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Effect of Fertilizer Management Practices on Grain Yields, Concentrations of Micronutrient Cations and Phytic Acid in Rice and Wheat Grains under a Long Term Fertility Trial

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ABSTRACT

The effects of fertilizer management practices on rice and wheat grain yields, concentrations of micronutrient cations and phytic acid were evaluated in a long term were analyzed. The highest grain yield of rice was recorded under treatment T9 (N₁₂₀P₄₀K₄₀+Znf+FYM) while that of wheat under treatment T₁₁ (N₁₈₀P₈₀K₄₀+Znf +FYM). Application of T6 (N₁₂₀P₆₀K₄₀), T7 (N₁₂₀P₄₀K₄₀+Znf), T8 (N₁₂₀P₄₀K₄₀+FYM@5 t/ha), T9 (N₁₂₀P₄₀K₄₀+Znf+FYM @5 t/ha), T10 (N₁₈₀P₈₀+Znf) and T13 (N₁₈₀P₈₀K₄₀+Znf) significantly increased in Zn content of dehusked rice grains by 34.8, 57.2, 38.4, 49.0, 44.0 and 60.1 percent over the control, respectively. Application of T5 (N₁₂₀K₄₀), T7 (N₁₂₀P₄₀K₄₀+Znf), T10 (N₁₈₀P₈₀+Znf) and T13 (N₁₈₀P₈₀K₄₀+Znf) increased in Fe content of dehusked rice grains significantly by 114.6, 89.9, 135.1 and 65.9 percent over the control, respectively. In wheat crop, application of T2 (N₁₂₀), T3 (N₁₂₀P₄₀), T5 (N₁₂₀K₄₀), T6 (N₁₂₀P₆₀K₄₀), T10 (N₁₈₀P₈₀+Znf), T11 (N₁₈₀P₈₀K₄₀+Znf+FYM), T12 (N₁₅₀P₄₀K₄₀) and T13 (N₁₈₀P₈₀K₄₀+Znf) increased in Zn content of wheat grains significantly by 30.3, 19.1, 20.5, 29.5, 35.1, 18.3, 28.7 and 40.3 percent over the control, respectively. Application of T9 (N₁₂₀P₄₀K₄₀+Znf+FYM @5 t/ha) and T13 (N₁₈₀P₈₀K₄₀+Znf) increased the content of phytic acid in the dehusked rice grains by 10.0 and 2.0 percent over the control, respectively while application of T3 (N₁₂₀P₄₀) decreased phytic acid by 12.2 percent in comparison to control. In wheat crop, application of T8 (N₁₂₀P₄₀K₄₀+FYM) and T12 (N₁₅₀P₄₀K₄₀) increased the content of phytic acid in the wheat grains by 1.9 and 2.5 percent, respectively and application of T2 (N₁₂₀) and T6 (N₁₂₀P₆₀K₄₀) decreased the content of phytic acid by 4.4 and 2.7 percent, respectively in comparison to control.

Keywords

Fertilizer management, Micronutrient cations, Phytic acid, Rice and wheat

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Introduction

In Asian countries, the staple diet is mainly cereal based, the consumption of cereals raised on Zn deficient soils often leads to inadequate intake of Zn in young children and population. Low dietary Zn levels cause the growth impairment and poor immune functions finally exposing the population to diarrhoea and pneumonia (Volkmar and Bremer, 1998; Graham, 2008). Brain function and development in newborns has been linked to Zn deficiency (Benton, 2008). Zinc deficiency has been reported to account nearly 450,000 deaths in children below five years age (Black *et al.*, 2008; Cakmak, 2010). Fertilizer management practices are likely to influence the level of micronutrients cations in cereal grains. The bioavailability of micronutrient cations present in the diet is influenced by the level of anti-nutrient factors present in the diet.

