 and FARO 52), the sub plot factor consisted of four seedling transplanting ages (7, 14, 21 and 28) and the sub-sub plot factor consisted of five inorganic N fertilizer rates (0, 60, 120, 180 and 240 kg N/ha). Rice grains and straw after harvest were analyzed for N, P, K, Fe and Zn content. The result of the rice grain and straw nutrient content revealed a significant effect of location on rice grain nitrogen and zinc content. Rice planted at Edozhigi gave significantly higher nitrogen and zinc content in rice grains in 2015 and 2016 planting seasons. Nitrogen fertilizer application had significant effect on rice grain nitrogen content in 2016 planting season. The result showed a significant (p<0.05) effect of variety on Zn content of rice grains. Rice variety Faro 44 produced significantly higher rice grain zinc content of 0.334 and 0.297 ppm during both planting seasons. Significantly (p<0.05) rice variety Faro 44 had higher rice straw nitrogen content of 0.172 and 0.165% in 2015 and 2016 planting seasons respectively. In conclusion, the application of 240 kg N/ha to 14 and 28 days old of Faro 44 rice variety revealed more nutrient content in rice grain and straw.

Keywords: nitrogen fertilizer, rice grains, rice straws, rice varieties and seedling transplanting age.

INTRODUCTION

Rice (*Oryza sativa* L.) is the second largest grown cereal crop after wheat and is the staple food of about one-half of the world's population (Anonymous, 2008-09). There is need to improve on the quality of rice produced by the farmers (DelaCruz and Khushi, 2000; Yoshihashi et al., 2004). Nowadays, consumers need rice with good grain quality as nutritional value of rice is important. Rice grain quality includes nutritional value which is affected by variety and environmental factors such as temperature, fertilizer application and drought (Chen et al., 2012). Nitrogen deficiency in soil affects rice quality. The rate of fertilizer application and the native soil fertility of rice fields have been reported to affect the mineral element content of rice (Nwilene et al., 2007). Different cultivars have varying degree of response to N fertilizers as a result of their agronomic traits. Pomeranz (1992) reported that rice nutrient content differs according to the variety. High-yielding rice cultivars remove much higher amount of K than P or even N (Sharma et al., 2013). When nitrogen fertilizer is applied either in excess or less than optimum rate, both yield and quality are affected to a remarkable extent (Manzoor et al., 2006). Nitrogen fertilizer application has influential role in determining the percentage of nitrogen in the rice grains and nitrogen uptake by the rice plants (Ebaid and Ghanem, 2001).

Optimum age of rice seedlings at transplanting supports the uptake of more nutrients from the soil. The nutrient composition of rice grains and straw is a translation of the age under which, seedlings are transplanted (Marschner, 1995). The nutrient content of rice grains and straw is a

Received 30 November 2023; accepted 26 February 2024.

