Octa Journal of Biosciences
International peer-reviewed journal
Octa J. Biosci. Vol. 5(1):24-28

ISSN 2321 – 3663
Jan-June 2017

Octa Journal of Biosciences

journal homepage: www.sciencebeingjournal.com

Scientific Planet Society
SPS

Effect of Different Nitrogen Levels on protein content of Upland Rice and influence of Grain moisture Content on Milling Recovery under Lowveld Conditions of Zimbabwe

Godwin Mtetwa, Zacharia Muchingami and Chirinze Norman

Department of Research and Specialist Services, Chiredzi Research Station, Zimbabwe

ARTICLE INFO

Received	07 Jan	2017
Revised	30 March	2017
Accepted	20 April	2017
Available online 30 June		2017

Keywords: Protein, de-husking, upland, rice and nitrogen

Email: godwin.mtetwa@gmail.com

ABSTRACT

Rice protein is one of the most nutritious components among cereals. A trial evaluating grain quality at different nitrogen levels was conducted in the Lowveld of Zimbabwe under irrigation. Effect of grain moisture content on de-husking quality was also assessed. Split plot design was used, variety as main-plot factor and nitrogen (N) fertilizer application rate as sub-plot factor (0 kgN/ha; 50 kgN/ha; 100 kgN/ha and 150 kgN/ha). Mhara1(M1) and Mhara2 (M2) are upland rice varieties. Five-grain moisture levels (12%; 14%; 16%; 18% and 20%) were considered during de-husking. Results showed that applied nitrogen significantly ($p<0.05$) increased crude protein (CP), total Nitrogen (TN) and grain yield. M1 had significantly higher CP compared to M2 at any applied nitrogen level. M1 had a higher rate of increase of (CP) and (TN). De-husking at 14% moisture gave best results for both varieties, attaining 86% full-grain. Moisture content above 18% increased breakages when de-husking.

INTRODUCTION

Rice (*Oryza sativa*) is the staple food in the diet for many people in the world especially in Asia providing 35-60% of the calories consumed (1). It runs a close second to wheat in its importance as a food cereal in the human diet and about 670 Million Metric Tons (MMT) of rice is grown annually compared to 680 MMT for wheat, 440 MMT for oil seeds, and 1090 MMT for coarse grains (2). It feeds more than half of the world population and therefore plays an important role in food security and poverty alleviation in the world (3). Rice protein is vital to more than half the world's population. It is the most important food grain in the diets of hundreds of millions of Asians, Africans, and Latin Americans living in the tropics and subtropics. In these areas, the rate of increase in population is higher than that of the increase in food productivity (4). Agricultural Scientists estimated that by the year 2020 rice production should reach 760 million tons in order to keep pace with the growing population. However, most of the countries where rice is grown have limited land resources forcing increases in productivity rather than in land size. There are only a few specific varieties of paddy and upland rice that can be grown in Zimbabwe and little has been documented concerning the local agronomic and value chain structure of the crop. Generally, most Zimbabwean rice is not of good quality and its production is mainly for subsistence purposes. Loss in grain yield occurs during de-husking process at either high or very low moisture content. The seed breaks and smaller particles are lost in the process. The broken rice does not have an appetizing appeal when cooked.

The domestic rice production in Zimbabwe is marginal, ranging from anything between 600 tons and 700 tons (5). However, Kapuya et al., (6) recorded that rice production in the 2009/2010 season was estimated at 778 tons, down from a 2008/2009 estimate of 3,046 tons. From September 2008 to August 2009, the Ministry of Agriculture Mechanization and Irrigation Development (MoAMID) indicated that rice imports amounted to a total of 146,738 tons. This implies that domestic rice grain supply only accounts for 0.4% of total rice consumed within Zimbabwe. Hence, production of rice has to be high to reduce the cost of imports and improve food security as specified in the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZimAsset).