Phytic acid (myo-inositol 1,2,3,4,5,6-hexakisphosphate) is a known anti-nutrient factor in the cereals because nearly 70% of total phosphorus in seeds is associated with phytic acid (Lott, 1984). Phytic acid strongly chelate micronutrients like Zn and Fe resulting in poor bioavailability of these minerals (Rhou and Erdman, 1995). In the present investigation, we attempted to study the effect of long-term fertilizer management practices under a long-term fertilizer management experiment of Department of Agronomy which was set-up in the year 1978 on the concentrations of micronutrient cations and also that of phytic acid in rice and wheat which form staple food for the majority of Indian population.

Materials and Methods

The initial soil properties of the experimental plot classified under the soil order Mollisol were, silt loam texture, 8.0 pH, 0.12 dSm⁻¹

E.C., 21.0g organic C kg⁻¹ soil, 0.1% total N, 20.0 kg Olsen's P ha⁻¹, 222 kg ammonium acetate extractable K ha⁻¹ and 0.80 mg DTPA extractable Zn kg⁻¹ soil. Considering 1.24 mg DTPA extractable Zn kg⁻¹ soil as the critical limit of Zn in mollisols for rice crop, the experimental soil was deficient in Zn (Srivastava and Gangwar, 1990). The details of treatments imposed in quadruplicate under randomized block design were: T1 Control; T2 N₁₂₀; T3 N₁₂₀P₄₀; T4 P₄₀K₄₀; T5 N₁₂₀K₄₀; T6 N₁₂₀P₆₀K₄₀; T7 N₁₂₀P₄₀K₄₀+Znf; T8 N₁₂₀P₄₀K₄₀+FYM@5 t/ha; T9 N₁₂₀P₄₀K₄₀+Znf+FYM@5 t/ha; T10 N₁₈₀P₈₀+Znf; T11 N₁₈₀P₈₀K₄₀ +Znf+FYM@5 t/ha; T12 N₁₅₀P₄₀K₄₀; T13 N₁₈₀P₈₀K₄₀+Znf; T14 N₁₂₀P₄₀K₄₀ (DAP). Among the treatments, P application as kg P₂O₅/ha was done through DAP in T14 while in other relevant treatments it was through SSP. The treatment (Znf) implied application of foliar spray of 0.5% ZnSO₄ solution neutralized by lime water. The gross plot size was 19.72 m² (5.8X3.4m) while the net plot size was 7.2 m² (4.0 m × 1.8 m). Rice (cv. PD 4) and wheat (cv. UP 2565) were raised following the standard agronomic practices. The crop yields were recorded and expressed in t ha⁻¹..

Rice (dehusked) and wheat grains were digested in di-acid mixture (HNO₃: HClO₄, 3:1 v/v) and analyzed for micronutrient cations using atomic absorption spectrophotometer (GBC AvantaM model). Phytic acid was estimated in grains using a method described by Harland and Oberleas (1977). The statistical analysis of data for all the parameters was carried out with analysis of variance.

The means were tested at $P > 0.05$ using the STPR software designed at the Department of Mathematics, Statistics and Computer Science, CBSH, G.B. Pant University of Agriculture and Technology, Pantnagar, India. The significant differences among the

treatments were calculated at 5% probability levels ($p \leq 0.05$) (Snedecor and Cochran, 1967).

Results and Discussion

Grain yields

Among the treatments, the highest grain yield of rice (6.29 t ha^{-1}) was recorded in the treatment T9 ($\text{N}_{120}\text{P}_{40}\text{K}_{40}+\text{Znf}+\text{FYM}$) (Fig. 1) and the highest grain yield of wheat (5.36 t ha^{-1}) was recorded in the treatment T₁₁ ($\text{N}_{180}\text{P}_{80}\text{K}_{40} + \text{Znf} + \text{FYM}$) (Fig. 2). This indicated that the lack of balanced application of nutrients and no use of FYM under rice-wheat rotation could threaten the sustainability of the cereal production. The response of Zn foliar spray in enhancing the grain yields of rice and wheat crops had been reported in Mollisols (Srivastava *et al.*, 2013).

