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Variability in Mineral Content of *indica* Rice Genotypes of Assam, India

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Significant genetic variations for grain concentration of all 9 mineral elements were observed. The range of macro elements like, phosphorous (P), sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) were recorded in the range of 0.272-0.412 per cent, 0.051-0.065 per cent, 0.190-0.232 per cent, 0.023-0.036 per cent and 0.039-0.049 per cent, respectively. The micro elements like iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) were found to be 2.34-4.21mg/100g, 1.02-3.87 mg/100g, 0.400-1.64 mg/100g and 2.10-4.66 mg/100g respectively. On average, the nine mineral content in rice genotypes were followed an order as P>K>Na>Mg>Ca>Zn>Fe>Mn>Cu. There is a significant correlation observed among different minerals. Highest estimate of GCV and PCV was recorded for Cu, which indicate plentiful variability of Cu content for genetic improvement. High heritability coupled with high genetic advance were observed for Cu, Mn, Zn and Fe which indicate preponderance of additive genetic effect in control of these minerals, which suggested the scope of genetic improvement of these minerals based on phenotypic performance.

Key Words: *Indica,* Rice, Mineral, Assam, Micronutrient

Introduction

With about half the world's human population dependent on rice (*Oryza spp*. L.) as a staple food, the grain provides the majority of dietary nutrients to billions of people (Shannon *et al.,* 2015). The deficiency of minerals and vitamins may result in various human disorders such as anemia, blindness, birth defects, retarded growth, diminished mental development and other health related problems (Darnton-Hill, 2005).Micronutrient deficiencies, particularly those involving iron (Fe) and zinc (Zn) are the most prevalent deficiency-related health disorders in the world (WHO, 2006). They also significantly and negatively impact on socio economic development at the individual, community and national levels (Darnton-Hill, 2005). The most prevalent nutrient deficiencies worldwide are Fe and Zn, with estimates that more than 25% of the world's population are at risk of mild to severe deficiency in one or both elements and with each element attributable for the deaths of 0.8 million persons per year (WHO, 2009; Maret and Sandstead, 2006). Low micronutrient densities in staple foods are generally the major reasons for human micronutrient malnutrition in developing countries (Cakmak, 2009; Gibson, 2006; Welch and Graham, 2004). Iron deficiency is responsible for up to 50% of the anaemia burden, making it the most widespread nutritional deficiency in the world (Stoltzfus 2011). It has been observed that the zinc deficiency is responsible for approximately 4% of child mortality (Black, 2008).

Assam is traditionally a rice growing state within North-East India and it plays a pivotal role in the economic and socio-cultural life of the people of the entire region. The *indica* type has enormous diversity in this region, which has resulted due to highly variable rice growing ecosystems and different cultural practices adapted by the local farmers. Unknowingly local farmers have selected many useful *indica* type cultivars, which have huge commercial prospects apart from being a staple food. Some of the special classes of *indica* rice in the region include aromatic rice, waxy or glutinous rice and soft rice. Wide variation of physiographic features and climatic characteristics have resulted three distinct growing seasons of *indica* type rice viz., *ahu* (Feb./March-June/July), *sali* (June /July-Nov /December) and *boro* (Nov/December-May /June).

Thus, the enhancement of rice grain micronutrient contents is viewed to be an important goal as part of global strategies for improving the nutritional quality of human diet. Rice varieties rich in micronutrients often

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seems to have other desirable qualities such as high yield, good tolerance to nutrition deficiency stress, and pest resistance. Moreover, rice improvement in grain mineral elements content is always one of the major targets for rice breeders. Enhancement of the rice grain's nutritional value through genetic improvements could include both increasing concentrations of desirable elements (e.g. Fe, Zn or Ca) and decreasing concentrations of undesirable elements (e.g., As or Cd) and could create new marketing strategies for nutritionally enhanced and value-added products.

The breeding efforts in Assam are mainly directed towards yield traits such as morphological and physicochemical characteristics of the grain without focusing on mineral content of various traditionally grown rice landraces. A clear understanding of genetic base, through the characterization of local landraces for their mineral content is essential to use them in a rice nutrient breeding programme. The information regarding those aspects in case of different local rice landraces of Assam is scanty and sporadic. Therefore, the present investigation was conducted to evaluate the extent of variability in terms of mineral content of *indica* rice genotypes to be used in rice nutrient breeding from Assam.

