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# Phosphorus effect on growth, biochemical changes and yield of rice plant during submergence

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An experiment was conducted to see the influence of phosphorus during submergence of rice at experimental site of Department of Crop Physiology, N.D. University of Agriculture and Technology, Kumarganj, Faizabad, UP, India. The two rice varieties *i.e.* FR13A (submergence tolerance) and Mahsuri (submergence susceptible) were exposed to seven days continuous complete submergence to 30 days of old seedling with different doses of phosphorus. Plant height, shoot dry weight, starch content, SOD activity and grain yield significantly reduced during submergence in both varieties irrespective of phosphorus treatment. Among the different levels, 80 kg $P_2O_5$ $ha^{-1}$ phosphorus was found more effective during submergence. As it sustained the growth and yield by increasing the shoot dry matter, starch content, and SOD activity of rice during submergence. The response of phosphorus was more significant in FR13A than Mahsuri. Therefore, the optimum phosphorus content in plant maintained growth activity by mitigating the adverse environmental effect under submergence condition.

Key words : Phosphorus, Submergence, SOD, Starch, Yield and rice

## INTRODUCTION

Rice is the staple food crop of India as well as many parts of the world. More than 80 per cent of our countrymen depend fully or partially on rice. Rice production faces a number of constraints. Among these, submergence due to flooding is well spread in South Asia, Bangladesh and North-East India and it affects approximately 22 m.ha (about 16 % of world rice area) including 15 million ha of potential flash flood (short duration flood) in rainfed lowland rice area and five million ha of deep water rice (Khush, 1984). Submerged rice plant experiences two drastic environmental changes:

The change from aerobic to anaerobic conditions during submergence and second subsequent change from anaerobic to aerobic conditions when the flood water resides. During submergence condition, $O_2$ concentrations are usually below air saturations and hypoxia or anoxia conditions. Levitt (1980) cited several mechanisms involved in adaptation to $O_2$ deficiency during flooding but failed to include interactive effect associated with other environmental factors during partial or complete submergence. Limited gas diffusion is most important factor during flooding (Setter *et al*., 1995). Since gas diffusion is $10^{-4}$ fold slower in water than in air (Armstrong, 1979), the depletion of $O_2$ is the major feature of the flooded field which creates a condition of low $O_2$ (hypoxia) or no $O_2$ at all (anoxia) around the plant tissue (Kennedy *et al*., 1992). Carbon assimilation during submergence will be affected by several factors including $CO_2$ supply, irradiation and a capacity of plants to photosynthesis under water. Phosphorus plays an important role in plant growth. It also stabilizes the survival and yield of rice plant by manipulating the metabolic activities during submergence. Present study concerned with the enhancing flooding tolerance in susceptible genotypes of rice by application of optimum amount of phosphorus.

## MATERIALS AND METHODS

Experiment was conducted with rice varieties FR13A (submergence tolerant) and Mahsuri (submergence susceptible) at experimental site of Department of Crop Physiology, N.D. University of Agriculture and Technology, Kumarganj, Faizabad. For creation of different level *i.e.* 0 (control), 40,80 and 120 kg $P_2O_5$/ha phosphorus treatment, the desired amount of single super phosphate was dissolved in water and sprayed on to the well pulverized soil and mixed thoroughly. Half of the nitrogen and full amount of the potash were also added to the phosphorus solutions before mixing to the soil. Two sets of the same material were prepared. First set was kept as control (without submerged) whereas the second set was completely submerged at 33 days after sowing (DAS) for seven days in submergence tank containing natural flood water. Twenty pots per treatment were maintained, for which ten were used for submergence. Growth observations were recorded at two stages of crop growth, *i.e.* before submergence and just after desubmergence. Three pots per replication were initially tagged for growth observations which were recorded over three replications. Thus a total of nine observations were recorded. The plant height was recorded from the base of stem, surface of the ground up to the apex of the plant. For dry matter content, three healthy and uniform plants from each treatment were sampled and separated into their respective shoot and root parts and oven dried at $70\pm1^0$c till constant weight. Starch was estimated following anthrone reagent method described by McCready *et al.* (1950). SOD activity was assayed by the method of Gianopolitis and Ries (1977). Grain yield per plant was recorded separately for each treatment.

