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Dry Matter Partitioning and Harvest Index Differ in Rice Genotypes with Variable Rates of Phosphorus and Zinc Nutrition

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Abstract: Phosphorus (P) and zinc (Zn) deficiencies are the major problems that decrease crop productivity under rice-wheat cropping system. Field experiments were conducted to investigate impacts of P (0, 40, 80 and 120 kg/hm^2) and Zn levels (0, 5, 10 and 15 kg/hm^2) on dry matter (DM) accumulation and partitioning, and harvest index of three rice genotypes 'fine (Bamati-385) vs. coarse (F-Malakand and Pukhraj)' at various growth stages (tillering, heading and physiological maturity). The experiments were conducted at farmers' field at Batkhela in Northwestern Pakistan for two years in summer 2011 and 2012. The two year pooled data reveled that there were no differences in percent of DM partitioning into leaves and culms with application of different P and Zn levels, and genotypes at tillering. The highest P level (120 kg/hm^2) partitioned more DM into panicles than leaves and culms at heading and physiological maturity stages. The highest Zn level (15 kg/hm^2) accumulated more DM and partitioned more DM into panicles than leaves and culms at heading and physiological maturity stages. The hybrid rice (Pukhraj) produced and partitioned more DM into panicles than F-Malakand and Bamati-385 at heading and physiological maturity stages. Higher DM accumulation and greater amounts of partitioning into panicles at heading and physiological maturity stages was noticed with increase in P and Zn levels, and the increase was significantly higher in the coarse rice genotypes than fine. We concluded that the growing hybrid rice with application of 120 kg/hm^2 P + 15 kg/hm^2 Zn not only increases total DM accumulation and partitioned greater amounts into the reproductive plant parts (panicles) but also results in higher harvest index.

Key words: dry matter partitioning; growth stage; harvest index; phosphorus level; rice; zinc level

Rice (*Oryza sativa* L.) is the staple food of mankind and provides 35%–60% of the dietary calories consumed by three billion people, making it inarguably the most important crop worldwide (Confalonieri and Bocchi, 2005). The demand for increasing rice production is particularly urgent, because the population of traditional rice-producing countries will require 70% more rice by 2025 (IRRI, 1995; Swaminathan, 2007). Phosphorus (P) and zinc (Zn) deficiencies are two of the most important nutritional constraints to rice growth (Ismail et al, 2007). Zn is absorbed by plants as cations (Zn^{2+}) and P is taken up by plants as phosphate anions ($H_2PO_4^{1-}$ or HPO_4^{2-}). These cations and anions attract each other, which facilitates the formation of chemical bonds that can form within the soil or the plant. If excess P binds a large quantity of Zn normally available to the plant, the result can be a P-induced Zn deficiency. This generally results in reduced shoot Zn concentration and reduced growth (Marschner, 2002). Fertilizers are a costly input, such that their use limits the profitability of rice farming for high- or low-input systems, and the use of fertilizers for these two rice nutrients is extremely inefficient (Rose et al, 2013). About the interaction of Zn and P, numerous studies have been done and all confirms that Zn and P imbalance in the plant, as a result of excessive accumulation of P, causing Zn imposed

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deficiency (Cakmak, 2000; Das et al, 2005; Gobarah et al, 2006; Alloway, 2009; Khorgamy and Farnia, 2009; Salimpour et al, 2010). Next to nitrogen (N) and P deficiency, Zn deficiency is now considered as the most widespread nutrient disorder in lowland rice (Quijano-Guerta et al, 2002; Singh et al, 2005). High soil pH appears to be the main factor associated with the widespread Zn deficiency in the calcareous soils of the Indo-Gangetic plains of India and Pakistan (Tahir et al, 1991; Qadar, 2002). The yield of rice is an integrated result of various processes, including canopy photosynthesis, conversion of assimilates to biomass and partitioning of assimilates to grains (Weng and Chen, 1984; Wu et al, 1998; Ying et al, 1998). Studies on Zn and P interaction and their impact on dry matter (DM) accumulation and partitioning into leaf, culm and panicle at different growth stages and harvest index (HI) of lowland rice are scanty. The hypothesis was tested that there is no difference in the DM accumulation and partitioning into various plant parts at different growth stages (tillering, heading and physiological maturity), and the HI of lowland rice genotypes when applied with variable rates of P and Zn.

MATERIALS AND METHODS

Experimentation

Field experiments were conducted to investigate the impact of different P (0, 40, 80 and 120 kg/hm^2) and Zn levels (0, 5, 10 and 15 kg/hm^2) on HI, DM accumulation and partitioning of three lowland rice genotypes 'fine (Bamati-385) vs. coarse (F-Malakand and Pukhraj)'. The experiments were carried out at farmers' field at Batkhela (34°37′0″ N, 71°58′17″ E), Malakand Agency Northwestern Pakistan during summer in 2011 and 2012. The experiments were conducted in the randomized complete block design with split-plot arrangement using three replications. Combination of three rice genotypes and four P levels (12 treatments) was allotted to main plots, while four Zn levels were allotted to subplots. A sub-plot size of 12 m^2 (3 m × 4 m) having 300 hills per subplot, and hill to hill distance of 20 cm apart was used. A uniform dose of 120 kg/hm^2 as urea and 60 kg/hm^2 SOP (sulphate of potash) or MOP (muriate of potash) were applied to all treatments. All potassium, P (triple super phosphate) and Zn (zinc sulphate) were applied at the time of transplanting, while N (urea) was applied in two equal splits, i.e. 50% each at transplanting and 30 d after transplanting. The amount of sulfur was maintained constantly in the Zn applied plots by adding additional sulfur using SOP. All subplots were separated by about 30 cm ridges to stop movement of water/nutrients among different treatments. Water to each treatment was separately applied from water channel.

Site description

The soil of the experimental site was clay loam, slightly alkaline in reaction (pH, 7.3), non-saline (ECe, 1.02 dS/m), moderately calcareous in nature ($CaCO_3$, 7.18%), low in soil fertility containing less organic matter (0.71%), extractable P (5.24 mg/kg) and Zn (0.93 mg/kg). The soils in Northwestern Pakistan are pedocal, a dry soil with a high concentration of calcium carbonate and a low content of organic matter, which are characteristic of a land with low and erratic precipitation in the region (Khan, 2010).

Data recording and handling

Data were recorded on DM accumulation and partitioning at tillering, heading and physiological maturity stages, and HI. At each growth stage, five hills (plants) within each treatment were harvested. Leaves, culms and panicles were separated, dried in paper bags and weighed by an electronic balance, and then average data (g/hill) on dry weights of leaf, culm and panicle were calculated. Total dry matter (TDM) was calculated as sum of the dry weights of the plant components. At harvest maturity, an area of 4 m^2 (2 m × 2 m) within each treatment of rice crop was harvested, and the material was sun-dried up to a constant weight, weighed and then converted into biological yield (biomass) (kg/hm^2). The harvested material for biomass yield was threshed. The grains were separated and weighed, and then converted into grain yield (kg/hm^2). HI was calculated according to the following formula: Harvest index (%) = Grain yield / Biological yield × 100.

Statistical analysis

Data were subjected to analysis of variance according to the methods described for the randomized complete block design with split plot arrangement combined over the years (Steel et al, 1996), and means between treatments were compared with the LSD (least significant difference) test ($P \leq 0.05$) using Statistic 8.1 (Analytical Software, Tallahassee, USA).

RESULTS

Dry matter partitioning into culms

At the tillering stage, the culm dry matter (SDM) was significantly affected by P and Zn levels, genotypes