RESEARCH PAPER
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Significance of zinc nutrition in improving growth rates and pattern of zinc accumulation in panicles at different stages of diversified rice (*Oryza sativa* L.) genotypes

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One hundred and thirty diverse rice germplasm lines were examined for leaf and seed zinc (Zn) content. A significant and wide genetic variability was observed for leaf and seed zinc levels. Based on Z-distribution analysis, 22 contrasting genotypes were selected. In this experiment, besides Zn content in leaf and seed, several growth parameters were also recorded to study the genetic variability in growth and productivity. The results showed that leaf area and total dry matter (TDM) showed positive relationship, indicating the contribution of leaf area for its increase in TDM (g/pl). Net assimilation rate (NAR) (g/cm^2) did not contribute to the extent observed variability in TDM. A positive relationship was observed between total leaf Zn and TDM. Some of the genotypes showed more TDM with higher total leaf Zn (mg/100g dry weight) per plant indicating total Zn acquisition by plant and this might have influenced the growth rate. Total seed Zn (mg/100g) increased the seed yield significantly but not the seed Zn per unit weight of seed. Higher seed Zn levels might positively influence cell metabolic activities and hence, improved grain growth and development was observed. An attempt was also made to identify the contrasting genotypes differing in Zn status to examine genetic variability in seed Zn levels of panicle development. The seed Zn levels increased at milky stage subsequently, it was reduced during late stages of grain filling period. This could be due to variation in duration of transport of Zn to developing grains.

Key words : Genetic variability, Growth parameters, Total dry matter, Net assimilation rate, Rice germplasm, Leaf Zn, Seed Zn, Total Zn

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INTRODUCTION

Zinc is a trace element found in all soils. It is an essential element for plants, animals and humans. As a component of proteins, Zn acts as a functional, structural and regulatory co factor of a large number of enzymes. It is involved in many important plant physiological processes, such as carbohydrate metabolism, protein metabolism, membrane integrity, starch formation and seed maturation (Fageria *et al.,* 2001).

Nearly, 70 per cent of the rice crop is produced in flooded soils, which increases the availability of fixed soil phosphorus (P) and thus P being antagonistic to Zn, reduces its availability due to fixation resulting in Zn deficiency to rice crop. It has been estimated that 50 per cent of paddy soils are affected by zinc deficiency. This could involve up to 35 m ha in Asia alone. It has been estimated from soil test samples that, on an average 49 per cent of soils from all the main agricultural areas in India are deficient in zinc (Sudhalakshmi *et al.,* 2007). Grain-yield reduction up to 80 per cent along with reduced grain Zn level has been observed under Zn deficiency (Cakmak and Marshner, 1998).

The main causes of zinc deficiency in crops are: low total zinc concentrations in soils (especially sandy, calcareous and sodic soils), low availability (high pH, calcareous and sodic soils), high levels of phosphate and nitrogen and restricted root zones due to soil compaction or high water table, particularly on soils of marginal zinc status (Alloway, 2004). There are two approaches to improve zinc acquisition by crops, agricultural strategies like zinc fertilization and another approach is to exploit genetic variability for zinc acquisition and transport to grains (Alloway, 2004).

Considerable genetic variation in rice genotypes was demonstrated in different rice genotypes, where 53 per cent of the observed variability was associated with Zn uptake and translocation from roots and shoots (Wissuwa *et al.*, 2006). Mechanisms responsible for genotypic variation in zinc efficiency were thoroughly reviewed by Rengel (2001), Hacisalihoglu and Kochian (2003).

Plant breeding approach to improve the Zn acquisition and its transport has a greater significance and relevance compared to agronomical approaches in improving the rhizospheric Zn levels by fertilizer application. However, for improving Zn acquisition, one of the primary prerequisite is significant genetic variability for Zn content and finally identifying a donor genotypic source with high Zn levels and also higher Zn concentrations in the grain.

Many divalent cations like Zn and Fe are poorly translocated to grains and therefore, one of the attempts has been made to improve seed Zn levels by identifying the genotypes with high Zn content especially in cereals.

