Zinc and Phosphorus on yield in Aman rice and distribution in post-harvest soil.

Authors:
M.A. Hye¹, K.M. Mahbubur Rahman², P.P. Das³, M. S. Islam⁴, M. A. Hossain⁵, B.P. Ray⁶*

¹, ², ³ Dept. of Agri. Chemistry, Bangladesh Agricultural University, Mymensingh.
⁴ Agronomy divisions, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh.
⁵ Biotechnology and Genetic Engineering department, Noakhali Science & Technology University, Bangladesh
⁶ Biotechnology division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh.

*Corresponding Author:
B.P. Ray*

*Biotechnology division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh.
E-mail: bpray2010@gmail.com

Abstract:
Many There were 3 levels of P (0, 25 and 50 kg P2O5 ha-1 from TSP) and 4 levels of Zn (0, 5, 10 and 20 kg Zn ha-² from zinc sulphate) along with basal doses of 100 kg N ha from urea, 40 kg K2O ha-¹ from mediate of potash and 12 kg S ha" from gypsum. The single and interaction effect of P and Zn had significant positive effect on the grain and straw yield. The highest grain yield (5.97 t ha-1) and straw yield (11.50 t ha-²) were obtained from Zn10 P50 treatment. Phosphorus application significantly increased the P content in grain and straw but zinc content significantly decreased while effect of zinc significantly decreased the P content in grain and straw but increased the Zn content. The highest amount of P content in grain and straw were 0.35% and 0.140% respectively obtained from Zn0 P50 treatment whereas the zinc content in grain and straw were 32.8 ppm and 50.60 ppm respectively obtained from Zn20 Po treatment. The availability of phosphorus gradually increased with the increasing levels of P and decreased with the increasing levels of Zn. The maximum water-soluble P (4.5mg kg-1) and labile P (1.8 mg kg-1) were obtained from Zn0 P50 treatment. The application of P and Zn gradually increased the Al/Fe-P, Mg/Ca-P and Total P with the increasing levels of P and Zn. The highest amount of Al/Fe-P, Mg/Ca-P and Total-P were obtained from Zn20 P50 treatment. The combined application of P and Zn increased the grain and straw yield but decreased P and Zn content and availability of P to from Al/Fe-P and Mg/Ca-P as a result of Zn-P interaction in soil solution.

Keywords: Soil, yield, Rice, Zinc, Phosphorus.

1. Introduction:
Rice (Oryza sativa L) is one of the most popular food and feeds over half population of the world. The existing population of the world is 7.5 billion as of July 2017 and growth rate of around 1.11% per year. Food scarcity has been and will remain a major
concern for Bangladesh, as currently (2017) population growth rate is 1.15% per year (Ray, 2018). Rice contributes 91.12% of the total intake of this country's people (MOA, 1996). Rice is grown in about 72.47% of the arable land of 10.12 million hectares. More than 2.0 mha of rice lands are unfavorably affected by excess water and reduces 5% average yield in Bangladesh (Ray et al., 2017). Out of total rice production in this country, about 60% come from Aman and the rest 18% and 22% come from Aus and Boro crops respectively (BBS, 1999).

Soil is the main source of plant nutrients. It supplies almost all of the essential nutrients to crop plants. The inherent nutrient supply capacity of Bangladesh soil has been found to declining due to continuous cultivation for growing more than one crop in the same piece of land in the same year. Until 1980, only the major three nutrients viz. NPK were usually supplied to our soils of which in majority case only N was supplied. The practice of intensive cropping with modern varieties cause a marked depletion of inherent nutrient reserve in soils of Bangladesh consequently in addition to N, P and K deficiencies some other nutrient such as B, Zn, and S deficiencies are being observed in many parts of the country (Jahiruddin et al., 1981; Hague & Jahiruddin, 1994).