Materials and Methods

For the present investigation, 100 different *indica* rice genotypes including another popular high yielding variety viz. Ranjit were collected from the Regional Agricultural Research Station (RARS), Titabar (Upper Brahamputra Valley Zone, UBVZ) and Regional Agricultural Research Station (RARS), Karimganz (Barak Valley Zone , BVZ) during the harvesting season in December-January, 2015. The grains of brown rice were grinded and converted into fine powder and oven dried at 100°C (± 2°C) and kept in a desiccator for mineral estimation.

For mineral estimation, the ash content was determined as described in the AOAC (1970). The mineral solution was prepared according to the method described by AOAC (1970). The all nine minerals (P, K, Na, Mg, Ca, Zn, Fe, Mn and Cu) were estimated using Atomic Absorption Spectrophotometer (Chemito, AA203D, Double beam atomic absorption spectrophotometer). The different standards were prepared for different minerals like, 1-2 ppm (P), 0.1 -0.6 ppm (Na), 0.5-2.0 ppm (K), 2-10.0 ppm (Fe), 2-8 ppm (Cu), 0.2-1.0 ppm (Zn), 1-4.0 ppm (Mn), 1-4.0 ppm (Ca) and 0.1-0.5 ppm (Mg).

Result and Discussion

The analysis of variance (ANOVA) revealed significant variation among genotypes for different minerals studied (Table 1), indicating abundant genetic variation in the genotypes under investigation. Choice of parents is a significant criterion for the successful breeding programme. Sometimes the *per se* performance of genotypes are used for choosing parents. The *per* se performance of genotypes for different minerals under investigation are shown in Table 2. Any crop improvement programmes mainly depend on extent of genetic variation and heritability for desirable characters in the genotypes, therefore conservation of variability has enormous potential in breeding programmes for future generations.

In the present investigation, the range of ash content of rice cultivars (1-2%) was almost similar with the findings of Yodmanee *et al.* (2011) and Oko *et al.* (2012). Oko and Ugwu (2011) reported similar ash content with the present study for some major rice varieties of South East Nigeria. However, a higher range of 3.16 to 3.79 per cent of ash in rice had been reported by Anjum *et al.* (2007).The variation in the ash content of different rice grains may primarily be due to cultivar differences, climatic condition as well as nutrient status of soil.

In the present study, analysis of variance indicated that the varietal effect on each of the minerals is highly significant. Correlation among the minerals themselves and with other parameters studied is shown in the Table 3.

Table 1. Analysis of variance for mineral content in *indica* rice genotypes from Assam, India

Characteristics	Sources of variation		
	Replication	Genotype	Error
df	2	99	198
Ash %	0.83253	0.19612*	0.043779
P %	0.9243	0.00649*	0.003795
K%	0.90501	0.00296*	0.003889
Na %	0.00133	0.00083*	0.000812
Mg %	0.01	0.00002*	0
Ca %	0.01	4.1E-05*	0
Zn (mg/100 g)	0.88649	0.76806*	0.003975
Fe (mg/ 100 g)	0.9243	0.51543*	0.003795
Mn (mg/100 g)	0.90501	0.74978*	0.003889
Cu (mg/100 g)	0.9243	0.19594*	0.003795

Df: Degrees of freedom; * Significant at 5% level. Data for mineral content are mean sum of square.

Table 2. Estimates of genetic parameters for mineral content in 100 indica rice genotypes from Assam, India

	Maximum	Minimum	Mean±SE	PCV (%)	GCV (%)	Heritability in broad sense (%)	Genetic advance (5%)
Ash %	2	1	1.4617	21.3298	15.6308	0.537	23.5963
P %	0.412	0.272	0.3476	19.3733	8.472	0.1912	7.632
K%	0.232	0.19	0.2098	27.7207	8.1523	-0.0865	-4.9388
Na %	0.065	0.051	0.0594	46.5783	3.9045	0.6742	0.007
Mg %	0.049	0.039	0.0445	5.8214	5.8214	1	11.992
Ca %	0.036	0.023	0.0297	12.5131	12.5131	1	25.777
Zn (mg/100 g)	4.661	2.103	3.4834	14.5765	14.4641	0.9846	29.5662
Fe (mg/ 100 g)	4.21	2.34	3.3154	12.572	12.4344	0.9782	25.3346
Mn (mg/100 g)	3.874	1.02	2.277	22.0131	21.843	0.9846	44.6487
Cu (mg/100 g)	1.64	0.4	0.7592	34.0477	33.0817	0.9441	66.2149