The differences in seed Zn content amongst the genotypes could be due to the longer duration of Zn transport to developing grains. To examine this aspect, an attempt was also made to study the duration of Zn transport to grain during grain filling stage in contrasting genotypes differing in seed Zn levels.

RESEARCH METHODOLOGY

In the year 2005, 135 different rice germplasm lines were grown in two replications using randomised complete block design. The germplasm lines included IET/IVT entries, IRRON – A and IRRON - B module, locally adapted cultivars, wild relatives and aromatic rice varieties like Jeera rice, Basmati rice etc along with international check varieties like IR-50, a very early maturing, IR-72, early maturing PSBRC-2, medium maturing variety and national check, Jaya. Module-A was the regular IRRON set and Module - B was the set of 32 breeding lines of new plant material type.

Crop was raised in the field as per the package of practices. Recommended dose of fertilizers were applied as in the previous year. Number of plants maintained per genotype was 28 with a spacing 20cm x10 cm.

Zinc was estimated in the grains and leaf sample using Polarized Zeeman Atomic Absorption Spectrophotometer (AAS-2-6100) (Piper, 1966).

Seed and leaf Zn content was estimated in all the entries. Significant genetic variability was observed for both the parameters. Further, to identify contrasting genotypes differing in acquisition of Zn and transport to seed, Z-distribution analysis between leaf and seed Zn was made. Based on distribution, the genotypes were classified as high leaf high seed Zn types (HLHS), low leaf high seed Zn types (LLHS), low leaf low seed Zn types (LLLS) and high leaf low seed Zn types (HLLS).

Since significant genetic variability exists in Zn levels, it is relevant to assess relationship between Zn levels and productivity across the genotypes to study the association between leaf Zn and, growth and productivity.

Keeping this above, specific genotypes (22) from each sub groups were selected and these genotypes included released varieties such as BPT-5204, IR-64, IR-20 and KPM-101. The selected genotypes were grown in the field as in the previous year by following package of practices. Crop was raised using RCBD with three replications. Zinc was estimated both in leaf and seeds.

At maturity, three plants each in 3 replications were harvested and total biomass, grain yield and also the leaf weight were separately measured. Specific leaf area (SLA) was estimated in all the genotypes from three randomly selected leaves. Based on SLA and leaf dry weight at harvest the leaf area was computed. Based on the biomass at harvest and total leaf area, TDM/LA was computed. The dry matter per unit leaf area will be a reflection of mean NAR over the crop growth. The relationship between growth characters *viz.*, leaf area, total dry matter, net assimilation rate, grain yield etc. and also the relationship between Zn level and productivity were assessed.

The differences in seed Zn content amongst the genotypes could be due to the longer duration of Zn transport to developing grains. To examine this aspect the Zn levels in panicles was assessed at weekly intervals after anthesis to harvest in different genotypes differing in seed Zn levels.

The selected genotypes were IR 30864, WAT 310-WAS-B-28-8-3-3-3, IR 73898-71-2-6-3, Samrat (HLHS Zn types) and KPM-101, Jaya and GMR 14 (LLLS Zn types). In the developing grains Zn content was estimated as discussed earlier.

RESEARCH FINDINGS AND ANALYSIS

Out of 135 genotypes examined, leaf Zn content showed the range between 4.05 and 9.68 mg/100g DW with a mean of 6.40 and the seed Zn was in the range of 2.03 to 5.00 mg/100g DW with a mean of 3.26. The results from Z-distribution showed the range for high leaf high seed Zn types (HLHS) from 3.53 to 5.00 mg/100g DW for seed Zn with a mean of 4.18 and 6.52 to 9.68 mg/100g DW with a mean 7.75 for leaf Zn (Table 1). In the genotypes which contain high leaf low seed Zn types (HLLS), range was 2.08 to 3.05 with a mean value of 2.48 for seed zinc and a mean value of 7.00 was observed for leaf Zn with a range of 6.77 to 8.81. It was 2.28 to 4.34 and 4.34 to 6.65 for low leaf high seed Zn (LLHS) types with a mean of 3.72 and 5.89, respectively, for seed and leaf Zn. In genotypes containing low leaf low seed Zn types (LLLS), the mean value was 2.67 for seed Zn and 4.95 for leaf Zn and their range was 2.03 to 3.33 and 4.05 to 5.03, respectively for seed and leaf Zn (Table 1).