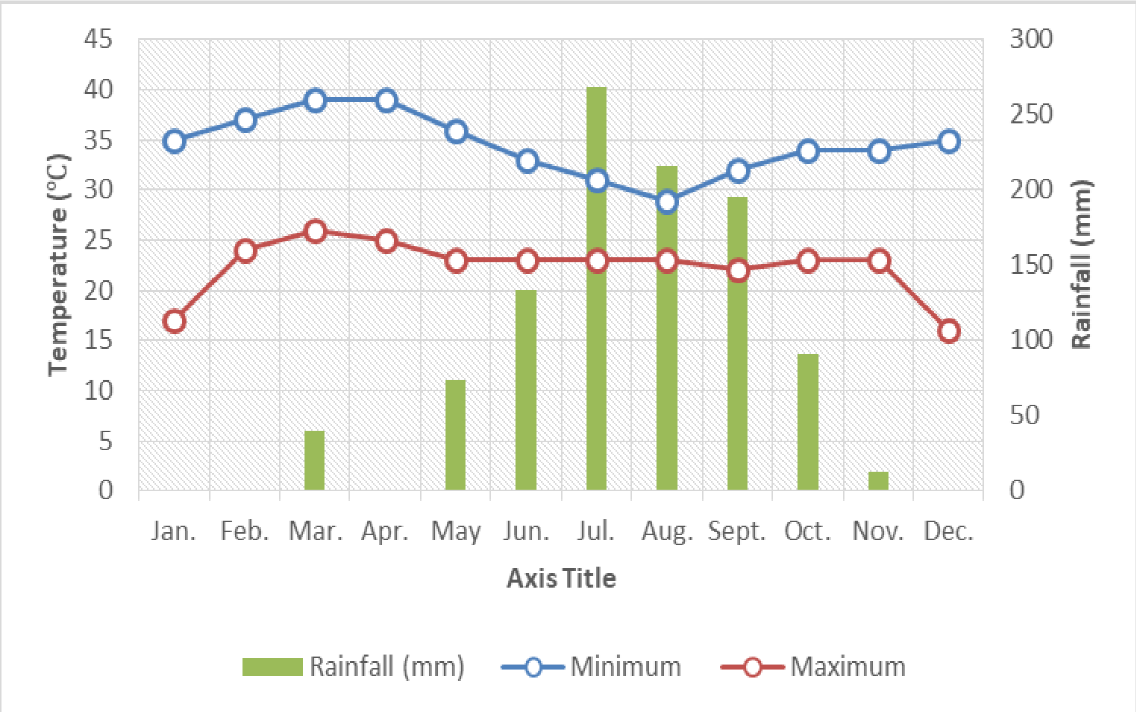
combination of all the changes which are faced by the plants. The nutrient content is directly or indirectly affected by many factors which include total concentration and available quantity of different nutrients, environmental conditions and other related soil parameters (Leigh and Wyn Jones, 1984). Beside all these, the seedling age of rice at transplanting has to play the deciding role. Seedling transplanting age influence rice grain and straw nutrient content. Sahoo et al. (2015) reported that total N, P and K uptake in rice grains and straws was produced by 12 days old transplanted seedlings than other seedling transplanting ages. This could be due to native soil fertility which might affect the nutrient content. Soils reveal different responses to seedling transplanting age and nitrogen fertilizer rates which affect the nutrient content of grains and straw. The genetic improvement of rice has created different varieties that need adjustment in seedling transplanting age and nitrogen fertilizer rates and has effect on nutrient content of rice grains and straw. The objective of the study was to evaluate the effect of variety, seedling transplanting age and N fertilizer rates on the nutrient content of rice grains and straws.

MATERIAL AND METHODS

Description of study area

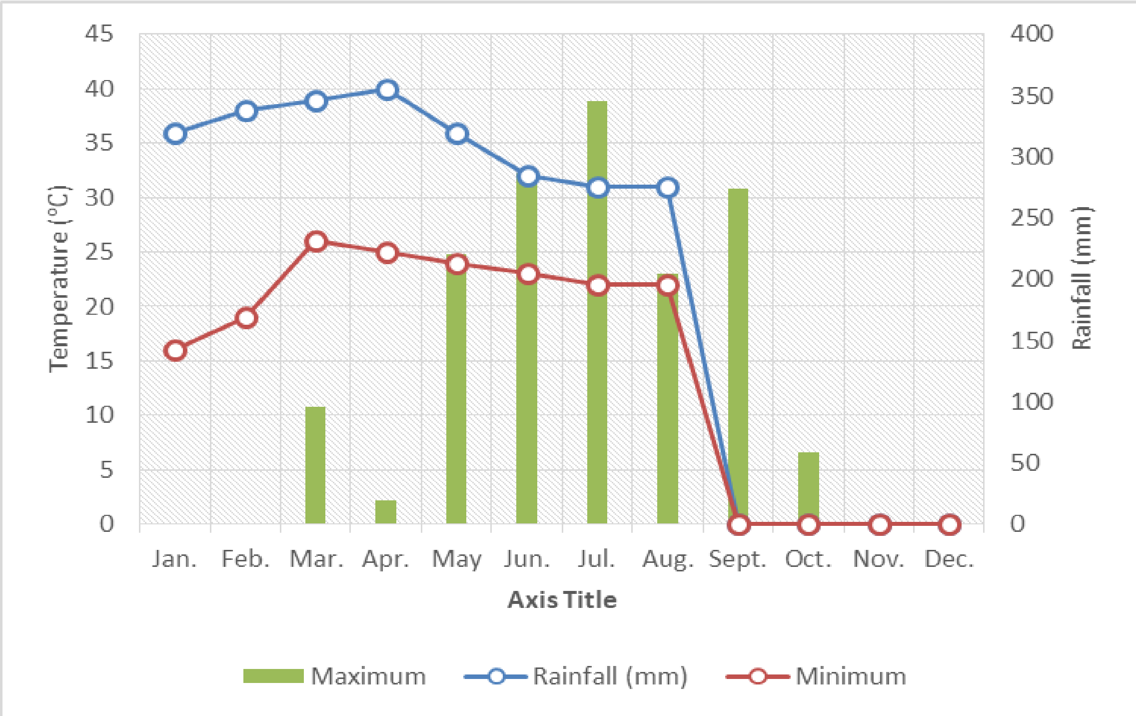
In 2015 and 2016, during the planting seasons, a 2-year agronomic field trial was carried out on the farm of the National Cereals Research Institute (NCRI) in lowland ecological settings. The soil at Edozhigi is classified as dystricgleysol, is a silt loam, and is poisonous to iron. On the other hand, soils at Badeggi site are sandy loam with bulk density of 1.489 g m^{-3} and classified as ultisol (Ayotade and Fagade, 1993).

