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Genotypic response for zinc efficiency in aerobic rice under normal and stress condition

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Abstract

To study association analysis and zinc efficiency among 246 Recombinant Inbred Lines (RILs) derived from a cross involving CO51 x CB-06-803-2 were evaluated along with the parents under aerobic condition in a zinc deficient soil (0.8 ppm) at Wetland, Department of farm management, Tamil Nadu Agricultural University, Coimbatore during Rabi 2014. A control plot (+Zn) was maintained by treating the soil with recommended dose of 25 Kg/ha Znso4. Plot yield had high and positive correlation with panicle length, productive tillers, hundred grain weight, harvest index and panicle harvest index under control condition whereas it had significant and positive correlation with panicle length, number of productive tillers, shoot zinc content, root zinc content, hundred grain weight, harvest index, panicle harvest index, zinc efficiency (ZE) in shoot and ZE in root under stress condition. ZE in shoot had Positive and significant correlation with ZE in root in stress condition. Therefore, selection for anyone of the above characters would bring in simultaneous improvement of zinc efficiency of shoot and root and ultimately improving the grain yield.

Keywords: Aerobic rice, Zinc efficiency, correlation analysis, zinc deficiency tolerance

Introduction

The Wonder Cereal, Rice (*Oryza sativa* L.) is the heart of our culture and the staple food crop consumed by more than 50 per cent of the world's population. Aerobic rice proves to be a viable technology by reducing water losses through seepage, percolation and evaporation. However, under aerobic condition several essential nutrients, especially zinc became unavailable due to positive soil redox potential. Therefore genetic improvement of rice genotypes for zinc deficiency under aerobic condition is essential to exploit the water saving potential of aerobic condition. In this study, we critically appraise the role of Zn in plant biology and its dynamics in soil and rice production systems. Strategies and options to improve Zn uptake and partitioning efficiency in rice by using agronomic, breeding and biotechnological tools are also discussed (Rahman *et al*., 2012). The term ZE is defined as the capacity of a genotype to grow well under -Zn deficient conditions and ZE is usually expressed as the ratio of shoot dry weight under Zn deficiency over that under adequate Zn supply (Graham *et al*., 1992). So far, however, breeding efforts has mainly focussed on the yield of aerobic genotypes and improvement of zinc efficiency needs attention. Hence, it is relevant to investigate whether there is association among ZE among rice genotypes for utilizing it in crop improvement programme.

Materials and Methods

Phenotyping F4 RILs of CO51 x CB-06-803-2 under aerobic condition in a zinc deficient soil

Two hundred and forty six Recombinant Inbred Lines (RILs) derived from a cross involving CO51 x CB-06-803-2 were evaluated along with the parents under aerobic condition in a zinc deficient soil (0.8 ppm) at Wetland, Department of farm management, Tamil Nadu Agricultural University, Coimbatore during Rabi 2014. To raise the crop under aerobic condition, land was prepared similar to upland condition and direct seeding was done. A control plot (+Zn) was maintained by treating the soil with recommended dose of 25 Kg/ha Znso4. Each entry was direct sown in a plot size of 3.6 m x 0.8 m by adopting a spacing of 20cmx20cm. The entries were replicated twice in Randomized block design. Single seedling per hill was maintained. The crop was irrigated everyday till establishment and thereafter the crop was irrigated once in 4-5 days (when hairline crack occurs).

Data were recorded on different characters *viz*., Vegetative vigour, Zinc score, Shoot length (cm), Root length (cm), Root dry weight (g), Shoot dry weight (g), Shoot zinc content (ppm), Root zinc content (ppm), Plant height at maturity (cm), Days to 50% flowering(days after sowing), Panicle length (cm), Number of productive tillers (Nos.), 100-grain weight (g), panicle harvest index, harvest index and plot yield (g).

Zn translocation was calculated as the ratio of Zn concentration to the total plant weight of a shoot Zn concentration and expressed as percentage

Zn translocation = (Zn in shoot) / (Zn in plant) ×100

[Zinc Efficiency = (Dry weight at low Zn level/Experimental mean dry weight at low Zn)/(Dry weight at high Zn level/Experimental mean dry weight at high Zn)] (Graham, 1984; Fageria, 2001).

Experimental Results

Correlation studies

The correlation coefficient among various component traits of yield and zinc deficiency tolerance in F_4 RILs under aerobic condition in a control (+Zn) and stress (-Zn) plots of field experiment were estimated and presented in Table 1 and 2.

