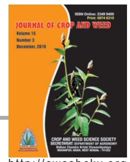
*Journal of Crop and Weed, 17(1): 195-202 (2021)*
ISSN- O : 2349 9400 ; P : 0974 6315



http://cwssbckv.org
www.cropandweed.com

# Characterization of some upland rice (*Oryza sativa* L.) genotypes under varying level of Phosphorus

**A. SYAM, *R. DAS, S. DAS AND RAMESH R.**
*AssamAgicultural University, Jorhat-785103*

***Received : 13.01.2021 ; Revised : 03.2.2021 ; Accepted : 23.02.2021***

**DOI :** https://doi.org/10.22271/09746315.2021.v17.i1.1424

**ABSTRACT**

*Phosphorus nutrition has a dynamic role in the growth and development of rice but it often becomes a restraining factor for crop productivity due to its low availability and strong fixation to soil particles. The study was carried out in AAU, Jorhat to characterize and identify some suitable upland rice genotypes for low P condition. A reduction in plant height and other morphological parameters was recorded at low dose of phosphorus treatment. PUE and P uptake was decreased under low P due to poor root development. Grain yield and related yield attributing traits were found to be less under low P condition but was superior in the genotype Maipholong.Results obtained during investigation revealed that low P had significant influence on various morpho-physiological and biochemical parameters. Amongst the genotypes, Maipholong, Kasalath and Ronga Ahu was found to be least affected by low P condition due to their better phosphorus utilization capability.*

***Keywords:*** phosphorus deficiency, rice genotypes, utilizing efficiency, uptake

Rice is the primary food grain crop of the North Eastern region of India occupying nearly 3.5 million hectares accounts 80% of the total cultivated area of the region (Ngachan *et al*., 2006). Increase in crop yield by 30-50 % have been reported by application of commercial chemical fertilizers (Stewart *et al*., 2005). Even though, the productivity of crop is increased significantly by 30-50% with an equivalent increase of fertilizer application together with phosphatic fertilizers (Stewart *et al*., 2005). Fageria (1994) has reported that amongst the essential plant nutrients, P deficiency is recognized as the most yield restrictive for rice crop grown on oxisolsoils. Phosphorus plays a key role in a plant for storing and allocation of energy produced during photosynthesis for subsequent use in growth and reproductive processes. An adequate availability of inorganic phosphate (Pi) is essential for plant growth and development. Phosphorus (P), a crucial element for plant growth, is absorbed by the root system in the form of inorganic phosphate (Pi) from soil matrices (Marschner and Rimmington, 1988; Ha and Tran, 2014; Frydenvang et al., 2015). Phosphorus being a major component in ATP, aids in providing energy to various plant processes *viz*. photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration (Wilson *et al*., 1998).

Phosphorus' primary role in a plant is to store and transfer energy produced by photosynthesis for use in growth and reproductive processes (Mullins, 2000).

Assam soil belongs to alluvial soil, red loam soil and lateritic soil (Chakravarty and Majumdar, 1971). Phosphorus is often the most limiting nutrient for crop and fodder production next to nitrogen. Phosphorus content of the plains of district soils of Assam nearly 50% and is medium while in the two hill districts is reported to be very low. Available phosphorous in Kamrup, Nagaon and Sonitpur district ranges from about 48 to 38.97kg/ha. Low soil pH sternly limits P accessibility to plants, which may cause deficiency symptoms even where high soil test P levels occur (Swaminathan and Sud, 1976).

Flooding the soil diminishes P-sorption by increasing the solubility of phosphates that are bound to aluminium and iron oxides (Silva *et al*., 2000). Under acidic conditions, the solubility of phosphate minerals depends on the soil pH. Phosphorus can react with aluminium and iron to form minerals such as strengite and varescite. P sorption and P precipitation diminishes the accessibility of P. After P fertilization, soils with greater P fixation capacity has less available P compared to soil having low P fixing capacity. The solubility of phosphate minerals is very reliant on soil pH under acidic conditions. Meanwhile together P-sorption and P precipitation diminish phosphorus accessibility, a soil with a great P-fixation capacity has less available phosphorus after fertilization than a soil with a low P-fixation capacity.

