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Effect of plant nutrition in insect pest management: A review

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Abstract
Nutrition concerns the chemicals required by organism for its growth, tissue maintenance, reproduction and necessary to maintain these functions. It may determine resistance or susceptibility to pests. Among several plant nutrients, only 17 are essential for proper growth and development of plants and each nutrient plays important role in their growth. These nutrients are required by insects for their growth, tissue maintenance, reproduction and energy. They fulfill their requirements through feeding on plants. Nitrogen has positive effects on individual insect performance, probably due to deposition-induced improvements in host plant chemistry. These improvements include increased nitrogen and decreased carbon-based defensive compound concentrations. Potassium provides high resistance against insect–pests. High levels of potassium enhance secondary compound metabolism, reduce carbohydrate accumulation and plant damage from insect pests. Phosphorus also decreases the host suitability to various insect-pests. Secondary macronutrients and micronutrients like calcium, zinc and sulphur also reduce the pest populations. Among mineral elements, silicon is involved in plant resistance against insect pest damage. The indirect effects of fertilization practices acting through changes in the nutrient composition of the crop have been reported to influence plant resistance to many insect pests. The need for more healthful foods is stimulating the development of techniques to increase plant resistance to phytophagous insects.

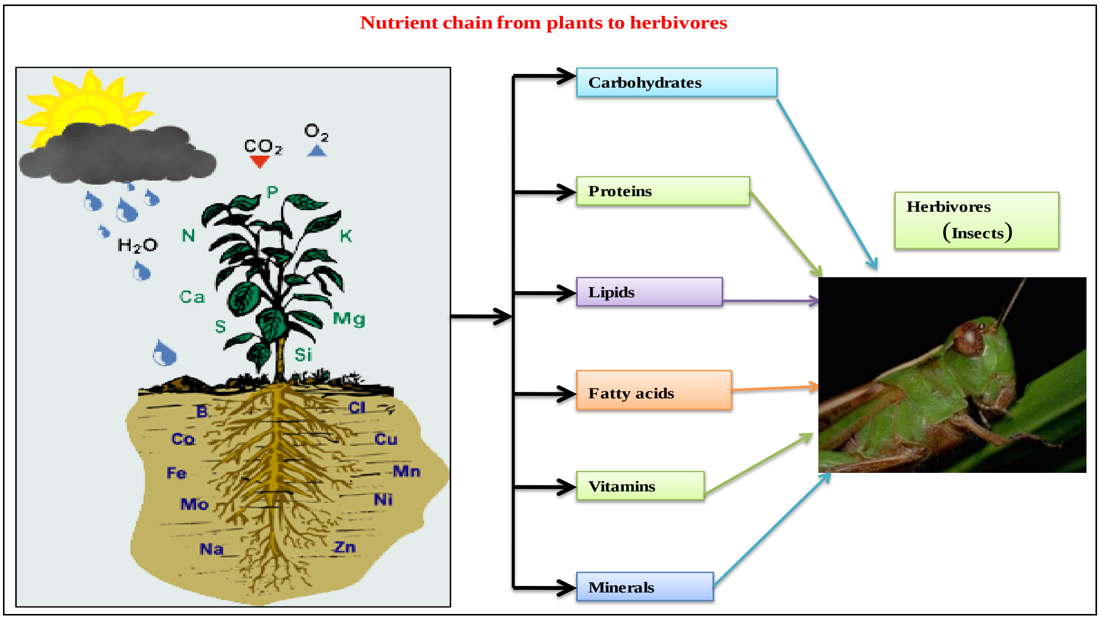
Keywords: management, plant nutrition, insect pest, tissue maintenance

1. Introduction

Terrestrial eukaryotic biodiversity is dominated by plants and the animals that eat them, the majority of which are insects (Simpson *et al.* 2015) [23]. Insect-pests are threat to agricultural productivity. They affect the crop yield, quality and aesthetic value. Nutritional quality of plant tissue is one of the main characteristics of host plant selection by phytophagous insects (Bernays and Chapman 1994) [6]. It has a substantial impact on the predisposition of plants to insect-pests. Unlike in human nutrition where the effect of nutrition on "health" has gained considerable importance, the implementation of "healthy" nutrition to improve resistance and tolerance of plants lags its potential.

