Nota / Note

SCREENING METHOD OF LOWLAND RICE GENOTYPES FOR ZINC UPTAKE EFFICIENCY

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ABSTRACT: Zinc deficiency in crop plants has been recognized as a worldwide nutritional constraint. A greenhouse experiment was conducted with the objective of developing a screening technique to evaluate lowland rice genotypes for zinc use efficiency. Ten lowland (*Oryza sativa* L.) genotypes were tested at low (0 mg Zn kg^{-1}) and high (10 mg Zn kg^{-1}) zinc levels applied to an Inceptisol. Genotypes differed significantly in grain yield and its components. Based on the grain yield efficiency index, genotypes were classified as efficient and inefficient. The most Zn efficient genotypes were: Metica 1, Epagri 108, CNA 7550, and CNA 8619. The most inefficient genotype was CNA 8319. The moderately efficient genotypes were: Javae, Rio Formoso, CNA 7556, and CNA 7857. The screening method used for Zn use efficiency is simple and does not require plant analysis. This methodology can be used for crop genotype evaluation of mineral stresses, which have direct bearings in genetic studies and breeding programes
Key words: *Oryza sativa*, Zinc deficiency, yield and yield components

AVALIAÇÃO DE GENÓTIPOS DE ARROZ NA EFICIÊNCIA DE USO DE ZINCO

RESUMO: A deficiência de Zn é reconecida como problema nutricional mundial para a produção das culturas. Foi conduzido um experimento em casa de vegetação, na Embrapa Arroz e Feijão, com o objetivo de se avaliar a eficiência do uso de Zn pelos 10 genótipos de arroz irrigado (*Oryza sativa* L.). Os genótipos foram testados aos níveis baixo (0 mg Zn kg^{-1}) e alto (10 mg Zn kg^{-1}), aplicados em um Inceptissolo. Diferenças significativas foram observadas entre os genótipos na produção de grãos e nos seus componentes. Baseado no índice de eficiência de produção, os genótipos foram classificados como eficientes e não eficientes. Os genótipos Metica 1, Epagri 108, CNA 7550, e CNA 8619 foram classificados como eficientes. O genótipo CNA 8319 foi não eficiente. Os genótipos Javaé, Rio Formoso, CNA 7556 e CNA 7857 foram classificados como moderadamente eficientes. O método de avaliação é simples e não precisa análise de plantas. Este métodologia pode ser usada na avaliação de genótipos para estresse nutricional que possui ligação direto com estudos genetíco e melhoramento.
Palavras-chave: *Oryza sativa*, deficiência de Zn, produção e componentes da produção

INTRODUCTION

Zinc deficiency has been reported in various parts of the world in annual crops (Cakmak et al., 1998). In a global study initiated by FAO, it was shown that about 30% of the cultivated soils of the world are Zn deficient (Sillanpaa, 1982). About 50% of the soils used worldwide for cereal production contain low levels of plant-available Zn (Graham et al., 1992). Zinc deficiency in crop plants reduces not only grain yield, but also the nutritional quality of grains. High consumption of cereal-based foods with low levels and poor bioavailability of Zn is thought to be a major factor for the widespread occurrence of Zn deficiency in human being (Welch, 1993).

In Brazil, zinc deficiency has been widely reported in upland as well as lowland rice (Fageria & Brarbosa Filho, 1994). This deficiency is related to low level of zinc in Brazilian highly weathered acid soils as well as high soil pH due to liming (Fageria & Baligar, 1993; Fageria & Gheyi, 1999). Crop species markedly differ in their ability to adapt to Zn deficient soils (Graham, 1984). Among the cereal species, rice, sorghum and corn are classified as Zn deficiency sensitive, whereas, barley, wheat and rye are classified as less sensitive (Clark, 1990). The objective of the present study was to develop a methodology for the screening of lowland rice genotypes in relation to Zn use efficiency.