Some studies reported that plants have evolved many traits to improve their adaptability to different P environments (Jia *et al*., 2011; Vance *et al*., 2003). These modulations cover: (1) increasing the root numbers and varying their architecture; (2) increasing P absorption by more P transporters; and (3) improving the activity of enzymes related to P utilization (Nilsson *et al*., 2010).

*Email: rdassam19666@gmail.com*

Two important mechanisms of PUE (Phosphorus Utilization Efficiency) are mainly due to the plant's ability to take up P from the soil and the effectiveness of allocation of P within the plant for biomass production, often known as external and internal PUE.

As phosphorus is tangled in many aspects of the plant's metabolism, a broad array of functional traits is expected to be involved in PUE. P scavenging and uptake can be improved by increasing transport capacity and allocation within the plant (Wang *et al*., 2010).Therefore, the presented study is of great concern to identify rice genotypes with proper plant type which can thrive under low phosphorus by enhancing the phosphorus utilization efficiency.

## MATERIALS AND METHODS

The experiment was carried out in the Stress Physiology Laboratory, Assam Agricultural University, Jorhat in the year 2017-18.The experimental site is located at 26°452 N latitude, 94°122 E longitude having an elevation of 87m MSL. Eight different rice genotypes were selected based on results of the earlier screening experiment (un published data). Experiment was arranged in factorial layout with genotypes as one factor and P level as another factor comprising of three replicates. Eight different genotypes *viz.* Kasalath (check), Ronga Ahu, Bizary, Sesapal, Amo Amkel, Bijor, Maipholong, Haringajali were collected from the different places of Assam. Treatments consisted of three levels of P level *viz*. $T_1$ = 0 % P +100% N+ 100% K; $T_2$ = 50% P+ 100% N+ 100% K; $T_3$ = 100% P + 100% N+ 100% K. Sterilized field soil was used to germinate the rice seeds of different lines in the earthen pots (15cm height and 15cm in diameter) filled with soil. Then the pots were fertilized according to the treatments mentioned. Intercultural operations were carried out to keep the experimental area weed and pest free. Irrigation and pesticide application were done as and when required. Three observational plants were tagged at random per treatment for studying the various morpho-physiological, biochemical characteristics. Only the physiologically active leaves were used for studies and four leaves from different plants were sampled each time. Plant height, tiller number hill$^{-1}$, number of leaves hill$^{-1}$ were counted during the maximum tillering stage. Shoot dry weight was calculated by uprooting the plant and dried in an oven at 80$^o$C until a constant weight was attained. Shoot biomass was recorded at harvesting stage using an electronic balance and was expressed in g plant$^{-1}$. Specific leaf weight was calculated by method suggested by Pearce *et al*. (1968). Phosphorus content (%) in grain and straw was determined by Vandomolybdo method as suggested by Jackson (1973). Phosphorus use efficiency was calculated at flowering stage by the formula suggested by Goodroad and Jellum (1988).

PUE= Grain yield (g plant$^{-1}$) X Total plant phosphorus (%) /100

Phosphorus uptake was calculated by following formula given by Goodroad and Jellum (1988).

PU= Grain yield (g) X Total plant phosphorus (%).

## RESULTS AND DISCUSSION

### *Morphological characters*

Significant variation amongst the genotypes and treatments were recorded in plant height, tiller number hill$^{-1}$ and number of leaves hill$^{-1}$. There was significant difference in above parameters due to the interaction (Table 1,2,3). Amongst the morphological parameters, it was recorded that plant height, tiller number hill$^{-1}$,and number of leaves hill$^{-1}$ under full dose of P was higher than that of low and moderate dose of phosphorus. Under low phosphorus, maximum reduction of plant height, tiller number and number of leaves was observed in genotypes Sesapal, Bijor, Haringijali and Bizary. On the other hand, the least reduction was observed in Maipholong, Kasalath and Ronga Ahu. Reduced tiller number and plant height was also noted in rice cultivars under low P availability (Vejchasarn *et al*., 2016). According to Sato *et al*., (1996), reduction in number of leaves per hill$^{-1}$ might be due to reduction in tiller numbers. Lynch *et al*.,(1991) reported that the reduction in leaf number was a result of reduced tiller number under low P condition which is in conformity to our result.