Table 1: Correlation analysis of variance for zinc deficiency tolerance and yield component traits of 246 F_4 RILs grown in a +Zn (control) plot under aerobic condition in field experiment

Character	ZS	SL	RL	SDW	RDW	DFF	PH	PL	PT	SZC	RZC	HGW	HI	PHI	ZE in shoot	ZE in root	PY
VV	0.09	-0.06	0.02	0.01	0.03	-0.06	-0.02	0.02	0.04	0.08	0.08	0.04	0.04	0.08	0.03	0.04	0.03
ZS		-0.09	0.04	-0.05	-0.06	0.07	-0.03	0.02	0.01	0.06	0.06	0.01	0.01	-0.02	-0.05	0.03	0.02
SL			0.16*	0.24**	0.21**	-0.13*	0.09	0.08	-0.02	0.05	0.13	-0.10	-0.14*	-0.06	-0.03	-0.02	-0.11
RL				0.11	0.21**	0.11	0.09	0.04	0.08	-0.07	-0.01	-0.05	-0.07	-0.02	0.07	-0.08	-0.05
SDW					0.59**	-0.12*	0.04	0.02	0.06	0.03	0.03	0.06	0.07	0.05	-0.11	-0.07	0.06
RDW						-0.05	0.09	0.06	0.05	0.01	0.01	0.04	0.07	0.04	0.09	-0.08	0.05
DFF							0.07	0.03	0.02	0.01	-0.02	-0.02	0.03	-0.03	0.06	-0.03	-0.03
PH								0.40**	0.20**	0.02	0.01	-0.10	-0.01	-0.10	0.05	0.01	-0.02
PL									0.11	0.01	0.01	-0.08	-0.02	-0.02	0.03	0.04	0.14*
PT										0.03	-0.06	0.20**	0.48**	0.29**	0.07	0.03	0.46**
SZC											0.76**	0.02	0.03	0.06	-0.03	-0.04	0.11
RZC												-0.09	0.13*	-0.05	-0.03	0.06	0.09
HGW													0.72**	0.07	0.01	-0.03	0.78**
HI														0.73**	0.04	0.06	0.93**
PHI															0.03	-0.02	0.81**
ZE in shoot																0.11	0.09
ZE in root																	0.11

VV – Vegetative Vigour, ZS – Zinc Score, SL – Shoot Length (cm), RL – Root Length (cm), SDW – Shoot Dry Weight (g), RDW – Root Dry Weight (g), DFF – Days to 50 per cent Flowering (days), PH – Plant Height (cm), PL – Panicle Length (cm), NPT – Number of Productive Tillers, SZC – Shoot Zinc Content (ppm), RZC – Root Zinc Content (ppm), HGW – 100-Grain Weight (g), PHI – Panicle Harvest Index, HI – plant Harvest Index, PY – Plot Yield (kg) and ZE – Zinc Efficiency (%).

*, ** significant at 1% and 5% levels respectively.

Table 2: Correlation analysis of variance for zinc deficiency tolerance and yield component traits of 246 F_4 RILs grown in a -Zn (stress) plot under aerobic condition in field experiment

Character	ZS	SL	RL	SDW	RDW	DFF	PH	PL	PT	SZC	RZC	HGW	HI	PHI	ZE in shoot	ZE in root	PY
VV	0.14*	0.03	-0.06	0.09	0.06	-0.25**	0.06	0.08	0.05	0.03	0.11	-0.02	0.04	0.04	-0.06	-0.01	0.04
ZS		-0.18**	0.06	-0.10	-0.07	-0.18**	0.03	-0.02	-0.09	-0.12*	-0.11	0.02	-0.02	-0.05	-0.05	0.04	0.05
SL			0.20**	0.43**	0.28**	-0.17**	0.22**	0.01	0.10	0.14*	-0.01	-0.02	0.01	0.09	0.11	-0.05	0.02
RL				0.09	0.17**	0.01	0.02	0.03	0.02	0.07	-0.10	0.04	0.12*	0.06	0.05	-0.02	-0.09
SDW					0.49**	-0.23**	0.07	0.05	0.12*	0.11	0.05	0.04	0.03	0.11	0.08	-0.06	0.08
RDW						-0.16**	0.05	0.02	0.06	0.09	0.02	0.05	0.09	0.05	0.02	0.09	0.08
DFF							0.01	0.04	-0.18**	0.07	0.09	-0.07	-0.05	-0.09	-0.06	0.02	-0.06
PH								0.30**	0.14**	0.13*	0.12*	-0.11	0.02	0.22**	0.11	0.11	0.04
PL									0.21**	-0.03	-0.02	0.13*	0.12*	0.17**	0.09	0.04	0.14*
PT										0.12*	0.18**	0.16**	0.40**	0.38**	0.11	0.15**	0.36**
SZC											0.88**	0.15*	0.13*	0.14*	0.17**	0.13*	0.15*
RZC												0.26**	0.24**	0.22**	0.42**	0.12*	0.17**
HGW													0.43**	0.13*	0.14*	0.12*	0.61**
HI														0.63**	0.23**	0.17**	0.80**
PHI															0.12*	0.19**	0.53**
ZE in shoot																0.13*	0.14*
ZE in root																	0.18**