Table 3. Correlation among the minerals at their genotypic level

	Ash %	P %	Fe (mg/100 g)	Mn (mg/100 g)	Cu (mg/100 g)	Zn (mg/100 g)	Na %	K%	Ca %	Mg %
Ash %	1	0.0188	-0.0963	0.0375	-0.064	-0.0628	0.4189**	-0.0004	-0.0601	0.0767
P %		1	-0.1096	-0.0004	-0.0279	-0.3614**	-0.0235	0.1979*	-0.1127	0.1874*
Fe (mg/ 100 g)			1	-0.0547	0.1732*	0.2261*	0.2964**	-0.001	-0.2004*	0.0433
Mn (mg/100 g)				1	-0.2977**	0.007	-0.1193	-0.0003	0.1167*	-0.1602
Cu (mg/100 g)					1	0.0965	-0.5329**	-0.001	-0.2904**	0.1121
Zn (mg/100 g)						1	-0.1267	-0.0056	-0.0533	-0.0142
Na %							1	0	-0.7792**	0.444**
K%								1	0	0
Ca %									1	0.0181
Mg %										1

*Significant at 5% level and ** Significant 1% level

Phosphorous

The phosphorus content in the rice cultivars varied widely from 0.272 to 0.412 per cent, with a mean value of 0.348 per cent. The highest value was recorded in Mouguti Bora and the lowest one in Sukoni Bora-2. The findings of the present study were almost similar with the findings of Singh *et al.* (1998). However, phosphorous content was found lower than the findings of Oko *et al*. (2012). The Phosphorous content of Ranjit was 0.393 per cent. Phosphorus was found to be the highest among all the minerals estimated for the rice samples.

Potassium

The potassium content was found to be highest (0.232%) in the cultivar Kmj Bora-5 and the lowest (0.190%) in the Kola Bora-5 and Kmj Bora-11 with an average content of 0.209 per cent in the rice cultivars under study .The present result is in good agreement with the result of Oko *et al.* (2012) who reported the potassium content of Nigerian rice cultivars within the range of 0.15-0.23 per cent. However, the range of K content was found lower than the findings of Tinalin and Hashmi (2008), who reported the K content of husked rice within the range of 263.33-438.33 (mg/100 g) in some Malaysian rice varieties. Zeng *et al.* (2004) gave even a wider range of K content (0.172-0.452%) in core collection of Yunnan rice. The check variety, Ranjit contained 0.212 per cent of potassium.

Sodium

In the present investigation, the range of Na content in 100 rice cultivars was 0.051-0.065 per cent with an average of 0.060 per cent. The values for Na content was found higher than the reported values by Sotelo *et al.* (1989) and Tinalin and Hashmi (2008). Ranjit had 0.059 per cent of sodium. Oko *et al*. (2012) reported much higher sodium content with a wider range of 0.09-0.17 per cent for some Nigerian rice varieties. The variation might be mainly because of the differences in the genetic makeup of the rice cultivars and to certain extent geographical location, cultural practices adopted and the environmental factors.

Magnesium

Magnesium content of 100 rice cultivars used in the present study was found to vary between 0.039-0.049

per cent with the average of 0.044 per cent. The Mg content in rice cultivars was found to be higher than those reported by Tinalin and Hashmi (2008) and Sharma *et al.* (2012). Oko and Ugwu (2011) reported a higher range of magnesium content (0.19-0.26%) in some rice varieties from South East Nigeria. Zeng *et al.* (2004) reported average magnesium content for 653 accessions from core rice collection of Yunan to be 0.159 per cent. Check variety, Ranjit was statistically with 0.44 per cent magnesium content.