Production of the protein basically depends upon presence of P as it is a constituent of phospholipids, nucleic acid, and phytin so adequate amount of phosphorus is necessary for protein metabolism for growth and development of the plant Our results are in conformity with Rupesh (2014). In our study, a reduction in leaf number under low P might be a consequence of reduced number of tillers as reported by Lynch *et al*., (1991). Sato *et al.* (1996) also reported reduction in number of leaves per hill$^{-1}$ due to reduction in tiller numbers.

### *Shoot dry weight*

A significant decrease in shoot dry weight was also observed under low and moderate phosphorus levels. Significant: variation was recorded in shoot dry weight due to the genotypic variation (Table 4). Amongst the different genotypes, the highest shoot dry weight was recorded in Maipholong followed by Kasalath and least shoot dry weight was observed in Sesapal. The reduction rate of shoot dry weight under low P was noted in Kasalath and Maipholong. Source and sink of

**Table 1: Variation in plant height (cm) in rice line/ cultivar under three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| **0%** | 65.94 | 54.34 | 54.06 | 64.63 | 49.75 | 52.33 | 52.81 | 53.93 | 55.97 |
| **50%** | 68.17 | 68.01 | 63.21 | 69.42 | 54.40 | 56.11 | 56.24 | 56.74 | 61.41 |
| **Full Dose** | **75.50** | **74.49** | **73.48** | **76.42** | **70.12** | **71.77** | **72.82** | **73.19** | **73.60** |
| **Mean** | **69.87** | **65.61** | **63.58** | **70.16** | **58.09** | **60.07** | **60.63** | **61.29** | |
| | | | | **SEd** | | **CD (0.05%)** | | | |
| **T** | | | | 0.598 | | 1.208 | | | |
| **G** | | | | 0.977 | | 1.973 | | | |
| **TXG** | | | | 1.893 | | 3.821 | | | |

**Table 2: Variation in tiller number hill$^{-1}$ in rice line/cultivar under three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| **0%** | 15.33 | 12.66 | 12.33 | 14.66 | 9.33 | 10.66 | 11.33 | 11.66 | 12.33 |
| **50%** | 17.33 | 15.85 | 15.67 | 18.42 | 12.00 | 13.33 | 14.67- | 15.33 | 15.32 |
| **Full Dose** | 19.33 | 18.66 | 17.67 | 20.46 | 15.66 | 16.33 | 18.00 | 18.33 | 18.05 |
| **Mean** | 17.33 | 15.72 | 15.22 | 17.85 | 12.33 | 13.44 | 14.66 | 15.11 | |
| | | **SEd** | | | | **CD (0.05%)** | | | |
| **T** | | 0.358 | | | | 0.722 | | | |
| **G** | | 0.584 | | | | 1.179 | | | |
| **TXG** | | 1.011 | | | | NS | | | |

**Table 3: Variation in number of leaves hill$^{-1}$ in rice line/ cultivar under three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| **0%** | 68 | 53.33 | 52 | 63.66 | 46.33 | 46.66 | 48 | 51.00 | 53.625 |
| **50%** | 75.66 | 71.33 | 67.33 | 80.33 | 57.66 | 58.66 | 62 | 64.667 | 67.208 |
| **Full Dose** | 84.00 | 83.33 | 82.33 | 85.667 | 77.00 | 79.33 | 80.66 | 81.667 | 81.875 |
| **Mean** | 75.88 | 69.33 | 67.22 | 76.556 | 60.333 | 61.556 | 63.556 | 65.77 | |
| | | | **SEd** | | | | **CD (0.05%)** | | |
| **T** | | | 0.801 | | | | 1.617 | | |
| **G** | | | 1.308 | | | | 2.641 | | |
| **TXG** | | | 2.265 | | | | 4.574 | | |