Micronutrient cations and phytic acid in rice (dehusked) grains

Among the treatments, application of T6 ($\text{N}_{120}\text{P}_{60}\text{K}_{40}$), T7 ($\text{N}_{120}\text{P}_{40}\text{K}_{40}+\text{Znf}$), T8 ($\text{N}_{120}\text{P}_{40}\text{K}_{40}+\text{FYM}@5 \text{ t/ha}$), T9 ($\text{N}_{120}\text{P}_{40}\text{K}_{40}+\text{Znf}+\text{FYM} @5 \text{ t/ha}$), T10 ($\text{N}_{180}\text{P}_{80}+\text{Znf}$) and T13 ($\text{N}_{180}\text{P}_{80}\text{K}_{40}+\text{Znf}$) increased in Zn content of dehusked rice grains significantly by 34.8, 57.2, 38.4, 49.0, 44.0 and 60.1 percent over the control, respectively (Table 1).

Interestingly, a comparison of Zn content in dehusked rice grain raised under T14 ($\text{N}_{120}\text{P}_{60}\text{K}_{40}$, supplied through DAP) with that of control revealed that continuous use of DAP did not help in raising the content of Zn in dehusked rice grains. Gianquinto *et al.*, (2000) also reported that applications of large amounts of fertilizer P to soils that are low in available Zn can depress tissue Zn concentration or may even induce Zn deficiency. Application of T5 ($\text{N}_{120}\text{K}_{40}$), T7 ($\text{N}_{120}\text{P}_{40}\text{K}_{40}+\text{Znf}$), T10 ($\text{N}_{180}\text{P}_{80}+\text{Znf}$) and T13 ($\text{N}_{180}\text{P}_{80}\text{K}_{40}+\text{Znf}$) increased in Fe content of

dehusked rice grains significantly by 114.6, 89.9, 135.1 and 65.9 percent over the control, respectively. Compared to wheat the dehusked rice grain is as such poor source of Zn and Fe minerals for human beings and foliar application of Zn appeared to be an effective strategy to improve dietary intake of these minerals in Asian countries. Davidsson *et al.*, (1995) also demonstrated that iron fortification of foods was unlikely to affect zinc absorption.

They examined the effect of iron fortification of bread (65 mg/kg), weaning cereal (500 mg/kg) and infant formula (12 mg/L) in human adults with the use of stable isotopes and found no significant negative effect on zinc absorption was found compared with the same foods without iron fortification.

Application of T7 ($\text{N}_{120}\text{P}_{40}\text{K}_{40}+\text{Znf}$) increased in Mn content of dehusked rice grains significantly by 33.7 percent over the control while application of T2 ($\text{N}_{120}\text{P}_{40}$), T5 ($\text{N}_{120}\text{K}_{40}$), and T8 ($\text{N}_{120}\text{P}_{40}\text{K}_{40}+\text{FYM}@5 \text{ t/ha}$) brought a significant decrease in Mn content of dehusked rice grains in comparison to control indicating that missing application of phosphatic fertilizer could lead to lower Mn content in rice grains. The content of Cu in dehusked grains of rice was not significantly influenced by the imposed treatments.

The content of phytic acid in dehusked grains of rice was significantly influenced by treatments. Application of T9 ($\text{N}_{120}\text{P}_{40}\text{K}_{40}+\text{Znf}+\text{FYM} @5 \text{ t/ha}$) and T13 ($\text{N}_{180}\text{P}_{80}\text{K}_{40}+\text{Znf}$) increased the content of phytic acid in the dehusked grains by 10.0 and 2.0 percent over the control, respectively while application of T3 ($\text{N}_{120}\text{P}_{40}$) brought a significant decrease of 12.2 per cent in the content of phytic acid in comparison to control. Higher content of phytic acid in dehusked rice grains could substantially reduce the bioavailability of both Zn and Fe in humans.

Table.1 Effect of different treatments on concentration (mg kg⁻¹) of micronutrient cations and phytic acid in dehusked rice (cv. PD4) grains.