Phosphorus plays a vital role in crop production since it is an integral part of metabolic processes. But the availability of this element in soil is very critical owing to its rapid fixation into complex forms. Annual crops planted after the application of phosphorus fertilizers often recover only 1-20% of the applied-P. A large part of the applied-P is rapidly become insoluble & unavailable to plants as a result of chemical reactions involving the formation of iron, manganese aluminum & magnesium phosphate. Under reduced condition the oxide bound-P become available hence wetland crops do not respond to phosphate application. Information on the amount of various chemical forms of phosphorus & their effect on P fertility is necessary to know the supplying power of soil before going for phosphate fertilization. Zinc deficiency has been detected as the third major nutritional problem for Bangladesh soil next to N & P limiting the growth of wetland rice. In some places of Bangladesh, yield loss due to zinc deficiency ranged from 10-18%. A survey on zinc nutrition in rice in Bangladesh showed that soil with high pH & calcareous soils of north western districts & also the soils which have been integrity cultivated with transplant rice have Zn deficiency problem. Zn plays an important role in many physiological functions of plants. It serves as a constituent of plant metabolic enzymes system as alcohol dehydrogenase, carbonic anhydrus & various peptidases. In consideration of the importance of these two plant nutrient elements in wetland rice production in Bangladesh the objectives of the studies to evaluate the effect of P & Zn on yield and yield attributes of rice, to find out the optimum doses of P & Zn for rice cultivation, to investigate the interaction effects of P & Zn on the yield & yield attributes of rice, to find out information on the effect of zinc on distribution of added P in different fractions of post-harvest soil.

2. Methods and Materials:
The experiment was conducted at Bangladesh Agricultural University with a view to finding out of the effect of phosphorus and zinc on yield, phosphorus and zinc content by rice (BR11) and phosphorus distribution in post-harvest soil fractions. The experimental field belongs to the agro ecological region of the Old Brahmaputra Flood plan. The region occupies a large area of Barahmaputra sediments, which are down before the river shifted into its present Jamuna channel about 200 years ago.

The experiment comprised of four levels of zinc (Zn), 0, 5, 10 and 20 kg Zn ha⁻¹ and three levels of phosphorus (P), 0, 25 and 50 kg P₂O₅ ha⁻¹. The total number of fertilizer treatment combinations was 12 and they were as follows:

<table>
<thead>
<tr>
<th>Zn0P0</th>
<th>Zn5P0</th>
<th>Zn10P0</th>
<th>Zn20P0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn0P25</td>
<td>Zn5P25</td>
<td>Zn10P205</td>
<td>Zn20P25</td>
</tr>
<tr>
<td>Zn0P50</td>
<td>Zn5P50</td>
<td>Zn10P50</td>
<td>Zn20P50</td>
</tr>
</tbody>
</table>
Under the trial, the total area was 400 square meters. The size of each plot was $10 \text{ m}^2$ (4m x 2.5 m). Inter block and inter plot spacing were 1.5 Ain and 0.3 m respectively.

The experiment was laid out in Randomize Complete Block Design (RCBD) having 12 fertilizer combinations each of them replicated 3 times. Application of N, K and S were used at rate of 100 kg N ha$^{-1}$, 40 kg P$_2$O$_5$ ha$^{-1}$, and 12 kg S ha$^{-1}$ respectively along with the treatment combination.

Sources used for the different elements were Urea (46% N), TSP (48% P$_2$O$_5$), MP (60% K$_2$O), Zinc sulphate (36% Zn) and Gypsum (18% S) which were collected from the local market, Mymensingh.

Total phosphorus was extracted from 2g soil sample that has been (passed through 0.5 mm sieve, was weighed and transferred to a 300 ml conical flask. Thirty milliliter of 60 percent HCl$_4$ was added and the digestion was carried out at 130°C in a special apparatus designed to remove from HC 10$f$ fumes. Phosphorus was determined from the extract by adding ammonium molybdate and SnCl$_2$ solution and measuring the color with the help of spectrophotometer at 660 nm. (Olsen et al., 1954).

Zinc concentrations in the extract of grain and straw samples were determined directly by atomic absorption spectrophotometer in Central laboratory (McLaren et al., 1984). The data of crop characters and nutrient content of plant and soil samples were analyzed statistically by means of computer package MSTAT. The difference among the treatments was adjusted by the Duncan’s Multiple Range Test (DMRT) as outlined by Gomez and Gomez, (1984).

3. Result and Discussion:

3.1 Grain yield:

3.1.1 Effect of phosphorus:

Highly significant variation was observed on grain yield of rice by the phosphorus application. The highest grain yield (5.51 t ha$^{-1}$) was obtained from P$_{50}$ treatment and that was significantly different from P$_{25}$ (5.10 t ha$^{-1}$) treatment. Both the treatments (P$_{25}$ and P$_{50}$) were significantly superior to P$_0$ (4.41 t ha$^{-1}$) treatment. Higher yields in both P$_{25}$ and P$_{50}$ treatments were attributed to the production of higher number of tillers hill$^{-1}$, higher number of grains panicle$^{-1}$ and production of heavier grain than P$_0$ treatment. Mahajan et al. (1994) and Subba Rao et al. (1995) were also reported that the application of phosphorus increased the grain yield of rice.