In the selected contrasting 22 genotypes, range for leaf Zn (mg/100g DW) was from 5.3 to 10.65 with a mean of 7.74 and for seeds, Zn content was in a range between 2.0 and 3.17 with a mean of 2.58 (Table 2).

The genotypes were grouped as four categories as in previous experiment. The range for HLHS group was from 8.33 to 9.51 with a mean of 8.90 and 2.83 to 3.17 with a mean of 2.99, respectively for leaf and seed Zn. It was from 8.92 to 10.65 and 2.05 to 2.16 with a mean of 9.66 and 2.16 for leaf and seed Zn of HLLS groups, respectively. The range for LLHS group was from 5.29 to 7.34 and 2.0 to 2.36 with a mean of 6.55 and 2.23 for leaf and seed Zn, respectively. The last group, LLHS showed the range of 5.42 to 6.31 with a mean 5.85 for leaf Zn content and it was from 2.84-3.17 with a mean of 2.96 for seed Zn content (Table 2).

Since for many physiological traits like Zn uptake and transport, the G x E interaction is very high, the consistency of genotypes for leaf and seed Zn content across the years was analyzed. The relationship between the years 2005 and 2006 showed high correlation. This indicates selected genotypes showed the consistency with respect to leaf and seed Zn in both the years (Fig.1).

The relationship between growth parameters in these selected genotypes, leaf area and total dry matter showed positive relationship (Fig.2a), indicating that leaf area has contributed for increase in TDM, whereas net assimilation did not contribute to the extent for the observed variability in TDM (Fig. 2b). Total dry matter was positively corelate to harvest index (Fig. 2d) and to grain yield (Fig. 2e).

A positive relationship was observed between total leaf Zn and TDM. Some of the genotypes showed more TDM with higher total leaf Zn/plant (Fig. 3c). However, leaf Zn (mg/100g) did not show association with TDM (Fig. 3 a). Total seed Zn increased the seed yield significantly but not the seed Zn/ unit weight of seed (Fig. 3e and f).

The contrasting genotypes representing high and low Zn types were selected to study the duration of Zn transport to grain during grain filling stage. In an initial experiment in

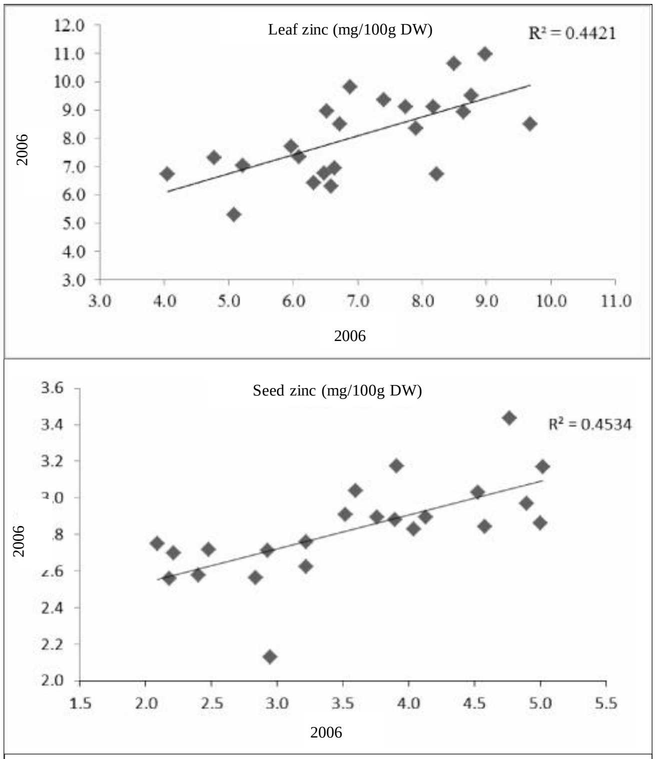


Fig. 1: Comparison between leaf and seed Zn content of the years 2005 and 2006

Table 1: Mean and range values of leaf and seed Zn content for contrasting genotypes