Plant nutrition is a study that deals with plants' need for certain chemical elements including their specific and interactive effects on all aspects of plant growth and development, their availability, absorption, transport, and utilization. These chemical elements are referred to as plant nutrients. A plant nutrient is a chemical element that is essential for plant growth and reproduction. Essential element is a term often used to identify a plant nutrient. Plant nutrients can be classified on the basis of mineral composition, nutrients concentration and on the basis of their physiological functions. Besides carbon, hydrogen and oxygen, which plants obtain from carbon dioxide and water, 14 nutrients are recognized as essential viz., primary macronutrients (nitrogen, phosphorus and potassium), secondary macronutrients (calcium, magnesium and sulphur) and micronutrients (iron, manganese, zinc, copper, boron, molybdenum, chlorine and nickel) for growth of plants. The relative availability of various nutrients affects the growth and fitness of herbivores, whose biomass generally contains much greater concentrations of elements as compared to plants (Boswell *et al.* 2008) [7]. Qualitative nutritional requirements of insects include carbohydrates, proteins, amino acids, fatty acids, minerals and vitamins. Insects get their nutrients from plants through feeding.

2. Insect Nutrition is the science that interprets the interaction of nutrients and other substances in food in relation to maintenance, growth, reproduction, health and disease of an organism. It includes food intake, absorption, assimilation, biosynthesis, catabolism and excretion.



3. Nutritional Requirements of Insects:

Carbohydrates	Dietary carbohydrates are used principally as sources of energy, for fat and glycogen synthesis. Sugars constitute the sole food of certain adult insects play a role in feeding behavior and in orientation of certain phytophagous insects on the host plants
Proteins and amino acid	Enzymes, morphogenesis Eg: Tyrosine (*Cuticular sclerotization*), tryptophan (visual screening pigment)
Lipids	Fatty acids, phospholipids and sterols are the components of cell wall. Diacylglycerides, triacylglycerides and derivatives of polyunsaturated fatty acids important in reproduction. Acetyl choline and phosphatidyl cholines are the phospholipids. Insects get sterols by feeding on the plant tissue (cholesterol)
Vitamins	Water soluble vitamins, beta carotene, vitamin E, biotin, folic acid etc. Lack of Vitamin C results in abortive ecdysis and death.
Minerals	Important in hardening the cuticle of mandibles in many insects Eg: Fe, Zn, Mn etc.

4. Influence of nutrients on different pest groups

Table 4.1 Effects of Nitrogen on various aphid spp.

Hemiptera			
Insect	**Spp.**	**Effects**	**References**
Aphids	*Aphis gossypii*	Lowest mean generation time, highest finite rate of increase when fed on chrysanthemum fertilized at a 150% fertilizer level.	Rostami *et al.* 2011
	Macrosiphum euphorbiae	➢ Positive relationship of fecundity and survival with increase concentration of Nitrogen. ➢ Aphid performance was significantly lower on unfertilised plants with low Nitrogen content, suggesting a positive effect of nitrogen.	Johanna *et al.* 2009
	Cereal Aphid (*Metopolophium dirhodum)*	➢ Longevity was unaffected by the level of fertilization, but aphid intrinsic rate of increase and fecundity increased with each level applied. ➢ Aphids reared in the glasshouse lived longer than those reared in the field.	Gash 2012
	Myzus persicae	➢ Aphid population increased over time at the three intermediate N levels. It remained stable at the lowest N level and decreased at the highest N level. Four weeks after the start of infestation, the number of aphids displayed a parabolic response to N level.	Sauge *et al.* 2010

Effect of nitrogen on population growth parameters of insects:

Growth rate and Potential fecundity
Developmental time and Population density
Intrinsic rate of increase and Life expectancy
Finite rate of increase and Mean generation time

Nitrogen is the major nutrient required by insects and in most cases the main limiting factor for optimal growth of insects (Rostami *et al.* 2012) [19]. Application of nitrogen fertilizer normally increases herbivore feeding preference, food consumption, survival, growth, reproduction, and population density except in few instances where nitrogen fertilizer reduces the herbivore performance.

Influence of Nitrogen on different insects pests groups:

Hemiptera
Thysanoptera
Lepidoptera
Diptera

Table 4.2: Effects of Nitrogen on Thysanoptera, Lepidoptera and Coleoptera

Thysanoptera			
Insect	**Species**	**Effects**	**References**
Thrips	Western flower thrips (*Frankliniella occidentalis*)	Population increased on hosts receiving higher rates of nitrogen fertilization. Higher fertilization rates produced flowers that had higher nitrogen content as well as variations in amino-acid profiles during the period of peak thrips populations. Abundance of adult females were highly correlated to flower concentrations of phenylalanine during population peaks.	Chen *et al.* 2004