Treatments	Zn	Cu	Fe	Mn	Phytic acid
T1 –Control	8.6	1.4	5.3	17.1	3417
T2 - N ₁₂₀	8.9	1.6	4.3	13.1	3237
T3 - N ₁₂₀ P ₄₀	10.6	1.4	6.1	16.0	3002
T4 - P ₄₀ K ₄₀	10.3	1.5	4.4	17.7	3244
T5 - N ₁₂₀ K ₄₀	9.2	1.7	11.4	9.6	3371
T6 - N ₁₂₀ P ₆₀ K ₄₀	11.6	1.3	6.6	15.9	3403
T7 - N ₁₂₀ P ₄₀ K ₄₀ +Znf	13.5	1.6	10.1	22.9	3246
T8 - N ₁₂₀ P ₄₀ K ₄₀ +FYM	11.9	1.4	7.2	14.0	3229
T9 - N ₁₂₀ P ₄₀ K ₄₀ +Znf+FYM	12.8	1.3	7.6	17.6	3757
T10 - N ₁₈₀ P ₈₀ +Znf	12.4	1.0	12.5	18.1	3227
T11 - N ₁₈₀ P ₈₀ K ₄₀ +Znf+FYM	11.5	1.2	5.2	16.2	3560
T12 - N ₁₅₀ P ₄₀ K ₄₀	7.3	1.0	5.4	16.9	3667
T13 - N ₁₈₀ P ₈₀ K ₄₀ +Znf	13.8	1.7	8.8	16.8	3484
T14 - N ₁₂₀ P ₄₀ K ₄₀ (DAP)	10.4	1.0	5.1	17.0	3442
S.Em.	0.9	0.2	0.9	0.8	87
C.D. (p=0.05)	2.6	NS	2.6	2.4	252

Table.2 Effect of different treatments on concentration (mg kg⁻¹) of micronutrient cations and phytic acid in wheat (cv. UP2565) grains

Treatments	Zn	Cu	Fe	Mn	Phytic acid
T1 -Control	25.5	6.0	24.1	10.5	13640
T2 - N ₁₂₀	33.2	6.5	28.1	11.7	13036
T3 - N ₁₂₀ P ₄₀	30.4	4.8	28.5	9.9	13398
T4 - P ₄₀ K ₄₀	25.8	4.2	23.2	13.4	13423
T5 - N ₁₂₀ K ₄₀	30.7	5.1	23.4	10.6	13696
T6 - N ₁₂₀ P ₆₀ K ₄₀	33.0	6.3	26.1	9.5	13276
T7 - N ₁₂₀ P ₄₀ K ₄₀ +Znf	24.7	5.1	20.1	8.8	13434
T8 - N ₁₂₀ P ₄₀ K ₄₀ +FYM	28.2	6.2	26.8	15.6	13904
T9 - N ₁₂₀ P ₄₀ K ₄₀ +Znf+FYM	26.3	4.8	25.5	9.8	13486
T10 - N ₁₈₀ P ₈₀ +Znf	34.5	6.2	21.8	9.0	13792
T11 - N ₁₈₀ P ₈₀ K ₄₀ +Znf+FYM	30.2	5.4	27.4	9.5	13553
T12 - N ₁₅₀ P ₄₀ K ₄₀	32.8	6.0	28.2	12.9	13986
T13 - N ₁₈₀ P ₈₀ K ₄₀ +Znf	35.8	6.4	27.1	10.6	13659
T14 - N ₁₂₀ P ₄₀ K ₄₀ (DAP)	26.4	5.1	25.9	13.8	13491
S.Em.	1.4	0.7	3.7	1	88
C.D. (p=0.05)	4.1	NS	NS	2.8	257

Fig.1 Effect of different long term treatments on grain yield of rice (cv. PD 4) crop. The vertical bars over histograms represent C.D values at $p \leq 0.05$.

