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Plant nutrients and insects development

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Abstract
The insects possess a close and subtle relationship with their host plants. The growth, incidence, behaviour, physiology, ecology and other aspects of an insect life are in one way or another are correlated within the context of nutrition. The growth pattern, the anatomy and morphology, chemical composition and particularly the nutrition of plants may have an impact on the growth, survival and overall performance of the herbivorous insects. Moreover, the food quality of plants plays vital roles in mediating the foraging behaviour, growth and reproductive performance, as well as population dynamics of herbivorous insects. Similarly, poor plant nutrition can have an adverse effect on the performance and fitness of sap feeders. The present review of the work is to help understand earlier work done to generate information on the role of plant nutrients on insect development.

Keywords: nutrients, plants, insects, performance, development

Introduction

Plants provide food and shelter to majority of insects (Mello and Filho, 2002) [39]. Insects feeding on plants are herbivores (Douglas, 1993; Fraser and Grime, 1997; Carson and Root, 2000) [17, 21, 8]. Growth of plants as well as insects is interdependent in many ways (Panda and Khush, 1995) [43]. Development of plants depends on nutrient availability while that of insects depends on the quality of food available from its host plants (McGuinness, 1987; Gogi *et al*., 2012) [38, 23]. The insect-plant relationship may be affected by the application of micro/ macro-nutrients to crop plants (Abro *et al*., 2004) [1] as nutrient deficient plants are weak and vulnerable to incidences of plant disease and insect pest attack (Marschner, 1995; Huber and Thompson, 2007) [36, 25].

Nutrient management improves plant health, which enables the plant to tolerate the incidence of herbivores - sucking as well as chewing insect-pests (Gogi *et al*., 2012) [23]. The agricultural production continues to be constrained by a variety of biotic (e.g., pathogens, insects and weeds) and abiotic (e.g., drought, salinity, cold, frost and water- logging) factors that can significantly reduce the quantity and quality of crop production (Wang *et al*., 2013) [34].

The phloem-feeding aphids, whitefly or scale insects have all been charged with reducing the vigour of their host plants (Cottam, 1985; Cottam *et al*., 1986) [14, 15]. Increasing evidence suggests that mineral nutrients plays a critical role in plant stress resistance (Kant and Kafkafi, 2002; Cakmak, 2005; Amtmann *et al*., 2008; Romheld and Kirkby, 2010; Marschner, 2012) [29, 7, 3, 47, 37]. Earlier studies indicate that plants with sufficient nutrients are stronger, healthier, and in general better able to compensate for pest damage than those under nutritional deficiencies (Teetes, 1980; Listinger, 1993) [55, 33]. Since the plants provide nutrients to herbivorous insects, an increase in the nutrient content of the plant is likely to increase its acceptability to pest populations (Scriber, 1984; McGuinness, 1987) [48, 38].

Fertilizers not only improve crop yield, but also influence crop suitability for insect development, depending on the type of fertilizer and pest species (Van Emden, 1966; Wooldbridge and Harrison, 1968; Kogan, 1994) [57, 62, 31]. Marschner (1995) [36] reported that nutrition of plants has a substantial impact on the predisposition of plants to be attacked or affected by pests and diseases. By affecting the growth pattern, the anatomy and morphology and particularly the chemical composition, the nutrition of plants may contribute either to an increase or decrease of the resistance and tolerance to pests and diseases. Choudhary *et al*., (2001) [10] studied the incidence of *Lipaphis erysimi* and *Myzus persicae* on *Brassica* species at three NPK levels and reported that increasing the fertilizer level resulted in increased aphid incidence in all cultivars, except Ethiopian mustard, which was highly resistant to aphid at all fertilizer levels. Setamou *et al*., (1993, 1995) [49, 50] have demonstrated that damage to crops by insect pests increased with the application of fertilizers. The application of nutrients to the soil aids plants to produce more broad, succulent and fresh leaves (Jahn, 2004) [26] which could serve as suitable surfaces for egg-laying by the various pests. Embden (1973) [20] reported that essential amino acids in the plant sap are essential for growth and reproduction of aphids. Willings and Dixon (1987) [61] reported that phloem feeders adversely affect both growth and amino- Nitrogen profile of their host plants. Cook and Denno (1994) [13] reported that poor plant nutrition can have adverse effects on the performance and fitness of sap feeders.

Klingauf (1987) [30] reported that variation in dietary concentrations of amino acids and sucrose affects aphid growth, survival and reproduction. The plant nutrient status had positive effects on population dynamics of herbivores, which contribute to higher survival rates, longer adult longevity and reproductive periods (Bi *et al*., 2001), shorter pre-oviposition period (Metcalfe, 1970) [40], greater rate of eggs laid per day (Nevo and Coll, 2001) [42], fecundity

(Metcalfe, 1970; Nevo and Coll, 2001) [40, 42] and high population densities (Jansson and Smilowitz, 1986; Liu and Wang, 1989; Cisneros, 2001) [27, 34, 12]. Douglas (2003) [18, 59] reported that phloem sap is an extreme food source that is used as the dominant or sole diet of very few animals, specifically insects of the order Hemiptera, including aphids, whitefly, plant hoppers and some pentatomid bugs.