Groups	Leaf Zn			Seed Zn		
	Range	Mean	S.D.	Range	Mean	S.D.
High leaf high seed Zn	6.52-9.68	7.75	0.86	3.53-5.00	4.18	0.48
High leaf low seed Zn	6.77-8.81	7.00	0.66	2.08-3.05	2.48	0.30
Low leaf high seed Zn	4.34-6.65	5.89	0.58	2.28-4.34	3.72	0.54
Low leaf low seed Zn	4.05-5.03	4.95	0.68	2.03-3.33	2.67	0.36
Mean		6.40				3.26

Table 2: Range and mean of leaf and seed Zn content for four groups of 22 genotypes

Category	Leaf Zn (mg/100gDW)			Seed Zn (mg/100gDW)		
	Range	Mean	S.D.	Range	Mean	S.D.
High leaf high seed Zn	8.33-9.51	8.90	0.60	2.83-3.17	2.99	0.202
High leaf low seed Zn	8.92-10.65	9.66	0.75	2.05-2.16	2.16	0.28
Low leaf high seed Zn	5.29-7.34	6.55	0.70	2.0-2.36	2.23	0.11
Low leaf low seed Zn	5.42-6.31	5.85	0.50	2.84-3.17	2.96	0.136
Mean		7.74				2.58