In Nigeria's Southern Guinea Savannah, there are two different seasons: a wet season from April to November and a dry season from November to March. In both the dry and wet seasons, the relative humidity ranges from 75 to 85%. The annual rainfall in these areas ranges from 1,200 to 1,400 mm, and the typical temperature is between 23°C and 33°C. The study's two locations' meteorological data are displayed in Figures 1 and 2.



Source: National Cereal Research Institute (NCRI) Meteorological Station Badeggi, Niger State.

Figure 1. Distribution of rainfall amount (mm) and minimum and maximum temperature (ºC) at Badeggi during 2015 planting season



Source: National Cereal Research Institute (NCRI) Meteorological Station Badeggi, Niger State.

Figure 2. Distribution of rainfall (mm) amount and minimum and maximum temperature (°C) at Badeggi during 2016 planting season

Experimental design

The experimental design at each site was a split-split plot arrangement fitted into randomized complete block design (RCBD) and replicated three times. Treatments consisted of two rice varieties (FARO 44 and FARO 52) as main plots and four seedling transplanting ages (7, 14, 21 and 28 days after sowing, DAS) as sub plots and five inorganic N fertilizer rates (0, 60, 120, 180 and 240 kg N/ha) as sub-sub plots. Hence, there were a total of 20 sub-sub plots per replication which gave a total of 60 plots per variety.

Agronomic practices and chemical analysis

At harvest stage of rice plant, representative samples of grain and straw were randomly taken from each experimental plot, the samples were taken to the National Cereal Research Institute Badeggi Laboratory for analysis. The straw samples collected were oven dried at 60°C till constant weight the grain samples were air dried. The oven dried samples of straw and air-dried samples of grains were ground to pass through 40-mesh sieve in a macro-Wiley mill. From each sample of rice grain and straw, 0.5 gram was weighed separately for chemical analysis to determine the content of N, P, K, Fe and Zn.

The nitrogen content in rice grains and straws samples were determined by modified Kjeldahl method (Jackson, 1958).

Available phosphorus (P) was determined by Bray 1 method (Estefan et al., 2013).

Exchangeable base (K) was determined following I Nacetate extraction as described by (Okalebo et al., 2002). For the estimation of (Fe, Zn) in the straws and grains, samples were digested in diacid mixture of conc. HNO_3 and $HClO_4$ in the ratio of 10:4 as described by Estefan et al. (2013). After digestion, the plant and grain samples were analyzed with Atomic Absorption Spectrophotometer.

Data analysis

Data generated was subjected to analysis of variance (ANOVA) using Gen-STAT and the difference between treatments mean tested using least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Effect of treatment factors on rice grain nitrogen content

Location had significant ($p<0.001$) effect on rice grain nitrogen content in 2015 and 2016 planting seasons as shown in Table 1. Rice planted at Edozhigi had significantly higher nitrogen content of 0.318 and 0.376% in 2015 and 2016 planting seasons respectively. Nitrogen fertilizer rates revealed significant ($p<0.034$) effect on rice grain nitrogen content during 2016 planting season. Rice fertilized with 60 and 240 kg N/ha had the highest nitrogen content of 0.350% during 2016 planting season. Seedling transplanting age showed significant ($p<0.05$) effect on rice nitrogen content during 2015 and 2016 planting seasons. During 2015 planting season, rice seedlings transplanted at 28 days after planting had significantly higher grain nitrogen content of 0.318%. During 2016 planting season, rice seedlings transplanted at 7, 14, and 28 days after planting had significantly higher grain nitrogen content of 0.332, 0.334 and 0.351% respectively. Variety revealed no significant ($p>0.005$) effect on rice grain nitrogen content during 2015 and 2016 planting seasons.