Rice quality is an important consideration in the production of the crop, and much research has shown that rice quality is controlled by genetic factors as well as light, temperature and management of water and nitrogen (7), (8) and (9). More than 75% of the world's rice is produced in irrigated rice fields, which are predominantly found in Asia. The judicious use of fertilizers contributes a lot towards improving the yield and quality of grain (10). Therefore high grain yield of rice can be achieved only through a proper combination of variety, agronomic practices, environment and optimum moisture for de-husking. Protein content is profoundly affected by the conditions under which rice is grown. Cropping season (primarily the effect of differing solar radiation and temperature during grain development), management and cultural practices (plant density, rate and time of nitrogen fertilization, water management, and weed control) employed are largely responsible for variations in the level of protein content (11). Large variations are also seen among hills within a plot, among panicles within a hill and among grains within a panicle, as well as among determinations of the same sample (12).

Protein and Amylose are the two of the most important determinants of grain quality in rice (13) and (14). Amylose a component of starch greatly influences eating quality, with intermediate amylose content and soft gel consistency as more desirable grain characteristics. International Rice Research Institute (IRRI) breeding programs have for a long time been geared towards improving amylose and protein content in rice because they are important grain quality parameters. Protein content tends to be low when there is high solar radiation during grain development (14). Temperature during grain ripening was also reported to affect protein content, but the effect seemed to vary with the variety type (12).

The objectives of the study were to determine the effect of different nitrogen fertilizer application rates on grain yield, crude protein and total nitrogen in rice grain of two rice varieties (Mhara 1 and Mhara 2 and to determine the varietal effect on milling recovery at different seed moisture contents.

MATERIALS AND METHODS

Sites

The experiments were conducted at Chiredzi Research Station, Chisumbanje and Save Valley Experiment Stations on different soil types namely paragneis (Sandy clay), vertisol (Heavy clay) and alluvial (Sandy clay) respectively in the South East Lowveld of Zimbabwe. The mean annual rainfall is 500mm with a seasonal range of 250-1000mm. The Natural Regions are a classification of the agricultural potential of the country from Natural Region 1, which represents the high altitude wet areas to Natural Region V, which receives low and erratic rainfall averaging 500mm per annum.

Experimental procedures and treatments

The trial was set up as a split plot design with two varieties as the main plot and nitrogen levels as sub-plot factors. Varieties were Mhara 1 and Mhara 2. Fertility levels were 0 kg/ha N (control); 50 kg/ha N; 100 kg/ha N and 150 kg/ha N. Each treatment factor was replicated three times. Variety main plots were 15.9m long by 3m wide. Gross fertility sub-plots were 3.6m long by 3m wide. Soil samples were taken before land preparation and analyzed. Samples taken were put in Vikings paper pockets, air dried and sieved and sent to Zimbabwe Sugar Association Experiment Station (ZSAES) for analysis. Soil texture was determined by the finger texturing method. Organic matter content was determined using the sulphuric acid-potassium dichromate method. Soil pH was done with 1:5 Suspensions (soil: CaCl2). Clay, sand and silt were determined using the sedimentation method by soil hydrometer. Mineral nitrogen was done using 0.01m KCL extract done by titrimetry. Phosphate analysis was done using the Resin extract on UV-Vis spectroscopy. Potash, calcium, magnesium and sodium were done by Atomic Absorption Spectroscopy (Weaver et al. 1962). The land was ploughed using a tractor drawn disc plough and disced to fine tilth. Two varieties (Mhara 1 and Mhara 2) were used in this experiment. Single Super phosphate at 80kg/ha P2O5 and Muriate of potash at 50kg/ha K2O was applied uniformly to all plots as basal application. Rice was harvested at 25% moisture content and samples were sent to International Crops Research Institute for the Semi Arid Tropics (ICRISAT) for crude protein and total nitrogen analysis and de-husking using a rice de-husker. A moisture meter was used from time to time to determine the moisture content of grain as the grain reduced its moisture from 25% to require levels.

Crop establishment, Measurements and management

Planting rows 25cm apart were marked by hand hoes. Seeding rate was 100 kg/ha. Plant heights at harvest, number of bearing panicles per square meter, days to flowering, maturity and grain yield per hectare were determined. A net plot of 7.75m2 was used for determination of grain yield. Grain yields were adjusted to 14% moisture content recommended by Grain Marketing Board of Zimbabwe.