VV – Vegetative Vigour, ZS – Zinc Score, SL – Shoot Length (cm), RL – Root Length (cm), SDW – Shoot Dry Weight (g), RDW – Root Dry Weight (g), DFF – Days to 50 per cent Flowering (days), PH – Plant Height (cm), PL – Panicle Length (cm), NPT – Number of Productive Tillers, SZC – Shoot Zinc Content (ppm), RZC – Root Zinc Content (ppm), HGW – 100-Grain Weight (g), PHI – Panicle Harvest Index, HI – plant Harvest Index, PY – Plot Yield (kg) and ZE– Zinc Efficiency (%).

*, ** significant at 1% and 5% levels respectively.

Character association under control condition

Under control conditions, plot yield had significant and positive correlation with panicle length (0.14), number of productive tillers (0.46), 100-grain weight (0.78), harvest index (0.93) and panicle harvest index (0.81). Shoot length recorded significantly positive correlation with root length (0.16), shoot dry weight (0.24) and root dry weight (0.21) while it was negatively correlated with days to 50 per cent flowering (-0.13) and harvest index (-0.14). Root length had significant and positive correlation with root dry weight

(0.21). Shoot dry weight had highly significant positive correlation with root dry weight (0.59) and negative correlation with days to fifty per cent flowering (-0.12). The trait plant height recorded high and positive correlation with panicle length (0.40) and number of productive tillers (0.20). Number of productive tillers had significant and positive correlation with 100-grain weight (0.20), harvest index (0.48) and panicle harvest index (0.29). Shoot zinc content showed highly significant positive correlation with root zinc content (0.76). Root zinc content exhibited significant positive correlation with harvest index (0.13). The character 100-grain weight had highly significant and positive correlation with harvest index (0.72). Harvest index and panicle harvest index had significant and positive correlation (0.73) among themselves.

Character association under stress condition

Under stress condition, plot yield recorded significant and positive correlation with panicle length (0.14), number of productive tillers (0.36), shoot zinc content (0.15), root zinc content (0.17), 100-grain weight (0.61), harvest index (0.80), panicle harvest index (0.53), ZE in shoot (0.14) and ZE in root (0.18). The trait, vegetative vigour showed significant and positive correlation with zinc score (0.14) whereas it had highly negative correlation with days to 50 per cent flowering (-0.25). Zinc score recorded significant and negative correlation with shoot length (-0.18), days to 50 per cent flowering (-0.18) and shoot zinc content (-0.12). Shoot length recorded high and positive correlation with root length (0.20), shoot dry weight (0.43), root dry weight (0.28), plant height (0.22) and shoot zinc content (0.14) while it was negatively correlated with days to 50 per cent flowering (-0.17). Root length had significant and positive correlation with root dry weight (0.17) and harvest index (0.12). Shoot dry weight had significant and positive correlation with root dry weight (0.49) and number of productive tillers (0.12) while it was negative correlation with days to fifty per cent flowering (-0.23). Root dry weight had negative and significant correlation with days to 50 per cent flowering (-0.16). Days to 50 per cent flowering had negative and significant correlation with number of productive tillers (-0.18). The trait plant height recorded high and positive correlation with panicle length (0.30), number of productive tillers (0.14), shoot zinc content (0.13), root zinc content (0.12) and panicle harvest index (0.22). Panicle length had high and positive correlation with number of productive tillers (0.21), 100-grain weight (0.13), harvest index (0.12) and panicle harvest index (0.17). Number of productive tillers had significant and positive correlation with shoot zinc content (0.12), root zinc content (0.18), 100-grain weight (0.16), harvest index (0.40), panicle harvest index (0.38) and ZE in root (0.15). Shoot zinc content exhibited significant positive correlation with root zinc content (0.88), 100-grain weight (0.15), harvest index (0.13), panicle harvest index (0.14), ZE in shoot (0.17), ZE in root (0.13). Root zinc content recorded positive correlation with 100-grain weight (0.26), harvest index (0.24), panicle harvest index (0.22), ZE in shoot (0.42), ZE in root (0.12). The character 100-grain weight showed significant and positive correlation with harvest index (0.43), panicle harvest index (0.13), ZE in shoot (0.14) and ZE in shoot (0.12). Harvest index had significant and positive correlation with panicle harvest index (0.63), ZE in shoot (0.23) and ZE in root (0.17). Panicle harvest index had positive and significant correlation with ZE in root (0.12) and ZE in root (0.19). ZE in shoot had positive and significant correlation with ZE in root (0.13).

