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FORTIFICATION OF GRAIN ZINC CONTENT IN RICE GENOTYPES THROUGH ZINC APPLICATION

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ABSTRACT

To investigate the effect of zinc application on grain physico chemical characters, the investigation entitled "Effect of Zn Application on Physiological Efficiency, Partitioning and Grain Zinc Fortification in Rice cultivars (*Oryza sativa* L.)" was conducted in consecutive years during *kharif* 2013 and 2014 at RC puram farm, (International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hyderabad, Telangana. The experiment was laidout in factorial RBD and replicated thrice with major treatments as four genotypes (Improved Chittimuthyalu (V1), VRB-MS (V2), RP-Bio-226 (V3) and IR-64 (V4)) and sub treatments as six zinc treatments viz. Control (T1), Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal (T2), Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage (T3), Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at grain filling stage (T4), Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage+ 0.2% $ZnSO_4$ spray at grain filling stage (T5) and 0.2% $ZnSO_4$ spray at panicle initiation stage+ 0.2% $ZnSO_4$ spray at grain filling stage (T6). The genotype VRB-MS (V2) recorded significantly highest zinc content in brown rice (39.25 ppm, 38.50 ppm) and polished rice (30.67 ppm, 29.60 ppm) followed by RP-Bio-226 (V3) while the lowest values for brown rice and polished rice were recorded with IR-64 (V4) (29.83 ppm, 2.12 ppm) and (19.40, 18.30 ppm). Among the treatmental effects basal application of $ZnSO_4$ @ 25 Kg ha^{-1} + 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T5) recorded highest zinc content in brown rice (37.73 ppm, 37.13 ppm) and polished rice (30.68 ppm, 29.13 ppm) followed by (T6) in both the years.

KEYWORDS: Farmer producer companies, Market readiness, Value chain, Marketing channel.

INTRODUCTION

Zinc is the twenty fourth most abundant element on earth's crust with a content of 75 mg kg^{-1}. Soil contains 5-770 mg Zn kg^{-1} with an average of 64 mg kg^{-1}, sea water has 30 µg Zn L^{-1}, and the atmosphere contains 0.1 - 4 µg Zn m^{-3}. However, zinc (Zn) is typically the second most abundant transition metal in organisms after iron and the only metal represented in all six enzyme classes (oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases). Zinc is an essential micronutrient for humans, animals and plants. Higher plants generally absorb Zn as a divalent cation (Zn^{2+}), which acts either as the metal component of enzymes or as a functional structural or a regulatory co-factor of a large number of enzymes.

However, zinc deficiency is one of the most common micronutrient deficiencies in human populations affecting health of over three billion people worldwide (Welch and Graham, 2004). According to a report published by the World Health Organization in 2002, deficiency of Zn rank fifth in terms of leading causes of diseases in developing high-mortality countries. Zinc deficiency causes impairments in brain development and wound healing and increases susceptibility to infectious diseases including diarrhea, pneumonia and malaria by weakening the immune system.

In most cases, the reason behind Zn deficiency is inadequate dietary intake of Zn (Welch and Graham, 2004). In our country, cereal crops are the main component of the diet and responsible for more than 50 per cent of the daily caloric intake (Cakmak, 2008). However, these crops are inherently too poor in Zn to meet the recommended dietary allowances for human beings and also rich in compounds reducing the bioavailability of Zn, such as phytic acid.

According to a Zn-staining study in wheat seed, Zn concentrations were found to be around 150 mg kg^{-1} in the embryo and aleurone layer and only 15 mg kg^{-1} in the endosperm. The Zn-rich parts of wheat seed are removed during milling, thus resulting in a marked reduction in

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flour Zn concentrations. Consequently, heavy consumption of high proportion of milled wheat and other cereal products may result in reduced intake of Zn.

Processing of food grains also affects Zn concentration. For example, although unhulled rice (paddy) contains 27 – 42 mg kg^{-1} Zn, polished rice contains only 13 mg kg^{-1} Zn. High consumption of cereal based foods with low contents of micronutrients is causing health hazards in humans. The contents of micronutrients in food can be elevated either by supplementation, fortification or by agricultural strategies i.e., biofortification and application of micronutrients containing fertilizers.

MATERIAL AND METHODS

The present investigation was conducted in two consecutive years during *kharif* 2013 and 2014 at RC puram farm, (International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hyderabad, Telangana. The experiment was laidout in factorial RBD and replicated thrice with major treatments as four genotypes (Improved Chittimuthyalu (V1), VRB-MS(V2), RP-Bio-226(V3) and IR-64 (V4)) and sub treatments as six zinc treatments viz. Control (T1), Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal (T2), Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage (T3), Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at grain filling stage (T4), Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage+ 0.2% $ZnSO_4$ spray at grain filling stage (T5) and 0.2% $ZnSO_4$ spray at panicle initiation stage + 0.2% $ZnSO_4$ spray at grain filling stage (T6). Grain physico and chemical characters were assesed as per the procedure given below.