Statistical analysis

The data was subjected to the analysis of variance procedure as a split plot design with variety as main plot and nitrogen levels as sub-plots using GenStat Discovery Edition a statistical package. MSTAT-C (Michigan State University) statistical package was used to separate the means at p<0.05.

RESULTS

Plant heights at harvest

Plant height was significantly increased (p<0.05) by nitrogen application (Table 1.) when nitrogen was increased from zero to 50 kg/ha at all sites and for both varieties. However, when nitrogen application increased from 50 kg/ha to 150 kg N/ha no significant differences were found except at Chisumbanje.

Number of bearing panicles per m^2

There were no significant differences on number of bearing panicles per square meter at Chiredzi (Table 1). At Chisumbanje Mhara 2 at 150kgN/ha had significant (p<0.05) higher numbers of bearing panicles as compared to low fertility levels of Mhara 1 (zero and 50kg/ha).

Days to flowering and maturity

There were significant differences (p<0.05) between treatments on number of days to flowering and maturity. Mhara1 at zero kgN/ha took significant shorter days to flower at Chiredzi and Chisumbanje compared to other rates within the same variety. Mhara 2 at Chisumbanje also took significantly shorter days to flower. At Chiredzi Mhara 2 did not show significant differences among the fertility levels. However, at Chisumbanje zero kgN/ha took significant short days to mature compared to the other levels. At Save Valley there were no significant differences between varieties and among fertility levels on days to maturity.

Percent Total nitrogen

There were significant differences (p<0.05) in total nitrogen content in the seed (Fig.1). Mhara 1 responded more than Mhara 2 to applied nitrogen in terms of Total Nitrogen content in seed. At 150kg/ha applied nitrogen Mhara 1 variety showed significantly higher (P<0.05) total nitrogen content in the grain compared to Mhara 2.

Table 1: Response of two varieties of rice to different fertility levels on plant height, bearing panicles, days to flowering and maturity under Lowveld conditions on three different soil types.

Treatment	Plant ht. at harvest (cm)			No. of bearing panicles/m^2		Days to flowering			Days to maturity		
	Chiredzi	Chisumbanje	Save Valley	Chiredzi	Chisumbanje	Chiredzi	Chisumbanje	Save Valley	Chiredzi	Chisumbanje	Save Valley
Mhara 1											
0Nkg/ha	95^{c}	84^{b}	63^{cd}	156^{a}	143^{b}	88.3^{b}	79^{b}	79^{ab}	109^{c}	91^{d}	105^{a}
50Nkg/ha	111^{ab}	94^{a}	79^{ab}	183^{a}	143^{b}	92.3^{a}	81^{ab}	80^{ab}	110^{ab}	98^{ab}	110^{a}
100kg/ha	112^{ab}	99^{a}	74^{abc}	185^{a}	174^{ab}	89^{ab}	82^{a}	81^{ab}	110^{ab}	97^{abc}	108^{a}
150kg/ha	120^{a}	95^{a}	81^{a}	170^{a}	183^{ab}	92.3^{a}	83^{a}	82^{a}	111^{a}	99^{a}	111^{a}
Mhara 2											
0kg/ha	103^{bc}	75^{bc}	57^{d}	177^{a}	177^{ab}	88.7^{ab}	76^{c}	77^{b}	109^{bc}	88^{d}	108^{a}
50kg/ha	112^{ab}	74^{c}	66^{bcd}	195^{a}	192^{ab}	91.3^{ab}	81^{ab}	80^{ab}	109^{c}	95^{c}	105^{a}
100kg/ha	115^{a}	77^{bc}	68^{abcd}	179^{a}	189^{ab}	90.7^{ab}	81^{ab}	81^{ab}	110^{bc}	96^{bc}	106^{a}
150kg/ha	115^{a}	84^{b}	65^{bcd}	216^{a}	215^{a}	90.3^{ab}	81^{ab}	80^{ab}	110^{bc}	99^{a}	109^{a}
Means	110.4	85.5	69.1	182.5	177.0	90.5	80.38	80.1	109.9	95.5	107.6
LSD	13.42	9.49	11.85	75.53	65.61	4.07	2.059	3.3	1.638	2.99	13.28
SE	3.55	3.24	5.19	24.9	22.43	1.34	0.704	1.28	0.43	1.02	1.94
CV%	6.945	6.57	13.02	23.64	21.95	2.57	1.52	2.76	0.68	1.85	3.13