Lepidoptera			
Insect	**Spp.**	**Effects**	**References**
Borers and leaf folders	*Scripophaga incertulas* and *Cnaphalocrocis medinalis*	Highest incidence was recoreded in Punjab Bas-2 variety of rice with an increase in nitrogen level. Incidence of leaf folder and stemborer was increased with an increase in nitrogen level	Randhawa *et al.* 2013
Moths	Diamond back moth (*Plutella xylostella)*	The feeding preference on cabbage plant is increased due to excessive dose of nitrogen	Altieri and Nicholas 2003

Coleoptera			
Insect	**Spp.**	**Effects**	**References**
Beetle	*Lochmaea suturalis*	Destabilizing effect of nitrogen deposition on plant–herbivore interactions is the cause of a recent increase in frequency of periodic outbreaks.	Brunsting *et al.* 1982

Table 4.3: Effects of Nitrogen on Arachnida

Arachnida			
Nutrients	**Mite species**	**Crop**	**Numerical response of insects**
Nitrogen	*Panonychus ulmi*	Apple	Increase
Nitrogen	*Tetranychus telarius*	Apple	Increase
Nitrogen	*Tetranychus telarius*	Beans	Increase
Nitrogen, Phosphorus, Potassium	*Two-spotted spider mite*	Beans/peaches	Increase

Why nitrogen increases the population of insects?

Profuse plant growth due to high nitrogen fertilizer retards spray coverage. Excessive dose of nitrogen fertilizer produce lush green plants, which will attract pest population. Plants given nitrogen fertilizer increases plant dry weight, leaf area, leaf chlorophyll content and grain yield. Increase in nitrogen increases the biosynthesis or accumulation of proteins, free amino acid and sugars that might have attracted insects Eg: whitefly for feeding in okra. It was found that application of only nitrogen or higher dosage of nitrogen increased the aphid population while application of phosphorus and potash with or without combination of nitrogen reduced the population build up. However, application of 120 kgha-1 nitrogen increased the yield despite higher population. Jauset *et al.* (1998) [15] reported that the nitrogen content of plants was directly related to the level of nitrogen fertilization, and that it affected among and within plant distribution of *Trialeurodes vaporariorum* adults on tomato (*Lycopersicon esculentum*). Whitefly females aggregated, and laid more eggs, on leaves and on plants with the highest nitrogen and water content. It is believed that increased nitrogen in the plant nutrition can change the plant quality and also reduce the plant's resistance against aphids in cotton and similarly to this (Cisneros and Godfrey 1999) [12].

Management through Nitrogen

Less dose of Nitrogen increase the Chlorogenic acid which acts as a resistance factor in chrysanthemum plants e.g.- phenylpropanoids chlorogenic acid and feruloyl quinic acid present in higher amount in thrips-resistant chrysanthemums. Proper application of nitrogen fertilizers would be beneficial to manage insect herbivores such as cotton aphid. The optimal regime of nitrogen fertilizer in irrigated paddy fields is proposed to improve the nitrogen use efficiency and reduce the environmental pollution. Cotton aphid population density was significantly affected by interaction of nitrogen and potassium fertilizers in field experiments of two years, these results indicated that cotton aphid population density at seedling stage was suppressed by potassium fertilizer and the combination of potassium and nitrogen fertilizers in proper rate (K:N = 1:0.9 or 1:1.2 kg/ha). Suggesting that proper application of potassium and nitrogen fertilizers should be beneficial to controlling insect herbivores such as cotton aphid and plant growth at seedling stage of Bt-cotton field in Central China (Ai TC *et al.* 2011) [3]. Positive correlation between population growth rate of potato green peach aphid, *Myzus persicae* and concentrations of free amino acids in leaves of plants that received the nitrogen fertilization was rooted by (Jansson and Smilowitz 1986) [14].

5. Influence of phosphorus on insects:

Hemiptera

Thysanoptera

Phytophagous insects have a much higher nitrogen and phosphorus content than their host plants, an elemental mismatch that places inherent constraints on meeting nutritional requirements (Huberty and Robert 2006) [13]. Phosphorus application with or without combination of nitrogen reduced the population build up of mustard aphid. Population decreased significantly with increase in rate of application. At 40 and 60 kg/ha, grain yields were significantly higher than at the lower rates of application. High phosphorus application increased population growth of Brown planthopper. Bug densities decreased significantly with increase in rate of application. A strong trend towards increased population growth resulting from increased foliar

Phosphorus concentration. Increase in adults (females) number due to luxurious growth of plant due to Phosphorus. Phosphorus had a positive effect on several parameters of aphid performance.