**Table 4: Variation in shoot dry weight (g plant$^{-1}$) in rice line/ cultivar under three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| **0%** | 34.253 | 28.033 | 28.29 | 29.71 | 26.29 | 26.587 | 26.74 | 27.89 | 28.47 |
| **50%** | 37.913 | 36.61 | 36.617 | 40.80 | 34.867 | 34.933 | 35.43 | 36.58 | 36.73 |
| **Full Dose** | 46.88 | 47.29 | 46.55 | 48.71 | 45.413 | 45.793 | 46.01 | 46.377 | 46.62 |
| **Mean** | 39.68 | 37.64 | 37.15 | 40.11 | 35.52 | 35.77 | 36.06 | 36.94 | |
| | | | | **SEd** | | | | **CD (0.05%)** | |
| **T** | | | | 0.092 | | | | 0.185 | |
| **G** | | | | 0.15 | | | | 0.302 | |
| **TXG** | | | | 0.259 | | | | 0.523 | |

**Table 5: Variation in specific leaf weight (g cm$^{-2}$) in rice line/ cultivar under three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 5.40 | 4.30 | 4.24 | 4.48 | 3.11 | 3.16 | 3.16 | 3.17 | 3.88 |
| 50% | 5.63 | 4.62 | 5.82 | 6.79 | 4.74 | 4.85 | 4.93 | 5.05 | 5.30 |
| Full Dose | 6.67 | 6.89 | 6.85 | 6.99 | 6.49 | 6.52 | 6.58 | 6.62 | 6.70 |
| Mean | 6.03 | 5.66 | 5.64 | 6.09 | 4.78 | 4.84 | 4.76 | 4.95 | |

| | SEd | CD (0.05%) |
|---|---|---|
| T | 0.03 | 0.06 |
| G | 0.048 | 0.097 |
| TXG | 0.084 | 0.169 |
| TXG | 3.233 | 6.529 |

**Table 7: Variation in phosphorus content in plant (%) of different rice genotypes in three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 0.034 | 0.027 | 0.025 | 0.030 | 0.021 | 0.018 | 0.020 | 0.026 | 0.024 |
| 50% | 0.042 | 0.042 | 0.039 | 0.044 | 0.033 | 0.035 | 0.037 | 0.039 | 0.039 |
| Full Dose | 0.045 | 0.048 | 0.047 | 0.047 | 0.039 | 0.044 | 0.045 | 0.043 | 0.45 |
| Mean | 0.040 | 0.038 | 0.037 | 0.409 | 0.031 | 0.032 | 0.034 | 0.034 | |

| | SEd | CD (0.05%) |
|---|---|---|
| T | 0.206 | 0.415 |
| G | 0.336 | 0.678 |
| TXG | 0.582 | 1.175 |

**Table 8: Variation in phosphorus use efficiency (%) of different rice genotypes in three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 0.175 | 0.164 | 0.154 | 0.171 | 0.140 | 0.145 | 0.148 | 0.154 | 0.156 |
| 50% | 0.185 | 0.183 | 0.177 | 0.188 | 0.16 | 0.17 | 0.175 | 0.176 | 0.176 |
| Full Dose | 0.197 | 0.194 | 0.193 | 0.199 | 0.172 | 0.189 | 0.192 | 0.193 | 0.191 |
| Mean | 0.185 | 0.180 | 0.174 | 0.186 | 0.157 | 0.168 | 0.171 | 0.174 | |

| | SEd | CD (0.05%) |
|---|---|---|
| T | 0.001 | 0.003 |
| G | 0.002 | 0.004 |
| TXG | 0.004 | 0.008 |

P depend upon the acquisition pattern in the plant system. Accumulation of more P in the shoots can be considered as strong sink which is involved in production of more Pi required for phosphorylation in photosynthesis (Rao and Terry, 1995; Louw-gaume *et al.*, 2010). Root traits determine phosphorus acquisition efficiency. Such traits are selected for rice breeders for higher productivity in low phosphorus soils (Vejchasarn *et al.*, 2016). Under sufficient P condition, plants are evolved to have more influx rate of P into shoots than roots (Cogliatti and Santa Maria, 1990; Burleigh and Harrison, 1999; Raghothama, 1998).