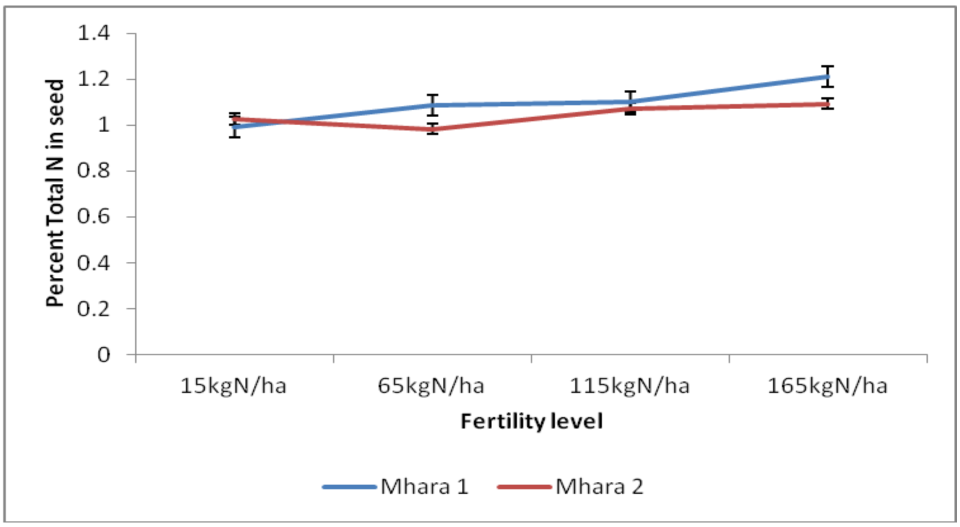

Fig. 1: Effect of applied nitrogen on percent total nitrogen in seed.

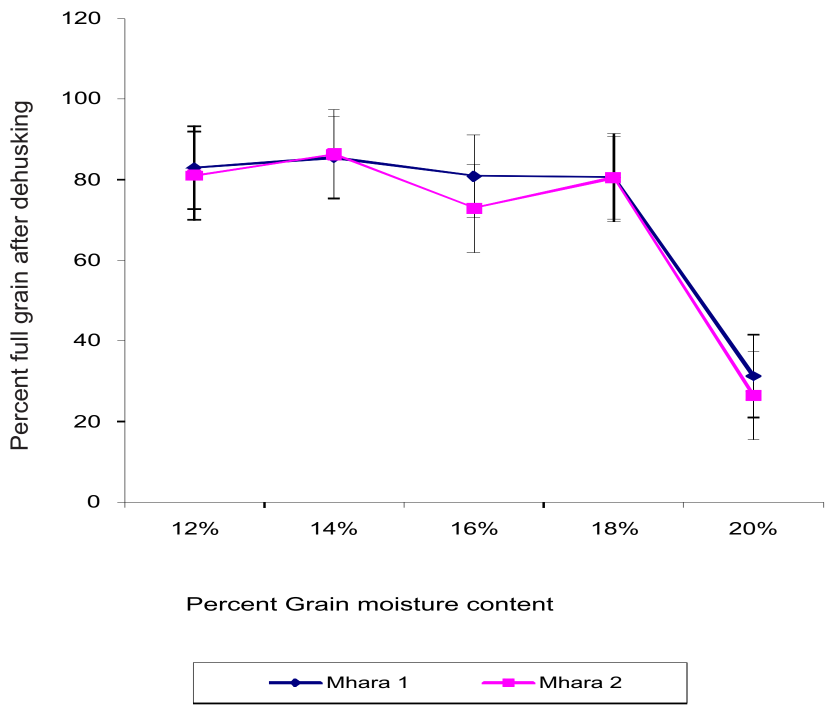

Fig. 2: Effects of grain moisture content on de-husking two rice varieties.