Effect of treatment factors on rice grain phosphorus content

Location revealed significant effect ($p<0.001$) on rice grain phosphorus content during 2015 planting season as indicated in Table 1. Rice planted at Badeggi had significantly higher phosphorus content of 25.85 ppm. Nitrogen fertilizer rate had no significant effect ($p>0.05$) on rice grain phosphorus content during 2015 and 2016 planting seasons. Seedling transplanting age showed significant effect ($p<0.05$) on rice grain phosphorus content during 2016 planting season. Rice seedling transplanted at 7, 14 and 28 days after planting had significantly higher rice grain phosphorus content of 26.04 and 26.54 ppm respectively. Variety had no significant ($p>0.005$) effect on rice grain phosphorus content during 2015 and 2016 planting seasons.

Effects of treatment factors on rice grain potassium content

Location revealed significant ($p<0.032$) effect on rice grain potassium content during 2015 planting season as revealed in Table 1. Rice planted at Badeggi had significantly higher rice grain potassium content of 0.253%. Nitrogen fertilizer rates revealed no significant effect on rice grain potassium content during 2015 and 2016 planting seasons. Seedling transplanting age showed significant ($p<0.012$) effect on rice grain potassium content during 2016 planting season. Rice seedling transplanted at 14 and 28 days after planting had significantly higher rice grain potassium content of 0.255 and 0.256% respectively. Variety had no significant effect on rice grain potassium content during 2015 and 2016 planting seasons.

Effects of treatment factors on rice grain iron content

Location showed significant ($p<0.030$) effect on rice grain iron content during 2015 planting season as indicated in Table 1. Rice planted at Edozhigi revealed significantly higher rice grain iron content of 0.029 ppm. Nitrogen fertilizer rates, seedling transplanting age and variety had no significant ($p>0.005$) effect on rice grain iron content during 2015 and 2016 planting seasons.

Effects of treatment factors on rice grain zinc content

Location showed significant ($p<0.001$) effect on rice grain zinc content during 2015 and 2016 planting seasons as revealed in Table 1. Rice planted at Edozhigi indicated significantly higher rice grain zinc content of 0.490 and 0.316 ppm during both planting seasons respectively.

Nitrogen fertilizer rates and seedling transplanting age showed no significant ($p>0.005$) effect on rice grain zinc content during 2015 and 2016 planting seasons.

Variety had significant effect ($p<0.05$) on rice grain zinc content during 2015 and 2016 planting seasons. Rice variety Faro 44 produced significantly higher rice grain zinc content of 0.334 and 0.297 ppm during both planting season.

Table 1. Effect of treatment factors on rice grain nutrients content during 2015 and 2016 planting seasons

Treatments	2015					2016				
	N (%)	P (ppm)	K (%)	Fe (ppm)	Zn (ppm)	N (%)	P (ppm)	K (%)	Fe (ppm)	Zn (ppm)
Location										
Badeggi	0.275	25.85	0.253	0.023	0.153	0.294	25.97	0.245	0.035	0.146
Edozhigi	0.318	23.57	0.237	0.029	0.490	0.376	25.81	0.253	0.024	0.316
LSD $_{(0.05)}$	0.016	0.926	0.015	0.005	0.018	0.010	0.801	0.010	0.033	0.018
N rates										
0	0.312	24.25	0.249	0.028	0.322	0.338	25.65	0.255	0.020	0.237
60	0.290	25.63	0.242	0.024	0.327	0.332	26.60	0.252	0.021	0.228
120	0.294	24.23	0.251	0.024	0.315	0.339	25.66	0.245	0.024	0.234
180	0.286	24.85	0.244	0.029	0.318	0.327	26.22	0.243	0.020	0.224
240	0.210	24.61	0.239	0.025	0.327	0.350	25.33	0.249	0.062	0.231
LSD $_{(0.05)}$	0.025	1.464	0.023	0.008	0.029	0.016	1.267	0.016	0.052	0.028
Trans age										
7 days	0.292	24.73	0.249	0.031	0.328	0.333	26.05	0.251	0.020	0.239
14 days	0.292	25.00	0.252	0.024	0.314	0.334	26.54	0.255	0.019	0.237
21 days	0.284	24.01	0.239	0.025	0.320	0.322	24.80	0.234	0.058	0.228
28 days	0.318	25.11	0.240	0.025	0.325	0.351	26.18	0.256	0.020	0.221
LSD $_{(0.05)}$	0.022	1.310	0.021	0.007	0.026	0.014	1.133	0.014	0.047	0.025
Variety										
Faro52	0.296	25.11	0.244	0.024	0.310	0.333	25.86	0.247	0.035	0.165
Faro44	0.297	24.32	0.246	0.028	0.334	0.337	25.93	0.251	0.023	0.297
LSD $_{(0.05)}$	0.016	0.926	0.015	0.005	0.018	0.010	0.801	0.010	0.033	0.018