***Specific leaf weight (SLW)***

It was evident from our experiment that Maipholong could maintain the highest specific leaf weight when compared to other genotypes including check genotype Kasalath (Table 5). A greater specific leaf weight in Maipholong might be due to greater thickness of mesophyll cell layer thereby increasing its

**Table 9 : Variation in phosphorus uptake (g ha$^{-1}$) of different rice genotypes in three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 3.38 | 2.79 | 2.63 | 3.10 | 1.86 | 2.12 | 2.19 | 2.33 | 2.55 |
| 50% | 4.30 | 4.22 | 3.99 | 4.61 | 3.33 | 3.55 | 3.81 | 3.93 | 3.96 |
| Full Dose | 4.89 | 4.80 | 4.75 | 5.09 | 4.05 | 4.48 | 4.56 | 4.48 | 4.64 |
| Mean | 4.19 | 3.94 | 3.79 | 4.27 | 3.08 | 3.38 | 3.52 | 3.58 | |

| | SEd | CD (0.05%) |
|---|---|---|
| T | 0.049 | 0.100 |
| G | 0.08 | 0.163 |
| TXG | 0.139 | 0.281 |

**Table 10: Variation in number of filled grain panicle$^{-1}$ of different rice genotypes in three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 91.00 | 73.00 | 71.33 | 82.33 | 60.66 | 65.00 | 69.867 | 70.33 | 72.91 |
| 50% | 94.66 | 92.33 | 91.33 | 101.00 | 76.66 | 80.00 | 87.33 | 88.66 | 89.00 |
| Full Dose | 124.33 | 123.00 | 122.33 | 132.00 | 108.00 | 112.66 | 121.00 | 121.66 | 120.62 |
| Mean | 103.33 | 96.11 | 94.99 | 105.11 | 81.77 | 85.88 | 92.66 | 93.55 | |

| | SEd | CD (0.05%) |
|---|---|---|
| T | 0.811 | 1.638 |
| G | 1.324 | 2.675 |
| TXG | 2.294 | 4.633 |

**Table 11: Variation in grain yield ( g plant$^{-1}$) of different rice genotypes in three different P levels**

| Treatment | Kasalath | Ronga Ahu | Amo Amkel | Maipholong | Sesapal | Bizary | Bijor | Haringajali | Mean |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 19.34 | 16.98 | 17.13 | 18.14 | 13.35 | 14.66 | 14.81 | 15.21 | 16.20 |
| 50% | 23.24 | 22.98 | 22.53 | 24.58 | 20.75 | 20.84 | 20.81 | 21.40 | 22.14 |
| Full Dose | 24.88 | 24.743 | 24.58 | 25.58 | 23.54 | 23.68 | 23.72 | 23.22 | 24.24 |
| Mean | 22.49 | 21.57 | 21.41 | 22.76 | 20.05 | 19.73 | 20.11 | 19.11 | |

| | SEd | CD (0.05%) |
|---|---|---|
| T | 0.171 | 0.345 |
| G | 0.279 | 0.564 |
| TXG | 0.484 | 0.976 |

photosynthetic rate. Maintenance of photosynthetic rate in the genotype Maipholong and Kasalath might be attributed towards maintenance of SLW under low phosphorus condition. Kirschbaum and Tompkins (1990) also reported photosynthesis and leaf growth rate as processes that are sensitive to phosphorus nutrition.

**Phosphorus content in plant, Phosphorus use efficiency (PUE) & Phosphorus uptake**

A significant difference in P content of plant, phosphorus uptake and phosphorus use efficiency has been observed due to the P treatments. Genotypic variation was also noted in terms of P content in plants, PUE and Phosphorus uptake (Table 6, 7 and 8). Highest reduction of phosphorus content, phosphorus uptake efficiency and phosphorus use efficiency were observed in Haringajali, Sesapal, Bizary and Bijor. Comparatively, Maipholong, Kasalth and Ronga Ahu were reported least reduction under low level of P. In our present study, the P content might have increased due to increase in root and shoot growth of the plant. Our results revealed improved uptake of phosphorus ion under full dose of P and an increase in phosphorus content in grain and straw. The results are in accordance with findings of Ali. *et al.* (2006) and Rao and Shukla (1999). In our study, a significant variation in PUE and phosphorus uptake has been observed amongst the genotypes. Genotype Kasalath, Maipholong and Ronga Ahu showed higher PUE which might be due to their ability to mobilize more P from older senescent leaves to the younger leaves. Improved uptake of phosphate from soil enhances the P efficiency and improve productivity per unit P taken up (P-use efficiency) (Veneklass *et al*., 2012). The efficient utilization of P depends upon recycling of P from mature and senescing part to actively growing tissue. The phosphates stored in vacuoles could be re-used when needed for other metabolic process. Akhtar *et al*., (2008) found high PUE in *Brassica* cultivars due to internal phosphate mobilization to active non-mature plant parts. Higher PUE in plant might be achieved by higher P uptake. Organic acids also have some indirect role in P utilization in the plant. Similarly micro organisms have a great role in P uptake which link to the exudation of the organic acids which affect the microorganism population and help in the nutrient mobilization (Jia *et al.,* 2011)