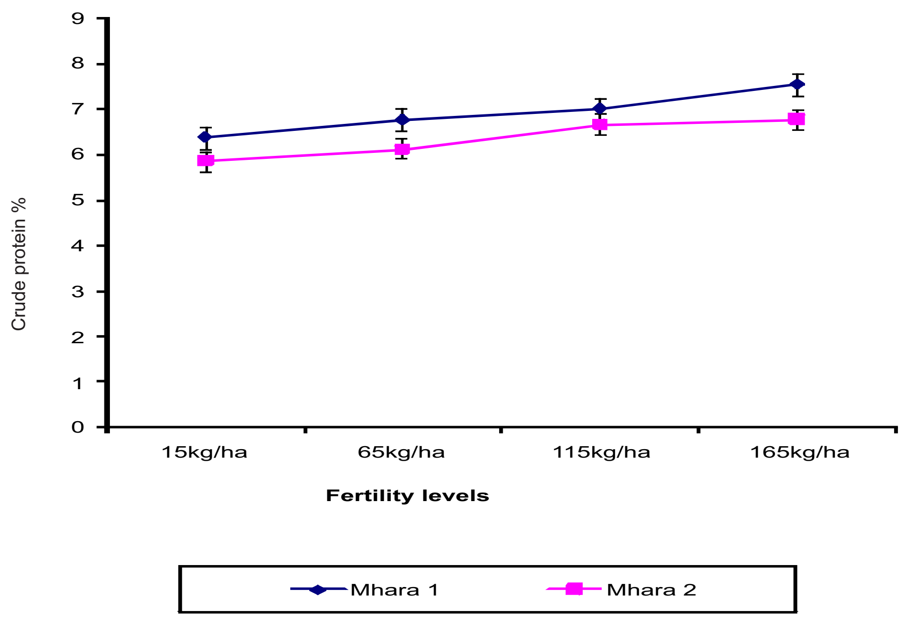

Fig. 3: Effect of nitrogen on percent crude protein of two rice varieties.

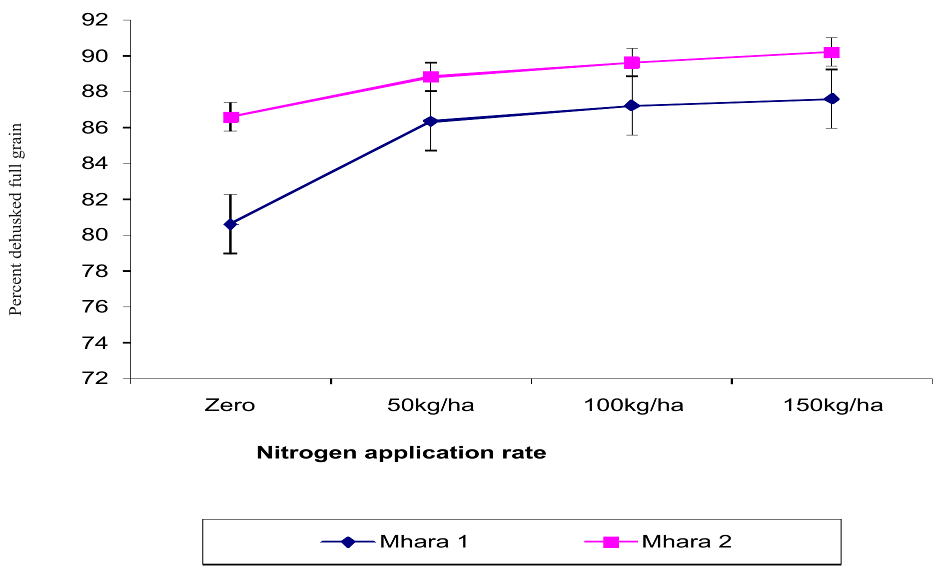

Fig. 4: Varietal effect on de-husked grain (full grain) at 14% moisture content with different nitrogen application levels.

Table 2: Response of two varieties of rice to different fertility levels under South East Lowveld conditions on three different soil types.