Effects of treatment factors on rice straw nitrogen content

Location, nitrogen fertilizer rates and seedling transplanting age revealed no significant ($p>0.005$) effect on rice straw nitrogen content during 2015 and 2016 planting seasons. However, variety showed significant ($p<0.001$) effect on rice straw nitrogen content during 2015 and 2016 planting seasons as shown in Table 2. Rice variety Faro 44 had significantly higher rice straw nitrogen content of 0.172 and 0.165% respectively.

Effects of treatment factors on rice straw phosphorus content

Location indicated significant ($p<0.005$) effect on rice straw phosphorus content during 2015 and 2016 planting seasons as revealed in Table 2. Rice planted at Edozhigi had significantly higher rice straw phosphorus content of 19.032 ppm during 2015 planting season. However, rice planted at Badeggi revealed higher rice straw phosphorus content of 19.005 ppm during 2016 planting season. Nitrogen fertilizer rates, seedling transplanting age and variety had no significant ($p>0.005$) effect on rice straw phosphorus content during 2015 and 2016 planting seasons.

Effects of treatment factors on rice straw potassium content

Location, nitrogen fertilizer rates, seedling transplanting age and variety had no significant ($p>0.005$) effect on rice straw potassium content during 2015 and 2016 planting seasons as shown in Table 2.

Effects of treatment factors on rice straw iron content

Location had significant ($p<0.001$) effect on rice straw iron content during 2016 planting season as indicated in Table 2. Rice planted at Badeggi had significantly higher rice straw iron content of 0.019 ppm. Nitrogen fertilizer rates and seedling transplanting age revealed no significant ($p>0.005$) difference on rice straw iron content during 2015 and 2016 planting seasons. Variety had significant ($p<0.001$) effect on rice straw iron content during 2016 planting season. Rice variety Faro 44 gave higher rice straw iron content of 0.0183 ppm.

Effects of treatment factors on rice straw zinc content

Location had significant (p<0.001) effect on rice straw zinc content during 2015 and 2016 planting seasons as revealed in Table 2. Rice planted at Edozhigi showed significantly higher rice straw zinc content of 0.162 ppm during 2015 planting season. However, rice planted at Badeggi had higher rice straw zinc content of 0.205 ppm during 2016 planting season. Nitrogen fertilizer rates and seedling transplanting age had no significant (p>0.005) effect on rice straw iron content during 2015 and 2016 planting seasons. Variety showed significant effect on rice straw zinc content during 2016 planting season. Rice variety Faro 44 revealed significantly higher rice straw zinc content of 0.202 ppm.