Vance *et al*., 2003 also reported that some enzymes like ribonucleases and acid phosphatases are more expressed under low P exudates which help to release phytate as fixed in organic form.

In plant cell membranes high-affinity transporters transport proteins located, which might be playing a pivotal role for uptake of the released P from the soil . So up-regulation of this mechanism is important at low soil P condition.

In barley, Huang *et al*. (2011) reported that there was correlation between expression of low-affinity PTs and non-coding RNA, IPS1 and P utilization efficiency and thereby increase the transfer of nutrient form shoot to grain . In our study also higher PUE has been attributed to improving the yield attributing traits in low P tolerant genotypes which might be due to translocaton of more P from vegetative part to reproductive parts.

### *Yield attributing traits*

In our experiment, an increase in number of filled grain/ panicle and grain yield has been observed at full dose of P (Table 9, 10) The reason behind this might be due to increase in phosphorus level. The increase might be linked to the more uptake of P in high PUE genotypes by improving the yield attributing characters as P being an integral component of nucleic acid phospholipids.

The increase might be linked to the more uptake of P in high PUE genotypes by improving the yield attributing characters as P being an integral component of nucleic acid phospholipids. Phosphorus plays an important role in primordial development and as well as it is a constituent of vast majority of enzymes which involved in fat and carbohydrate metabolism. Therefore, P has a greater role for enhancing the yield in the field condition (Rupesh, 2014).

Phosphorus plays a crucial role in translocation of photo assimilates from source to greater sink like panicle and also important constituent of protoplasm (Ishizuka, 1971). In our study, the longer panicle and higher grain number at full dose of P might be due to phosphorus nutrients. A significantly positive correlation have been observed between PUE utilization and grain yield (Fageria *et al*, 2013). Hence it can be confirmed that by increasing phosphorus levels enhanced grain yield can be obtained.

Kasalath and Maipholong recorded higher number of filled grain and ultimately higher grain yield when compared to other genotypes. They could maintain a higher yield even under low P levels as compared to other genotypes. These genotypes also recorded higher P content under various P levels, indicating that they have high P uptake and PUE. Alam *et al*. (2009) reported that correlation exists between Phosphorus nutrition and grain per panicle. According to Alam *et al*., (2009), phosphorus acts as limiting factor for grain filling.

Various workers like Wang *et al*., (2016) reported that P remobilization from matured leaf to grain might be involved up regulation of some specific gene and at that time of P starvation was noticed in vegetative growth that may be linked with remobilization process from vegetative to reproductive growth. Variability in rice grain yield has been attributed to increase in tiller number, shoot dry weight and panicle number (Fageria *et al*., 2013).

Plants grown under low phosphorus, might have affected the photosynthetic processes in the plant, since phosphorus is the key element in photophosphorylation for production of ATP and reduction of NADPH in light reaction of photosynthesis. This energy is involved in photosynthetic carbon reduction (PCR) processes where photosynthates are produced. Moreover, phosphate bind to sugars, provides energy to make total soluble solids, which ultimately help in biomass production of the plant. In our study, reduction in yield attributing characters in genotypes like Sesapal and Bizary might be due to poor availability of assimilates due to inefficient photosynthetic process. This might be the probable reason for lower grain yield in Sesapal and Bizary. Our results are in accordance with the findings of Reich *et al*. (2009).