MATERIAL AND METHODS

A greenhouse experiment was conducted in Santo Antônio de Goías, GO, Brazil, to evaluate Zn-use efficiency of ten lowland rice (*Oryza sativa L)* genotypes. The soil used in the experiment was Typic Haplaquept. It had the following chemical and a textural properties before the application of Zn treatments: pH 5.3 (1:2.5 soil-water ratio), extractable P 8.9 mg kg^{-1}, K 70 mg kg^{-1}, Ca 1.7 $cmol_c$ kg^{-1}, Mg 1.1 $cmol_c$ kg^{-1}, Al 0.7 $cmol_c$ kg^{-1}, Cu 0.8 mg kg^{-1}, Zn 1.2 mg kg^{-1}, Fe 77 mg kg^{-1}, Mn

6 mg kg^{-1}, and organic matter 50 g kg^{-1} of soil. Textural analysis values were 450 g kg^{-1} clay, 230 g kg^{-1} silt, and 320 g kg^{-1} sand. Phosphorus and K were extracted by the Mehlich 1 extracting solution (0.05 M HCl + 0.0125 M H_2SO_4). Phosphorus was determined colorimetrically, and K by flame photometry. Calcium, Mg, and Al were extracted with 1 M KCl. Aluminum was determined by titration with NaOH, and Ca and Mg by titration with EDTA. Micronutrients were determined on a portion of the extract of P by atomic absorption spectrophotometry. Organic matter was determined by the Walkley-Black method, and textural analysis by the pipette method. Soil analysis methods used in this study are described in a soil analysis manual published by Embrapa (1997).

The treatments consisted of two Zn levels, i.e., without Zn application called low (0 mg Zn kg^{-1} of soil) and high (10 mg Zn kg^{-1} of soil) level, through application of zinc sulfate, and 10 lowland rice genotypes: Javaé, Rio Formoso, CNA 6343, CNA 7550, CNA 7556, CNA 7857, CNA 8319, CNA 8619, Epagri 108 and Metica 1. A completely randomized design was used in a factorial arrangement, and treatments were replicated three times. The study was conducted in plastic pots with 5 kg of soil each. At sowing time, in addition to Zn treatments, each pot received a basal application of 400 mg N as $(NH_4)_2SO_4$, 787 mg P as triple superphosphate and 797 mg K as KCl. Each pot also received 400 mg N as topdressing at the start of tillering (20 days after sowing) and at the panicle initiation (55 days after sowing). These fertilizer rates were based on the recommendations of Fageria & Baligar (1999). Each pot contained four plants, which were flooded to maintain about 3 to 5 cm water depth for two weeks after sowing

At maturity, plant height, dry matter yield of shoot, grain yield, number of panicles, panicle length, weight of 1000 grains, and harvest index were determined. Dry plant material (shoot and grain) was dried in a forced-draft oven at about 70°C. When grain yield or dry matter is not having significant effect of nutrient level but exist 5 to 10% incraese in yield due to nutrient application, a efficiency index can be used to classify genotypes. Grain yield efficiency index was calculated using the following formula (Graham, 1984):

Grain yield efficiency index = (Yield at low Zn level/ Experimental mean yield at low Zn) / (Yield at high Zn level/Experimental mean yield at high Zn)

All data were analyzed by analysis of variance, and the F-test was used to evaluate treatment significance. Tukey's test was used to compare treatment means at the 5%.