## RESULTS AND DISCUSSION

There is a genetic variability in plant height of rice varieties (Table 1). Application of phosphorus increased the plant height significantly up to 80 kg $P_2O_5$ $ha^{-1}$ over the control. When 33 days rice plants were submerged for seven days, a progressive increase in plant height was observed in both varieties irrespective of P levels. The elongation rate in Mahsuri was observed higher in comparison to FR13A during submergence condition. But in non submerged condition the trends of elongation rate became reversed as FR13A attained more elongation than Mahsuri. Increase in shoot elongation during submergence is one of the possible mechanisms to escape submergence by rice plants. This is more useful for deep water rice which needs maximum elongation ability, but for rainfed lowland rice, rapid elongation would be undesirable since the plant will lodge once the flood water recedes (Malik *et al.*, 1995). Thus, rainfed lowland rice needs only moderate elongation to avoid submergence but if submergence is for a short period, zero elongation would be quite useful because the available carbohydrates and dry matter would be saved for regeneration of growth on desubmergence.

With increases in phosphorus levels the shoot dry weight increased significantly up to 80 kg $P_2O_5$ /$ha^{-1}$ over control (Table 2). The shoot dry weight decreased significantly in FR13A and Mahsuri variety in submerged condition. The maximum reduction in shoot dry weight due to submergence treatment was recorded in mahsuri than FR13A under each treatment. Phosphorus treatment decreased the magnitude of reduction in both varieties. The reduction in shoot dry weight is due to reduced photosynthesis during submergence and utilization of reserve food during submergence are the major cause of loss of shoot dry weight. Application of phosphorous enhanced dry matter production in tolerant as well as susceptible in both submergence and without submergence condition. The beneficial effect of phosphorus on plant

**Table 1: Effect of phosphorus levels and submergence on plant height (cm) of two rice varieties 0 days after desubmergence**

| Phosphorus levels(p) kg/ha | Variety (V) | | | | | | Mean P | Mean E | |
|---|---|---|---|---|---|---|---|---|---|
| | FR-13A ($V_1$) | | | Mahsuri ($V_2$) | | | | | |
| | WS($E_1$) | Sub($E_2$) | Mean | WS($E_1$) | Sub($E_2$) | Mean | | WS($E_1$) | Sub($E_2$) |
| P0 | 58.0 | 60.4 | 59.2 | 43.2 | 53.7 | 48.5 | 53.8 | 50.6 | 57.1 |
| P40 | 60.2 | 62.3 | 61.3 | 50.0 | 61.2 | 55.6 | 58.4 | 55.1 | 61.8 |
| P80 | 66.4 | 69.9 | 68.2 | 53.7 | 66.3 | 60.0 | 64.1 | 60.1 | 68.1 |
| P120 | 67.9 | 71.4 | 69.7 | 54.3 | 68.3 | 61.3 | 65.5 | 61.1 | 69.9 |
| Mean | 63.1 | 66.0 | 64.6 | 50.3 | 62.4 | 56.3 | | 56.7 | 64.2 |
| C.D. (P=0.05) | V=0.95 P=1.35 E=0.95 VxP=NS VxE=1.35 PxE= NS VxPxE=NS | | | | | | | | |

**Table 2 : Effect of phosphorus levels and submergence on shoot dry weight (g $plant^{-1}$) of two rice varieties 0 days after desubmergence**

| Phosphorus levels(p) kg/ha | Variety (V) | | | | | | Mean P | Mean E | |
|---|---|---|---|---|---|---|---|---|---|
| | FR-13A ($V_1$) | | | Mahsuri ($V_2$) | | | | | |
| | WS($E_1$) | Sub($E_2$) | Mean | WS($E_1$) | Sub($E_2$) | Mean | | WS($E_1$) | Sub($E_2$) |
| P0 | 3.383 | 2.336 | 2.860 | 1.972 | 0.999 | 1.486 | 2.713 | 2.678 | 1.668 |
| P40 | 3.541 | 2.574 | 3.058 | 2.204 | 1.181 | 1.693 | 2.375 | 2.873 | 1.878 |
| P80 | 4.403 | 2.925 | 3.664 | 3.767 | 2.694 | 3.208 | 3.436 | 4.085 | 2.787 |
| P120 | 4.527 | 3.038 | 3.783 | 3.899 | 2.678 | 3.289 | 3.536 | 4.213 | 2.858 |
| Mean | 3.964 | 2.718 | 3.341 | 2.961 | 1.877 | 2.419 | | 3.462 | 2.298 |
| C.D. (P=0.05) | V=0.0822 P=0.1162 E=0.0822 VxP=NS VxE=NS PxE=NS VxPxE=NS | | | | | | | | |

growth and dry matter production has been well recognized. Rice plants fertilized with both nitrogen and phosphorus were minimized overhead flooding than those fertilized with nitrogen alone (Reddy and Mittra *et al.*, 1985).