Table 2. Effect of treatment factors on rice straw nutrients content during 2015 and 2016 planting seasons

Treatments	2015					2016				
	N (%)	P (ppm)	K (%)	Fe (ppm)	Zn (ppm)	N (%)	P (ppm)	K (%)	Fe (ppm)	Zn (ppm)
Location										
Badeggi	0.163	18.526	0.45	0.131	0.152	0.154	19.005	0.28	0.019	0.205
Edozhigi	0.154	19.032	0.28	0.014	0.162	0.149	18.526	0.45	0.014	0.149
LSD $_{(0.05)}$	0.012	0.376	0.437	0.230	0.008	0.009	0.375	0.437	0.001	0.017
N rates										
0	0.165	18.814	0.47	0.014	0.156	0.154	18.818	0.47	0.019	0.178
60	0.162	18.699	0.20	0.014	0.164	0.155	18.661	0.20	0.014	0.176
120	0.154	18.854	0.48	0.014	0.154	0.149	18.816	0.48	0.017	0.179
180	0.149	18.734	0.17	0.014	0.154	0.148	18.737	0.18	0.017	0.176
240	0.161	18.794	0.52	0.306	0.153	0.150	18.794	0.52	0.017	0.176
LSD $_{(0.05)}$	0.017	0.594	0.690	0.364	0.013	0.014	0.593	0.690	0.002	0.027
Trans age										
7 days	0.162	18.813	0.68	0.014	0.158	0.148	18.786	0.68	0.017	0.178
14 days	0.155	18.494	0.18	0.014	0.153	0.151	18.494	0.18	0.016	0.178
21 days	0.160	18.733	0.43	0.015	0.160	0.155	18.703	0.43	0.017	0.177
28 days	0.158	19.075	0.17	0.247	0.152	0.152	19.078	0.17	0.016	0.176
LSD $_{(0.05)}$	0.015	0.532	0.617	0.326	0.011	0.013	0.531	0.617	0.002	0.025
Variety										
Faro52	0.144	18.876	0.43	0.131	0.152	0.138	18.848	0.43	0.015	0.152
Faro44	0.172	18.681	0.31	0.014	0.160	0.165	19.078	0.31	0.018	0.202
LSD $_{(0.05)}$	0.012	0.376	0.437	0.230	0.008	0.009	0.375	0.437	0.001	0.017

Increased N fertilization may be the cause of the higher N content in rice treated with 60 and 240 kg N/ha. This is in line with the findings of Malidareh et al. (2009), who found that applying N fertilizer at particular rates increased the amount of nitrogen (N) in grains. The ideal range for N in most cereals, according to Havlin et al. (2003), was between 2.0% and 5.0%. Rice straw's resistance to the effects of nitrogen fertilizer may be ascribed to the fertility of the soil.

This contradicts Mbaga's (2015) research, which showed that nitrogen fertilization increased the percentage of nitrogen in biomass straw. Rice and straw with low phosphorus content may be a result of native soil fertility. This contradicts the results of Qiao-gang et al. (2013), who found that increasing nitrogen fertilizer resulted in an increase in the total phosphorus of rice plants at each growth stage. The increased P content in rice grains and straws, according to Ma and Takahashi (1990), may be the result of improved P transfer from roots to shoots. Regardless of the nitrogen treatment rates, rice grains and straws had low potassium levels.

Despite the fact that Juan and Francisco (2013) claimed that the quantity of nitrogen fertilizer used had an impact on plant potassium concentration. In a previous study, Kapoor et al. (2008) found that rice plants took up more K when they received more nitrogen or mixed nitrogen and phosphorus fertilization. Increased root activity that improves soil nutrient availability could be the cause of this (Jawahar and Vaiyapuri, 2013). The results of Ram (2015), who claimed that nitrogen fertilizer had no discernible impact on iron and zinc levels in rice, support the low Fe and Zn levels in rice and straw.

Transplanted rice plants can take in more nutrients from the soil when they are at the ideal seedling age. The results of Ram et al. (2015) and Hussain et al. (2014), who indicated that older seedlings showed larger N nutrient content, and the higher N and P contents in rice grains from 28-day-old and 14-day-old transplanted seedlings, respectively, were in good accord. The content of K, Fe, and Zn in rice grain and straw did not change as transplanted seedling age increased, however the content of K in rice grain did change in seedlings that were 28 days old. According to Nwilene et al. (2007), the natural fertility of paddy fields has been shown to have an impact on the nutritional value of rice grains and straw. A plant's response to various soil conditions and other inputs depends on its genetic makeup.

