Differential response of rice plants to foliar application of iron and phosphate is regulated by antioxidant scavenging system

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INTRODUCTION

Phosphorus and iron are indispensable for plant growth and development. Phosphorus is the major structural component of plasma membrane and nucleotides apart from its role in energy transfer reactions. Fe forms an integral part of cytochrome and electron transport chain and also acts as co-factor of many enzymes. Since these nutrients are less bio-available in soil, foliar application is one of the best alternatives for their supplementation. Rapid availability of nutrients through foliar fertilization helps plant in fast recovery from deficient conditions with smaller amount of fertilizer (Fageria et al. 2009). Even though foliar application of nutrients prevail over the absorption through root, plant response depends upon various factor such as, form of nutrient, right concentration, timing of foliar application and correct stage of crop growth (Fernández V and Brown 2013). Experiments were conducted to understand the response of rice plants to foliar application of different Fe and P compounds.

MATERIALS AND METHODS

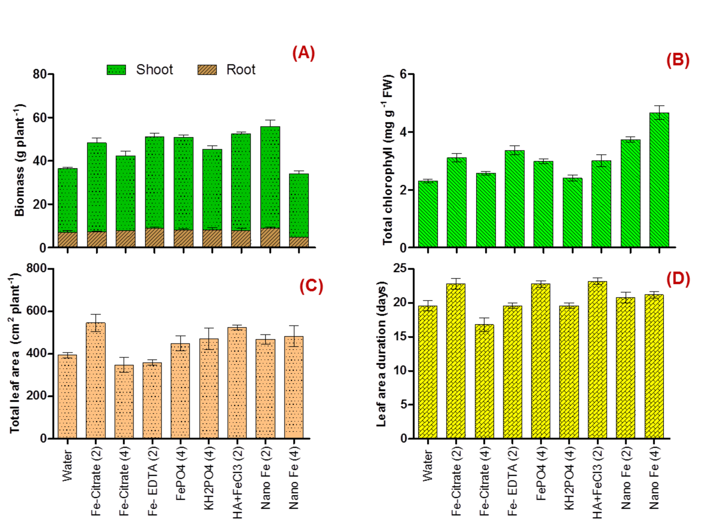
Rice seedlings 15 days after transplanting

Rice plants at maximum tillering stage

Rice plants at anthesis stage

The rice (*Oryza sativa* cv. MAS-946-1) was grown in pots under natural condition with recommended dose of NPK. Application of various compounds of Fe and P (Ferric citrate, 2 and 4 mM; Ferric EDTA, 2 mM; Ferric phosphate, 4 mM; monopotasium phosphate, 4 mM; humic acid,25 mg+ferric chloride, 2 mM; nano Fe, 2 and 4 mM) were carried out as foliar spray including double distilled water as control. Foliar application was done at anthesis stage and observations were recorded on sixth day after the foliar treatment. Antioxidant enzymes (superoxide dismutase, catalase and peroxidase) and extent of lipid peroxidation (TBARS) were analysed to understand the physiological basis of differential plant response to foliar application of nutrients. At maturity, the yield traits were recorded including number of panicles per plant, grains per panicle, percentage of filled grains, test weight and total grain yield.

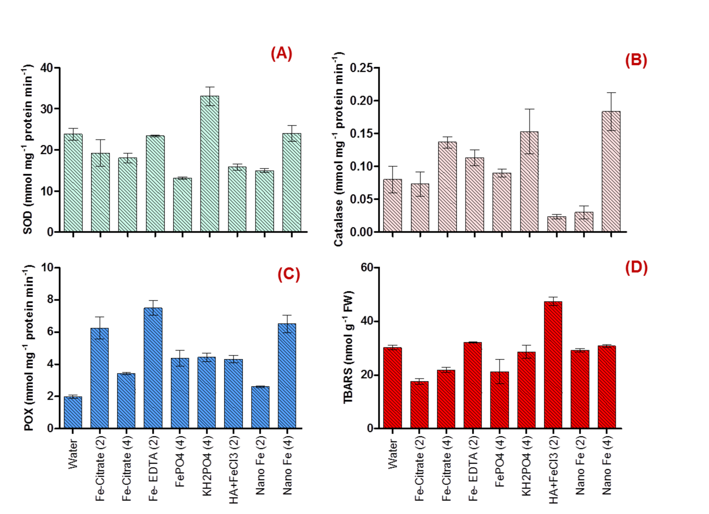
RESULTS



Results showed that highest biomass was recorded in nano-Fe (2 mM) while at higher concentration (4 mM), it reduced the biomass accumulation as compared to control (Fig 1A). There was no significant difference in biomass accumulation among Fe-citrate (2 mM), Fe-EDTA and Ferric phosphate.

The total chlorophyll concentration in leaf (Fig 1B) was highest in nano-Fe (4 mM) followed by Fe-EDTA and Fe-citrate (2 mM).