Treatment	Grain yield kg/ha Chiredzi	Chisumbanje	Save Valley
Mhara 1			
0Nkg/ha	2288.4[ab]	1050[ab]	489[b]
50Nkg/ha	2382.3[ab]	1160[ab]	1175[a]
100kg/ha	2565.0[ab]	1285.9[a]	743[ab]
150kg/ha	3395.2[a]	1090[ab]	869.8[ab]
Mhara 2			
0kg/ha	1737.9[b]	943.5[ab]	980.6[ab]
50kg/ha	2400.0[ab]	901.8[b]	1045[a]
100kg/ha	2449.0[ab]	862.1[b]	984[ab]
150kg/ha	2730.6[ab]	1002.4[ab]	1052[a]
Means	2493.6	1037.04	917.3
LSD	1253.1	348.9	546.8
SE	413.1	119.25	186.9
CV%	28.7	19.9	35.29

Effect of moisture level on milling recovery (full grain)

Results showed significant differences ($p<0.05$) in effects of moisture contents in grain recovery. De-husking at 14 percent moisture content was the best giving an average of 86 percent full grain. De-husking at 12 and 18 percent gave almost the same results of 82% and 80% respectively with no significant differences. De-husking at 20 percent moisture content gave significantly high breakages of rice grain ($p=0.01$) with 29% full grain. The other moisture content levels had no significant differences between varieties and among nitrogen levels.

Effect of nitrogen on crude protein on two rice varieties

Fig. 3 shows that crude protein content increased significantly as the amount of nitrogen was increased from zero N applied (15 kgN/ha residual) to 50kgN/ha. Mhara 1 had significantly higher crude protein compared to Mhara 2 at all nitrogen fertilizer application rates. In the control, crude protein in both rice varieties was about 6%. Mhara 1 had a higher rate of return of crude protein per given nitrogen level and showed an increase of 1.2% crude protein from control to 150kgN/ha whilst Mhara 2 showed an increase of 0.9% crude protein.

Effect of nitrogen on breakages when de-husking rice

There were no significant differences on the percent full grain across all nitrogen levels although, the percent full grain increased as the nitrogen increased (Fig.4).

Grain Yield

At Chiredzi there were significant yield differences among nitrogen levels (Table 2) with Mhara 1 at 150 kg/ha N showing significant differences to Mhara 2 at no nitrogen application. At Chisumbanje there were significant differences ($p<0.05$) with Mhara 1 out yielding Mhara 2 at the same rate of 100 kgN/ha and Mhara 1 at 100 kgN/ha significantly out yielded Mhara 2 at 50 kgN/ha. At Save Valley Mhara 1 at zero nitrogen had significantly lower yields compared to 50 kgN/ha of both varieties and Mhara 2 at 150 kg/Nha. However percent yield increase ranged from 6 to 23% at Chisumbanje, 48 to 57% at Chiredzi and 7 to 78% at Save Valley.

DISCUSSION

More numbers of panicles /m^2 at Chiredzi might be due to the more availability of nitrogen that played a vital role in cell division. According to Ebrahim (2013), as the amount of nitrogen absorbed by the crop increased, there was also an increase in the number of bearing panicles per square meter. This was due to nitrogen supply which increased the panicle numbers (Irshad et al. 2000). When nitrogen application was increased from 50 kg N/ha to 150 kg N/ha, no significant plant height differences were observed (Irshad et al. 2000). The increase in plant height in response to application of N fertilizers from 0-50 kg/ha is probably due to enhanced availability of nitrogen which enhanced more leaf area resulting in higher photo-assimilates and thereby resulted in more dry matter accumulation. These results are supported by the findings of Mandal et al. (1992). Rupp and Hubner (1995) also reported increased level of leaf N with applied N.