Starch content in shoot of tolerant rice varieties FR13A was significantly higher than that of Mahsuri at all level of P treatments (Table 3). Starch content of shoot decreased significantly in both varieties under submergence condition as compared to its control but susceptible variety Mahsuri showed higher reduction than FR13A. Phosphorus response at 80 kg $P_2O_5$/$ha^{-1}$ showed better performance as it increased more starch content in shoot of rice plants under both submerged and non submerged condition in comparison to another doses of phosphorus. Reduction in carbohydrates during submergence is one of the essential biochemical events, which effects the survival and growth during submergence. This fall is perhaps due to reduced photosynthesis during submergence and utilization of available carbohydrate in anaerobic respiration during submergence (Vergara *et al.*,1976; Setter *et al.*,1996, Singh *et al.*,1997). Tolerant variety maintained higher starch content before submergence and during submergence in comparison to susceptible variety. During submergence high content of starch might be due to efficient mechanisms of pyruvate decarboxylase and alcoholic dehydrogenase enzyme system in tolerant varieties (Malik *et al.*,1995).

Under control condition, there was no significant difference observed in SOD activity in rice varieties (Table 4). The activity of SOD increased with increasing phosphorus level up to 80 kg $P_2O_5$ $ha^{-1}$. The overall activity of FR13A was almost double the activity of Mahsuri under submergence condition. The population of super oxide anion during anoxia is very well studied (Hunter *et al.*, 1983 and Crawford and Wollenweher-Ratzer, 1992). The active $O_2$ leads to lipid per- oxidation and death of the plants. In this investigation, the higher super oxide dismutase activity of tolerant variety (FR 13A) over the susceptible variety Mahsuri might contribute the flooding tolerance by improving detoxification of super oxide radicals upon readmission of oxygen. Srivastava *et al.* (2008) also reported that submergence tolerant genotypes showed much higher increase in SOD activity just after submergence period in comparison to submergence susceptible genotypes. The high SOD activity of FR13A properly insured an active oxygen scavenging system which intern lead to higher survival and yield over Mahsuri.

Submergence of rice plant markedly influenced the yield of rice plant during submergence (Table 5). It is clear from the data that with increase in phosphorus level a progressive and significant increase in grain yield per

**Table 3 : Effect of phosphorus levels and submergence on starch content (mg $g^{-1}$ dry wt. in shoot) of two rice varieties 0 days after desubmergence**

| Phosphorus levels(p) kg/ha | Variety (V) | | | | | | Mean P | Mean E | |
|---|---|---|---|---|---|---|---|---|---|
| | FR-13A ($V_1$) | | | Mahsuri ($V_2$) | | | | WS ($E_1$) | Sub ($E_2$) |
| | WS($E_1$) | Sub ($E_2$) | Mean | WS ($E_1$) | Sub ($E_2$) | Mean | | | |
| P0 | 85.3 | 68.7 | 77.0 | 48.0 | 23.3 | 35.7 | 56.3 | 66.7 | 46.0 |
| P40 | 101.3 | 75.3 | 88.3 | 63.3 | 34.7 | 49.0 | 68.7 | 82.3 | 55.0 |
| P80 | 112.7 | 86.3 | 99.5 | 93.3 | 52.7 | 73.0 | 86.3 | 103.0 | 69.5 |
| P120 | 114.0 | 86.7 | 100.4 | 96.0 | 54.7 | 75.4 | 87.9 | 105.0 | 70.7 |
| Mean | 103.3 | 82.8 | 91.3 | 75.2 | 41.4 | 58.3 | | 89.2 | 60.3 |
| C.D. (P=0.05) | V=2.81 P=3.97 E=2.81 VxP=NS VxE=NS PxE=5.61 VxPxE=NS | | | | | | | | |