5.1 Effect of Phosphorus on different insects

Hosts	Herbivore species	Factor	Response
Mustard	*Lipaphis erysimi*	Population	Decrease
Cowpea	*Clavigralla sp.*	Population	Decrease
Cotton	*Bemisia tabaci*	Incidence	Decrease
Cotton	*Empoasca sp.*	Population	Increase
Busy Lizzy	*Frankliniella occidentalis*	Population (Female Adults)	Increase

Management through Phosphorus

Phosphorus decreases the host suitability of potato plants against various insect-pests by changing secondary metaboiltes such as phenolics and terpenes and accumulation of phenolics (tannin, lignin) acts as barrier having deterring (antifeedent) or directly toxic(insecticidal) effects on herbivores (Facknath and Lalljee 2005) [10]. Phenolics interfere with digestion, slow growth, block enzyme activity and cell division. Terpenes like monoterpenes, sesquiterpenes, terpene polymers interefere with neural transmission, block phosphorylation and gum up insects. Excessive dietary P (1%) reduced growth and survival of some insects. Eg.- *Schistocerca Americana.*

Table 6.1: Influence of potassium on different aphids sp.

Host plant	Herbivore species	Factor	Response
Mustard	Mustard aphid (*Lipaphis eryisimi*)	Population	Decrease
Canola	Green peach aphid (*Myzus persicae*)	Population	Decrease
Wheat	Green bug (*Schizaphis graminum*)	Population	Decrease
Pea	Pea aphid (*Acyrthosiphon pisum*)	Number of nymphs/plant	Decrease
Cotton	Cotton aphid (*Aphis gossypii*)	Population	Decrease

6. Effect of potassium in different pest groups:

- Hemiptera
- Thysanoptera
- Lepidoptera
- Diptera
- Arachnida

Most indications (89%) concern five pest groups which are in order of importance Hemiptera, Lepidoptera, Arachnida, Coleoptera and Thysanoptera. The beneficial effect of potassium largely predominates in the case of plant hoppers and Coleoptera while for Lepidoptera and mites, numbers of indications of a depression or stimulation are similar. Potassium provides high resistance against insect–pests. High levels of potassium enhance secondary compound metabolism, reduce carbohydrate accumulation and plant damage from insect pests. A significant interaction between nitrogen and potassium levels was found in which the greatest increases of shoot and root dry matter with increasing N levels were found at the highest potassium level. High potassium application decreased population build up and dry weight of Brown plant hopper (Rashid *et al.* 2013) [18]. Incorporating potassium silicate into nutrient solutions did not confer resistance to pest populations developing on poinsettia leaves and applications of the silicon fertilizer failed to enhance the plant growth against *Trialeurodes vaporariorum*. The percent surviving larvae, their body weight and population of sugarcane borer (*Chilo suppressalis*), rice leaf folder (*Cnaphalocrocis medinalis*) decreased due to high potassium application.

Management through potassium

High dose of potassium decreases the nitrogen uptake. It adversely affects the biology and behavior of insects. Increase in potassium dose decreases intake and assimilation of food. Excessive amount of potassium causes quantitative changes in nutrients and allelochemicals. They strongly influence the chemical environment of the plant and play an important role in suppressing the population. High accumulation of potassium by crops during optimal growing conditions may be considered as an “insurance strategy” to enable the plant to better survive under sudden environmental stress.

7. Influence of secondary macronutrients and micronutrients

Besides primary macronutrients some secondary macronutrients and micronutrients also influence the pest population. Secondary macronutrients and micronutrients like Calcium, Zinc and Sulphur also reduce the pest populations. Among mineral element, silicon is involved in plant resistance against insect pest damage. High silica content in leaves of cotton plant reduces the spiny bollworm (*Earias insulana*) and (*Helicoverpa armigera*) infestation. The first report on Silicon increased plant resistance to an insect pest was associated with the rice stem borer (Sasamoto, 1953). Increase in number of applications of calcium silicate reduced thrips population due to mortality of nymphs in tomato. Silicon involved in plant resistance against insect pest damage via two major defense mechanisms:

- Physical defense
- Induced biochemical defense

It is deposited as *Opaline phytoliths* increasing hardiness and abrasiveness of tissues. It creates feeding deterrent which reduce the palatability and leaves no pesticide residue in food or the environment. It easily integrated with other pest management practices. It has prophylactic against a wide range of insect feeding guilds, including lepidopteran borers, folivores, phloem feeding insects and other plant feeders.