During grain filling increase photosynthesis might be the reason for maintaining the source sink relation under increased level of phosphorus as described by number of workers in rice like Place *et al.* (1970) Samonte *et al*. (1998) and Krishna *et al*. (2008). Our study suggests that the genotype Kasalath, Maipholong and Ronga Ahu could be the option to be grown in farmer's field under phosphorus deficient soil.The better performance of the genotypes *viz*. Maipholong, Kasalath and Ronga Ahu could be further incorporated in various plant breeding programmes for identifying the *PHT 1* genes involved.

## REFERENCES


Akhtar M.S.; Oki Y. and Adachi T. 2008. Intraspecific variations of phosphorus absorption and remobilization, P forms, and their internal buffering in Brassica cultivars exposed to a P-stressed environment. *J. Integr. Plant. Biol*. 50: 703-716

Alam, M.M.; Ali, M.H.; Ruhul, A.K.M. and Hasanuzzaman, M. 2009. Yield attributes, yield and harvest index of three irrigated rice varieties under different levels of phosphorus. *Advances in Biological Research*. 3(3-4): 132-139.

Ali, T.; Kirmani, N.A.; Sofi, J.A. and Chesti, M.H. 2006. Critical limit of phosphorus for rice in some alfisols of Kashmir. *Journal of Soils and Crops.* 16(1): 33-36.

Burleigh, S.H. Harrison M.J. 1999.The down regulation of Mt4-like genes by phosphate fertilization occurs systematically and involves phosphate translocation to the shoots. *Plant Physiol*.119: 241-248.

Chakravarty, D.N. and Majumdar, N.N. 1971. A study of phosphate status of Assam soils ll. Fractionation of inorganic phosphorus.*Indian J. agrie. Chem*. 4:51-55.

Cogliatti, D.H. and Santa Maria, G.E. (1990). Influx and efflux of phosphorus in roots of wheat plants in non-growth-limiting concentrations of phosphorus. *J. Exp. Bot*. 41: 601-7.

Delhaize, E., Taylo, P., Hocking, P.J., Simpson, R.J., Ryan P.R. and Richardson, A.E. 2009.Transgenic barley (*Hordeum vulgare* L.) expressing the wheat aluminium resistance gene (TaALMT1) shows enhanced phosphorus nutrition and grain production when grown on an acid soil. *Plant Biotechnol J*. 7: 391-400

Fageria, N.K. 1994. Soil acidity affects availability of nitrogen, phosphorus and potassium. *Better Crops International*. **10**: 8-9.

Frydenvang, J., van Maarschalkerweerd, M. and Carstensen, A. 2015.Sensitive detection of phosphorus deficiency in plants using chlorophyll a fluorescence. *Plant Physiol.* **169**: 353-361.

Ha, S. and Tran, L.S. 2014. Understanding plant responses to phosphorus starvation for improvement of plant tolerance to phosphorus deficiency by biotechnological approaches.*Crit. Rev. Biotechnol.* **34**: 16-30.

Huang,C.Y., Shirley,N., Genc, Y., Shi, B. and Langridge, P. 2011. *Plant Physiology* , **156 (3)**: 1217-1229

Ishizuka, Y. (1971). Physiology of rice plant. *Advs. Agro*.; **23**: 241-315.

Jia, H., Ren, H. and Gu, M. 2011. The phosphate transporter gene OsPht1; 8 is involved in phosphate homeostasis in rice. *Plant Physiol.* **156**: 1164-1175.

Kirschbaum, M.U.F. and Tompkins, D. 1990. Photosynthetic responses to phosphorus nutrition in Eucalyptus grandis seedlings. *Australian Journal of Plant Physiology*. **17**: 527-535.

Krishna, L.; Raju, C.D. and Raju, C.S. 2008. Genetic variability and correlation in yield and grain quality characters of rice germplasm. *The Andhra Agric. J*., **55(3)**: 276-279.

Louw-gaume, A.,Idupulapati, M.R., Gaume, A. and Frossard, E. 2010. A comparative study on plant growth and root plasticity responses of two Brachiaria forage grasses grown in nutrient solution at low and high phosphorous supply. *Plant Soil* **328:**155-164.

Lynch, J., Lauchli, A. and Epstein, E. 1991. Vegetative growth of common bean in response to phosphorus nutrition. *Crop Science*. **31**: 380-387.