The total nitrogen in grain increased significantly with increases in nitrogen applied giving a better quality grain with higher nutritive value. When the amount of nitrogen applied increased, the crude protein content also increased significantly (Kausar et al. 1993). Nitrogen did not show significant effect on breakage of rice grain. However with increasing N fertilizer to 150 kg/ha, the protein content was elevated and the grain breakage was reduced. Dilday (1987) found that the greatest percentage of broken kernels and the lowest head rice yields occurred when no nitrogen fertilizer was applied. Hao et al. (2007) (Hao et al. 2007) reported that grain protein content increases with nitrogen input fertilizer application. Rice protein, when compared to that of other grains, is considered one of the highest quality proteins. It has no fat, no cholesterol and no sodium. This along with being non-allergenic and gluten free makes rice well suitable for persons with special dietary needs (Raviana 2011). Because rice is very low in fat, and contains no cholesterol, it is an excellent food to include in all types of diets for better human health.

A very high moisture content of 20%, affected milling recovery because the grain was soft and easily broken. This gives a very high breakage rate and loss to the farmer. The best moisture content was 14%, which gave 86% whole grains on average for the two varieties. High milling recovery is generally associated with hardness and an absence of chalky spots in the endosperm and not nitrogen (Chang 1979). However, high protein stored in the seed endosperm cells in the region of breakage, causes the resilience of grain and reduces the rice grain cracking during milling processes. As a result, increased grain protein content increases its hardness and thus increases the milling recovery (Leesawatwong 2003). Mhara 2 did not break much compared to Mhara 1 at 14% moisture content.

Nitrogen stress hastened flowering and maturity in both varieties in Chiredzi and Chisumbanje. When plants are stressed they flower early in a bid to produce grain as a survival mechanism for propagating the next generation. They try to produce grain from the little nitrogen reserves that are available. Hence quicken flowering and maturity before the reserves are exhausted. There were no significant yield differences with increases in applied nitrogen at Chiredzi except for Mhara 2 without applied nitrogen and Mhara 1 with 150 kg/ha N. This can be explained by the nutrient theory which states that both large, medium, and trace elements are equally important and indispensable (equally important irreplaceable law). Therefore if one essential element is most limiting no matter how much nitrogen is applied yield will be determined by that limiting element (Leesawatwong 2003). On the other hand grain weight is a genetically controlled trait, which is also greatly influenced by environment during the process of grain filling (Qiang 2013). Application of nitrogen to rice increased grain yield up to 78 percent. Less response to nitrogen application was at Chisumbanje because the soils have high inherent fertility. Soils at Save Valley have poor inherent fertility causing grain yield to be very low when no nitrogen is applied. However the response to nitrogen was highest at Save Valley. Therefore application of nitrogen increases productivity and enhances food security in societies.

CONCLUSION

Nitrogen stress hastened flowering and maturity in both varieties in Chiredzi and Chisumbanje and reduced grain yield. Save Valley soils needs more nitrogen compared to Chisumbanje and Chiredzi whilst Chisumbanje should be applied the least amount of nitrogen. Milling of rice should be done at 14% moisture content to avoid breakages. Mhara 2 has a better milling recovery (86.2%). Mhara 1 has more crude protein and total nitrogen.

RECOMMENDATION

Mhara 1 is recommended for production because of its high protein and total nitrogen content of the seed in the Lowveld. Farmers should apply 100 kg/ha of nitrogen for optimum rice production under two different soils (Chiredzi and Save Valley) while Chisumbanje needs about 50 kg/ha N in the Lowveld. Milling recovery is best at 14% moisture content for both varieties.

Acknowledgments

The author wishes to thank Lowveld Research Institute for the funds and support for carrying out the Research and also the technical staff for their invaluable contributions.

Disclosure statement

No potential conflict of interest was reported by the author.