Keeping *et al.* (2012) [16] observed the effect of high silicon content on borers of sugarcane:

Table 7.1: Effect of silicon on Lepidoptera

Herbivores Species	Host	Factor	Response
Shoot borer (*Chilo infuscatellus*)	Sugarcane	% larval damage	Decrease
Stalk borer *(Eldana saccharina)*	Sugarcane	% larval damage	Decrease
Stem Borer *(Diatraea saccharalis)*	Sugarcane	% larval damage	Decrease
Rice stem borer *(Chilo simplex)*	Paddy	% larval damage	Decrease

Management through secondary macronutrients and micronutrients

Production of antibiosis effects like toxic metabolites (alkaloids, glucosides) and by inducing sufficiency of essential nutrients. Eg: Zinc and Iron content produces antibiosis effect in paddy against Brown plant hopper. With increase in Zinc and sulphur content the brown plant hopper population decreased. Application of silicon in crops provides a variable component of integrated management of insect pests and diseases because it leaves no pesticide residue in food or environment, and it can be easily integrated with other pest management practices. Almeida *et al.* (2009) [4] observed that increase in number of applications of calcium silicate reduced population thrips due to mortality of nymphs in tomato. Silicon reduced borer survival and percentage stalk length bored (Keeping *et al* 2012) [16].

Ma and Takahashi (2002) [17] reported that high mortality of larvae at higher rates of silica gel and high accumulation of silicon in the rice stems.

Table 7.2: Effect of silica gel in rice stems

Parameters	Amounts of silica gel supplied (g/pot)			
	0	1.5	4.5	6.0
SiO_2% in the stem	1.35	1.71	2.02	2.11
NLB	22	7	4	2
Amounts of faeces* (mg)	139	29	11	9

Forty-fourth instar larvae were incubated in each Petri dish containing 5 cut stems of various SiO_2 contents. Number of larvae which bored into the rice stems (NLB) were counted 24 h after inoculation (Ma and Takahashi, 2002).

8. Management through fertilizers

The indirect effects of fertilization practices acting through changes in the nutrient composition of the crop have been reported to influence plant resistance to many insect pests. Excessive and/or inappropriate use of inorganic fertilizers can cause nutrient imbalances and lower pest resistance (Rashid *et al.* 2016) [18]. Proper fertilization is necessary to give the plants a certain level of resistance against pests. Primary pest defense of plants like physical and biochemical properties can be enhanced by balanced fertilization with plant nutrients. It is concluded that when soil amendments such as poultry manure and inorganic fertilizers are applied to restore or increase fertility, pest control measures such as the use of chemical insecticides and other pest management options should be put in place to mitigate the effects of infestation of insect pests on crop productivity. Rising levels of available nutrients have altered the global nutrient cycle substantially with consequential changes in terrestrial and aquatic systems (Aber *et al.* 2003) [1].

Chatterjee *et al.* (2013) [8] observed that the use of inorganic fertilizers with FYM, vermicompost and biofertilizers reduces the whitefly incidence in tomato.

Table 8.1: Effect of inorganic fertilizers with FYM, vermicompost and biofertilizers

Treatments	Number of white flies leaf^{-1}		Fruit yield (t ha^{-1})
	30 DAT	45 DAT	
T_1-100% RDF (100 : 60 : 60 kg N P K ha^{-1})	2.86	2.67	15.42
T_2-100% RDF + 6 t ha^{-1} FYM + biofertilizer	2.38	2.24	21.67
T_3-100% RDF + 2 t ha^{-1} VC + biofertilizer	2.12	1.97	22.20
T_4-100% NPK + 3 t ha^{-1} FYM + 1 t ha^{-1} VC + biofertilizer	1.89	1.71	21.89
T_5 -75% RDF + 6 t ha^{-1} FYM	1.76	1.64	19.68
T_6 -75% RDF + 6 t ha^{-1}FYM + biofertilizer	1.69	1.58	20.23

9. Conclusion

Unlike in human nutrition where its effect on “health” has gained considerable importance, the implementation of “healthy” nutrition to improve resistance and tolerance of plants lags its potential. In modern agriculture, the most critical problem for increasing yield and developing sustainable agriculture is sufficient fertilizers supply and successful crop protection against herbivores. Herbivores are sensitive to alternation in host plant nutrition. Nutrient enrichment from agricultural and atmospheric sources has the potential to alter plant–insect interactions via changes in plant growth and defense. Optimized management of chemical fertilizers will be essential for achieving sustainability of intensive farming. If integrated crop production is to be extensively used in the future, a greater understanding of relationships among soil characteristics, fertilization practices, plant nutrient content and the ability of pests to reduce yield or crop quality will be required. The need for more healthful foods is stimulating the development of techniques to increase plant resistance to phytophagous insects.

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