Marschner, H. and Rimmington, G. 1988. Mineral nutrition of higher plants. *Plant Cell*

Mullins, G. 2000. Phosphorus, Agriculture and The Environment: 2-4.

Ngachan, S.V., Mohanty, A.K. and Pattanayak, A. 2006. Rice in North East India: 1-3.

Place, G.A., Sims, J.L. and Half, V.L. 1970. Effect of nitrogen and phosphorus fertilization on growth, yield and cooking characteristics of rice. *Agronomy Journal*. **62(2)**: 239-243.

Raghothama, K.G. 1998. Tomato phosphate transporter genes are differentially regulated in plant tissues by phosphorus. *Plant Physiol*. **116**: 91-99.

Rao, C.P. and Shukla, D.N. 1999. Yield and nutrient uptake of rice (*Oryza sativa*) as influenced by sources and levels of phosphorus and zinc under transplantedconditions. *Indian Journal of Agronomy.* **44 (1)**: 94-98.

Reich, P.B., Oleksyn, J. and Wright, I. 2009. *J. Oecologia.* **60**: 207.

Rupesh, M.K. 2014. Effect of phosphorus levels and bio-organic sources on growth and yield of rice (*Oryza sativa* L.) M.Sc.(ag) thesis submitted to Banaras Hindu University, Vanarasi, India.

Samonte, S.O.P.B., Wilson, L.T. and McClung, A.M. 1998. Path analysis of yield and yield related traits of fifteen diverse rice genotypes. *Crop Science.***38**: 1130-1136.

Sato, A., Oyanagi, A. and Wada, M. 1996. Effect of phosphorus content on the emergence of tillers in wheat cultivars. *Japan Agricultural Research Quarterly*. 1: 27-30.

Sharma, S.N.; Prasad, R.; Shivay, Y.S.; Dwivedi, M.K.; Kumar, S. and Kumar, D. 2009. Effect of rates and sources of phosphorus on productivity and economics of rice (*Oryza sativa*) as influenced by crop-residue incorporation. *Indian Journal of Agronomy.* 54 (1): 42-46.

Shivay, Y.S., Singh, S. and Shivakumar, B.G. 2002. Response of transplanted rice (*Oryza sativa*) to phosphorus and zinc fertilization. Extended summaries 1:563-564 2nd International Agronomy congress, New Delhi.

Silva, J. A., Evensen, C. I., Bowen, R.L., Kirkby R., Tsuji, G.Y. and Yost R.S. 2000. Managing Fertilizer Nutrients to Protect the Environment and Human Health. *PlantNutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture* : 7-22.

Stewart, W., Dibb, D., Johnston, A. and Smyth, T. 2005. The contribution of commercial fertilizer nutrients to food production. *Agron. J.* 97 : 1-6.

Swaminathan, K. and Sud, K.C. 1976. Studies on the equilibria of nutrient elements in Gamma-lrradiated soils. I. Phosphate availability and reversion of applied phosphate in gamma irradiated hill soils. *J.lndian Potato Assoc*. 3:6-13.

Vance, C.P., Uhde-Stone, C. and Allan, D.L. 2003. Phosphorus acquisition and use: critical adaptations by plants for securing a non-renewable resource. *New Phytol.*157 : 423-447.

Veneklass, E., Lambers, H., Brag J., Finegan P., Lovelock, C, Plaxton, W., Price, C., Scheible, W. R., Shane, M. W., White, P. and Raven, J. 2012. Opportunities for improving phosphorus-use efficiency in crop plants. *New Phytologist* 195 (2): 306-20.

Wang, F., Rose, T., Jeong, K., Kretzschmar, T. and Wissuwa, M. 2016. The knowns and unknowns of phosphorus loading into grains, and implications for phosphorus efficiency in cropping systems. *Journal of Experimental Botany*. 67: 1221-1229.

Wang, X., Yan, X. and Liao H. 2010. Genetic improvement for phosphorus efficiency in soybean: a radical approach. *Ann. Bot*. 106: 215-222.

Yosef, T.S. 2012. Effect of nitrogen and phosphorus fertilizer on growth and yield rice (*Oryza Sativa* L). *International journal of Agronomy and Plant Production* 3(12): 579-584.