Improvement of Zinc Content in Rice Grains through Conventional and Molecular Breeding

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INTRODUCTION

Rice (*Oryza sativa* L.) is the second most widely consumed cereal in the world and India is the second largest producer with a production 89.13 million tonnes from 41.85 m ha (India Stat, 2011). The concentration and bioavailability of micronutrient zinc (Zn)) in rice is very low and its consumption alone cannot meet the Recommended Daily Allowance. To address this problem, a genetic approach called *biofortification* (Bouis, 2002) which aims at enrichment of foodstuffs with vital micronutrients have been evolved and used. Ideally, once rice is biofortified with vital nutrients, the farmer can grow the variety indefinitely without any additional input to produce nutrient-rich rice grains in a sustainable way. Zinc malnutrition is the most common (Ronaghy, 1987). In Asia and Africa an estimated 500-600 m people are at risk for low Zn intake (Harvest Plus, 2010) leading to several health problems (Solomons, 2003; McClain *et al*., 1985). Males aged between 15-74 years need ~12-15 mg of Zn daily while females aged between 12-74 need ~68 mg of Zn (Sandstead, 1985). Targeting this, the Directorate of Rice Research in collaboration with National Institute of Nutrition, started a bio-fortification programme.

METHODS

To identify the high Zn rice varieties from the available popular varieties and land races, 173 varieties and 21 hybrids were collected from all over India, were grown at Hyderabad and grain Zn contents were determined after microwave digestion: Approx 0.8 g of the sample was taken in Teflon PFA digestion vessels to which the acid mixture (3ml HNO_3:1 ml H_2O_2) was added and digested in Mars Express CEM microwave digestion system. Zinc was quantified using a Varian Techtron AAS.

RESULTS AND DISCUSSION

Among the 173 varieties, Zn concentrations (mg kg^{-1}) varied from 10.1 (Karjat 3) to 32.7 (Ratna). Out of them, ten varieties with high Zn concentrations (Table 1) were identified and some of them were used in the breeding programme to develop high Zn containing genotypes. Selections were made in segregating populations and stabilized lines with high Zn content with good quality and yield are identified.

Table 1: Rice varieties with high Zn concentrations in grain.

Name	Grain Type	Zn (mg kg^{-1}) concentrations in polished rice		
		0%	5%	10%
Chittimutyalu	SB	30.5	25.7	24.4
Poornima	SS	31.3	27.8	27.0
ADT-43	MS	30.9	26.6	20.9
Ranbir Basmati	LS	30.9	28.3	27.4
Type-3	LS	30.3	28.3	26.5
Udayagiri	SB	30.1	19.5	11.3
Ratna	LS	32.7	25.2	23.0
Jyothi	LB	31.3	22.4	20.6
Pant Sugandh 17	LS	32.5	24.7	20.6
Kesari	MS	31.5	19.9	19.3

Associated studies revealed that grain yield was significantly positively correlated with productive tillers plant^{-1}, test weight and number of grains plant^{-1}. However, grain Zn concentration had no correlation with grain yield. Hence, simultaneous selection/breeding can be adopted to enhance grain Zn concentration. Based on heterosis, IR64 × Chittimutyalu and PR 116 × Chittimutyalu found to be good heterotic hybrids for grain Zn concentration.

A line derived from BPT 5204 x Chittimuthyalu with short bold grains, semi dwarf with high yield potential (> 4.5 t ha^{-1}) and medium duration with high Zn (40 mg/ kg in brown rice and 26.9 mg kg^{-1} in 10% polished rice) was identified with good quality characters (Fig. 1).

Figure 1. High Zn rice line developed through conventional breeding

Based on the candidate genes associated with Zn metabolism information as derived from the rice genome sequence, several microsatellite markers were designed and mapped in $F_{2:3}$ of two mapping populations viz., BPT 5204/Chittimuthyalu and BPT 5204/Ranbir Basmati. Five loci associated with Zn metabolism across chromosomes 3, 4, 5, 6 and 12 were identified in two donors.

CONCLUSIONS

Using a plant breeding approach to address micronutrient malnutrition would provide a new 'tool' in combating the problem. The micronutrient-density traits are stable across environments. It will be possible to improve the content of several limiting micronutrients together. High nutrient density not only can benefit the consumer but also produce more vigorous seedlings in the next generation. Because of staple foods are eaten in large quantities everyday by malnourished poor, adding even small quantities of micronutrients makes a big difference. With the help of molecular markers, the loci associated with nutrient concentration in grains can be identified and used for Marker Assisted Selection (MAS) in regular breeding programs.

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