Zinc content in grains was identified by X-Ray Fluorescence Spectrometry. Five grams of weighed grain sample was taken into pre-identified aluminium cup having properly loaded with disposable inner and XRF film arranged in sample tray. The tray along with the aluminium cups were tapped by holding the ends of tray with both hands in order to spread the grain uniformly in all the aluminium cups and placed in each aluminium cup into a sample sleeve of XRF machine without disturbing the grain starting from 1 to 10. After turning on the X-ray lamp the names of each sample were entered using the keyboard and suitable method was selected for analysis. At the end of analysis time, Zinc values appear in a new window on the screen as mg kg^{-1} were note down.

The experimental data were analyzed statistically by following standard procedure outlined by Panse and Sukhatme (1985). Significance was tested by comparing "F" value at 5 per cent level of probability.

RESULTS AND DISCUSSION

The results pertaining to zinc content in brown and polished rice are presented in tables and discussed as below.

Grain Zinc Content in Brown Rice (ppm)

The data on effect of soil and foliar application of zinc on zinc content before polish in rice genotypes was recorded during *kharif* 2013 and 2014 are presented in the Table 1.

Interpretation of statistical data on tested varieties with effect of zinc application reported that during *kharif* 2013 and *kharif* 2014, the genotype VRB-MS (V2) recorded significantly highest zinc content in brown rice (39.25 ppm, 38.50 ppm) compared to Improved chittimutyalu (V1) (35.85 ppm, 35.30 ppm) and RP-BIO-226 (V3) (32.80 ppm, 31.70 ppm) while the lowest values were recorded with IR-64 (V4) (29.83 ppm, 2.12 ppm). Such significant varietal differences for zinc content before polish in response to zinc application.

Among the treatmental effects the data revealed that during *kharif* 2013 and *kharif* 2014 basal application of $ZnSO_4$ @ 25 Kg ha^{-1} + 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T5) recorded better zinc content (37.73 ppm, 37.13 ppm) followed by 0.2% $ZnSO_4$ foliar spray at panicle initiation stage and grain filling stage (T6) (36.25 ppm, 35.63 ppm) and $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage (T4) (35.98 ppm, 34.73 ppm). During both the years lowest values for zinc content in brown rice were recorded with (T1) *i.e.,* control (30.18 ppm, 29.28 ppm). The increase in the Zn uptake in the grain with zinc application indicates that Zn is having role in the synthesis of starch which is the main constituent in rice grain. Similar increase in the uptake of Zn by grain due to Zn application was also reported by Metwally (2011), Stalin *et al*. (2011).

Data on interaction effects of varieties and treatments revealed that during *kharif* 2013 higher values for zinc content before polish were recorded with V_2T_5 *i.e.,* Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$

Table 1. Effect of zinc application on grains in rice genotypes during *kharif* 2013 and 2014

Treatments	2013		2014	
	Zinc before polish	Zinc after polish	Zinc before polish	Zinc after polish
Varietal effects (V)				
V1	35.85	27.93	35.30	26.93
V2	39.25	30.67	38.50	29.60
V3	32.80	24.55	31.70	23.60
V4	29.83	19.40	29.12	18.30
SE(m)	0.17	0.13	0.17	0.12
CD	0.49	0.36	0.48	0.35
Treatmental effects (T)				
T1	30.18	19.38	29.28	18.08
T2	32.63	23.63	31.85	22.88
T3	33.85	25.13	33.33	24.25
T4	35.98	27.13	34.73	26.15
T5	37.73	30.68	37.13	29.13
T6	36.25	27.90	35.63	27.18
SE(m)	0.21	0.15	0.20	0.15
CD	0.60	0.44	0.58	0.42
Interaction effects (V × T)				
V1T1	30.50	21.60	29.40	20.20
V1T2	33.10	25.10	32.10	24.60
V1T3	35.10	27.20	35.00	26.50
V1T4	37.90	29.80	37.50	29.20
V1T5	40.40	33.70	39.90	31.30
V1T6	38.10	30.20	37.90	29.80
V2T1	34.60	23.80	34.10	22.40
V2T2	37.70	29.30	37.10	28.70
V2T3	38.30	30.50	37.80	29.40
V2T4	40.70	32.90	39.40	31.30
V2T5	42.60	35.20	42.10	34.70
V2T6	41.60	32.30	40.50	31.10
V3T1	28.90	17.30	27.50	16.50
V3T2	31.40	22.40	30.40	21.80
V3T3	32.40	24.60	31.40	23.70
V3T4	34.90	26.50	32.60	25.20
V3T5	35.70	29.50	35.10	28.10
V3T6	33.50	27.00	33.20	26.30
V4T1	26.70	14.80	26.10	13.20
V4T2	28.30	17.70	27.80	16.40
V4T3	29.60	18.20	29.10	17.40
V4T4	30.40	19.30	29.40	18.90
V4T5	32.20	24.30	31.40	22.40
V4T6	31.80	22.10	30.90	21.50
SE(m)	0.42	0.31	0.41	0.30
CD	1.19	0.88	1.17	0.85