Calcium

The average calcium content for all the 100 cultivars used in the study was 0.030 percent with maximum in Kmj Bora-92 (0.036%) and minimum in Pokor Kola Bora (0.023%). The result is in good agreement with the results of Dutta and Baruah (1978) and Bhagabati (2000) who worked with glutinous rice varieties of Assam. However, there are several reports with much higher calcium content with a greater range (Oko and Ugwu, 2011; Oko *et al.*, 2012). Average calcium content for 465 glutinous rice landraces was reported to be 0.015 per cent against 0.013 per cent for non glutinous rice (Zeng *et al.*, 2004). The Ca content of Ranjit was found to be 0.028 per cent.

Zinc

In the present investigation, the range of Zn content in the rice cultivars was 2.103-4.66 mg/100 g with an average of 3.483 mg/100 g was almost similar with the findings of Jiang *et al.* (2007), Tinalin and Hashmi (2008). Tinalin and Hashmi (2008) reported that Zn content of husked rice was 2.52 to 3.42 mg/100 g in some Malaysian rice varieties. Thongbam *et al.* (2012) found the Zinc content to range from 1.33 to 3.42 mg/100 g in some indigenous rice cultivars from Tripura. Moreover, some Pakistani coarse rice varieties were also reported to have lower Zn content with a range between 1.44-2.97 mg/100 g (Anjum *et al.*, 2007). A comparable average Zn contents (3.68 mg/100 g) was reported by Zeng *et al.* (2004) for the glutinous rice landraces from Yunnan province. Ascheri *et al.* (2012) found Zn content in semi polished red rice grains to be 2-2.5 mg per 100 g. Zinc content in 100 rice cultivars was found to have significant positive correlation with Fe content and this was supported by earlier results (Abilgos *et al.*, 2002; Zeng *et al.,* 2004; Cheng *et al.*, 2006; Jiang *et al.*, 2007). Ranjit had 3.12 mg/100 g of zinc.

Iron

The range of iron content in 100 rice cultivars (2.34-4.21 mg/100 g) was almost similar with the findings of Singh *et al*. (1998), Ahmed (2004) and Borua *et al.* (2004). A much lower range of iron content of 1.37-1.94 mg/100 g was reported by Anjum *et al.* (2007) for some Pakistani coarse rice varieties. The average iron content of 3.31 mg/100 g observed in the present study was much lower than the average value of 5.58 mg/ 100 g for the glutinous rice landraces of Yunnan province (Zeng *et al.*, 2004). Significantly positive correlations were recognized between Fe and Zn by many workers (Abilgos *et al.*, 2002; Zeng *et al.,* 2005; Cheng *et al.*, 2006; Jiang *et al*., 2007) which holds good for the present investigation also. These results suggested that high Fe content might be accompanied with high Zn contents of rice. The iron content of Ranjit was 2.94 mg/100 g.

Manganese

Manganese content of 100 rice cultivars was found in the range between 1.02-3.87 mg/100 g with an average of 2.277 mg/100 g. Stork *et al.* (2005) reported that the polished white rice had manganese content in the range of 0.7 to 2.0 mg/100 g. The average manganese contents of core collection, glutinous and non glutinous rice landraces of Yunnan province were reported as 1.52, 1.47 and 1.52 mg/100 g respectively (Zeng *et al.*, 2004). Anjum *et al.* (2007) reported a range of 1.57-2.33 mg/100 g of manganese for Pakistani coarse rice varieties. The Mn content of Ranjit was 2.684 mg/100 g.

Copper

The average copper content in 100 rice cultivars was 0.759 mg/100 g with highest in cultivar Kmj Bora-50 (1.64 mg/100 g) and the lowest in Kmj Bora-9 (0.4 mg/100 g). A wider and higher range of copper content (0.7 to 2.7 mg/100 g) in polished white rice was reported by Stork *et al.* (2005). Jiang *et al.* (2007) reported copper content in milled rice to vary between 0.3-2.5 mg/100 g. The glutinous and non glutinous rice landraces from Yunnan province had the average copper content as 1.58 and 1.7 mg/100 g, respectively (Zeng *et al.*, 2004). Thus, Assam cultivars were having lower copper contents as compared to rice from different sources. This difference might be because of the differences in the rice cultivars used for the studies. The Cu content of the check variety Ranjit was 1.08 mg/100 g.