Rice grains from Faro 52 and Faro 44 responded similarly to the amount of nitrogen fertilizer applied, indicating that the two cultivars exhibited characteristics that were independent of the nitrogen application rate. However, since genetic makeup influences how a plant responds to various soil conditions and other inputs, the greater N concentration in Faro 44 rice straw may be a result of that trait. The intrinsic fertility of the soil may be the cause of the lack of variation effect on the P and K content of rice and straw. According to Nwilene et al. (2007), rice and straw's nutrient content are influenced by the inherent fertility of paddy fields. According to Lin et al. (2014), there was no discernible relationship between variety and phosphorus and potassium concentrations in brown rice in various regions and years. However, it has been noted that the rice cultivars IR68144-3B and IR64 respond significantly to nitrogen fertilization rates (McClure et al., 1990). Active transmembrane transport in rice allows for the uptake of metal chelates like iron and zinc (Abrol, 1990; Marschner, 1995). The genetic makeup of each variety of rice may play a role in variations in the iron and zinc levels of rice grain and straw. According to Chandel et al. (2010), cultivar variations were the primary influences on the Fe and Zn contents of grain and straw.

CONCLUSIONS

In this study, location played a significant role in the rice grain nutrient content. Rice planted at Edozhigi location showed higher grain nitrogen, iron and zinc content while rice planted at Badeggi showed higher grain phosphorus and potassium content. Nitrogen fertilizer rate did not affect most of the grain and straw nutrient content except grain nitrogen content. Application of 60 and 240 N kg/ha showed higher nitrogen content in rice grain.

The seedling transplanting age played a pivotal role in rice grain nutrient content. Seedlings transplanted at 14 and 28 days showed higher grain nitrogen, phosphorus and potassium content. Rice straw nutrient content was not affected by seedling transplanting age in this study. Variety showed a significant role in rice straw nutrient content. Rice variety, Faro 44 had higher straw nitrogen, iron and zinc content.

REFERENCES

Abrol, Y.P., 1990. *Pattern of nitrate assimilation and grain nitrogen yield of field grown wheat Triticum aestivum L.)*. In: van Burschem, M.L. (eds.), Proceedings of the Eleventh International Plant Nutrition Colloquium. Wageningen, the Netherlands, Kluwer Academic Publisher: 773-778.

Anonymous, 2008-09. *Economic survey 2008*. Published by Ministry of Finance, Govt. of India.

Ayotade, K.A., and Fagade, S.O., 1993. *Wet land utilization for rice production in Sub-Saharan Africa*. Proceedings of an International Conference on Wet land utilization held at Ibadan Nigeria, 4-8 Nov. 1993: 25-26.

Chandel, G., Banerjee, S., See, S., Meena, R., Sharma, D.J., Verulkar, S.B., 2010. *Effects of different nitrogen fertilizer levels and native soil properties on rice grain Fe, Zn and protein contents*. Rice Science, 17: 213-227.

Chen, Y., Wang, M., Ouwerkerk, P.B., 2012. *Molecular and environmental factors determining grain quality in rice*. Food and Energy Security, 1(2): 111-132.

DelaCruz, N., and Khush, G.S., 2000. *Rice grain quality evaluation procedures*. Singh, R.K., Singh, U.S., Khush, G.S. (eds.), Aromatic Rice. Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi, India: 16-28.

Ebaid, R.A., and Ghanem, S.A., 2001. *Evaluation of some rice varieties under different nitrogen levels*. Journal of Agricultural Science Mansoura University, 26(4): 1833-1840.

Estefan, G., Sommer, R., Ryan, J., 2013. *Methods of soil, plant and water analysis: A manual for the West Asia and North Africa Region*. 3rd ed. ICARDA, Beirut, Lebanon.

Havlin, J.W., Nelson, L., Beaton, J.D., 2003. *Extractable micronutrients: The soil fertility and fertilizers*. http://courses.soil.ncsu.edu/ssc342.

Hussain, S., Fujii, T., McGoey, S., Yamada, M., Ramzan, M., Akma, M., 2014. *Evaluation of Different Rice Varieties for Growth and Yield Characteristics*. The Journal of Animal and Plant Sciences, 24(5): 1504-1510.

Jackson, M.L., 1958. *Soil chemical analysis*. New Delhi: Prentice Hall of India.

Jawahar, S., and Vaiyapuri, V., 2013. *Effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice*. International Research Journal of Chemistry, 1: 34-43.

Juan, H., and Francisco, R., 2013. *Increasing nitrogen rates in rice and its effect on plant nutrient composition and nitrogen apparent recovery*. Chilean Journal of Agricultural Research, 73(4): 385-390.