RESULTS AND DISCUSSION

The results of the analysis of variance for the variables measured showed no effect of Zn treatment, however, genotypes had significant differences in relation to yield and yield components (TABLE 1). Plant height varied from 67 to 79 cm among genotypes (TABLE 2). Genotypes Metica 1 and CNA 8619 were significantly taller compared with the other genotypes. Similarly, genotypes CNA 7556, CNA 7857 and Rio Formoso were significantly short as compared with other genotpes. Remaing genotypes had intermediate height. Shoot dry weight varied from 84.73 to 119.12 g per four plants and the overall shoot dry weight was 98.75 g per four plants. Grain yield variation was significant among genoptyes and varied from 28.67 to 80.67 g per four plants. Maximum grain yield of 80.67 g per four plants was produced by the genotype Metica 1, which is 56% higher than the average of all genotypes. Genotype CNA 8319 produced 28.67 g grain yield which was lowest among the genotypes. The heighest grain yield of genotype Metica 1 and the lowest of genotype CNA 8319 may be related to the harvest index. Harvest index is the ratio of grain yield to total biomass production, and was 0.45 for the genotype Metica 1, which was maximum among genotypes and 0.22 for the genotype CNA8319, the lowest value. The harvest index values reported in the literature for semidwarf indica lowland rice cultivares is in the range of 0.45 to 0.55 under favorable environmental conditions (Yoshida, 1981). Only the genotype Metica 1 produced the minimum value of harvest index and all the remaining genotypes showed lower harvest index as reported in the literature. The lower values of harvest index may be due to low temperature which occurred around the flowering growth stage.

TABLE 1 - Significance of F values derived from analysis of variance for variables measured on 10 lowland rice genotypes at two zinc levels..

Variable	Zn level	Genotype	Zn X G	CV(%)
Plant height	NS	**	NS	5
Shoot dry wt.	NS	*	NS	15
Grain yield	NS	**	NS	28
Panicle number	NS	NS	*	17
Panicle length	NS	**	NS	7
1000 grain wt.	NS	**	NS	4
Harvest index	NS	**	NS	23

*, ** Significant at the 5 and 1% levels, respectively, and NS = not significant.

Panicle length and 1000 grain weight were significantly different among genotypes. Panicle length varied from 19.17 to 21.15 cm and 1000 grain weight varied from 18.16 to 24.14 g. These two yield components showed not as much influence on grain yield, because the highest yield producing genotypes, Metica 1 and Epagri 108, had not maximum panicle length and 1000 grain weight as compared with other genotypes. Variation in 1000 grain weight is generally small since seed size of rice is rigidly controlled by the size of the hull (Yoshida, 1981). Under most conditions, 1000 grain weight of field crops is one of the very stable varietal characters (Yoshida, 1981).

TABLE 2 - Yield and yield components of 10 lowland rice genotypes across two Zn levels.

Genotype	Plant height	Shoot dry wt.	Grain yield	Panicle	1000 grain weight	Harvest index
	cm	------------- g/4 plants -----------		cm	g	
Javae	70 bc	93.55 ab	49.83 bc	18.30 bc	21.08 d	0.35 abc
Rio Formoso	67 c	96.15 ab	44.38 bc	20.97 ab	23.44 ab	0.31 abc
CNA 6343	70 bc	119.12 a	50.60 bc	18.72 abc	18.16 e	0.30 bc
CNA 7550	73 abc	97.98 ab	53.07 abc	19.78 abc	24.14 a	0.35 abc
CNA 7556	68 c	93.03 ab	49.02 bc	18.58 abc	23.42 ab	0.34 abc
CNA 7857	68 c	107.00 ab	46.23 bc	18.17 c	22.38 bcd	0.31 abc
CNA 8319	71 bc	104.95 ab	28.67 c	18.68 abc	21.76 cd	0.22 c
CNA 8619	79 a	84.73 b	53.83 abc	21.15 a	23.67 ab	0.39 ab
Epagri 108	77 ab	96.47 ab	60.50 ab	19.70 abc	23.22 abc	0.38 abc
Metica 1	79 a	94.58 ab	80.67 a	19.60 abc	20.83 d	0.45 a
Average	70	98.75	51.68	19.37	22.21	0.34

Means followed by the same letter in the same column are not significantly different at 5% level by the test of Tukey.

TABLE 3 - Panicle number as influenced by zinc levels and grain yield efficiency index for 10 lowland rice genotypes.