Nitrogen and phloem feeders

Nitrogen is one of the most important factors influencing the performance of herbivorous insects (Douglas, 1993) [17]. Nitrogen has been found to affect the reproduction, longevity and overall fitness of certain pests (Jahn, 2004) [26]. Synthetic fertilizer application, especially Nitrogen fertilizer resulted in the more serious insect herbivores occurrence and crop damage from these insects by reducing plant resistance (Bi *et al*., 2001; Ge *et al*., 2003). Bhinde (1993) reported that low Nitrogen contents in the plants enhance the resistance of plants against pests, but high Nitrogen contents cause vigorous growth along with consequent decrease in resistance against pests. Ahmed *et al*., (2007) [2] found that the highest rates of Nitrogen resulted in the highest per leaf mean population of jassid, whitefly and thrips.

The plant nutritional quality and defense mechanism against herbivores are altered by Nitrogen fertilization (Chen *et al*., 2008) [9] as it may affect incidences of pests and their natural enemies (Chen and Ruberson, 2008) [9]. Cisneros and Godfery (1998) [11] reported that Nitrogen affected the population dynamics of naturally occurring aphids with higher densities in plots receiving high Nitrogen rates. High levels of Nitrogen fertilization also appear to promote increased cotton aphid reproduction and the build-up of high in-field aphid populations (Godfery *et al*., 1999) [24].

Bi *et al*., (2003) in another study observed a positive response between Nitrogen application rates and the numbers of adult and immature whiteflies appearing during population peaks. Kumar *et al*., (1998) [32] concluded that mustard aphid infestation increased with increasing level of Nitrogen. According to Singh *et al*., (1995) [53] an increase in the level of Nitrogen application resulted in an increase in the infestation of *Lipaphis erysimi* on musturd. Ebert (1996) [19] reported that Nitrogen is taken up by plants in two different forms, nitrate or ammonium. The amino acid compositions were different among plants with different Nitrogen treatments, and amino acid content and carbohydrate-to-amino acid ratios were linked to changes in aphid development.

Coulibaly (1990) [16] reported that the increasing application of Nitrogen fertilizer reduced the fibre content in sugarcane and resulted in increased damage by the stem borer. Lu *et al*., (2007) reported that Nitrogen is one of the most important factors in development of herbivore populations. The application of Nitrogen fertilizer in plants can normally increase herbivore feeding preference, food consumption, survival, growth, reproduction, and population density. Prudic *et al*., (2005) [46] reported that plant nutritional quality and plant defenses that directly act on herbivores are altered by Nitrogen fertilization and herbivorous insects can distinguish between plants receiving different Nitrogen applications.

Van Emden (1966) [57] found that in 41 percent of studies he reviewed aphids responded positively to Nitrogen fertilization, in 36 percent they responded negatively and in 23 percent, there was no response. In a more recent review, Waring and Cobb (1992) [60] showed that in approximately 55 percent of the studies the response of sucking pests was positive due to Nitrogen fertilization and in 25 per cent there was no response. Scriber (1984) [48] while reviewing 50 years of research relating to crop nutrition and insect attack found 135 studies showing increased damage and/or growth of leaf-chewing insects or mites in Nitrogen fertilized crops, versus fewer than 50 studies in which herbivore damage was reduced by normal fertilization regimens.

Phosphorous and phloem feeders

Skinner and Cohen (1994) [54] reported that higher Phosphorous levels are associated with higher insect levels. Jansson and Ekbom (2002) [28] found that as Phosphorous fertilizer levels increased, the development time of aphid (*Macrosiphum euphorbiae*) shortened while the lifespan of adult and its number of offspring increased. Even though recent reports showed that, the application of Phosphorus reduced the population densities and damage of pod sucking bugs (Pitan *et al*., 2000) [45] and *Empoasca dolichi* Paoli (Shri Ram *et al.*, 1987, 1990) [51, 52], not much is known of its effects on other insect pests. Waring and Cobb (1992) [60] concluded that Phosphorous often does not influence sucking insects (about 48%) or influences them positively (approximately 38%).

Potassium and phloem feeders

Potassium has been considered a key component of plant nutrition that significantly influences crop growth and some pests infestation. Amtmann *et al*., (2008) [3] suggested that Potassium ion from soil supply may affect a number of physiological, metabolic and hormonal processes in plant tissues. These processes are likely to be crucial for plants susceptibility or resistance to pathogens and insects. Potassium fertilizer is negatively associated with occurrence of *Aphis glycines* (Myers and Gratton, 2006) [41], leafhoppers and mites (Parihar and Upadhyay, 2001) [44]. Potassium nutrition has a profound effect on the profile and distribution of primary metabolites in plant tissues, which in turn could affect the attractiveness of plant for insects and pathogens as well as their subsequent growth and development (Amtmann *et al*., 2008) [3].

Amtmann *et al*., (2008) [3] provide a potential mechanism to explain the relationship between Potassium deficiency and increased insect attack. Potassium deficiency results in reduced synthesis of proteins, starch, and cellulose, and increased accumulation of lower molecular weight compounds such as amino acids, nitrate, soluble sugars, and organic acids. These lower weight molecular compounds are more easily utilized as nutrient sources by sucking insects. Thus in other words, Potassium deficiency on its own may not correlate with higher insect attack, but the subsequent impact of Potassium deficiency on plants, makes plants more readily attacked by sucking insects. This is better explained by (Walter and DiFonzo, 2007) [58] who reported that low Potassium fertility was associated with high foliar levels of the amino acid serine and higher aphid infestations**.** Vaithillingan and Baskaran (1983) [56] reported that increase Potassium level led to accumulation of more phenols which probably contributed to increase insect resistance in some rice cultivars (Baskaran *et al*., 1982) [4]. Moreover, Potassium induced changes in rice plant had profound effect on insect- host interactions.

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