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Impact of Nitrogen, Phosphorus and Potassium on Brown Planthopper and Tolerance of Its Host Rice Plants

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Abstract: The brown planthopper (BPH), *Nilaparvata lugens* (Stål), appeared as a devastating pest of rice in Asia. Experiments were conducted to study the effects of three nutrients, nitrogen (N), phosphorus (P) and potassium (K), on BPH and its host rice plants. Biochemical constituents of BPH and rice plants with varying nutrient levels at different growth stages, and changes in relative water content (RWC) of rice plants were determined in the laboratory. Feeding of BPH and the tolerance of rice plants to BPH with different nutrient levels were determined in the nethouse. Concentrations of N and P were found much higher in the BPH body than in its host rice plants, and this elemental mismatch is an inherent constraint on meeting nutritional requirements of BPH. Nitrogen was found as a more limiting element for BPH than other nutrients in rice plants. Application of N fertilizers to the rice plants increased the N concentrations both in rice plants and BPH while application of P and K fertilizers increased their concentrations in plant tissues only but not in BPH. Nitrogen application also increased the level of soluble proteins and decreased silicon content in rice plants, which resulted in increased feeding of BPH with sharp reduction of RWC in rice plants ultimately caused susceptible to the pest. P fertilization increased the concentration of P in rice plant tissues but not changed N, K, Si, free sugar and soluble protein contents, which indicated little importance of P to the feeding of BPH and tolerance of plant against BPH. K fertilization increased K content but reduced N, Si, free sugar and soluble protein contents in the plant tissues which resulted in the minimum reduction of RWC in rice plants after BPH feeding, thereby contributed to higher tolerance of rice plants to brown planthopper.

Key words: *Nilaparvata lugens*; relative water content; host tolerance; nitrogen; phosphorus; potassium; rice; nutrient subsidy

The brown planthopper (BPH), *Nilaparvata lugens* (Stål) (Homoptera: Delphacidae), is a major insect pest of rice in Asian countries, causing heavy crop damage through ‘hopper burn’ (Bottrell and Schoenly, 2012; Ali et al, 2014). Nutrition management is one of the most important practices for high production system, but it may affect on host-insect interaction. Insect behavior and life parameters are affected by environmental factors, such as temperature, moisture, habitat morphological and chemical components of host plants, especially by the nutrients, such as nitrogen, sugars, amino acids and semio-chemicals in host plants (Fischer and Fiedler, 2000), and plant water content is another important factor (Slansky and Rodriguez, 1987). Several studies have indicated the importance of host plant quality on herbivorous insects (Awmack and Leather, 2002; Bado et al, 2002). Abiotic heterogeneity through crop nutrition can affect the susceptibility of plants to insect pests by altering plant tissue nutrient levels (Altieri and Nicholls, 2003) and morphology (Moon and Stiling, 2000). Excessive and/or inappropriate use of inorganic fertilizers can

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cause nutrient imbalances and lower pest resistance (Altieri and Nicholls, 2003; Marazzi et al, 2004). Outbreaks of planthopper populations are sensitive barometers of crop mismanagement (Sogawa et al, 2009).

Nitrogen (N) content is regarded as an indicator of plant quality and also one of the most important performance limiting factors of herbivores (Lu and Heong, 2009). N application is reported to induce succulence in rice plants which makes them more prone to insect pests (Salim, 2002b). Heavy applications of N fertilizer may not affect insect biology directly but change the host-plant morphology, biochemistry and physiology, which can improve nutritional conditions for herbivores (Bernays, 1990), thus playing a key role in modifying and reducing host resistance to them (Barbour et al, 1991). N limitation is well documented in insect herbivores, but phosphorus (P) limitation is poorly studied (Huberty and Denno, 2006), although insect herbivores require not only N but also P to synthesize their proteins (Sterner and Elser, 2002). P is required for ATP and nucleic acid synthesis (RNA and DNA), and thus protein production (Sterner and Elser, 2002). As a result, its limitation can impose severe consequences for cellular function and ultimately the growth rate of consumers (Elser et al, 2000; Sterner and Elser, 2002). P limitation has been documented widely in many species of aquatic invertebrates, particularly in *Daphnia* (Elser et al, 2001). Potassium (K) has a critical role in plant physiology (Wyn Jones, 1999). In rice, K provides regulatory control over different processes like transpiration, starch synthesis, sucrose translocation, respiration and lipid synthesis (Tisdale et al, 1985). K nutrition has a profound effect on the profile and distribution of the primary metabolites in plant tissues. Changes in metabolite concentrations induced by K are multiple and it includes K dependence of metabolic enzymes, photosynthesis and long-distance transport. The primary metabolites such as soluble sugars particularly reducing sugars, organic acids and amino acids tend to increase in K deficient plants (Amtmann et al, 2008). Approximately 60 enzymes have been shown to depend on K *in vitro* for their activities, many of which are involved in sugar or N metabolism (Wyn Jones and Pollard, 1983). It is also important to note that a direct effect of K nutrition on enzyme activity occur only if cytoplasmic K concentrations are changed (Amtmann et al, 2008). Because of efficient cellular K homeostasis (Walker et al, 1996), a decrease of cytoplasmic K concentration can be expected to occur only during prolonged K deficiency (Wyn Jones, 1999). It was reported that plant damage by insect is comparatively less in K applied plants due to reduced carbohydrate accumulation, elimination of amino acids (Baskaran et al, 1985), higher silica content and increase in the sclerenchymous layer (Dale, 1988). The mechanism of rice plants damaged by BPH through hopper burn is similar with that of drought stress which is closely related to the relative water content (RWC) of plants. Typical RWC in rice plants at wilting is in the range of 60% to 70% (Lu et al, 2004).

Host plant tolerance to BPH is an important issue for management of BPH. A little information is available on the effects of N, P and K on biochemical composition of BPH and its host rice plants. Information on the relationships between biochemical compositions of rice plants and its tolerance to BPH particularly in reference to different nutritional status is also very limited. We studied the effects of three major plant nutrients i.e. N, P and K on the biochemical compositions of both BPH and its host rice plants, feeding of the insect, fluctuations of RWC in plants, and tolerance of plants to the pest BPH.

MATERIALS AND METHODS

Preparation of soil and host plant establishment

The potted plants of different nutrient levels were prepared separately for the experiments at nethouse of Bangladesh Rice Research Institute, Gazipur, Bangladesh. Pot soil was fertilized with three levels of each nutrient: N (0, 100 and 200 kg/hm^2), P (0, 20 and 40 kg/hm^2) and K (0, 60 and 120 kg/hm^2) and combination of all the levels. The soil was slightly acidic (pH 5.3), low organic carbon (0.72%) and deficient in N, P and K, where levels of all the three nutrients were below the critical level. Approxiamately 2 kg dry soil was taken in each pot with 16 cm height and 14 cm diameter. The exact amount of input fertilizers was calculated based on the amount of soil in each pot. Fifteen-day-old rice seedlings were transplanted (3 hills per pot and 2 seedlings per hill) in each pot. The rice variety BR3 was selected because of its year round growing habit and susceptibility to BPH. To obtain continuous supply of host plant materials for each BPH culture, the experiment seedlings were transplanted at a 15 d interval. Plants with different nutrient treatments were labeled and placed under natural condition in nethouse. All the factorial pot