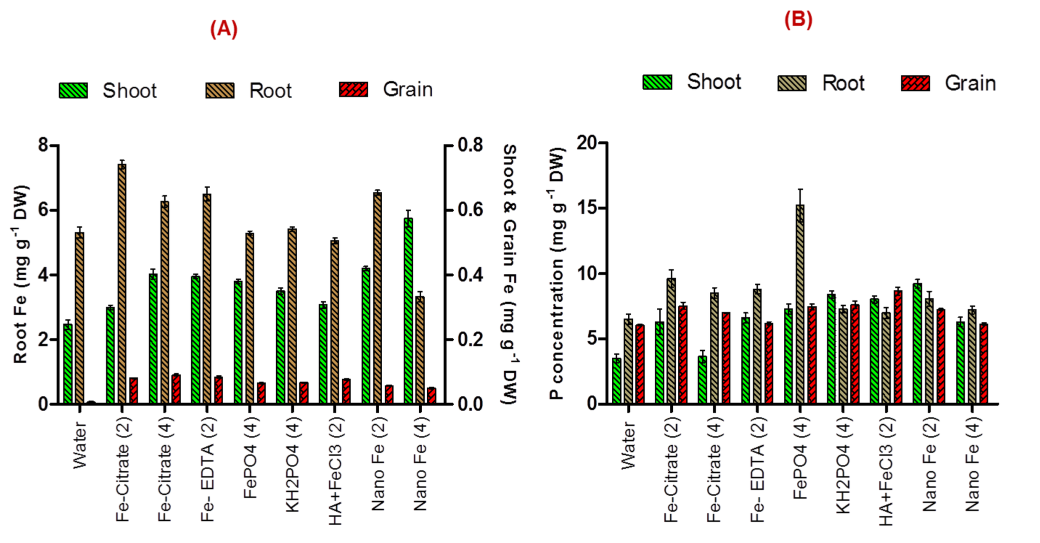
Total leaf area was maximum in Fe-citrate at low (2 mM) concentration while at higher concentration, leaf area was significantly reduced (Fig. 1C). Fe-EDTA also showed similar reduction in leaf area.



Photosynthetically active area of flag leaf was recorded and expressed as leaf area duration (LAD). The number of days was counted till the green area of flag leaf was reduced to 50%. Foliar treatments of Fe-citrate (2 mM), Fe-phosphate and HA+$FeCl_3$ significantly increased the LAD as compared to control while Fe-citrate at higher concentration (4 mM) reduced it (Fig. 1D).

The SOD activity was significantly higher in plants sprayed with potassium phosphate with a corresponding increase in both catalase and peroxidase activity resulting in lower lipid peroxidation as compared to control (Fig. 2A-D).

In plants treated with HA+$FeCl_3$, the SOD and catalase activity were less with highest TBARS contents indicating that the plants were under oxidative stress. However, in plants treated with Fe-citrate (2 mM) and Fe-phosphate exhibited significantly lower SOD activity compared to control but higher peroxidase activity resulting in lower TBARS content as compared to control. Similarly, Nano-Fe at lower concentration (2 mM) showed less SOD activity while at higher concentration (4 mM) subjected the plants to oxidative stress which was efficiently scavenged by catalase and peroxidase resulting in less lipid peroxidation.



In general, the concentration of Fe was highest in root tissue and lowest in grains (Fig 3A). Compared among foliar treatments, Fe-citrate (2 mM) showed highest Fe concentration in root while nano-Fe (2 mM) and Fe-citrate (4 mM) exhibited maximum Fe concentration in shoot tissues. However, Fe-citrate and Fe-EDTA application resulted in maximum Fe partitioning towards grains as compared to other foliar treatments.

Treatment	No. of panicle per plant	No. of grains/ panicle	Total grain yield (g/plant)	% filled spikelet	1000 grain wt. (g)
Control	17	150	17.1	77.7	20.5
Fe-Citrate (2)	20	162	24.8	90.6	23.6
Fe-Citrate (4)	19	178	20.2	86.8	21.2
Fe- EDTA (2)	18	163	19.2	82.4	20.5
$FePO_4$(4)	19	181	22.6	82.1	21.7
KH_2PO_4 (4)	19	167	22.0	88.1	21.0
HA+ $FeCl_3$ (2)	19	175	28.9	88.2	21.4
Nano Fe (2)	16	172	24.0	71.9	20.9
Nano Fe (4)	20	163	22.1	89.4	22.1
CD (5%)	2.0	27.0	2.57	10.0	1.00
CD (1%)	3.0	35.0	3.43	13.8	1.34

On an average the root tissue P concentration was higher in plants (Fig. 3B). The ideal P concentration in different tissues is exhibited by Fe-EDTA, Fe-citrate (2 mM) and Fe-phosphate. Higher partitioning of P towards grains is not desirable while it should be highest in root followed by leaf tissues.

The yield attributing traits such as number of panicles per plant, number of grains per panicle, % filled spikelets per panicle, grain yield per plant and test-weight were significantly influenced by foliar treatments (Table 1). Among treatments, Fe-citrate (2 mM) exhibited highest number of panicles per plant, % filled spikelets and test-weight resulting in maximum grain yield.

CONCLUSIONS

- The foliar application of Fe-citrate (2 mM) showed increased leaf area, biomass, grain yield and partitioning of Fe towards the grain. This study also illustrated that an optimal concentration of compound is required for better growth and development while higher concentrations subject plants to oxidative stress.
- SOD activity was negatively associated with yield traits such as number of panicles per plant and % filled grain while catalase and peroxidase were positively correlated. Though the correlation was not significant but SOD influenced negatively more than 50% the number of panicles per plant (R = -0.640) and % filled grain (R = -0.536) while peroxidase showed positive influence on these traits as R = 0.602 and R = 0.571, respectively.
- The LAD also showed positive association with total grain yield (R = 0.680) and test-weight (R = 0.553).

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