3.1.2 Effect of Zinc:

Application of zinc fertilizer significantly increased the grain yield of rice. The highest grain yield was obtained from Zn$_{20}$ (5.47 t ha$^{-1}$) treatment. The lowest grain yield was obtained from Zn0 (4.58 t ha$^{-1}$) treatment which was significantly inferior to Zn$_5$ and Zn$_{10}$ treatments. The effect of zinc was in agreement with the findings of Ram et al. (1995).

3.1.3 Effect of interaction:

The effect of interaction of phosphorus and zinc on grain yield was significant. The highest grain yield
(5.97 t ha\(^{-1}\)) was obtained from Zn\(_10\) P\(_50\) treatment and was similar with Zn\(_10\) P\(_{25}\) (5.74 t ha\(^{-1}\)) but significantly higher than those of all other treatment combinations of phosphorus and zinc. The lowest grain yield (4.24 t ha\(^{-1}\)) was obtained from Zn0 Po treatment and which was significantly lower than all other interactions of phosphorus and zinc. Zamal \textit{et al.} (1994) stated that application of P and Zn had a positive effect on grain yield of rice.

3.2 Straw yield:

3.2.1 Effect of phosphorus:

The highest ghost straw yield (9.64 t ha\(^{-1}\)) was obtained from P\(_{50}\) treatment but it was significantly higher than all other treatments. Though apparently it was seen that P\(_{25}\) (9.10 t ha\(^{-1}\)) over control Po (8.46 t ha\(^{-1}\)) but it was lower than P\(_{50}\) treatment. Po treatment produced the lowest straw yield (8.46 t ha\(^{-1}\)).

3.2.2 Effect of zinc:

Application of zinc shows a significant effect on straw yield. The highest straw yield was observed at Zn\(_{20}\) (10.23 t ha\(^{-1}\)) treatment whereas control treatment Zn0 produced the lowest straw yield (8.57 t ha\(^{-1}\)). Another two treatments (Zn\(_0\) and Zn\(_{10}\)) produced statistically identical straw yield over control treatment.

3.2.3 Effect of interaction:

Interaction effect of phosphorus and zinc was significant in producing straw yield. The highest straw yield (11.5 t ha\(^{-1}\)) was obtained from Zn\(_10\) P\(_{50}\) treatment and the lowest yield (8.20 t ha\(^{-1}\)) from control (Zn0 Po) treatment. Bunta \textit{et al.} (1989) reported that application of P at any rates, whether in combination with Zn or not increased grain and straw yield of rice.

4. Phosphorus and Zinc content in grain:

The single effect of phosphorus and zinc on P and Zn content in rice grain is presented in Table 1 and their interaction effects presented in Table 2.

(A) Phosphorus content:

a. Effect of phosphorus:

Phosphorus application increased P content in grain significantly. The highest P content (0.305%) in grain was obtained from the P\(_{50}\) treatment and the lowest P content (0.274%) was obtained from the P0 treatment (Table 1). The treatment P\(_{25}\) produced 0.290% P content in grain, which was significantly higher than P0 treatment but it was lower than P50 treatment. Padihar and Dikshit (1985) also reported that P content in rice plant increased when P levels was increased.

b. Effect of zinc:

P content in grain was decreased significantly by zinc application (Table 1). The maximum amount of P content in grain (0.322%) was obtained from the control (Zn0) treatment and the minimum amount of P content in grain (0.267%) was obtained from the Zn\(_{20}\) treatment (Table 1). Zn\(_10\) treatment produced 0.270% P content in grain, which was identical with Zn\(_{20}\) treatments. 0.300% P content obtained from Zn\(_5\) treatment which was significant with Zn\(_{20}\) and Zn\(_{10}\) treatment.