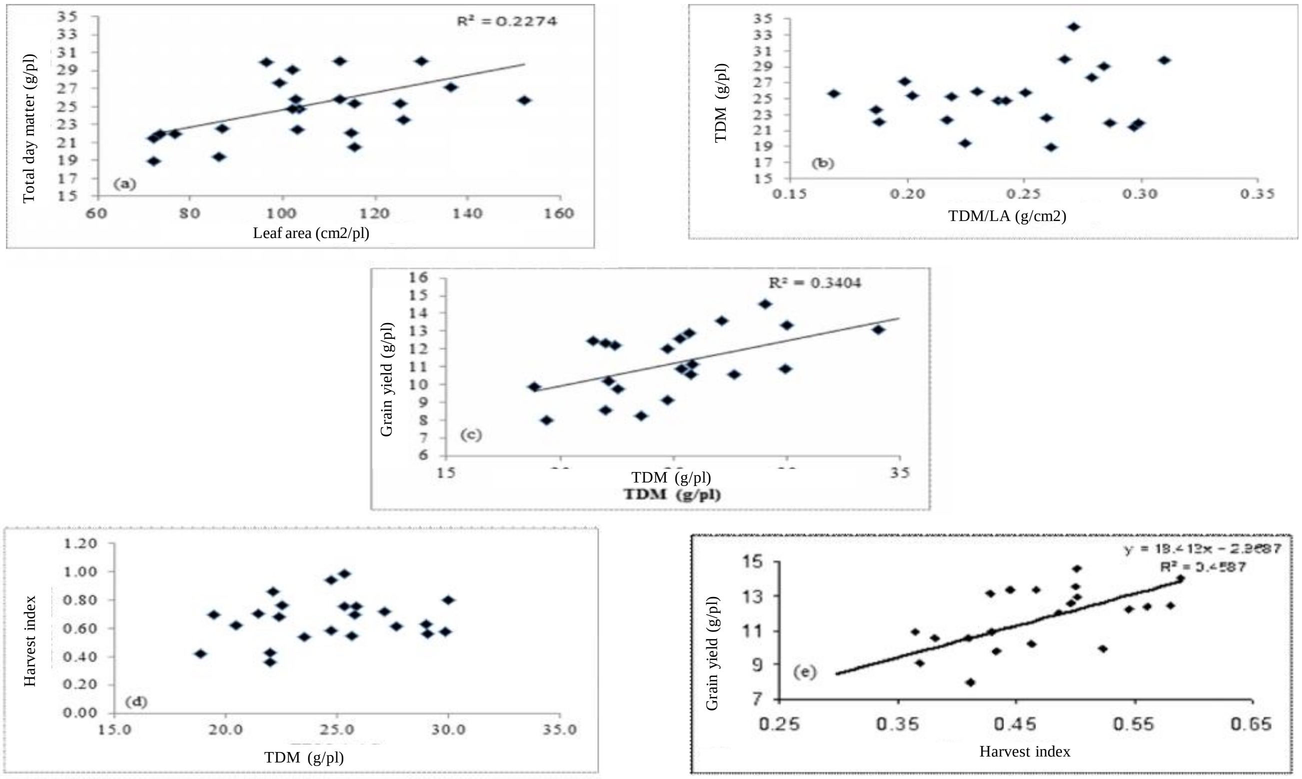


Fig. 2 : Relationship between growth parameters in selected 22 genotypes

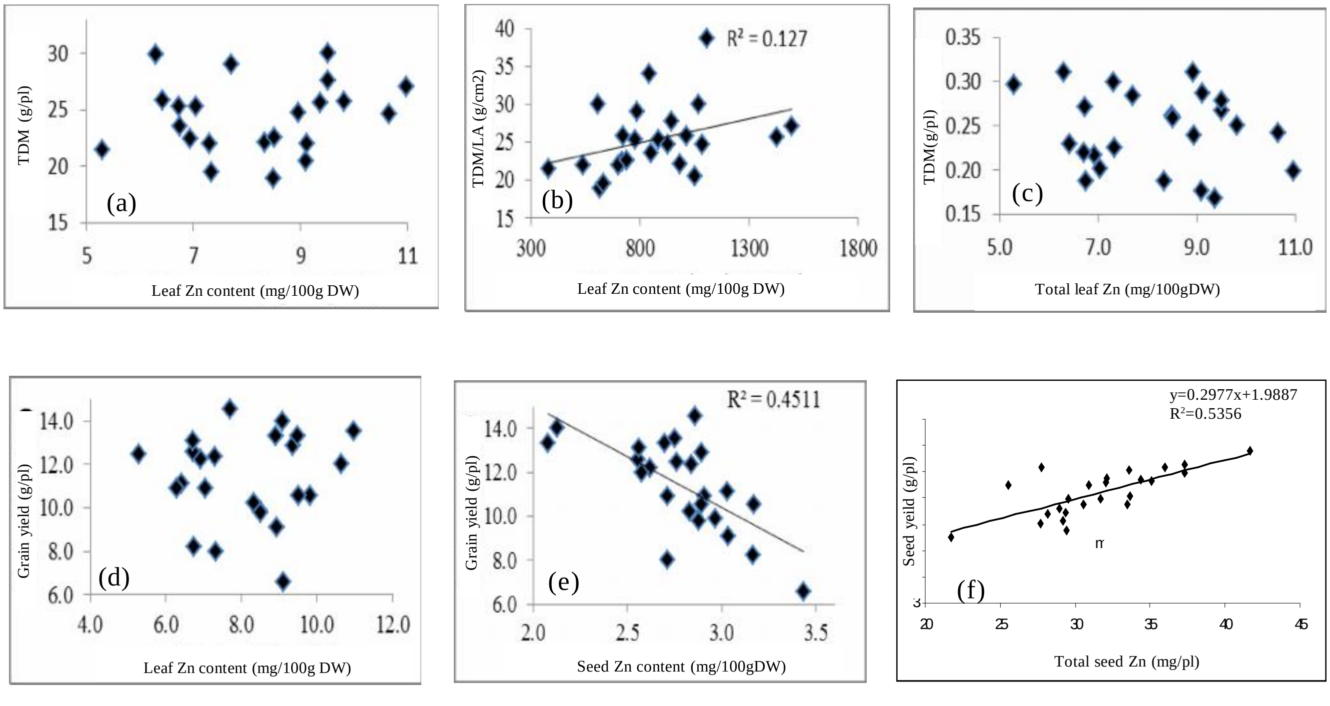


Fig. 3 : Relation between leaf and seed Zn levels and yield parameters in 22 genotypes