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spray at panicle initiation stage and grain filling stage (T5) on VRB-MS (V2) genotype (42.60 ppm) respectively, followed by V2T6 *i.e.,* 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T6) on same genotype (41.60 ppm) and V2T4 *i.e.,* soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at grain filling stage(T4) on VRB-MS (V2) genotype (40.70 ppm). However, during *Kharif* 2014 higher values for zinc content before polish were recorded with V_2T_5 *i.e.,* Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T5) on VRB-MS (V2) genotype (42.10 ppm) respectively, followed by V2T6 *i.e.,* 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T6) on same genotype (40.50 ppm) and V_1T_5 *i.e.,* Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T5) on Improved chittimutyalu (V1) genotype (39.90 ppm). During both the years lower zinc values in brown rice were recorded with V4T1 (26.70 ppm, 26.10 ppm).

In both years V × T interaction effects revealed that V_2T_5 has recorded higher zinc content before polish followed by V_2T_6, V_2T_4 and V_3T_5. While the lowest zinc content in brown rice was recorded with V4T1. The increase in Zn content might be due to its increased absorption from soil application and foliar spray of zinc and rapid translocation to grain besides arresting the fixation losses. These results are in conformity with findings of Stalin *et al.* (2011).

Grain zinc content in polished rice (ppm)

Zinc content in grains after polish in rice genotypes as influenced by soil and foliar application of zinc was recorded during *kharif* 2013 and 2014 are presented in the Table.1.

The data on tested varieties with effect of zinc application reported that during *kharif* 2013 and during *kharif* 2014, VRB-MS (V2) recorded significantly highest zinc content in polished rice (30.67 ppm, 29.60 ppm) compared to Improved chittimutyalu (V1) (27.93 ppm, 26.93 ppm) and RP-BIO-226 (V3) (24.55 ppm, 23.60 ppm) while the lowest values were recorded with IR-64(V4) (19.40 ppm, 18.30 ppm). Such significant varietal differences for zinc content after polish in response to zinc application were also reported by Praneeth, 2013.

Among the treatmental effects the data revealed that during *kharif* 2013 and *kharif* 2014 basal application of $ZnSO_4$ @ 25 Kg ha^{-1} as + 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T5) recorded highest zinc content in polished rice (30.68 ppm, 29.13 ppm) followed by 0.2% $ZnSO_4$ foliar spray at panicle initiation stage and grain filling stage (T6) (27.90 ppm, 27.18 ppm) and $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage (T4) (27.13 ppm, 26.15 ppm). During both the years lowest values for zinc content in polished rice were recorded with (T1) *i.e.,* control (19.38 ppm, 18.08 ppm). The grain Zn was significantly increased with Zn application (soil+ foliar) over no Zn application. The present results might be due to translocation of Zn from leaf to the grain and are in agreement with the results reported by Ram *et al.* (2011).

Interaction effects of varieties and treatments revealed that during *Kharif* 2013 and 2014 higher values for protein content were recorded with V_2T_5 *i.e.,* Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T5) on VRB-MS (V2) genotype (35.20 ppm, 34.70 ppm) respectively, followed by V_1T_5 *i.e.,* Soil application of $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T5) on Improved chittimutyalu (V1) genotype (33.70 ppm, 31.30 ppm) and V_2T_4 *i.e.,* $ZnSO_4$ @ 25 Kg ha^{-1} as basal + 0.2% $ZnSO_4$ spray at panicle initiation stage (T4) on VRB-MS (V2) (32.90 ppm, 31.30 ppm).

In both years V × T interaction effects revealed that V_2T_5 has recorded higher zinc content values in polished rice followed by V_1T_5 and V_2T_4. While the lowest values for zinc content in polished rice were recorded with V4T1.

The increased zinc content in whole grain might be due to direct application of zinc at critical growth stages, which might have helped in increased absorption in the grain during ripening and also due to its direct absorption in plant tissue resulted in increased grain content of zinc. Similar findings were also reported by Khan et al. (2003); Stalin *et al.* (2011).

Based on results of present study it was concluded that VRB-MS (V2) and RP-BIO-226 (V3) genotypes has responded better to the zinc applications, while basal application of $ZnSO_4$ @ 25 Kg ha^{-1} as + 0.2% $ZnSO_4$ spray at panicle initiation stage and grain filling stage (T5) and 0.2% $ZnSO_4$ foliar spray at panicle initiation stage and grain filling stage (T6) proved effective in enhancing the grain zinc in achieving fortification of zinc.

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