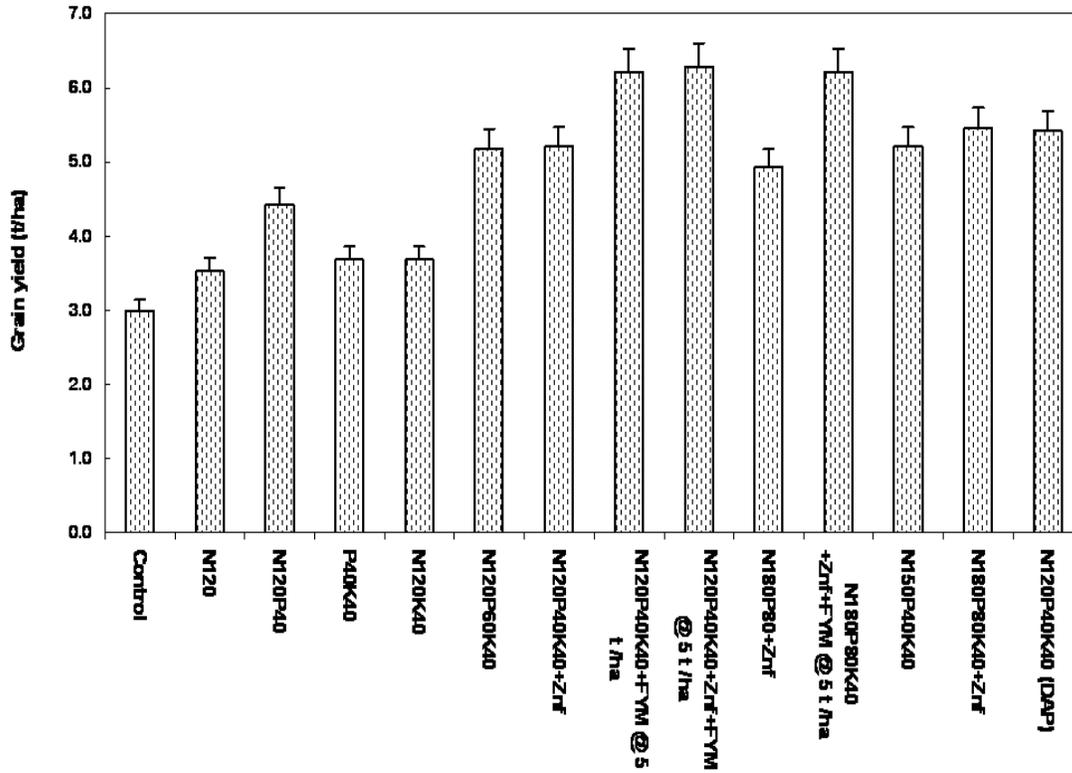
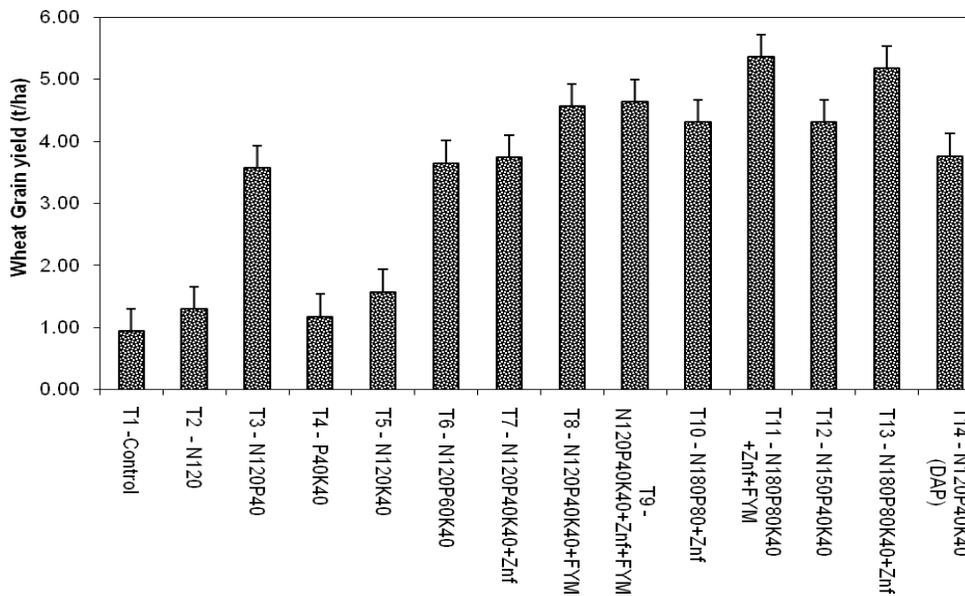