one of the genotypes IR 30864, the mean panicle Zn levels were determined at different intervals (Fig. 4). It was interesting to observe that Zn level increased at milky stage but there was a substantial decline during grain filling stage. The reason for observed decline after milky stage is that quantity of Zn transported in relation to other constituents was less. With the existing data it is difficult to arrive at differential contribution of seed Zn from direct transport and remobilization from shoot reserves.

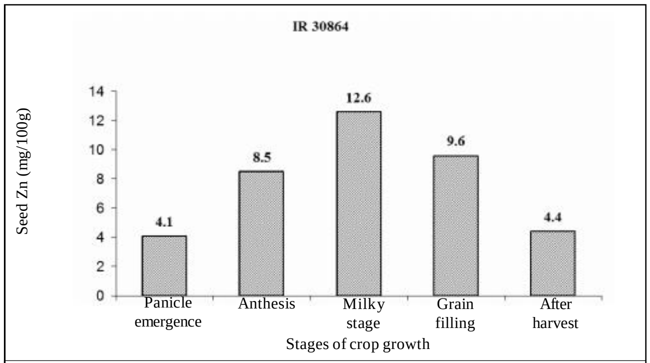
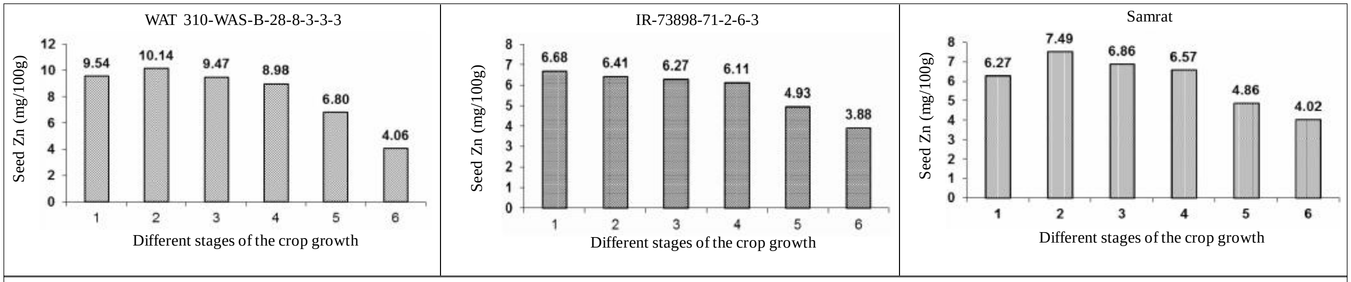

IR 30864

Fig. 4 : Seed Zn (mg/100g) in IR 30864 at different stages of crop period from anthesis to harvest