Genetic coefficient of variation (GCV) and Phenotypic coefficient of variation (PCV) provides reliable estimate of magnitude of genetic variability. Highest estimate of GCV and PCV was recorded for Cu, which indicate plentiful variability of Cu content for genetic improvement. Moderate estimate of GCV and PCV value were recorded for Mn, Ash, Zn, Fe, and Ca. The difference between GCV and PCV was less for all characters except P, K and Na, which indicate less influence of environment and greater role of genetic architecture on expression of these minerals. Therefore simple selection will be effective in genetic improvement of these minerals. High heritability coupled with high genetic advance were observed for Cu, Mn, Zn and Fe which indicate preponderance of additive genetic effect in control of these minerals and suggested the great chance of genetic improvement of these minerals based on phenotypic performance. Thus the variability found in the present study material could be utilized successfully in different breeding programs for the genetic improvement of existing high yielding varieties through backcross breeding and for the development of desirable genotypes through hybridization.

Genotypic Correlation among Different Minerals

The Table 3 has shown the correlation among different minerals (P, Fe, Mn, Cu, Zn, Na, K, Ca, and Mg) and their ash content in different rice genotypes analyzed. It has been found that there is a significant positive correlation in between ash content and Na. The P content was found to be positively correlated with K and Mg and negatively correlated with Zn. In rice, most of the seed P is found in the form of a mixed K–Mg salt of phytic acid in the aleurone layer and germ (Bryant *et al*., 2005), so one possible explanation of the positive P–Mg–K intercorrelations might be that their levels are all driven by phytate levels in the grain. There is a positive correlation observed between Fe with Zn. Significantly positive correlations were also recognized between Fe and Zn by many workers (Abilgos *et al*., 2002; Zeng *et al.* 2005; Cheng *et al*., 2006; Jiang *et al*., 2007) which holds good for the present investigation also. These results suggested that high Fe content might be accompanied with high Zn contents of rice. Mn was found negatively correlated with Cu .The Cu was found negatively correlated with Na and Ca.

The composition of all the minerals varied significantly among the rice cultivars used in the study. The mean mineral content values in brown rice of the cultivars were as follows: P>K>Na>Mg>Ca>Zn>Fe>Mn>Cu. There are reports on slightly different order of mean mineral content values in rice. Jiang *et al.* (2008) found an order of mean mineral content values for eight minerals in brown rice as K>Mg>Ca>Na>Zn>Fe>Mn>Cu.

In recent years, Jiang *et al.* (2007) observed that a significant correlations among the contents of some mineral elements in milled rice. Therefore, the indirect selection could be used for simultaneously improving the mineral elements contents of milled rice. A high genotypic variation has been observed among different parameters of genotypes studied in present investigation. However, the nutritional composition of rice also differs with nature of the soil, environmental conditions and fertilizers applied (Amissah *et al.,* 2003). Studies showed that agricultural practices could influence the nutrient composition of the rice grain, such as iron and zinc contents were influenced by nitrogen application and soil nature (Senadhira *et al.,* 1998). Thus, further investigation is necessary to analyze the mineral element content in milled rice of different genotypes grown in various environments.

It is implied that the genotypic variations provided opportunities to select materials with dense contents of mineral elements (Yang *et al.,* 1998; Gregorio *et al.,* 2002). The first step toward breeding rice cultivars with an enhanced elemental composition (or ionome) is to understand the genetic diversity in germplasm collections available to breeders (Shannon *et al.,* 2015).

Conclusions

Significant genetic variations for grain concentration of all 9 mineral elements were observed, but not a single germplasm was found superior over the others for the all nine mineral content studied. In this case, breeder can go for independent selection of genotype for parental line for a particular mineral for rice breeding programme.

Highest estimate of GCV and PCV was recorded for Cu, which indicate plentiful variability of Cu content for genetic improvement. High heritability coupled with high genetic advance were observed for Cu, Mn, Zn and Fe which indicate preponderance of additive genetic effect in control of these minerals and suggested the great chance of genetic improvement of these minerals based on phenotypic performance. Thus the variability among different land races found in the present investigation could be rich resource for incorporation into rice breeding programme.

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