Financial and proprietary interest: Nil

Financial support: Nil

REFERENCES

1. Azarpour E., (2013). Path coefficient analysis for the yield components of rice Cultivars in Iran under different nitrogen levels. Journal of Biodiversity and Environmental Sciences .3, (10) 24-30.
2. Bao J.S., Xia Y.W., (2000). Effects of genotypex environment interaction on eating and cooking quality of indica rice. Journal of Zhejiang Univ. Agri. Life Sci. 26: 144-150.
3. Chandel G., Baxerjee S., See S., Sharma D.J., Verular S.B., (2010), Effect of Different Nitrogen Fertilizer levels and Native Soil properties on Rice Grain Fe, Zn, and Protein Content.
4. Chang T.T., Somrith B., (1979). Genetic studies on the grain quality of rice. Proceedings of the workshop on chemical aspects of rice grain quality 49-54.
5. Chen Y., Wang M., Pieter B.F. (2012). Molecular and environmental factors determining grain quality article 11 Dec. 2012. Food and Energy Security.
6. Dilday R.H. (1987). Effect of nitrogen fertilizer on milling quality of rice. 7. FAO (2009). Food and Agricultural Organization. FAO/WFP Crop and Food Supply Assessment Mission to Zimbabwe Various Special Reports. FAO Corporate Document Repository.
8. Guerra LC., Bhuiyan S.I., Tuong T.P., Barker R., (1998). Producing more rice with less water from irrigated systems. SWIM 5. Sri Lanka.
9. Hao H.L., Wei Y.Z., Yang X., Feng Y., Wu C.Y. (2007): Effects of different nitrogen fertilizer levels on Fe, Mn, Cu and Zn concentration in shoot and quality in rice (*Oryza sativa*). Rice Science 14(4): 289-294.
10. Irshad A., Abbas G., Khaliq A., (2000). Effect of different Nitrogen application Techniques on the Yield and Yield Components of Fine Rice: Internatinal J. Agri. Biol., 2(3), 2000
11. Jin S., (2003). Diagnosis on growth and analysis of rice growth. Training Rice Production Technology (2).
12. Kapuya T., Saruchera D., Jongwe A., Mucheri T., Mujeyi K., Traub L. N., Meyer F., (2010). The grain industry value chain in Zimbabwe. Food and Agricultural Organisation United Nations Agricultural Commodities Programme.
13. Kausar K., Akbar M., Rasul E., Ahmad. A.N., (1993). Physiological responses of nitrogen phosphorus and potassium on growth and yield of wheat. Pakistan J. Agric. Res., 14: 2–3.
14. Leesawatwong M., Jamjod S., Rerkase B., Pinjai S., (2003): Determination of a premium priced, special quality rice. International Rice Research Notes 28(1): 34.
15. Liang C., Zhang Q., XU G., Wang Y., Ryu O., Li T., (2013). High Temperature During Rice Grain Filling Enhances Aspartate Metabolism in Grains and Results in Accumulation of Aspartate- Family Amino Acids and Protein Components. Rice Science, 2013, 20(5): 343−348, China National Rice Research Institute.
16. Longping Y., Xiaojin W., Fuming L., Guohui M., Qiusheng X., (2012). Hybrid Rice Technology. Sponsored by the Ramon Magsaysay Foundation, Philippines.
17. Mandal N.N., Chaudhry P.P., Sinha D., (1992). Nitrogen, phosphorus and potash uptake of wheat (var. Sonalika). Env. and Eco. 10: 297 (Field Crop Abst. 46 (1): 30; 1993).
18. Mo H.D., (1993). Quality improvement of rice grain in China. Sci. Agric. Sin. 26: 8-14.
19. Pete V., (2010). Rice Production in the World and in the U.S. 1.
20. Place G.A., Sims T.L., Halls V.L., (1970). Effect of NPK on the growth, yield and cooking. Proceedings of the workshop on chemical aspects of rice grain quality 49-54.
21. Qiang W., (2013). The Basic Knowledge and Application of Fertilizer Notes. Hunan Academy of Agriculture Science.
22. Raviana P., (2011). Importance of Rice Protein American Dietetic Association.
23. Rupp D., Hubner H., (1995). Influence of Nitrogen fertilization on the mineral content of apple leaves. Erwerbsobstbau 37:29-31.
24. Shah F., Huang J., Cui K., Nie L., Shah T., Chen C., and Wang K1., (2011). Impact of high-Temperature stress on rice plant and its traits related to tolerance. Journal of Agricultural Science, 1 (12). © Cambridge University Press 2011
25. Weaver R.W., Angle J.S., Bottomley P.S., (1962). Methods of soil analysis Part 2. SSSA Book series 5.
26. Zhou G.Q., Xu M.L., Tan Z., Li X., (1997). Effects of ecological factors of protein and amino acids of rice. Acta Ecol. Sin. 17: 537-542.