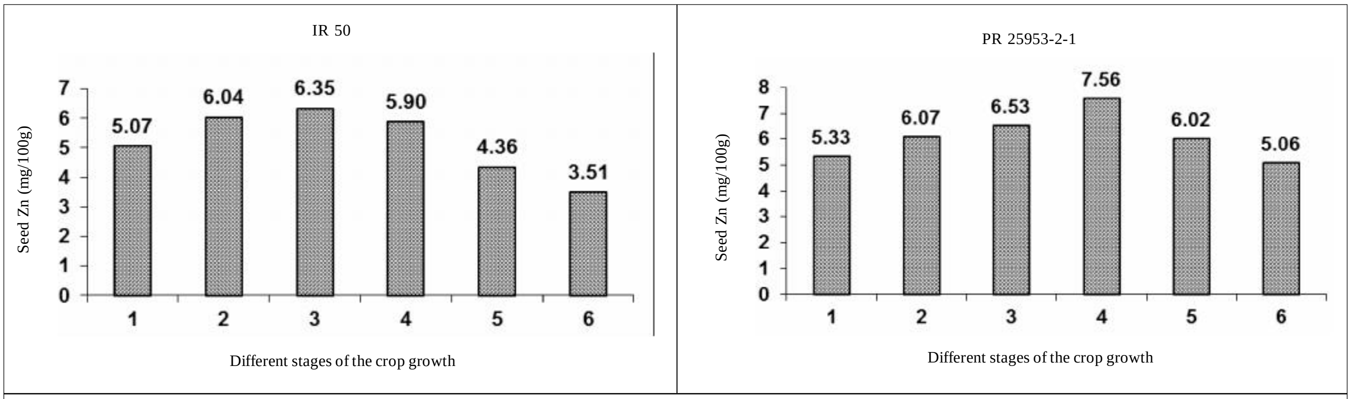
We examined the seed Zn levels at different stages from anthesis in three contrasting groups, HLHS, LLHS and LLLS. In general, in all genotypes there is a decline in panicle (seed) Zn levels during later stages of grain filling period. However, high Zn types maintained constant Zn levels up to 4th stage and subsequently a decline (Fig. 5). Seed Zn content in these high Zn types was relatively high even at 6th stage *i.e.*, during maturity period. Such a trend was also seen in low leaf high seed (LLHS) group (Fig. 6). However, in the low seed Zn


WAT 310-WAS-B-28-8-3-3-3

IR-73898-71-2-6-3

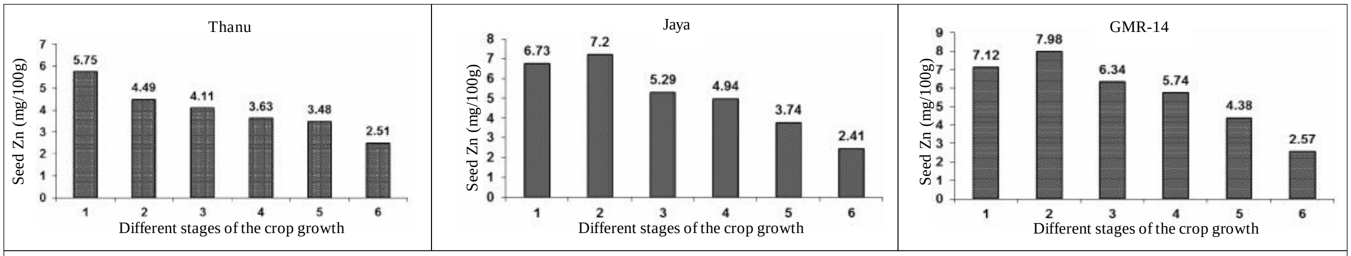
Samrat

Fig. 5: Seed Zn content (mg/100g) in high leaf high seed Zn types at weekly intervals of crop growth period from anthesis to harvest


IR 50

PR 25953-2-1

Fig. 6 : Seed Zn content (mg/100g) in low leaf high seed Zn types at weekly intervals of crop growth period from anthesis to harvest


Thanu

Jaya

GMR-14

Fig. 7: Seen Zn content (mg/100g) in low Zn types at weekly intervals of crop growth period from anthesis to harvest

types there was a steady decline in seed Zn content from the first or second stage itself. Besides, as expected at harvest, seed Zn level was also low in these genotypes (Fig. 7). In one of the genotypes, PR 25953-2-1, a LLHS types, the initial Zn level was low and it maintained high Zn content till 4th stage. In genotypes like WAT 310-WAS-B-28-8-3-3, IR 73898-71-2-6-3 and Samrat, longer duration of Zn transport may be one of the reasons for high Zn levels in these genotypes.

These results clearly indicate that in high Zn types both the rate of transport and also the duration of Zn transport to seed during grain filling stage was longer. It is likely that in low Zn types the transport of Zn is a constraint at later stages or the other possibility is remobilization of Zn to seed could be less in this genotype, since these are intrinsically low Zn acquiring genotypes it is likely that the rate of transport is also less.

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