Kapoor, V., Singh, U., Patil, S., Magre, H., Shrivastava, L., Das, R.O., 2008. *Rice growth, grain yield, and flood water nutrient dynamics as affected by nutrient placement method and rate*. Agronomy Journal, 100: 526-536.

Leigh, R.A., and Wyn Jones, R.G., 1984. *A hypothesis relating critical potassium concentrations for growth to the distribution and functions of this ion in the plant cell*. New Phytol., 97: 1-13.

Lin, Z., Ning, H., Bi, J., Qiao, J., Liu, Z., Li, G., Wang, Q., Wang, S., Ding, Y., 2014. *Effects of Nitrogen Fertilization and Genotype on Rice Grain Macronutrients and Micronutrients*. Rice Science, 21(4): 233-242.

Ma, J., and Takahashi, E., 1990. *Effect of Silicon on the growth and Phosphorus uptake of rice*. Plant and Soil, 126: 115-119.

Malidareh, G.A., Kashani, A., Nourrnohammadi, H.R., Mobasser, A.V., 2009. *Effect of silicon application and nitrogen rates on N and Si content and yield of rice (Oryza sativa L.) in two water systems in north of Iran*. World Applied Sciences Journal, 6(6): 719-727.

Manzoor, Z., Awan, T.H., Safdar, M.E., Ali, R.I., Ashraf, M.M., Ahmad, M., 2006. *Effect of nitrogen levels on yield and yield components of basmati*. Journal of Agricultural Research, 44(2): 115-120.

Marschner, H., 1995. *Mineral Nutrition of Higher Plants, 2nd edition*. Academic Press, London.

Mbaga, H.R., 2015. *Response of rice to nitrogen and phosphorus applied to the dominant soil type at the Dakawa irrigation scheme, Morogoro Tanzania*. M.Sc. thesis Sokoine University of Agriculture, Morogoro, Tanzania.

McClure, P.R., Kochian, L.V., Spanswick, R.M., Shaff, J.E., 1990. *Evidence for co-transport of nitrate and protons in maize roots: I. Effects of nitrate on membrane potential*. Plant Physiology, 93: 281-289.

Nwilene, F.E., Oikeh, S.O., Agunbiade, T.A., Oladimeji, O., Ajayi, O., Sie, M., Gregorio, G.B., Togota, A., Taura, A.D., 2007. *Increasing rice production in sub-Saharan Africa, challenges and opportunities*. A Production Handbook, Africa.

Okalebo, J.R., Gathua, K.W., Woomer, P.I., 2002. *Laboratory methods for soil and plant analysis: working manual second edition*. Sacred Africa, Nairobi.

Pomeranz, Y., 1992. *Effect of drying on rice quality*. Encyclopedia of Food Science and Technology 1, 35.

Qiao-gang, Y.U., Jing, Y.E., Shoana, Y., Jian-rong, F.U., Jun-wei, M.A., Wan-chun, S., Li, J., Qiang, W., 2013. *Effects of Nitrogen Application Level on Rice Nutrient Uptake and Ammonia Volatilization*. Plant Science, 20(2): 139-147.

Ram, H., Singh, J.P., Bohra, J.S., Yadav, A.S., Sutaliya, J.M., 2015. *Assessment of productivity, profitability and quality of rice (Oryza sativa) under system of rice intensification in eastern Uttar Pradesh*. Indian Journal of Agricultural Sciences, 85(12): 38-42.

Sahoo, K.C., Pramanik, K., Rath, B.S., Sahoo, S.K., 2015. *Effect of age of seedlings, weed and nutrient management on root growth and nutrient uptake under SRI in Odisha*. International Journal of Bio-resource, Environment and Agricultural Sciences, 1(2): 46-50.

Sharma, S., Chander, G., Verma, T.S., Verma, S., 2013. *Soil potassium fractions in rice-wheat cropping system after twelve years of Lantana residue incorporation in a Northwest Himalayan acid alfisol*. Journal of Plant Nutrition, 36: 1809-1820.

Yoshihashi, T., Nguyen, T.T.H., Kabaki, N., 2004. *Area dependency of 2- acetyl-1-pyrroline content in an aromatic rice variety, KhaoDawk Mali 105*. Japan Agricultural Research Quarterly, 38(2): 105-109.