Genotype	Panicle number per 4 plants at 0	Panicle number per 4 plants at 10	Grain yield efficiency index
	---------------------------- mg Zn kg^{-1} ------------------------------		
Javae	62.00 a	48.33 ab	0.92 ab
Rio Formoso	41.33 ab	48.33 ab	0.79 b
CNA 6343	47.33 ab	48.67 ab	0.99 ab
CNA7550	42.00 ab	39.67 b	1.09 ab
CNA7556	50.33 ab	45.67 ab	0.89 b
CNA7857	46.67 ab	46.67 ab	0.82 b
CNA8319	33.67 b	43.33 ab	0.31 b
CNA8619	35.33 b	30.00 b	1.05 ab
Epagri 108	31.00 b	40.33 ab	1.35 ab
Metica 1	44.00 ab	60.33 a	2.31 a
Average	43.37	45.13	1.05

Means followed by the same letter in the same column are not significantly different at 5% level by the test of Tukey.

Due to significant genotype X Zn interaction, values of the number of panicles are presented for two zinc levels (TABLE 3). Panicle number differed significantly among genotypes and varied from 31 to 62 at the lower Zn level and 30 to 60.33 at the higher Zn level. Overall, panicle number increased with the application of Zn in the growth medium. With the application of Zn, about 5% increase was obsreved in panicle number as compared with the control treatment. The highest grain yield producing genotype Metica 1 also produced maximum panicle number at the higher zinc level.

Grain yield of field crops is estimated by various yield components. The important yield components in cereals are panicle or ear number per unit area, number of spikelets per panicle or ear, and spikelet weight. The relative importance of number of panicles, 1000 grain weight, panicle length and harvest index was evaluetd by Fageria & Baligar (1999) in lowland rice. Panicle number was the most important component of yield, accounting 87% of the variation in yield, while 1000 grain weight accounted only 3%. Grain yield was significantly related to the number of panicles and harvest index, but not to panicle length or 1000 grain weight.

Number of panicles and harvest index can be manipulated in favour of higher grain yield with the use of appropriate genotypes in lowland rice. The relationship between rice yield and yield components has been studied extensively at the phenotypic level (Gravois &

Helms, 1992). In general, panicle number per unit area was the most important component of yield (Gravois & McNew, 1993). Similarly, efficiency of grain production in crop plants is frequently expressed as harvest index. Sinclair (1998) stated that harvest index has been an important trait associated with a dramatic increase in crop yield that has occurred in the twentieth century. Harvest index reflects the partitioning of photosynthate between the grain and the vegetative plant, and improvement in the harvest index emphasizes the importance of carbon allocation for grain production. From a breeding standpoint, increasing both panicle number and harvest index should be emphasized when the objective is to select for increased grain yield.

Grain yield efficiency index was used to classify genotypes into efficient and inefficient groups. This index is useful in separating high yielding, stable and Zn-efficient genotypes from low yielding, unstable and Zn-inefficient ones. Genotypes with grain efficiency index higher than 1 are considered Zn-efficient. Inefficient genotypes are in the range of 0-0.5 efficiency index, and genotypes in between these two limits are considered intermediate in Zn-use efficiency. This grouping, although arbitrarily selected, is valid when grain yield means are compared by Tukey's test (TABLE 2). According to this criterion, the most Zn-efficient genotypes were: Metica 1, Epagri 108, CNA7550, and CNA8619. The most inefficient genotype was CNA8319. The genotypes Javae, Rio Formoso, CNA 6343, CNA7556, and CNA7857 were moderately efficient in Zn utilization. Genotypic differences in Zn use have been reported in lowland rice (Clark, 1990; De Datta & Neue, 1993). The rice genotypes studied showed marked differences in V_{max} (maximum ion uptake rate) and K_m (Michaelis-Menten constant, equal to the substrate ion concentration giving half the maximal rate of uptake) values. The genotypes varied twofold for zinc affinity. Genotypes more resistant to Zn deficiency had higher Zn uptake rates and lower affinity for zinc than genotypes more susceptible to zinc deficiency ((Clark, 1990). Tolerant genotypes increase Zn translocation to the shoot and regulate Ca, Cu, Fe, Mg, and P transport in order to maintain balanced nutrient ratios with respect to Zn (Cayton et al., 1985). Resistance to Zn deficiency appeared to be controlled polygenically in rice and seemed to be a dominant trait (Mahadevappa et al., 1981).

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