Discussion

Correlation study was made to establish the extent of association between component traits with zinc deficiency tolerance and yield and among themselves under aerobic condition in rice. It is an index of degree of relationship between two continuous variables (Kennedy and Rangasamy, 1998).

In this study, plot yield had high and positive correlation with panicle length, number of productive tillers, 100-grain weight, harvest index and panicle harvest index under control condition whereas it had significant and positive correlation with panicle length, number of productive tillers, shoot zinc content, root zinc content, 100-grain weight, harvest index, panicle harvest index, ZE in shoot and ZE in root under stress condition. Similar kind of results were reported by Bekele *et al*. (2013), Moosavi *et al.* (2015), Sarker *et al.* (2014), Venkanna *et al.* (2014) and Lakshmi *et al.* (2014) for yield component traits. The trait, vegetative vigour showed significant and positive correlation with zinc score and it showed negative correlation with days to 50 per cent flowering under stress condition.

Zinc score recorded significant and negative correlation with shoot length, days to 50 per cent flowering and shoot zinc content under stress condition. Shoot length recorded high and positive correlation with root length, shoot dry weight and root dry weight while it was negatively correlated with days to 50 per cent flowering and harvest index in control whereas it had significant and positive correlation with root length, shoot dry weight, root dry weight, plant height and shoot zinc content while it was negatively correlated with days to 50 per cent flowering under stress condition. Similar kind of result was reported by Vishnu (2011) and Asadi *et al*. (2012) for correlation between shoot length and dry weight. Positive associations between root length and grain yield have been documented in rice (Mambani and Lal, 1983; Lilley and Fukai, 1994). Root length had significant and positive correlation with root dry weight in control whereas it had significant and positive correlation with root dry weight and harvest index in stress.

Shoot dry weight had significant and positive correlation with root dry weight and negative correlation with days to fifty per cent flowering in control whereas it had significant and positive correlation with root dry weight and number of productive tillers; negative correlation with days to fifty per cent flowering in stress condition. Root dry weight had negative and significant correlation with days to 50 per cent flowering in stress condition. Toorchi *et al.* (2002) and Vishnu (2011) reported that root dry weight showed significant positive correlation with total dry weight and shoot length.

The trait plant height recorded high and positive correlation with panicle length and number of productive tillers under control whereas it had significant and positive correlation with panicle length, number of productive tillers, shoot zinc content, root zinc content and panicle harvest index in stress condition. Similar results were reported by Moosavi *et al.* (2015), Sarker *et al.* (2014) and Venkanna *et al.* (2014) for plant height and yield component traits. Panicle length had high and positive correlation with number of productive tillers whereas it had significant and positive correlation with number of productive tillers, 100 grain weight, harvest index and panicle harvest index. Venkanna *et al.* (2014) and

Purusothaman (2010) for panicle length and component traits. Number of productive tillers had significant and positive correlation with 100-grain weight, harvest index and panicle harvest index under control whereas it had significant and positive correlation with shoot zinc content, root zinc content, 100-grain weight, harvest index, panicle harvest index and ZE in root in stress condition. This was in agreement with Sarker *et al.* (2014), Lakshmi *et al.* (2014), Venkanna *et al.* (2014) and Yadi *et al*. (2012).

Shoot zinc content had high and positive correlation with root zinc content under control whereas it had significant and positive correlation with root zinc content, 100 grain weight, harvest index, panicle harvest index, ZE in shoot and ZE in root under stress condition. Root zinc content recorded positive correlation with harvest index under control whereas it had significant and positive correlation with100 grain weight, harvest index, panicle harvest index, ZE in shoot and ZE in root under stress condition. Similar kind of results were reported for yield components and zinc content by Wissuwa *et al*., 2006 and Bekele *et al*., 2013. The character 100 grain weight showed significant and positive correlation with harvest index in control whereas it had significant and positive correlation with harvest index, panicle harvest index, ZE in shoot and ZE in root in stress condition. Harvest index had significant and positive correlation with panicle harvest index in control whereas it had significant and positive correlation with panicle harvest index, ZE in shoot and ZE in root under stress condition. Similar kind of results was reported by Ramchander, 2010. Panicle harvest index had positive and significant correlation with ZE in root and ZE in root in stress condition. ZE in shoot had positive and significant correlation with ZE in root in stress condition. Similar kind of results was reported by Gao *et al*., 2005.

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