Fig.2 Effect of different long term treatments on grain yield of wheat crop. The vertical bars over histograms represent C.D values at $p \leq 0.05$.



Micronutrient cations and phytic acid in wheat grains

As regards the concentration of micronutrient cations in wheat grains, the application of T2 (N₁₂₀), T3 (N₁₂₀P₄₀), T5 (N₁₂₀K₄₀), T6 (N₁₂₀P₆₀K₄₀), T10 (N₁₈₀P₈₀+Znf), T11 (N₁₈₀P₈₀K₄₀ +Znf+FYM), T12 (N₁₅₀P₄₀K₄₀) and T13 (N₁₈₀P₈₀K₄₀+Znf) increased in Zn content of wheat grains significantly by 30.3, 19.1, 20.5, 29.5, 35.1, 18.3, 28.7 and 40.3 percent over the control, respectively (Table 2). Niyigaba *et al.*, (2019) also noted that foliar spray of Zn improved Zn concentration in winter wheat grains. Like dehusked rice grains, a comparison of Zn content in wheat grains raised under T14 (N₁₂₀P₆₀K₄₀, supplied through DAP) with that of control revealed that continuous use of DAP did not help in raising the content of Zn in wheat grains. The contents of Cu and Fe in wheat grains were not significantly influenced by different treatments. Application of T4 (P₄₀K₄₀), T8 (N₁₂₀P₄₀K₄₀+FYM@5 t/ha) and T14 [N₁₂₀P₄₀K₄₀ (DAP)] increased the content of Mn in wheat grains significantly by 27.3, 48.9 and 31.6 percent over the control, respectively.

The content of phytic acid in grains of wheat was significantly influenced by the treatments. Application of T8 (N₁₂₀P₄₀K₄₀+FYM) and T12 (N₁₅₀P₄₀K₄₀) increased the content of phytic acid in the grains by 1.9 and 2.5 percent over the control, respectively while application of T2 (N₁₂₀) and T6 (N₁₂₀P₆₀K₄₀) brought a significant decrease of 4.4 and 2.7 per cent in the content of phytic acid in comparison to control, respectively.

In general, wheat grains appeared to be relatively richer in micronutrient cations as compared to dehusked rice grains possibly because in cereals the micronutrients are accumulated in the aleuron layer and the process of dehusking and polishing removes

these nutrients. A comparison of phytic acid concentrations in dehusked rice grains and wheat grains also revealed that dehusked rice grains had more than two folds higher concentration of phytic acid; an anti-nutrient factor than in wheat grains, therefore, the extent of reduction in the bioavailability of Zn and Fe in dehusked rice grains would be much higher than the case in wheat grains.

Thus, fertilizer application practices have an important bearing on the status of micronutrient cations as well as on the concentration of phytic acid in cereal grains. Long-term use of di-ammonium phosphate as a source of P fertilizer may cause reduced concentrations of Zn in dehusked rice and wheat grains and therefore, the use of single superphosphate as P fertilizer source has to be promoted among the farmers. In order to ensure relatively higher concentrations of Zn and Fe in cereals, the liberal foliar application of Zn in cereals must be promoted among the farmers. The consumption of wheat grains as a staple food offers an advantage over the consumption of dehusked rice.

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