**Table 4 : Effect of phosphorus levels and submergence on super oxide dismutase activity (unit * $g^{-1}$ fw) in leaves rice varieties 0 days after desubmergence**

| Phosphorus levels(p) kg/ha | Variety (V) | | | | | | Mean P | Mean E | |
|---|---|---|---|---|---|---|---|---|---|
| | FR-13A ($V_1$) | | | Mahsuri ($V_2$) | | | | WS ($E_1$) | Sub ($E_2$) |
| | WS ($E_1$) | Sub ($E_2$) | Mean | WS ($E_1$) | Sub ($E_2$) | Mean | | | |
| P0 | 187.0 | 388.7 | 287.9 | 177.3 | 346.7 | 262.0 | 274.9 | 182.2 | 367.7 |
| P40 | 212.3 | 469.3 | 340.8 | 197.3 | 411.7 | 304.5 | 322.7 | 204.8 | 440.5 |
| P80 | 232.3 | 669.3 | 450.8 | 220.0 | 458.7 | 339.4 | 395.1 | 226.2 | 564.0 |
| P120 | 241.3 | 688.7 | 465.0 | 224.0 | 469.3 | 346.7 | 405.8 | 232.7 | 579.0 |
| Mean | 218.2 | 554.0 | 386.1 | 204.7 | 421.6 | 313.7 | | 211.4 | 487.8 |
| C.D. (P=0.05) | V=14.28 P=20.20 E=14.28 VxP=28.56 VxE=20.20 PxE=28.56 VxPxE=NS | | | | | | | | |

**Table 5 : Effect of phosphorus levels and submergence on number of grains yield plant$^{-1}$ (g) rice varieties 0 days after desubmergence (2000)**

| Phosphorus levels(p) kg/ha | Variety (V) | | | | | | Mean P | Mean E | |
|---|---|---|---|---|---|---|---|---|---|
| | FR-13A ($V_1$) | | | Mahsuri ($V_2$) | | | | | |
| | WS ($E_1$) | Sub ($E_2$) | Mean | WS ($E_1$) | Sub ($E_2$) | Mean | | WS ($E_1$) | Sub ($E_2$) |
| P0 | 11.6 | 9.0 | 10.3 | 9.8 | 5.4 | 7.6 | 9.0 | 10.7 | 7.2 |
| P40 | 14.9 | 11.9 | 13.4 | 12.5 | 8.9 | 10.7 | 12.1 | 13.7 | 10.4 |
| P80 | 17.4 | 12.7 | 15.1 | 15.4 | 10.9 | 13.2 | 14.1 | 16.4 | 11.8 |
| P120 | 18.2 | 13.1 | 16.4 | 16.4 | 12.0 | 14.2 | 14.9 | 17.3 | 12.6 |
| Mean | 15.5 | 11.7 | 13.5 | 13.5 | 9.3 | 11.4 | | 14.5 | 10.5 |
| C.D. (P=0.05) | V=0.37 P=0.52 E=0.37 VxP=NS VxE=NS PxE=NS VxPxE=NS | | | | | | | | |

plant was observed up to 120 kg $P_2O_5$ /ha phosphorus over control ($P_0$). FR13A gave higher grain yield in both non submergence and submergence condition as compared to Mahsuri. Grain yield decreased significantly under each treatment in submergence condition as compared to without submergence in both varieties. Maximum decrease in grain yield due to submergence was recorded in susceptible variety, Mahsuri, irrespective of phosphorus level. Submergence at seedling stage inhibited the production of basal tillers and reduced the tiller numbers, thereby decreasing eventual grain yield (Lockard, 1958). Reduced grain yield under submergence condition is also affected by less chlorophyll content, reduced photosynthesis and consequently low biomass production under submerged condition. Submergence tolerant varieties have efficient scavenging mechanism and neutralize the effect of free oxygen radicals when plant shifted from anaerobic to aerobic condition and maintained the intrigrity of biological system and ultimately helped the survival of plant and its yield.

## *Conclusion:*

Submergence condition at seedling stage significantly influenced growth, development and ultimately yield of rice plant. Submergence tolerance rice varieties affected less due to expression of its special mechanism during submergence condition. Phosphorus treatment ameliorates the adversity of submergence by sustaining the growth and survival of susceptible rice variety under submergence condition. Therefore, optimum phosphorus treatment improves the survival and yield of rice plant up to some extent by maintaining basic biochemical mechanisms during submergence.

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