(B) Water soluble phosphorus in soil:

a. Effect of phosphorus:

Water-soluble phosphorus in soils showed a wide variation among the treatments. The maximum amount of water soluble-P (3.6 mg kg\(^{-1}\)) was observed from P\(_{50}\) treatments which are highly significant with all other treatments. The minimum amount of P (1.85 mg ka\(^{-1}\)) was observed from P0 treatment which was lower than all other treatments. P\(_{25}\) treatment shows water soluble-P (2.9 mg ka\(^{-1}\)) which was significantly higher than control treatment. The shows a increasing trend of water soluble-P in soil with the increasing levels of P treatments.

b. Effect of zinc:

The application of zinc gradually decreased the water soluble-P in soil. The highest amount of water-soluble-P (3.33 mg kg\(^{-1}\)) was obtained from control treatment (Zn\(_0\)) which are high significant with any other treatments. The lowest amount of water
soluble-P (2.33 mg kg$^{-1}$) was obtained from Zn$_{20}$ treatment.

c. Effect of interaction:
The interaction effect of phosphors and zinc on water-soluble phosphorus in soil was highly significant. The maximum amount of water-soluble P (4.5 mg kg$^{-1}$) was found in treatment Zn$_0$ P$_{50}$. The minimum amount of water-soluble P (1.5 mg kg$^{-1}$) was found in Zn$_{20}$ P$_0$ treatment. The figure shows the increasing trend of water-soluble-P with the increase of P levels and the decreasing trend of water-soluble-P with the increase of Zn level because antagonistic effect of P-Zn in soil.

(C) Labile Phosphorus in soil:

a. Effect of phosphorus:
Labile phosphorus in soils showed a wide variation among the treatment. The highest amount of labile-P (1.475 mg kg$^{-1}$) was obtained from P$_{50}$ treatments which are highly significant with any other treatments. The lowest amount of this P (0.55 mg kg$^{-1}$) was obtained from P$_0$ treatment which was lower than any other treatments. The figure shows the increasing trend of labile-P in soil with the increasing levels of P treatment.

b. Effect of zinc:
The application of zinc gradually decreased the labile P in soil. The highest amount of labile-P (1.3 mg kg$^{-1}$) was obtained from control treatment (Zn$_0$) which are high significant with any other treatments. The lowest amount of labile-P (0.733 mg kg$^{-1}$) was obtained from Zn$_{20}$ treatments. The figure shows a decreasing trend of labile-P in soil with the increase of Zn levels.

c. Effect of interaction:
The interaction effect of phosphors and zinc on labile phosphorus in soil was highly significant. The highest amount of labile-P (1.8 mg kg$^{-1}$) was found in treatment Zn$_0$ P$_{50}$. The lowest amount of labile-P (0.3 mg kg$^{-1}$) was obtained from Zn$_{20}$ P$_0$ treatment. The data shows the increasing trend of labile-P in soil with the increase of P levels and the decreasing trend of labile-P with the increase of Zn levels because of antagonistic effect of P-Zn in soil solution.

(D). Al/Fe banded P in soil:

a. Effect of phosphorus:

From figure 6 Al/Fe banded P in soil showed a wide variation among the treatments. The highest amount of Al/Fe-P (33.725 mg kg$^{-1}$) was obtained from P$_{50}$ treatments which are highly significant with any other treatments and the lowest amount (17.225 mg kg$^{-1}$) was obtained from P$_0$ treatment.

b. Effect of zinc:
Zinc application gradually increased the Al/Fe-P in soil. The maximum amount of Al/Fe-P (32.2 mg kg$^{-1}$) was obtained from Zn$_{20}$ treatment which was highly significant with any other treatments. The minimum amount of Al/Fe-P (22.80 mg kg$^{-1}$) was obtained from Zn$_0$ treatment.

c. Summary:
The P content in grain and straw increased with increasing rate of P application but the content decreased with the increasing rate of Zn application. The highest P content in grain (0.305%) and straw (0.108%) was obtained from the highest rate of applied P that is P50 treatment while the lowest P content that is grain (0.267%) and straw (0.077%) was obtained from the highest rate of applied Zn in Zn$_{20}$ treatment.

Phosphorus application significantly decreased the zinc content in grain and straw while zinc application increased the zinc content. The highest Zn content in grain (27.46 ppm) and straw (39.15 ppm) were observed in the P control (P$_0$) treatment while the highest Zn content in grain (29.54 ppm) and straw (46.93 ppm) was found in the highest rate of applied Zn that is in the Zn$_{20}$ treatment. The results reflected that the combined application of Zn10 and P50 treatment played a significant role on production of the highest yield. This has got positive effect also on yield contributing characters. However, application of zinc decreases phosphorus concentration in both
grain and straw and water soluble-P and labile-P in soil but consequently increases AUFe-P, Mg/Ca-P and total-P in the soil resulting a Zn-P interaction in soil solution.

5. References: