Role of mineral nutrition in the management of pests in chilli

By

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DECLARATION

I, hereby declare that this thesis entitled **"ROLE OF MINERAL NUTRITION IN THE MANAGEMENT OF PESTS IN CHILLI."** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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- **Muphrys law**

INTRODUCTION

1. INTRODUCTION

Chilli (*Capsicum annum* L.), a tropical and sub-tropical crop of which, India is the largest producer, exporter and consumer in the world. In the Indian subcontinent, chillies are raised twice in a year both during the dry and wet season. Cultivation of chilli is mostly concentrated in the southern states viz., Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, occupying nearly 75 per cent of the total area under this crop in India (Subbiah and Jeyakumar, 2009). Out of this Andhra Pradesh stands first with 49 per cent area of the chilli. As per 2009 estimate average production of chilli in India was around 11.67 lakh tonnes from 7.5 lakh hectares according to 50-60 per cent share of the global production (Reddy, 2010).

Chilli is well-known for its pleasant aromatic flavour and pungency. It is widely used in pharmaceutical, culinary and beverage industries throughout the world. It is a condiment used for imparting pungency and colour to the food. It is rich in vitamin C, A, B, oleoresin and red pigment.

In order to compete in the international market India's productivity of chilli has to be increased to 5000 kgha^{-1} from the present level of 1500kg ha^{-1} (Reddy, 2010).

Cultivation of this "wonder spice" is limited by several factors, among them insect pests such as thrips (*Scirtothrips dorsalis* Hood), whiteflies (*Bemisia tabaci* Genn), aphids (*Aphis gossipii* Glover) and mites (*Polyphagotarsonemus latus* Banks) are of prime importance (Hosmani, 1993). These pests cause substantial yield loss either directly by sucking the plant sap or indirectly by transmitting viruses. Estimated yield loss due to chilli thrips and mites is 50 per cent (Ahmed *et al.,* 1987; Kandasamy *et al.,* 1990). The yield loss due to chilli mite can shoot up to 96.39 per cent (Borah, 1987) which usually cause complete crop failure (Kulkarni, 1922). Thrips accelerates crop loss during dry weather and cause yield loss of 30 to 50 per cent in South India (Varadharajan, 1994). Hence pest and disease management is one of the main areas of concern in chilli production. The increased use of pesticides and fungicides, have not only lead to the increase in the cost of production but have also resulted in pesticide-induced pest resurgence, residual effect, undesirable problems like destruction of natural enemies and failure of control strategies leading to outbreak of pests causing chilli leaf curl known as Murda disease complex.

Pesticide residues on chillies (Joia *et al*., 2001) are a major problem from the point of domestic consumption and exports. Various workers have reported pesticide residues in chillies growing in India (Nandihalli, 1979; Awasthi *et al*., 2001; Dhotre *et al.,* 2001). There are instances where chilli consignments from India were rejected by European countries due to residues of ethion, triazophos, chlorpyriphos, phosphamidon, cypermethrin, fenvalerate and dicofol (Sreenivasa Rao, 2005). Deviating from the scientifically validated Good Agricultural Practices (GAP) and excessive and unscientific use of pesticides leading to pesticide residue in the farm produce is a matter of concern.

Integrated pest management of any crop has its foundation on the Integrated Nutrient Management. Plants acquire resistance to pests and disease when adequate quantities of nutrient elements are given (Spann and Schumann, 2010). The use of mineral nutrients in the suppression of pest population was recognized long before itself and the evidences were reported by different researchers (Gogi *et al*., 2012; Habashy *et al*., 2010; Ebaid and Mansour, 2006; Ghallab *et al*., 2014; Sarwar, 2011; Basagli *et al.,* 2003; Horng *et al*., 1990; Najafabadi *et al*., 2011). When the cowpea was treated with NPK along with Ca and Mg according to the recommendation of POP, KAU, 2016 and three foliar application of mineral nutrients such as K, S, Cu, Zn, B and Si, pod borer infestation was observed to be at minimum percentage (Vishnupriya, 2017) The timing, amount, and type of mineral used can suppress or stimulate pest population, depending upon the pest species and the crop concerned.

Certain nutrients have the ability to help in the biosynthesis of secondary metabolites like polyphenol, alkaloids, terpenes, lignin, saponins, cyanogenic glucosides etc which protect the plant from herbivores and pathogen (Al-Humaid, 2005). Mineral elements particularly Mn, B, Zn, Cu and Fe increases alkaloids in plants (Lovkova, 2005) and thus protect plants from herbivores.

Balanced use of mineral nutrients will impart resistance to insect pest as well as improve the plant's health. Excess use of nitrogen provides excessive vegetative growth and increase the succulence of the plant, which may lead to increased pest damages. Similarly, deficiency of K can lead to accumulation of amino acids which in turn can increase the attack by insects (Marchner, 1995).

There is depletion of nutrients from agricultural lands and Kerala soils are inherently deficient in mineral nutrients (SSO, 2007). This may predispose the crops including chilli to pests and diseases, which necessitates supplementation of mineral nutrients. Supplementation of mineral nutrients in combating major pests of chilli needs to be elucidated. So a detailed study was undertaken with the following objective

- To evaluate the effect of mineral nutrients particularly K, Ca, Mg, S, Cu, Zn, B and Si in the management of major pest of chilli *viz* thrips (*Scirtothrips dorsalis* Hood), whiteflies (*Bemisia tabaci* Genn) and mites (*Polyphagotarsonemus latus* Banks)

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1. CHILLI

Chilli (*Capsicum annum L*) is an indispensable spice in the worldwide cuisine. Origin of chilli is said to be Latin American regions of the Mexico and Guatemala as wild crop around 7500 BC. By late 16th century chilli crop came to Asian continent when Portugal and Spanish explorers identified new sea routes.

Chilli has a complex pest spectrum of more than 293 insects and a mite species devastating the crop in the field and storage as well (AVRDC, 1987).

The major sucking pests of chilli are mite (*Polyphagotarsonemus latus* Banks), thrips (*Scirtothrips dorsalis* Hood) and whitefly (*Bemesia tabaci* Genn) (Berke and Shieh, 2000). Chilli mite, *P.latus* is a tiny spider-like creature found on the underside of the leaves in large numbers; both nymphs and adults suck the sap and devitalize the plants leading to severe malformation of leaves, rat tailing symptom, downward curling and stunting (Butani, 1976).

Chilli thrips, *S.dorsalis* is a polyphagous pest; both nymph and adult lacerate the leaf tissue and suck the oozing juice. Pest infestation increases with dry weather and the symptom shown by plant is upward curling, crinkling and brittleness (Butani, 1976).

Whitefly, *B.tabaci* damages the crops both directly and indirectly. In direct damage, the pest sucks the cell sap in the leaves which strip the plant of vital nutrients, resulting in the poor health and productivity. In indirect damage, the pest produces a honeydew secretion which leads to the growth of sooty moulds (Lopez and Cock, 1986).

2.2. SUCKING PESTS RESPONSE TO PLANT NUTRIENT CONCENTRATION

From the earlier decades onwards, studies have proved that nitrogen have a positive correlation to sucking pests. Most studies on edible crops show that with greater nitrogen fertilization, fecundity of *Tetranychus urticae* and *T. pacificus* (McGregor) increases (van de Vrie *et al.* 1972; Suski and Badowska, 1975; Wilson *et al.* 1988).

Wilson (1994) reported that the rate of reproduction of *T. urticae* is positively correlated with nitrogen levels in cotton. A study by Wermelinger *et al.* (1985) came to a conclusion that when female *T. urticae* was reared on the apple leaf disc fertilized with a low concentration of nitrogen, which lead to long pre-imaginal development time, pre-oviposition period, and decreased female weight, fecundity, and oviposition rate of the mites.

According to Bentz *et al.* (1995) sweet potato whitefly, *B. tabaci* showed more acceptability to Poinsettia, *Euphorbia pulcherrima* fertilized with ammonium nitrate than to unfertilized plants. The higher rate of oviposition by the whitefly was found on treated plants which indicate the acceptability in response to plant cues.

A similar effect was observed by Jauset *et al.* (1998) from the study on the effect of various doses of nitrogen (308 ppm, 140 ppm and 84 ppm) on oviposition and feeding site selection by greenhouse whitefly adults, *Trialeurodes vaporariorum* comprehended that plants fertilized with high nitrogen dose showed high oviposition and the adults preferred feeding on the upper leaf surface.

In a study by Huelsman *et al.* (2000) in Jamaican sweet potato, they found that at high nitrate and phosphorus levels in soil, the incidence of insect pest increases. Besides, there was a positive correlation between levels of phosphorous and chewing insect population.

Chau and Heinz (2006) concluded that fertilization at 50% of the recommended level (375 ppm N) reduced the mean rate of change in *Frankliniella occidentalis* abundance from 0.05 to 0.03 and mean number of thrips per plant by 44% in potted chrysanthemum.

Chow *et al.* (2008) conducted a study on optimizing fertilization and predator combinations for biological control of western flower thrips on cut roses. The result showed that, at 33% of the recommended level of fertilization (150 ppm N) there was enhanced biological control of *F. occidentalis* with the predatory mite *Amblyseius swirskii* (Anthias-Henriot).

Chow *et al.* (2009) conducted studies with the three levels of nutrients 33% (50 ppm N), 50% (75 ppm N), and 100% (150 ppm N) in the rose plant. The result indicated that the population of *T. urticae* became twofold on roses fertilized with 100 percent when compared to 33 or 50 percent of the recommended levels.

An experiment was conducted by Hosseini *et al.* (2010) to investigate the performance and population growth rate of cotton aphid in cucumber plant to different nitrogen levels (90, 110, 150 and 190 ppm) in the greenhouse. Among the different levels of nitrogen, level 190 ppm had aphids with significantly shorter development time and produced more progenies per capita when compared to the aphids grown up in lower nutrient levels.

An increase in nitrogen level enhanced the mite population on bean leaves (Najafabadi *et al.,* 2011).

According to Hosseini *et al.* (2015) reducing nitrogen, status is an effective method for pest management in floriculture plants. He studied the effect of different levels of nitrogen fertilizer (0, 30, 60, and 100% of recommended dose of 2 kg m^{-3}) on the biological parameters of *Aphis craccivora* (Hemiptera: Aphididae). The result indicated that the aphid population was the highest population in 100 percent of recommended nitrogen.

In contrast to the above aforementioned studies, there are also studies which show negative correlation of sucking pests with nitrogen.

English-Loeb (1990) is one of the studies that did not find the same response to nitrogen as the above studies. In this study, the fertility of the two-spotted spider mite was documented when feeding on bush beans induced with differing nitrogen concentrations. A total of 30 bean plants were used in experiment 1 and had six different nitrogen rates (105.0 ppm, 73.5 ppm, 42.0 ppm, 15.7 ppm, 5.2 ppm, and 0.0 ppm), experiment 2 consisted of 40 bean plants; 20 plants in each chamber were assigned five different rates (157.5 ppm, 105.0 ppm, 52.5ppm, 10.5 ppm, and 0.0 ppm), and the 3rd experiment consisted of 20 plants assigned to four different nitrogen treatments (105.0 ppm, 78.7 ppm, 31.5, and 0.0 ppm). The majority of all rates were below standard and so this study observed bean plants under nitrogen stress. Results found a non linear response, in that the intermediate treatments performed better than the high and low nitrogen concentration treatments.

Similar results were obtained when Park *et al.* (2009) conducted a study to find the influence of different concentrations of nitrogen fertilization on the cultivar preference, honeydew production and development by greenhouse whitefly, *T. vaporariorum* in two cherry tomato cultivars. The experiment exhibited a negative correlation between the nitrogen concentration and the developmental times of nymphs and eggs on both cultivars. The upper plant stratum was the preferred site for oviposition and the honeydew production of nymphs increased with decreasing nitrogen concentration.

Potassium helps plants resist drought and stress caused by excessive temperatures. Potassium also aids plants in the production of starches, regulate stomata opening and closing, and can help plants resist disease as well as pests . Potassium has the ability to regulate over 60 different enzyme systems in the plant and aids in the plants overall vigor. Potassium applied in adequate amounts has been known to promote the growth of plant fibers, creating long and strong shoots.

Harries *et al.* (1998) experimentally proved the efficacy of potassium (K) fertilizer in reducing the two-spotted spider mite infestation on cotton. Potassium has also been proved to improve the rice plant tolerance to adverse climatic conditions, lodging, insect pest and diseases (Tiwari, 2002).

Other researches also prove the resistance imparting nature of potassium such as in the study conducted by Sawar (2011), damage caused by larvae of rice stem borer could be recovered by the application of K fertilizer which in turn led to increasing yield and reduction in environmental pollution.

Khairnar and Patel (2015) reported that the application of potassic fertilizers at the rate of 40 and 60 kg/ha imparted host plant resistance against insect pests such as Aphid, Jassid, Whitefly and Thrips of cowpea, and also improved morphological characters such as plant height, number of leaves and stem thickness.

Study by Geddes (2010) did not reduce the pest population by imparting resistance instead increased the population. Application of potassium resulted in the highest density of mite eggs *Eutetranychus willamettei* (60.0 ± 18.0 mite eggs per leaf) and nitrogen (42.5 ± 13.4 mite eggs per leaf) in grapes The result was due the fact that potassium favoured Willamette spider mites and their survival, by providing a disease free, drought resistant plant. Their feeding presumably does not affect the plants health as quickly as it would without K because of the ability to resist stress and hence mite populations are therefore favored by this macronutrient.

Pest management can be done with the help of macronutrients combinations by inducing resistance, tolerance, improving plant health and compensating the loss caused by the infestation. Studies with combination of macronutrients and their effect on pests are as below

Abou-Awad (1980) reported that two applications of ammonium sulfate along with manganese sulfate at 30 or 20 ppm decreased the number of *Tetranychus urticae* in cotton plants during a field study.

Keeping and Meyer (2002) reported that fertilization of sugarcane plant with calcium silicate @ 10,000 kg/ha and 5000 kg/ha can impart a higher rate of resistance against the stalk borer *Eldana saccharina* than unfertilized plants.

Chen *et al.* (2007) studied the response of ivy geranium (*Pelargonium peltatum* (L.)) and the two-spotted spider mite to six different combinations of nitrogen (2, 8, 16, 24, and 32 mM (equivalent to 28, 112, 224, 336, and 448 ppm, respectively) and phosphorus (0.08, 0.32, 0.64, 1.28, and 2.56 mM (equivalent to 1.12, 4.48, 8.96, 17.92, and 35.84 ppm, respectively; conversion=1mM=14ppm). This study proved that pest suppression can be done by nutrient management and the macronutrients (N, P, and K) not only improves plant health but reduces the pest population as well.

A study was conducted by Zehnder and Hunter (2009) on milkweed plant to examine the impact of phosphorus and nitrogen on the growth rate of *Aphis nerii*. The study revealed that foliar nitrogen levels were increased with the addition of nitrogen and phosphorous @ 10 g/m^2 which cause a reduction in aphid performance. This indicates that excessive nutrient levels can reduce herbivore population growth rates whereas phosphorus concentration on leaf had no direct effect on insect performance.

When cabbage plants were treated with NPK fertilizers, they showed largest leaf damage (31 percent) compared to control (11 percent) with pests such as *Plutella xylostella, Brevicoryne brassicae, Hellula undalis* and *Pieris rapae* (Mochiah *et al.*, 2011).

2.3. EFFICACY OF MICRONUTRIENTS IN PEST MANAGEMENT

Micronutrients are inherently deficient in most of the soils as a result their content in plant decreases. These micronutrients play an important role in producing the secondary metabolites which impart resistance in plants against diseases and pests. The reviews below mentions some of the research works on the role of micronutrients in pest management.

The experiment conducted by Beanland *et al.* (2003) to understand the growth and developmental performance of three soybean pests; soybean looper (*Pseudoplusia includens*), Mexican bean beetle (*Epilachna varivestis* Mulsant), Velvetbean caterpillar (*Anticarsia gemmatalis* Hubner) fed with plants grown in hydroponic solution containing different proportions of Boron, Iron, Zinc reveals that all three insect species showed highest developmental performance when fed with plants grown in solutions without Boron.

Boric acid and Borates are naturally occurring compounds containing the element boron, recommended as least toxic pesticides for killing insects, mites, algae and fungi (Caroline, 2004).

Micronutrients like Zn 12%, Mn 12%, Fe 12%, Cu 12%, liquid Boron 6% along with plant growth regulators (GGR_6) and detergent imparts resistance against sucking pests (Aphids, Leafhoppers, Thrips etc.) and attract predaceous insects (lady beetle, lacewing and true spiders) on cotton plant (Ebaid and Mansour, 2006).

Tollett *et al.* (2008) conducted a study to assess the toxicity of cadmium, lead, and copper on dragonfly larvae and concluded that the high concentration of lead and cadmium has no insecticidal effect. On the contrary, an exposure to copper has shown a considerable decrease in the survival of larvae.

Treatment with zinc at 30 kg/ha noticeably minimised the infestation of stem borer in rice, while applied at 20-25 kg/ha exposed slightly more white head and dead heart incidence, but differed from unfertilized plot considerably (Shu *et al.*, 2009).

Habashy *et al.* (2010) made a comparative study on the effect of two rates of micronutrients in the management of aphids (*Aphis gossypii*) on strawberry plants. Foliar spray of Boric acid 85%, Borax 80%, Cupric oxide 79.5%, Magnesium sulphate 98% and Sulphur SC 7.5 % at 10 gm/L could reduce the population of *A. gossypii, T. urticae, T. tabaci* on strawberry plants in the greenhouse.

Dash *et al.* (2011) reported that when NPK 60: 30: 30 kg/ha was applied with the $ZnSo_4$ recorded minimum incidence of rice borer irrespective of rice varieties and insecticidal treatment.

A study was conducted by Gogi *et al.* (2012) to evaluate and compare the effect of two commercial nutrient formulations which contains N, B, Zn, P and K in the management of *B. tabaci* in Bt-cotton. They reported that nutrients like N, B, Zn, P and K have a significant role in imparting resistance to whitefly *B. tabaci* in Bt-cotton with N (80.62 %) giving maximum reduction in whitefly population followed by B (1.20 %), Zn (1.30 %), P (0.94 %) and K (0.1 %) and as a result, population of whitefly in treated plots ranged from 1.04 to 2.36 per leaf which is approximately 3.02 and 1.3 times less than control plots.

Comparative study on the effect of mineral nutrients in the management of sucking pests of bean plants shows maximum reduction in population density of sucking pests (*T. urticae, T. cucurbitacearum, B. tabaci,* and *T. tabaci)* when mixture of primary nutrients were applied initially followed by micronutrients (Zn, Mn, Fe, Cu, B, and Mo) and primary nutrients alone (Ghallab *et al.,* 2014).

Silicon fertilization of plants has proven to be effective in controlling insect herbivores and other arthropods. Way back in 1960 Miller *et al.* reported that

Hessian fly attack can be resisted by silica depositions on certain varieties of wheat plant tissue. Silica depositions in resistant varieties are more uniform and complete than those of susceptible varieties.

Similarly in 1961, Sasamoto found an increase in the silicon content of rice plants when silicon was additionally supplied in the soil which resulted in the lessening of susceptibility to the stem borer *Chillo suppressalis* Walker.

Pan *et al.* (1979) conducted an experiment where different forms of silicon including bagasse furnace ash and silica slag were applied which resulted in a reduction in the incidence of borer damage in Si-treated sugarcane.

According to Elawad *et al.* (1985) with improved silicon nutrition, there was an increase in sugarcane resistance to the stem borer *Diatraea saccharalis F.*

Asian corn borer (*Ostrinia furnacalis* Guenee) reared on an artificial diet containing 0, 1, 3, 5, and 10 percent silica displayed a negative correlation in fecundity, pupal weight, and reproductive rate. (Horng and Chu, 1990).

According to subsequent studies gave positive confirmation on the effect of silicon in increasing the resistance of sugarcane to the stalk borer (Anderson and Sosa, 2001).

According to Ma and Takahashi (2002), the number of larvae which bored into stem was negatively correlated with the silicon content of the rice stem.

Sodium silicate imparts resistance against green aphids (*Schizaphis graminum*) in wheat by reducing preference, longevity, and production of nymphs (Basagli *et al.,* 2003).

Application of silicon in crops provides a viable component of the integrated management of insect pests and disease because it leaves no pesticide residue (Laing *et al.,* 2006).

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A study was conducted by Korndorfer *et al.* (2011) to understand the effect of silicon on the nymphal mortality and longevity of males and females of spittlebug, *Mahanarva frimbiolata*. Spittlebugs were reared on two sugarcane cultivars SP79 -1011 and SP80-1876 and sprayed with potassium silicate. The cultivars SP79 showed highest silicon content on the leaves and recorded highest nymphal mortality and shortest female longevity.

De Toledo and Reis (2018) conducted a study to evaluate the effect of leaf spraying of potassium silicate (K_2SiO_3) to control the southern red mite in coffee plants. Plants were treated with different doses of potassium silicate (Dose 0 (control), 2, 4, 6, 8 and 10 liters of silicate potassium ha−1), regardless of the applied dose infestation of *Oligonychus ilicis* lowered compared to the control. The silicon content in leaves was higher in plants treated with the highest dose of potassium silicate.

2.4. ROLE OF ALKALOIDS IN PEST MANAGEMENT

Micronutrient application augments the production of alkaloids in plants that contain toxic substances which protect plants from insect attack (Peach and Tracy, 1953).

Reports of Buzuk (1986) suggested that micronutrients especially Zinc, Iron, and Copper increases alkaloids in plant tissue, which are toxic substances that protect plants from sucking pest attack.

Tannins impart resistance against whitefly in cotton with a negative correlation of r = - 0.7543 (Butter *et al.*, 1992).

Studies have shown that glandular trichomes contain a high concentration of phenol and alkaloids which enhanced their biochemical defense against insects (Oghiakhe *et al.,* 1992).

Hemming and Lindroth (2000) reported that phenolic glycosides diminished the performance of Gypsy moth larvae and Forest tent caterpillar in terms of long developmental time and reduced growth rates. When insects were reared on diets containing phenolic glycosides, the activity of midgut β-glucosidase was reduced.

Williams *et al.* (2002) studied the effect of lectin accumulation on the feeding site and reported that due to the accumulation of lectin, the larval attempt to establish a feeding site failed. The accumulation of a high mannose N-glycan-specific jacalin-like lectin occurs in resistant wheat plants due to the production of higher levels of *Hfr-1* transcripts (Hessian fly-responsive) when Hessian fly attack.

Resistance against pod bug in cowpea was acquired due to the presence ofcompounds such as Cyanogenic heteroside, Flavonoids, Tannins, and Trypsin in pod bug resistant variety (Dabire-Binso *et al.,* 2010).

According to Pyati *et al.* (2012), Aphids, when fed with a liquid diet containing HFR1 and HFR3, gave a significant reduction in the growth and survival. Moreover, HFR3 binds to the midgut of cereal aphids and the degradation by gut enzymes is stabilized up to 48 h.

In a study conducted by Frah *et al.* (2013), there was three percent increase in the mortality of *Aphis craccivora* when reared on diet containing 100 ppm of flavanoids whereas, 2.25 percent and 1.25 percent mortality on 150 and 200 ppm of flavanoids respectively.

The study of Atalah *et al*. (2014) proved that the pea aphid (*Acyrthosiphon pisum*) showed low LC50 value (79 μg/mL) for Orysata (mannose-binding lectin on a bioaasy), which indicate that lectin has a strong negative effect on pea aphid.

In strawberry plants when 100 percent recommended nitrogen fertilization was applied there was a considerable enhancement in the protein content and reduction in the production of phenol content. But with 80 percent fertilization, the protein content reduced and phenol content increased which is benificial for pest management (Alizade *et al.,* 2016).

2.5. ROLE OF ELEMENTS IN THE BIOSYNTHESIS OF THE ALKALOIDS

Elements such as Co, Ni, Zn, and Mn stimulated the synthesis and accumulation of alkaloids in the seedlings of periwinkle (Lovkova *et al*., 2005). The optimal concentration of Co, Ni, and Zn stimulating alkaloid production was 0.1 mM and this parameter for Mn was 0.001 mM. Increasing the concentration of Cu, Cr, B, Mo, and Fe enhanced the accumulation of alkaloids but this process was preceded by a decrease in the number of alkaloids in the seedlings below control.

The effect of compound fertilization in the alkaloid content and growth of datura plant was evaluated. Plants fertilized with N-20 per cent, P-20 per cent, K-20 per cent, S-0.4 per cent, Mg-0.4 per cent, Fe-17ppm, Zn-14 ppm, Cu-16ppm, Mn-42 ppm, B-22 ppm and Mo-14 ppm at 600 Kg/ ha was found to produce more alkaloid content and profuse growth when compared to 800 kg/ ha (Al-Humaid, 2005).

From the review it's clear that a few works have been done on role of mineral nutrition in the pest arrangement of crop. A comprehensive study in chilli on the nutrient management is lacking. Hence this study is of immense importance.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The research programme entitled "Role of mineral nutrition in management of pests in chilli." was undertaken at College of Agriculture, Padannakkad during 2017-2018. Two field trials were carried out in the field from August 2017 to February 2018 and November 2017 to May 2018. The details of the experiment are presented below.

3.1 POT CULTURE EXPERIMENT

The experiment was conducted in completely randomized design with 12 treatments and three replications. The plants were raised in 144 pots under three different nutrient regimes. Each nutrient regime contained 48 pots with single plant per pot. Four plants were maintained in each replication. Seedlings were transplanted after one month.

The potting mixture was prepared by mixing laterite soil, sand and cow dung in the proportion 1:1:0.5. Forty eight pots were maintained as non chemical nutrient regime (without application of NPK). NPK fertilizers such as Urea, Rajphos and Muriate of potash were added to another 48 pots filled with potting mixture. The remaining 48 pots were filled with potting mixture and NPK along with calcium carbonate and magnesium sulphate (as per Package of Practices recommendations, KAU (2016). The filled pots were kept for 2 weeks before sowing for proper solubilization of calcium carbonate. Details of the quantity of chemical fertilizers per pot were as follows:

Urea	- 3.3 g
Rajphos	- 4.5g
Muriate of potash	- 0.84g
Calcium carbonate	- 7g
Magnesium sulphate	- 1.16g

3.2.1 Design and Layout

Crop : Chilli

Variety : Ujwala

Design : CRD factorial

Treatments : 12 (2 factors 3+4 levels)

Replication : 3

3.2.2 Details of treatments

Factor 1: Soil nutrient level (3 levels)

P_1: Non chemical nutrient level (Potting mixture alone)

P_2: NPK nutrient level (Potting mixture with NPK)

P_3: NPK + Ca + Mg nutrient level (Potting mixture with NPK + Ca + Mg)

Factor 2: Foliar nutrition levels (4 levels)

F_0: No foliar nutrition

F_1: One foliar nutrition

F_2: Two foliar nutrition

F_3: Three foliar nutrition

Treatment combinations

T_1 (P_1F_0) - Potting mixture with no foliar nutrition

T_2 (P_1F_1) - Potting mixture + one foliar nutrition

T_3 (P_1F_2) - Potting mixture + two foliar nutrition

T_4 (P_1F_3) - Potting mixture + three foliar nutrition

T_5 (P_2F_0) - Potting mixture + NPK with no foliar nutrition

T_6 (P_2F_1) - Potting mixture + NPK + one foliar nutrition

T_7 (P_2F_2) - Potting mixture + NPK + two foliar nutrition

T_8 (P_2F_3) - Potting mixture + NPK + three foliar nutrition

T_9 (P_3F_0) - Potting mixture + NPK + Ca + Mg with no foliar nutrition

T_{10} (P_3F_1) - Potting mixture + NPK + Ca + Mg + one foliar nutrition

T_{11} (P_3F_2) - Potting mixture + NPK + Ca + Mg + two foliar nutrition

T_{12} (P_3F_3) - Potting mixture + NPK + Ca + Mg + three foliar nutrition

3.2.3. Details of foliar nutrition

Mineral nutrient mixture of potassium, calcium, silicon, boron, zinc and copper were applied as a foliar spray of 0.8 % at different time intervals. Mineral nutrients mixture for foliar application consist of boric acid – 0.2 %, Copper Sulphate – 0.2 %, and Zinc Suphate – 0.2 %. Potassium Silicate – 0.2 %.First foliar nutrition was applied 10 days after transplanting, second application after 30 days of first and third foliar nutrition 30 days after second foliar nutrition. Potassium Silicate was applied separately at an interval of 10 days after the application of the mineral nutrition each time .

3.2.4. Observations on damage of pests

The major pests on which observations were taken were thrips, *Scirtothrips dorsalis* Hood, whiteflies, *Bemisia tabaci* Genn. and mites, *Polyphagotarsonemus latus* (Banks).

3.2.4.1 Population densities of mites and thrips

For recording the incidence of thrips and mites, three leaves were taken from top, middle and bottom canopy of each plant, at biweekly intervals from the start of incidence of the pest and the count of pest load was taken with the help of stereo binocular microscope and the data were converted to $\sqrt{x} + 1$ transformed value and later subjected to two way analysis of variance.

3.2.4.2 Leaf curl index

Ten plants were selected randomly in each treatment and scored for leaf curling visually following the standard scoring procedure as described by Niles (1980) at biweekly intervals. Leaf curl index for mites and thrips were taken separately based on their symptom. Leaf curl index was calculated with the formula LCI = number of curled leaves / total number of leaves.

Table 1: Score chart for leaf curl index in chilli

Score	Symptoms
0	No symptoms
1	1 – 25% leaves / plant showing curling
2	26 – 50% leaves / plant showing curling moderately damaged
3	51 – 75% leaves / plant showing curling, heavily damaged, malformation of growing points, reduction in plant height.
4	More than 75% leaves/plant showing curling severe to complete destruction of growing point, drastic reduction in plant height, defoliation, severe malformation.

3.2.4.3 Evaluation of whitefly colonies

Numbers of whitefly colonies were taken by counting number of colonies under the leaf surfaces. Observation was taken at biweekly intervals after the incidence of the pest.

3.2.5. Biometric observations

Biometric observations such as number of leaves, plant height, length of fruits and days to flowering were taken. Number of leaves was recorded at biweekly interval; whereas the height of plant was taken at the end of season and expressed in centimeters. Mean length of the fruits were recorded by taking five randomly selected fruits from each replication.

3.2.6. Yield parameters

Yield parameters such as fresh weight of fruits (g/plant), marketable yield (g/plant) and plant dry weight (g/plant) were recorded.

3.2.7. Plant analysis

The plant samples were collected at the end of crop season and subjected to nutrient analysis for estimating the content of N, K, Ca, Mg, S, Cu, Zn, B and Si by using standard procedures given in the Table 2.

3.2.8. Soil analysis

Soil samples were collected from three different nutrient regimes before and after crop season. The samples were air dried, ground, sieved with 2mm sieve. They were analyzed for available mineral nutrients such as N, K, Ca, Mg, S, Cu, Zn, B and Si as per the standard procedures given in the Table 3.

3.2.9. Statistical analysis

Data collected from the pot culture experiment was tabulated and subjected to statistical analysis using analysis of variance (ANOVA).

Plate 1 : An overall field view of both the field trials

Table. 2 Analytical methods for plant nutrient analysis

Sl.No	Parameters	Method	Reference
1	Total N	Modified kjeldhal digestion method	Jackson (1958)
2	Total K	Flame photometry	Jackson (1958)
3	Total Ca	Atomic absorption spectroscopy	Issac and Kerber (1971)
4	Total Mg	Atomic absorption spectroscopy	Issac and Kerber (1971)
5	Total S	Turbidimetric method	Bhargava and Ragupathi (1995)
6	Total Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
7	Total B	Azomethane – H colorimetric method	Bingham (1982)
8	Total Cu	Atomic absorption spectroscopy	Emmel *et al.* (1977)
9	Available Silicon	Photoelectric colorimetry	Korndorfer *et al.*, 2001

Table 3. Analytical methods followed for soil nutrient analysis

Sl.No	Parameters	Method	Reference
1	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
2	Available K	Flame photometry	Pratt (1965)
3	Available Ca	Atomic absorption spectroscopy	Jackson (1958)
4	Available Mg	Atomic absorption spectroscopy	Jackson (1958)
5	Available S	Photoelectric colorimetry	Massoumi and Cornfield (1963)
6	Available Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
7	Available B	Photoelectric colorimetry	Bingham (1982)
8	Available Cu	Atomic absorption spectroscopy	Emmel *et al.* (1977)
9	Available Silicon	Photoelectric colorimetry	Korndorfer *et al.*, (2001)

RESULTS

4. RESULTS

Pot culture experiments were conducted at the instructional farm of College of Agriculture, Padannakkad to assess the role of various mineral nutrients like potassium, calcium, magnesium, sulphur, copper, zinc, boron and silicon in managing pests in chilli.

The observations on pests, yield and biometric parameters and plant and soil analysis were recorded, tabulated, analysed and interpreted statistically. The results are presented in this chapter.

4.1. INFLUENCE OF MINERAL NUTRIENTS ON MITE POPULATION

4.1.1. Population density of mites during first field trial

The effect of mineral nutrients in the development of mite population on leaves was evaluated and the populations were recorded as average mites per leaf the results are presented in the Table 4 and 5. Foliar application of nutrients was given 10, 40 and 70 days after transplanting. Observations were taken at biweekly intervals.

The data in the Table 4 showed that the population densities of mites were significantly influenced by the soil and foliar nutrition levels. From the table, it is evident that the NPK nutrient level P_2 had significantly higher population densities of mites throughout the season whereas it was minimum in the non chemical nutrient level without NPK (P_1). Throughout the growth phase the mite population decreased gradually.

On 45 days after transplanting (DAT), maximum mite population was observed in the NPK nutrient levels P_2 (30.10/leaf) which was significantly superior to the other soil nutrition levels. There was a gradual decrease in the population of mite in the later fortnights in the P_2 nutrient level. The maximum population of mites during the subsequent fortnights *viz.* 60 DAT, 75 DAT and 90 DAT are 28.18, 25.75 and 15.04 per leaf respectively belonged to the P_2 level.

Minimum mite population was obtained in the non chemical nutrient level P_1 on 45 DAT (7.93/leaf), 60 DAT (8.77/leaf) and 75 DAT (4.18/leaf). On 90 DAT the minimum population was found in NPK + Ca + Mg nutrient level P_3 (2.87/leaf).

Among the levels of foliar nutrition, highest population density was observed in third level of foliar nutrition on 45 DAT (47.11/leaf), 60 DAT (42.83/leaf), 75 DAT (33.63/leaf) and 90 DAT (20.27/leaf) whereas minimum mite population on 45 DAT (4.167/leaf), 60 DAT (3.44/leaf), 75 DAT (2.02/leaf) and 90 DAT (1.52/leaf) was recorded in plants where no foliar nutrition was given. The mite population first increased with the foliar applications and suddenly decreased after third level of foliar nutrition.

The interaction of the soil nutrient levels and the foliar nutrition levels in the table 5 showed a significant difference in the population densities of mites. The data obtained on 45 DAT, 60 DAT, 75 DAT and 90 DAT revealed that throughout the season the maximum mite population was recorded in T_7 (NPK nutrient level and two applications of foliar nutrition) i.e. 84.75, 82.25, 80.0 and 49.66 respectively.

From the result, it is evident that minimum mite population was recorded in T_2 (0.25) on 45 DAT which is on par with T_1 (1.00). On 60 DAT minimum mite population was obtained in T_2 (0.25), whereas on 75 DAT and 90 DAT no mite population was seen in T_1.

Mites harbouring on plants in soil nutrient level P_1 had a positive relation with the increase in levels of foliar nutrition with the exception of T_2 whereas in

P_2 and P_3 levels the mite population increases till third foliar nutrition level and then decreases.

Table 4. Mean population (mites per leaf) of chilli mites in soil and foliar nutrition levels during first field trial

Soil nutrition levels	Mean population of chilli mites			
	45 DAT	**60 DAT**	**75 DAT**	**90 DAT**
P_1	7.93 (2.63)	8.77 (2.76)	4.18 (1.98)	3.64 (1.88)
P_2	30.10 (4.95)	28.18 (4.72)	25.75 (4.31)	15.04 (3.30)
P_3	23.47 (4.38)	9.58 (2.76)	5.20 (2.09)	2.87 (1.78)
SE(m)	**0.06**	**0.063**	**0.036**	**0.033**
CD	**0.19**	**0.185**	**0.106**	**0.097**
Foliar nutrition levels	**Mean population of chilli mites**			
F_0	4.167 (2.16)	3.44 (2.00)	2.02 (1.61)	1.52 (1.50)
F_1	7.77 (2.60)	6.33 (2.34)	5.75 (2.21)	2.36 (1.70)
F_2	47.11 (6.53)	42.83 (6.26)	33.63 (5.08)	20.27 (4.00)
F_3	22.72 (4.66)	9.44 (3.07)	5.444 (2.27)	4.58 (2.08)
SE(m)	**0.07**	**0.07**	**0.042**	**0.038**
CD(0.05)	**0.22**	**0.21**	**0.122**	**0.112**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients; Figures in the parentheses are $\sqrt{x+1}$ transformed values ; n = 108 number of leaves

Table 5. Interaction effect of soil and foliar nutrition levels on the mean population of chilli mites (mites per leaf) during first field trial

TREAMENTS		Mean population of chilli mites			
		45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	1.00 (1.41)	1.41 (1.55)	0.00 (1.00)	0.00 (1.00)
T_2	P_1F_1	0.25 (1.11)	0.25 (1.11)	0.583 (1.25)	0.41 (1.18)
T_3	P_1F_2	11.91 (3.59)	14.83 (3.97)	2.33 (1.82)	1.83 (1.68)
T_4	P_1F_3	18.58 (4.42)	18.58 (4.42)	13.83 (3.85)	12.33 (3.65)
T_5	P_2F_0	8.58 (3.09)	7.58 (2.92)	5.25 (2.49)	3.83 (2.19)
T_6	P_2F_1	19.16 (4.49)	16.91 (4.23)	16.08 (4.13)	6.08 (2.66)
T_7	P_2F_2	84.75 (9.24)	82.25 (9.11)	80.00 (8.99)	49.66 (7.11)
T_8	P_2F_3	7.91 (2.98)	6.00 (2.63)	1.66 (1.63)	0.58 (1.25)
T_9	P_3F_0	2.91 (1.97)	1.33 (1.52)	0.83 (1.35)	0.75 (1.32)
T_{10}	P_3F_1	3.91 (2.21)	1.83 (1.68)	0.58 (1.25)	0.58 (1.25)
T_{11}	P_3F_2	44.66 (6.75)	31.41 (5.69)	18.58 (4.42)	9.33 (3.21)
T_{12}	P_3F_3	42.41 (6.58)	3.75 (2.17)	0.83 (1.34)	0.83 (1.34)
SE(m)		0.13	0.12	0.211	0.066
CD		0.38	0.37	0.072	0.195

T_1 : P.M (potting mixture) + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). Figures in the parentheses are $\sqrt{x+1}$ transformed values. n = 108 number of leaves

4.1.2. Population density of mites (mites per leaf) during second field trial

The effect of nutrients on the mite population during the time period from November 2017 to May 2018 was recorded, analysed and presented in the table 6 and 7. It was found that the mite population was significantly affected by the nutrient management on 45 DAT, 60 DAT and 75 DAT, whereas on 90 DAT there was no significant difference.

The highest population of mites was observed in the P_2 nutrient level on 45 DAT (2.18), 60 DAT (1.97) which is on par with P_3 nutrient level (1.93) and 75 DAT (3.29). Nutrient level P_1 had the minimum number of mite population on 45 DAT (0.33) 60 DAT (0.89) and 75 DAT (0.60).

The effect of foliar nutrition on the mite population was found to be significant on 45 DAT, 60 DAT and 75 DAT. On 45 DAT and 75 DAT, the mite population was highest in the third level of foliar nutrition (2.44 and 4.47 respectively) whereas the mite population on 60 DAT was highest in fourth level foliar application (2.86). Minimum mite population was recorded for treatment with no foliar application on 45 DAT (0.32), 60 DAT (0.13) AND 75 DAT (0.66).

Interaction effect of foliar nutrition and different soil nutrition levels in the table 7 showed a significant difference in the mite population. The data revealed that throughout the season the maximum mite population was recorded in T_7 (NPK nutrient level and two applications of foliar nutrition) i.e. 4.33, 7.66 and 7.00 respectively, with the exception on 60 DAT where T_{12} showed the highest value.

According to the table 7, plants of T_1 were free of mite infestation on 45 DAT, 60 DAT, 75 DAT and 90 DAT. On 45 DAT T_3 also showed no infestation whereas T_2 and T_9 had no mite population on 60 DAT. No mite population was observed on plants of T_2 and T_8 on 75 DAT and T_3, T_8, T_9, T_{10} on 90 DAT.

Out of the non chemical nutrient level, T_4 had highest population of mites throughout the growth span of the plant whereas T_7 recorded highest among the second nutrient level. In third nutrient level T_{11} and T_{12} harboured large number of mites. From this we can conclude that there was a positive relation between the number of foliar application and the number of mites.

Table 6. Mean population of chilli mites (mites per leaf) in different soil nutrition levels and foliar nutrition during second field trial

Soil nutrition levels	Mean population of mites 45 DAT	60 DAT	75 DAT	90 DAT
P_1	0.33 (1.13)	0.89 (1.33)	0.60 (1.22)	0.87 (1.34)
P_2	2.18 (1.73)	1.97 (1.69)	3.29 (1.92)	2 (1.56)
P_3	1.91 (1.65)	1.93 (1.63)	2.67 (1.83)	1.09 (1.26)
SE(m)	0.022	0.028	0.026	0.121
CD (0.05)	0.065	0.081	0.078	NS
Levels of foliar nutrition				
F_0	0.32 (1.14)	0.13 (1.06)	0.66 (1.27)	1.80 (1.49)
F_1	0.72 (1.30)	0.91 (1.35)	1.66 (1.52)	0.41 (1.18)
F_2	2.44 (1.76)	2.48 (1.84)	4.47 (2.20)	2.33 (1.60)
F_3	2.42 (1.82)	2.86 (1.95)	1.95 (1.64)	0.73 (1.27)
SE(m)	0.026	0.032	0.031	0.139
CD (0.05)	0.075	0.094	0.09	NS

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients; Figures in the parentheses are $\sqrt{x+1}$ transformed values. n = 108 number of leaves

Table 7. Interaction effect of soil and foliar nutrition levels on the mean population of mites (mites per leaf) during second field trial

TREAMENTS		Mean population of mites			
		45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	0 (1)	0 (1)	0 (1)	0 (1)
T_2	P_1F_1	0.16 (1.07)	0 (1)	0 (1)	0.5 (1.22)
T_3	P_1F_2	0 (1)	1.3 (1.51)	0.25 (1.11)	0 (1)
T_4	P_1F_3	1.16 (1.47)	2.26 (1.80)	2.16 (1.77)	2 (1.73)
T_5	P_2F_0	0.75 (1.32)	0.41 (1.18)	1 (1.41)	0.25 (1.11)
T_6	P_2F_1	1 (1.41)	2 (1.73)	4.5 (2.34)	0.75 (1.32)
T_7	P_2F_2	4.33 (2.30)	3.16 (2.04)	7.66 (2.93)	7 (2.82)
T_8	P_2F_3	2.66 (1.91)	2.33 (1.82)	0 (1)	0 (1)
T_9	P_3F_0	0.23 (1.11)	0 (1)	1 (1.41)	4.16 (1.94)
T_{10}	P_3F_1	1 (1.41)	0.75 (1.32)	0.5 (1.22)	0 (1)
T_{11}	P_3F_2	3 (1.99)	3 (1.98)	5.5 (2.54)	0 (1)
T_{12}	P_3F_3	3.43 (2.10)	4 (2.23)	3.7 (2.16)	0.20 (1.09)
SE(m)		0.045	0.055	0.053	0.241
CD (0.05)		0.131	0.162	0.155	0.70

T_1 : P.M + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). Figures in the parentheses are $\sqrt{x+1}$ transformed values. n = 108 number of leaves

4.1.3. Leaf curl index due to mite attack during first and second field trial

The result of the effect of mineral nutrition on the intensity of leaf curl in both the trials caused by mites is presented in table 8 and 9. When the intensity of leaf curl was scored the maximum number of plants gave the score 1, hence statistical analysis was not able to be carried out. The score of the plants are presented in table10.

During the growth span of plant, there was a slight increase in the leaf curl index till 60 DAT and a gradual decrease from 75 DAT onwards. This pattern was exhibited in both the trials.

4.1.3.1. Leaf curl index of first field trial

The data in the Table 8 showed that the leaf curl index was significantly influenced by the soil nutrition levels and foliar nutrition. At 45, 60, 75, and 90 DAT lowest average leaf curl index were recorded in plants of first nutrient level (P_1). Highest leaf curl index was recorded in the plants of second nutrient level (P_2) with values 24.46, 25.38, 21.22 and 20.93 at 45, 60, 75 and 90 DAT respectively. Values of leaf curl index of third nutrient level were found to be between P_1 and P_2 nutrient level.

In the case of foliar nutrition, there was a gradual reduction in the average leaf curl index throughout the growth period of the plant. At 45,60 and 75 DAT, the lowest leaf curl index were recorded in plants with one foliar application of nutrients (F_2) whereas at 90 DAT, lowest LCI was in F_1 and highest LCI was constantly observed in the plants of F_2. At 60 and 75 DAT, lowest LCI was obs erved in F_1 which is on par with F_0.As the number of foliar nutrition increased the LCI first showed an increase in two foliar application levels, followed by a decrease. This trend during the crop period holds time.

The interaction effect of soil nutrition levels and foliar nutrition had profound influence on the LCI and is presented in the Table 9.The lowest LCI was recorded in T_2 throughout the growing phase *viz* 0.00, 5.93, 5.96 and 5.50 at 45, 60, 75 and 90 DAT respectively whereas highest was observed in T_7 with 43.69, 52.38, 39.79 and 38.27 at 45, 60, 75 and 90 DAT respectively. When we consider the nutrient levels separately it is evident that in each nutrient level LCI increases with the increase in levels the foliar nutrition with some exceptions. In the first nutrient level that is from T_1 to T_4 the LCI increased with the increase in the foliar nutrition with T_2 as an exception. In second and third nutrient level, there was an increase in the LCI with the foliar nutrition levels but with a reduction in the fourth level of application.

4.1.3.2. Leaf curl index of second field trial

The LCI was found to be lower in comparison to the first field trial and a gradual increase was seen with the growth span of the plant. At 45 DAT lowest leaf curl index was recorded in plants of first nutrient level with a mean of 3.54. During the subsequent fortnights, the same trend was followed with the first nutrient levels recording lowest leaf curl index on 60 (5.00), 75 (6.19) and 90 (6.38) DAT. Highest leaf curl index was recorded in the plants of second nutrient level with a mean of 8.13, 10.77, 12.31 and 12.058 at 45, 60, 75 and 90 DAT respectively. Leaf curl index of third nutrient levels was found to be higher than the first nutrient level and lower than the second.

In the case of foliar nutrition, there was a gradual increase in the mean of leaf curl index till 75 DAT and then a decrease. At 45, 60, 75 and 90 DAT, the lowest leaf curl index (LCI) of 2.40, 3.53, 4.16 and 3.50 respectively was recorded in plants with no foliar nutrition (F_0). Highest LCI of 8.18, 12.29 and 13.05 was observed at 45, 60 and 90 DAT respectively, in the plants with F_3 foliar nutrition levels which was on par with F_2 with 7.99, 11.94 and 12.16 at 45, 60 and 90 DAT respectively. At 75 DAT, highest LCI of 13.05 was recorded on F_2 which is on par with F_3 (12.77).

The interaction effect of soil nutrition levels and foliar nutrition levels is presented in the Table 9. The lowest LCI was recorded in T_1 and T_9 throughout the growing phase since there was no curled leaves present whereas second lowest was recorded in T_{10} with 3.93, 4.19, 8.56 and 7.6 at 45, 60, 75 and 90 DAT respectively with exceptions. Highest was observed in T_7 with 11.49, 15.48, 17.46 and 17.26 at 45, 60, 75 and 90 DAT respectively. During the growth phase there was a gradual increase in the mean of leaf curl index till 75 DAT and then a decrease.

When the average leaf curl indices observed at different intervals of the crop growth of both the trials were compared, it was seen that the lowest average leaf curl index was observed in P_1 level and with one or two levels of foliar nutrition.

Table 8. Leaf curl index of chilli during first and second field trial

	LCI of first field trial				LCI of second field trial			
Soil nutrition levels	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
P_1	14.84	14.89	14.45	9.89	3.54	5.00	6.19	6.38
P_2	24.46	25.38	21.22	20.93	8.13	10.77	12.31	12.05
P_3	16.19	17.32	18.44	15.88	6.64	8.17	9.58	8.20
SE(m)	**0.154**	**0.187**	**0.209**	**0.486**	**0.144**	**0.235**	**0.397**	**0.265**
CD (0.05)	**0.453**	**0.548**	**0.613**	**1.426**	**0.423**	**0.691**	**1.167**	**0.777**
Foliar nutrition levels	**LCI of first field trial**				**LCI of second field trial**			
F_0	13.18	12.90	12.44	8.39	2.40	3.53	4.16	3.50
F_1	11.47	12.88	12.34	10.50	5.85	4.97	7.84	6.70
F_2	30.51	34.30	31.61	28.72	7.99	11.94	13.05	12.16
F_3	18.81	16.58	15.76	15.12	8.18	12.29	12.77	13.05
SE(m)	**0.178**	**0.216**	**0.241**	**0.561**	**0.166**	**0.272**	**0.459**	**0.305**
CD (0.05)	**0.523**	**0.633**	**0.707**	**1.647**	**0.488**	**0.798**	**1.347**	**0.897**

Table 9. Interaction effect of soil nutrition levels and foliar nutrition levels on the mean LCI of mites during first and second field trial

		LCI of first field trial				LCI of second field trial			
TREATMENTS		45 DAT	60 DAT	75 DAT	90 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	14.93	12.81	12.40	12.30	0	0	0	0
T_2	P_1F_1	0.00	5.93	5.96	5.5	9.55	5.79	4.69	4.21
T_3	P_1F_2	18.78	19.95	18.58	18.95	0	5.07	8.14	8.41
T_4	P_1F_3	25.68	20.49	20.87	20.63	4.63	9.12	11.95	12.89
T_5	P_2F_0	12.98	12.62	12.73	12.33	7.20	10.59	12.48	10.51
T_6	P_2F_1	23.00	19.33	18.15	19.10	4.06	4.91	9.18	8.30
T_7	P_2F_2	43.69	52.38	39.79	38.27	11.49	15.48	17.46	17.26
T_8	P_2F_3	18.15	17.19	14.22	14.04	9.77	12.1	10.13	12.15
T_9	P_3F_0	11.64	13.29	12.19	12.83	0	0	0	0
T_{10}	P_3F_1	11.42	13.36	12.93	11.04	3.93	4.19	8.56	7.60
T_{11}	P_3F_2	29.09	30.57	36.47	28.94	11.00	12.86	13.54	10.80
T_{12}	P_3F_3	12.60	12.06	12.19	10.69	10.15	15.64	16.24	14.41
SE(m)		**0.308**	**0.374**	**0.417**	**0.972**	**0.288**	**0.471**	**0.795**	**0.529**
CD (0.05)		**0.905**	**1.097**	**1.225**	**2.853**	**0.846**	**1.382**	**2.333**	**1.553**

T_1 : P.M + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). n = 10 number of plants

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Table 10. Score of LCI of both the trials.

Score of LCI of first field trial						Score of LCI of second field trial			
TREATMENTS		**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
T_1	**P_1F_0**	1	1	1	1	0	0	0	0
T_2	**P_1F_1**	0	1	1	1	1	1	1	1
T_3	**P_1F_2**	1	1	1	1	0	1	1	1
T_4	**P_1F_3**	2	1	1	1	1	1	1	1
T_5	**P_2F_0**	1	1	1	1	1	1	1	1
T_6	**P_2F_1**	1	1	1	1	1	1	1	1
T_7	**P_2F_2**	2	3	2	2	1	1	1	1
T_8	**P_2F_3**	1	1	1	1	1	1	1	1
T_9	**P_3F_0**	1	1	1	1	0	0	0	0
T_{10}	**P_3F_1**	1	1	1	1	1	1	1	1
T_{11}	**P_3F_2**	2	2	2	2	1	1	1	1
T_{12}	**P_3F_3**	1	1	1	1	1	1	1	1

From the table 10 it's clear that only T_7 and T_{11} of first field trial had plants which scored 2 i.e. plants showing moderately damaged leaf curl indices. All the other treatments scored one i.e. plants showing curling with an exception of T_2 showing 0 i.e. no symptom during first trial and T_1 and T_9 showing score 0 in second field trial.

Plate 2. Leaf curl index due to mites of plants of T_7 of first field trial

Plate 3. Leaf curl index due to mites of plants of T_7 of second field trial


Plate 4. Plant of treatment T_{10} low infestation of mites during first field


Plate 5. Plant of T_9 without infestation of mites during second field trials

4.1.4. Number of curled leaves and total number of leaves in the first field trial

The result of the effect of mineral nutrition on the number of leaf curl in chilli caused by mites is presented in table 11 and 12 along with the total number of leaves at the same time.

At 45 DAT, number of curled leaves and total number of leaves was lowest in plants of first nutrient level P_1 with an average of 2.52 and 50.47 respectively. In the growth span of th

e plant the same trend followed by the first nutrient level recording lowest number of curled leaves on 60 (3.38), 75 (3.58) and 90 (3.58) DAT. The plants exhibited lowest number of leaves in the first nutrient level with 50.47, 55.62, 65.60 and 72.79 at 45, 60, 75 and 90 DAT respectively. Maximum number of curled leaves was recorded in the plants of second nutrient level with an average of 12.68, 16.62, 18.20, 19.00 at 45, 60, 75 and 90 DAT respectively. The effect of nutrient level on the number of leaves was significant and recorded highest in the third nutrient levels at 60, 75 and 90 DAT with 125.97, 137.87 and 146.91 respectively whereas at 45 DAT, second nutrient level recorded maximum number of leaves (105.10).

The effect of different levels of foliar nutrition levels had significant difference; there was a gradual increase in the average number of curled leaves as well as the total number of leaves throughout the growth span. At 45, 60, 75 and 90 DAT, the lowest number of curled leaves such as 2, 2.84, 3.27 and 2.94 respectively was recorded in plants with no foliar application of nutrients (F_0). Highest number of curled leaves such as 17.11, 23.94, 28.97 and 29.05 was observed at 45, 60, 75 and 90 DAT respectively. Lowest number of leaves was recorded in first level of foliar nutrition (F_0) and highest in the fourth level of foliar application of nutrients.

When the average number of leaf curl observed at different intervals of the crop growth were compared to check the interaction effect of soil nutrition levels and foliar application of nutrients, it was seen that the lowest average number of curled leaf was observed in T_2 that is 0.00, 0.25, 0.25 and 0.25 whereas highest in T_7 that is 33.50, 47.33, 51.25 and 51.33 at 45, 60, 75 and 90 DAT respectively. Throughout the growth phase there was a gradual increase in the number of curled leaves.

When different soil nutrition levels were taken separately, the first level showed a sudden decrease and then gradual increase in the number of curled leaves. The other two soil nutrition levels behaved in a similar manner that is a gradual increase then a sudden decrease. The number of leaves increases throughout the growth span of the plants in all the nutrition levels and shows a positive relation with the increase in levels of foliar application. Maximum number of leaves was observed in T_7 (124.75) at 45 DAT which is on par with T_8 (119.16), whereas at 60, 75 and 90 DAT the maximum number of leaves were recorded in T_8. Minimum number of leaves was recorded in T_1 which is on par T_2 and T_3.

Table 11. Number of curled leaves and number of leaves in the first field trial

Soil nutrition levels	Number of curled leaves				Total number of leaves			
	45 DAT	60 DAT	75 DAT	90 DAT	45 DAT	60 DAT	75 DAT	90 DAT
P_1	2.52	3.38	3.58	3.58	50.47	55.62	65.60	72.79
P_2	12.68	16.62	18.20	19.00	105.10	120.37	133.41	142.12
P_3	5.68	7.64	10.77	10.87	90.79	125.97	137.87	146.91
SE(m)	**0.073**	**0.129**	**0.137**	**0.121**	**1.068**	**1.538**	**1.47**	**1.61**
CD (0.05)	**0.215**	**0.377**	**0.401**	**0.357**	**3.136**	**4.515**	**4.316**	**4.749**
Levels of foliar nutrition	**Number of curled leaves**				**Total number of leaves**			
F_0	2.00	2.84	3.27	2.94	73.02	91.97	105.11	112.13
F_1	3.50	4.27	4.77	5.61	76.27	95.00	107.02	116.41
F_2	17.11	23.94	28.97	29.05	87.50	105.72	115.47	123.52
F_3	5.25	5.80	6.38	7.00	91.69	109.94	121.58	130.36
SE(m)	**0.084**	**0.148**	**0.158**	**0.140**	**1.233**	**1.775**	**1.697**	**1.868**
CD (0.05)	**0.248**	**0.436**	**0.463**	**0.412**	**3.621**	**5.213**	**4.983**	**5.484**

Table 12. Interaction effect of soil and foliar nutrition levels on the number of leaves and curled leaves during the first trial

Treatments		Number of curled leaves first trial				Total number of leaves first trial			
		45 DAT	60 DAT	75 DAT	90 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	0.83	1.62	1.58	1.58	45.41	49.00	61.33	64.75
T_2	P_1F_1	0.00	0.25	0.25	0.25	45.41	52.08	62.50	71.41
T_3	P_1F_2	3.41	5.25	5.25	5.50	51.25	55.41	63.25	72.50
T_4	P_1F_3	5.83	6.41	7.25	8.33	59.83	66.00	75.33	82.50
T_5	P_2F_0	2.58	3.08	4.08	4.33	82.58	93.58	110.91	119.0
T_6	P_2F_1	8.00	8.75	9.50	11.83	93.91	108.16	123.33	131.58
T_7	P_2F_2	33.50	47.33	51.25	51.33	124.75	133.50	144.00	151.58
T_8	P_2F_3	6.66	7.33	8.00	8.50	119.16	146.25	155.41	166.25
T_9	P_3F_0	2.58	3.83	4.16	4.25	91.08	133.33	143.08	152.58
T_{10}	P_3F_1	2.50	3.83	4.58	4.75	89.50	124.75	135.25	146.25
T_{11}	P_3F_2	14.41	19.25	30.41	30.33	86.50	128.25	139.16	146.50
T_{12}	P_3F_3	3.25	3.66	3.91	4.16	96.08	117.58	134.00	142.33
SE(m)		**0.146**	**0.257**	**0.273**	**0.243**	**2.136**	**3.075**	**2.940**	**3.235**
CD (0.05)		**0.430**	**0.755**	**0.802**	**0.713**	**6.272**	**9.029**	**8.631**	**9.498**

T_1 : P.M + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). Figures in the parentheses are $\sqrt{x+1}$ transformed values. n = 12 number of plants

4.1.5. Number of curled leaves and number of leaves in the second field trial

Different nutrient level had significant effect on the number of curled leaves as well as total number of leaves and it is presented in table 13 and 14. At 45, 60, and 75 DAT, the highest number of curled leaves was found on P_3 (1.18), P_2 (1.80), P_2 (2.5) respectively which is on par with P_2 (1.12), P_3 (1.52) and P_3 (2.25) whereas at 90 DAT highest number of curled leaves was observed in P_2 (3.08).

With regard to number of leaves, was recorded P_3 had produced highest number of leaves and the lowest number of leaves was exhibited in the plants of P_1. P_2 level had produced a little less number of leaves when compared to P_3. Hence in proportion to the number of leaves produced plants in P_2 level showed highest number of curled leaves.

In the case of foliar nutrition, it was observed that with the increase in foliar nutrition the number of curled leaves increases. Along the growth phase also, there was a gradual increase in the number of curled leaves. Highest number of curled leaves was found in both F_2 and F_3. At 45, 60 and 90 DAT, highest was found in F_3 (1.19, 2.13 and 3.38 respectively) which was on par with F_2 (1.55, 1.97 and 3.22 respectively). Highest number of leaf curl at 75 DAT was found in F_2 (2.86) which were on par with F_3 (2.61).

With regard to the number of leaves, highest values were recorded in F_3 (49.44, 42.66, 49.33 and 64.01) which was on par with F_2 with values 48, 41.88, 48.66 and 63.65 at 45, 60, 75 and 90 DAT respectively.

Interaction effect on the number of curled leaves is found to be significant. Highest number of curled leaves was recorded on T_7 that is 2, 3.33, 4.66 and 6 which is on par with the T_{12} (1.83, 3.5, 4.5 and 5.83 respectively). There was no curled leaf on T_1 and T_9.

When we take the number of leaves, the interaction effect have significant different only during 60 and 75 DAT. The highest number of leaves was observed in the T_{12} which was par with T_7, T_8, T_9, T_{10} and T_{11} at 60 DAT whereas at 75 DAT.

Table 13. Number of curled leaves and total number of leaves in the second field trial

	Number of curled leaves				Total number of leaves			
Soil nutrition levels	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
P_1	0.31	0.35	0.66	0.89	36	30.5	35.66	45.56
P_2	1.12	1.80	2.5	3.08	49.91	45.25	51.16	64.43
P_3	1.18	1.52	2.25	2.20	55.91	47	57	74.63
SE(m)	**0.054**	**0.068**	**0.129**	**0.099**	**0.601**	**0.645**	**0.544**	**0.854**
CD (0.05)	**0.158**	**0.201**	**0.379**	**0.291**	**1.764**	**1.34**	**1.13**	**1.773**
Levels of foliar nutrition	**Number of curled leaves**				**Total number of leaves**			
F_0	0.25	0.5	0.77	0.66	45.22	38.33	44.88	57.97
F_1	0.5	0.30	0.97	0.97	46.44	40.77	46 .88	60.83
F_2	1.55	1.97	2.86	3.22	48	41.88	48.66	63.35
F_3	1.19	2.13	2.61	3.38	49.44	42.66	49.33	64.01
SE(m)	**0.062**	**0.079**	**0.149**	**0.115**	**0.694**	**0.745**	**0.629**	**0.986**
CD (0.05)	**0.884**	**0.232**	**0.437**	**0.336**	**2.037**	**1.548**	**1.305**	**2.047**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients; n = 10 number of plants

Table 14. Interaction effect of soil and foliar nutrition levels on the number of curled leaves and number of leaves during the second field trial

Treatments		Number of curled leaves				Number of leaves			
		45 DAT	60 DAT	75 DAT	90 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	0	0	0	0	32.66	25.33	30.66	42.41
T_2	P_1F_1	1	0.33	0.25	0.25	36.33	31.66	37.33	46.5
T_3	P_1F_2	0	0.25	0.75	1	36.66	32	36.66	46.83
T_4	P_1F_3	0.25	0.83	1.66	2.33	38.33	33	38	46.5
T_5	P_2F_0	0.75	1.5	2.33	2	47.66	43.33	49.33	60
T_6	P_2F_1	0.25	0.33	1.33	1.33	49.66	44	51	62
T_7	P_2F_2	2	3.33	4.66	6	50.33	46.66	51.66	68.06
T_8	P_2F_3	1.5	2.06	1.66	3	52	47	52.66	67.66
T_9	P_3F_0	0	0	0	0	55.33	46.33	54.66	71.5
T_{10}	P_3F_1	0.25	0.25	1.33	1.33	53.33	46.66	58.33	74
T_{11}	P_3F_2	2.66	2.33	3.16	2.66	57	47	57.67	75.16
T_{12}	P_3F_3	1.83	3.5	4.5	5.83	58	48	57.33	77.86
SE(m)		**0.108**	**0.137**	**0.258**	**0.198**	**1.202**	**1.291**	**1.089**	**1.708**
CD (0.05)		**0.316**	**0.401**	**0.757**	**0.582**	**NS**	**2.68**	**2.26**	**NS**

T_1 : P.M + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). n = 10 number of plants

4.2. INFLUENCE OF MINERAL NUTRIENTS ON THRIPS POPULATION

4.2.1. Population density of thrips during first field trial

The efficacy of the mineral nutrients in the management of chilli thrips was evaluated during August 2017 to February 2018 and the data recorded at fortnight intervals from the beginning of pest incidence and presented in Table 15.

On 45 days after transplanting, pest incidence began. Maximum thrips population of 0.66 was observed in the nutrient level P_2 and no infestation in the nutrient level P_1. There was a gradual increase in the thrips population in the next fortnight i.e. 60 DAT but was not significantly different. At 75 DAT maximum population of 0.58 was recorded in the P_2 nutrient level whereas both the other soil nutrition levels showed a minimum population of 0.33. At 90 DAT there was no significant difference between treatments.

Foliar application of nutrients had a significant effect during 45 and 75 DAT and non significant on 60 and 90 DAT. At 45 DAT maximum population was observed in one application of foliar nutrition and minimum was recorded in two foliar nutrition levels. During 75 DAT, the maximum population was recorded when no foliar spray was applied whereas when two levels of foliar nutrition were applied minimum population of 0.33 was observed.

Interaction effect of foliar nutrition levels and different soil nutrition levels in the table 16 showed a significant difference at 45 and 75 DAT. Only at 45 DAT no infestation was found in T_1, T_2, T_3, T_4 and T_{11} and maximum population of 1.33 occurred in T_8 i.e. NPK nutrient level with three levels of foliar nutrition. No infestation was seen in T_2 for 75 DAT whereas the maximum population of 0.83 was seen in T_6. The thrips population didn't follow any specific trend as the pest is a low density pest.

4.2.2. Population density of thrips during second field trial

There was no infestation of thrips during the period from December 2017 to May 2018.

Table 15. Mean population of thrips in different soil and foliar nutrition levels during first field trial

	Mean population of thrips			
Soil nutrition levels	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
P_1	0.00 (1.00)	0.27 (1.12)	0.33 (1.15)	0.35 (1.15)
P_2	0.66 (1.28)	0.70 (1.29)	0.58 (1.25)	0.12 (1.05)
P_3	0.37 (1.16)	0.43 (1.19)	0.33 (1.15)	0.31 (1.14)
SE(m)	**0.006**	**0.037**	**0.013**	**0.004**
CD (0.05)	**0.019**	**NS**	**0.038**	**NS**
Levels of foliar nutrition	**Mean population of thrips**			
F_0	0.16 (1.07)	0.44 (1.19)	0.50 (1.22)	0.33 (1.15)
F_1	0.58 (1.24)	0.55 (1.23)	0.41 (1.18)	0.16 (1.07)
F_2	0.11 (1.05)	0.36 (1.16)	0.33 (1.15)	0.30 (1.12)
F_3	0.52 (1.21)	0.52 (1.22)	0.41 (1.18)	0.25 (1.11)
SE(m)	**0.007**	**0.043**	**0.015**	**0.005**
CD (0.05)	**0.022**	**NS**	**0.043**	**NS**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients; Figures in the parentheses are $\sqrt{x+1}$ transformed values; n = 108 number of leaves

Table 16. Interaction effect of soil and foliar nutrition levels on the mean population of thrips during first field trial

		Mean population of thrips			
TREAMENTS		45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	0.00 (1.00)	0.25 (1.11)	0.50 (1.22)	0.50 (1.22)
T_2	P_1F_1	0.00 (1.00)	0.08 (1.03)	0.00 (1.22)	0.00 (1.00)
T_3	P_1F_2	0.00 (1.00)	0.33 (1.15)	0.25 (1.00)	0.91 (1.38)
T_4	P_1F_3	0.00 (1.00)	0.41 (1.18)	0.58 (1.11)	0.00 (1.00)
T_5	P_2F_0	0.25 (1.11)	0.58 (1.25)	0.50 (1.25)	0.50 (1.00)
T_6	P_2F_1	0.75 (1.32)	0.83 (1.35)	0.83 (1.22)	0.25 (1.11)
T_7	P_2F_2	0.33 (1.15)	0.50 (1.21)	0.50 (1.35)	0.00 (1.00)
T_8	P_2F_3	1.33 (1.52)	0.91 (1.37)	0.50 (1.22)	0.25 (1.11)
T_9	P_3F_0	0.25 (1.11)	0.50 (1.21)	0.50 (1.22)	0.50 (1.22)
T_{10}	P_3F_1	1.00 (1.41)	0.75 (1.31)	0.41 (1.18)	0.25 (1.11)
T_{11}	P_3F_2	0.00 (1.00)	0.25 (1.11)	0.25 (1.11)	0.00 (1.00)
T_{12}	P_3F_3	0.25 (1.11)	0.25 (1.11)	0.16 (1.07)	0.50 (1.22)
SE(m)		**0.013**	**0.074**	**0.026**	**0.009**
CD (0.05)		**0.038**	**NS**	**0.075**	**NS**

T_1 : P.M + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). Figures in the parentheses are $\sqrt{x+1}$ transformed values. n = 108 number of leaves

4.2.3. Number of curled leaves and total number of number of leaves during first field trial

Significant effect of different soil nutrition levels was evidently reflected on the number of curled leaves and is presented in table 17. At 45 and 60 DAT, NPK nutrient level (P_2) showed highest number of curled leaves of 1.41 and 1.70 respectively. At 75 and 90 DAT, highest number of curled leaves was recorded in P_3 with 1.8 and 1.02 which is on par with P_2. P_1 level plants had no curled leaves at 45 DAT, 0.56 nos at 60 DAT, 1.31nos at 75 DAT and 0.39 at 90 DAT.

Highest number of leaves was recorded in P_3 level with exception at 45 DAT where P_2 exhibited highest. Nutrient applied through foliar revealed a significant effect on the number of curled leaves. When three foliar nutrition levels was provided plants showed highest leaf curl throughout the growth phase that is 1.25 at 45 DAT, 1.52 at 60 DAT, 1.75 at 75 DAT and 1.75 at 90 DAT and lowest leaf curl was observed on plants of F_0 0.50 at 45 DAT, 1.00 at 60 DAT, 1.02 at 75 DAT and 1.23 at 90 DAT. Number of leaves was more in the F_3 which slightly reduced the severity of the leaf curl.

Interaction effect of the soil nutrition levels and foliar nutrition levels was found to be significant and presented in table 18. At 45 DAT there was very less mean number of curled leaves out of which the highest was in T_8 and least T_1, T_2, T_3 , T_4, T_{11} (without curled leaves). Highest number of curled leaves was found to be on plants of T_8, followed by T_{10}. Lowest values of curved leaves was found in T_2 ,T_9 ,T_{11} at 75 DAT. Least values were seen in T_2 and T_1. At 90 DAT, highest values were seen again in T_8 and T_7 followed by T_4 and the least values in T_2, T_3, T_5, and T_{11}.

As the soil and foliar nutrition levels increased there was a gradual increase in the number of leaves in general. The number of leaves increases as the plant acquire more age. At 45 DAT, maximum number of leaves was recorded in

T_7 and T_8 and minimum in T_1 and T_2. At 60 DAT maximum leaves again in T_8, follow by T_7 and T_9 and minimum value in T_1, T_2 and T_3. At 90 DAT, maximum number of leaves in T_8, followed by T_7 and T_9 and least value in T_1, T_2 and T_3.

Table 17. Number of curled leaves due to thrips and total number of leaves during first field trial

	Number of curled leaves				Total number of leaves			
Soil nutrition levels	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
P_1	0.00	0.56	1.31	0.39	50.47	55.62	65.60	72.79
P_2	1.41	1.70	1.85	0.37	105.10	120.37	133.41	142.12
P_3	0.91	1.39	1.87	1.02	90.79	125.97	137.87	146.91
SE(m)	**0.036**	**0.017**	**0.040**	**0.027**	**1.068**	**1.538**	**1.47**	**1.61**
CD (0.05)	**0.106**	**0.050**	**0.117**	**0.079**	**3.136**	**4.515**	**4.316**	**4.749**
Levels of foliar nutrition	**Number of curled leaves**				**Total number of leaves**			
F_0	0.50	1.00	1.02	1.23	73.02	91.97	105.11	112.13
F_1	1.11	1.44	1.44	1.44	76.27	95.00	107.02	116.41
F_2	0.25	0.91	1.66	1.66	87.50	105.72	115.47	123.52
F_3	1.25	1.52	1.75	1.75	91.69	109.94	121.58	130.36
SE(m)	**0.042**	**0.020**	**0.046**	**0.031**	**1.233**	**1.775**	**1.697**	**1.868**
CD (0.05)	**0.022**	**0.058**	**0.135**	**0.091**	**3.621**	**5.213**	**4.983**	**5.484**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients;

Table 18. Interaction effect of soil and foliar nutrition levels on the of curled leaves due to thrips and total number of leaves during first field trial

Leaf curl index of thrips									
		Number of curled leaves				Number of leaves			
Treatments		45 DAT	60 DAT	75 DAT	90 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	0.00	0.75	1.18	1.18	45.41	49.00	61.33	64.75
T_2	P_1F_1	0.00	0.00	0.00	0.00	45.41	52.08	62.50	71.41
T_3	P_1F_2	0.00	0.75	1.75	0.00	51.25	55.41	63.25	72.50
T_4	P_1F_3	0.00	0.75	1.91	1.50	59.83	66.00	75.33	82.50
T_5	P_2F_0	0.75	1.50	1.25	0.00	82.58	93.58	110.91	119.0
T_6	P_2F_1	1.66	2.33	1.41	0.75	93.91	108.16	123.33	131.58
T_7	P_2F_2	0.75	1.25	1.75	1.75	124.75	133.50	144.00	151.58
T_8	P_2F_3	2.50	2.75	2.50	1.83	119.16	146.25	155.41	166.25
T_9	P_3F_0	0.75	0.75	1.25	1.00	91.08	133.33	143.08	152.58
T_{10}	P_3F_1	2.08	2.25	1.91	0.75	89.50	124.75	135.25	146.25
T_{11}	P_3F_2	0.00	0.75	1.50	0.00	86.50	128.25	139.16	146.50
T_{12}	P_3F_3	0.83	1.63	1.73	1.03	96.08	117.58	134.00	142.33
SE(m)		**0.072**	**0.034**	**0.080**	**0.054**	**2.136**	**3.075**	**2.940**	**3.235**
CD (0.05)		**0.212**	**0.100**	**0.234**	**0.158**	**6.272**	**9.029**	**8.631**	**9.498**

T_1 : P.M + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). n = 12 plants

4.2.4. Leaf curl index of thrips

The result of the effect of mineral nutrition on the of leaf curl index caused by thrips is presented in table 19 and 20.

Leaf curl index gave the information on the number of curled leaves and the mineral nutrition have a significant effect on it .The nutrient level P_2 gave highest leaf curl index at 45 DAT (8.42) and 60 DAT (8.48) whereas at 75 and 90 DAT highest LCI was observed on P_3 8.24. As the levels of nutrition increased there is a general trend of increasing the LCI upto P_2 during 45 and 60 DAT. LCI further increases as the level of nutrition increased from P_1 to P_3 in 75 and 90 DAT.

In the case of foliar application at 45, 60, 75 and 90 DAT, the highest leaf curl index (LCI) was recorded in plants with three foliar application of nutrients (F_3) 6.89, 7.82, 9.40 and 8.56 respectively. At 45 and 90 DAT, lowest LCI of 1.97 and 4.26 was observed in the plants where three foliar nutrition levels were provided. At 60 and 75 DAT, lowest LCI was observed in F_1 6.66 and 5.87 respectively.

When interaction effect is taken into consideration, highest LCI was recorded in T_8 during 45 DAT (10.58) which was on par with T_{10} (10.45) and T_6 (10.22), whereas T_1, T_2, T_3, T_4 and T_{11} with zero LCI at 45 DAT. On 60 DAT, T_{10} (10.00) showed highest LCI which was on par with T_6 (9.99) and T8 (9.99) whereas lowest on T_2 with zero LCI. On 75 DAT lowest LCI was shown in the treatment T_2 with zero LCI and highest LCI on T_1 (10.80), T_3 (10.64) and T_4 (10.30). On 90 DAT, highest LCI was found on T_1 (10.38) whereas lowest LCI was recorded on treatments T_2 (zero) and T_3.

Table 19. Leaf curl index of thrips at first field trial

LCI of thrips				
Soil nutrition Levels	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
P_1	0	5.53	7.93	5.04
P_2	8.42	8.48	7.80	7.06
P_3	5.81	7.55	8.24	7.20
SE(m)	**0.105**	**0.063**	**0.113**	**0.078**
CD(0.05)	**0.308**	**0.186**	**0.331**	**0.229**
Levels of foliar nutrition	**LCI of thrips**			
F_0	4.40	7.39	8.22	7.70
F_1	5.70	6.66	5.87	5.22
F_2	1.97	6.88	8.33	4.26
F_3	6.89	7.82	9.40	8.56
SE(m)	**0.121**	**0.073**	**0.13**	**0.09**
CD(0.05)	**0.35**	**0.215**	**0.382**	**0.265**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients; n = 10 plants

Table 20. Interaction effect of soil and foliar nutrition levels leaf curl index of thrips first field trial

Treatments		Leaf curl index of thrips 45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	0	7.74	10.80	10.38
T_2	P_1F_1	0	0	0	0
T_3	P_1F_2	0	7.46	10.64	0
T_4	P_1F_3	0	6.92	10.30	9.80
T_5	P_2F_0	6.95	8.57	8.36	7.85
T_6	P_2F_1	10.22	9.99	9.20	8.56
T_7	P_2F_2	5.93	7.39	6.80	6.57
T_8	P_2F_3	10.58	9.99	9.44	5.82
T_9	P_3F_0	6.27	5.87	8.04	7.46
T_{10}	P_3F_1	10.45	10.00	9.42	7.11
T_{11}	P_3F_2	0	5.79	7.56	6.20
T_{12}	P_3F_3	6.53	8.54	7.93	7.49
SE(m)		**0.21**	**0.127**	**0.226**	**0.156**
CD (0.05)		**0.616**	**0.372**	**0.662**	**0.458**

T_1 : P.M + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). N= 10 plants

Plate 6. LCI due to thrips in plants of T_8

4.3. INFLUENCE OF MINERAL NUTRIENTS ON WHITEFLY COLONY

4.3.1. Mean number of whitefly colonies during first field trial

In the pot culture experiment conducted during August 2017 to February 2018, the effect of mineral nutrients in the development of whitefly colonies was evaluated and results are presented in the Table 21 and 22. Observations were recorded at biweekly interval from 30 days after transplanting.

On 30 DAT, the whitefly colonies started to build up and the highest number of colonies was seen in the soil nutrient level P_1 with 1.77 colonies and a similar trend was followed in the later fortnight's *viz.* on 45, 60, 75, 90, 105, and 120 and 135 DAT. The number of whitefly colonies was 3.66, 8.93, 14.45, 23.79, 28.35, 32.00 and 36.47 respectively. Hence throughout growth phase, there was a gradual increase in the number of colonies.

Lowest number of colonies was found in the nutrient level P_3, throughout the experiment with 1.58, 2.06, 5.77, 8.93, 13.33, 17.54, 20.93 and 24.83 mean number of whitefly colonies on 30, 45, 60, 75, 90, 105, 120 and 135 DAT respectively. There was no discernible difference between the P_2 and P_3 nutrient levels.

Foliar nutrition levels had significant effect on the mean number of whitefly colonies. Maximum number of whitefly colonies was observed in F_1 which is on par with F_2 on 30 and 45 DAT. Minimum number of whitefly colonies was recorded in F_3 which is on par with F_0 30 and 45 DAT. At 60 DAT maximum number of whitefly colonies was observed in F_0 (7.27) and minimum was recorded in F_3 (6.00) which is on par with F_2 and F_1. Same trend was recorded on 90, 105 and 120 DAT. At 135 DAT, maximum number of whitefly was recorded in F_0 and minimum in F_2.

The interaction effect of the different nutrient level and the foliar nutrition levels are presented in the table 22.

The data pertained in Table 22 showed that on 30 days after transplanting (DAT) the number of whitefly colonies was seen maximum on the plants in the nutrient levels without NPK and one foliar application of nutrients T_2 (3.00) and a minimum number of whitefly colonies was observed in the T_8 (0.83).

On 45 DAT, the number of whitefly colonies was recorded maximum on plants of T_7 (5.41) and it was on par with T_2. The minimum number of whitefly colonies was observed on the plants of nutrient level NPK + Ca + Mg with one, two and three foliar application *viz.* T_{10}, T_{11} and T_{12}.

On 60, 75, 90 and 105 DAT maximum numbers of whitefly colonies were observed on plants of T_2 whereas minimum number of whitefly colonies was recorded on the plants of T_{10} with 2.75, 3.91, 7.08 and 9.33 respectively.

On 120 and 135 DAT maximum number of whitefly was observed on plants of T2 and a minimum number on plants of T_{11}.

Table 21. Number of whitefly colonies in soil and foliar nutrition Levels during first field trial.

	Number of whitefly colonies							
Soil nutrition levels	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**	**120 DAT**	**135 DAT**
P_1	1.77 (1.65)	3.66 (2.15)	8.93 (3.02)	14.45 (3.86)	23.79 (4.93)	28.35 (5.36)	32.00 (5.69)	36.47 (6.05)
P_2	1.60 (1.59)	3.60 (2.12)	5.85 (2.60)	9.20 (3.18)	13.97 (3.76)	18.14 (4.23)	22.18 (4.67)	26.60 (5.21)
P_3	1.58 (1.60)	2.06 (1.73)	5.77 (2.56)	8.93 (3.08)	13.33 (3.77)	17.54 (4.33)	20.93 (4.77)	24.83 (4.96)
SE(m)	**0.01**	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**	**0.03**	**0.02**
CD	**0.03**	**0.06**	**0.07**	**0.05**	**0.05**	**0.05**	**0.11**	**0.07**
Foliar nutrition Levels	**Number of whitefly colonies**							
F_0	1.41 (1.55)	3.52 (2.12)	7.27 (2.87)	10.25 (3.35)	19.94 (4.55)	24.38 (5.02)	28.88 (5.44)	34.33 (5.93)
F_1	1.97 (1.71)	3.02 (1.97)	7.02 (2.70)	11.97 (3.40)	17.22 (4.05)	21.00 (4.46)	25.41 (4.96)	29.52 (5.35)
F_2	1.91 (1.69)	3.52 (2.09)	6.38 (2.70)	10.88 (3.40)	15.47 (3.99)	20.19 (4.54)	22.80 (4.80)	26.27 (5.11)
F_3	1.30 (1.51)	2.36 (1.82)	6.00 (2.62)	10.36 (3.34)	15.50 (4.02)	19.80 (4.51)	24.38 (4.98)	27.08 (5.24)
SE(m)	**0.01**	**0.02**	**0.02**	**0.02**	**0.01**	**0.02**	**0.04**	**0.030**
CD	**0.04**	**0.07**	**0.08**	**NS**	**0.05**	**0.06**	**0.13**	**0.087**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients; Figures in the parentheses are $\sqrt{x+1}$ transformed values

Table 22. Interaction effect of soil and foliar nutrition levels on the number of whitefly colonies during the first field trial.

		Number of whitefly colonies							
TREAMENTS		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	105 DAT	120 DAT	135 DAT
T_1	P_1F_0	1.50 (1.58)	3.33 (2.08)	7.16 (2.85)	9.41 (3.22)	24.83 (5.08)	29.50 (5.52)	33.75 (5.89)	40.66 (6.45)
T_2	P_1F_1	3.00 (2.00)	4.83 (2.40)	14.00 (3.87)	24.00 (5.00)	33.91 (5.12)	41.16 (6.49)	45.58 (6.82)	51.58 (7.24)
T_3	P_1F_2	1.16 (1.47)	3.50 (2.12)	7.16 (2.85)	15.16 (4.02)	20.91 (4.68)	25.08 (5.10)	27.66 (5.35)	31.50 (5.70)
T_4	P_1F_3	1.417 (1.55)	3.00 (1.99)	5.25 (2.50)	9.25 (3.20)	15.50 (4.06)	17.66 (4.32)	21.00 (4.69)	22.16 (4.81)
T_5	P_2F_0	1.50 (1.58)	4.00 (2.23)	7.00 (2.82)	10.41 (3.37)	15.25 (4.03)	21.75 (4.76)	22.41 (4.16)	31.33 (5.68)
T_6	P_2F_1	1.16 (1.47)	2.58 (1.89)	4.33 (2.30)	8.00 (2.99)	10.66 (3.41)	12.50 (3.67)	16.33 (5.47)	19.75 (4.55)
T_7	P_2F_2	2.91 (1.97)	5.41 (2.53)	7.66 (2.94)	11.16 (3.48)	17.25 (4.27)	24.25 (5.02)	28.91 (5.47)	35.25 (6.02)
T_8	P_2F_3	0.83 (1.35)	2.41 (1.84)	4.41 (2.32)	7.25 (2.87)	10.16 (3.34)	14.08 (3.88)	17.08 (4.25)	20.08 (4.59)
T_9	P_3F_0	1.25 (1.50)	3.25 (2.05)	7.66 (2.94)	10.91 (3.45)	19.75 (4.55)	21.91 (4.78)	30.50 (5.61)	31.00 (5.65)
T_{10}	P_3F_1	1.75 (1.65)	1.66 (1.63)	2.75 (1.93)	3.91 (2.21)	7.08 (2.84)	9.33 (3.21)	14.33 (3.91)	17.25 (4.27)
T_{11}	P_3F_2	1.66 (1.63)	1.66 (1.63)	4.33 (2.30)	6.33 (2.70)	8.25 (3.04)	11.25 (3.50)	11.83 (3.58)	12.08 (3.61)
T_{12}	P_3F_3	1.66 (1.63)	1.66 (1.63)	4.33 (2.05)	6.58 (2.94)	8.83 (3.67)	12.66 (4.35)	13.08 (5.00)	13.00 (4.32)
SE(m)		**0.02**	**0.04**	**0.04**	**0.03**	**0.03**	**0.03**	**0.07**	**0.051**
CD(0.05)		**0.07**	**0.13**	**0.14**	**0.10**	**0.99**	**0.11**	**0.23**	**0.151**

T_1 : P.M + no foliar application (P_1F_0); T_2: P.M+ 1 foliar application (P_1F_1) ; T_3: P.M+ 2 foliar application (P_1F_2); T_4: P.M+ 3 foliar application (P_1F_3); T_5: P.M + NPK with no foliar application (P_2F_0); T_6: P.M +NPK + 1 foliar application (P_2F_1) ; T_7: P.M+ NPK + 2 foliar application (P_2F_2); T_8: P.M +NPK + 3 foliar application (P_2F_3); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_3). Figures in the parentheses are $\sqrt{x+1}$ transformed values. n = 12 plants

4.3.2. Number of whitefly colonies during second field trial

In the pot culture experiment conducted during November 2017 to May 2018, the effect of mineral nutrients in the development of whitefly colonies was evaluated and results are presented in the Table 23 and 24. Observations were recorded at biweekly interval from 15 days after transplanting (DAT).

On 15 days after transplanting (DAT) there was no significant difference in the number of whitefly colonies in all the three Soil nutrition Levels whereas on the 30 DAT maximum number of whitefly colony 9.66 was recorded on the plants in the P_1 nutrient level without NPK (only potting mixture). A minimum of 7.66 number of whitefly colonies was found in P_3 soil nutrient level with NPK + Ca + Mg which is on par with the number of colonies (7.83) in the P_2 nutrient level.

On 45, 60, 75 and 90 DAT, highest count of whitefly colonies i.e 14.16,7.5, 4.5, and 1.75 respectively, was found in the soil nutrient level P_1 and lowest in the P_3 nutrient level with 10.33, 5.16, 3.33 and 0.25 values respectively.

With the increase in soil nutrition levels for P_1 to P_3 there was a gradual decrease in the whitefly colonies during the entire growth phase of the crop. As the plant grew, the number of whitefly colonies increased upto 45 DAT, and then showed a gradual decrease till 90 DAT.

Foliar application of nutrients had significant effect on the number of whitefly colonies during 15, 30 and 45 DAT. On 15 DAT, highest count of whitefly colonies was obtained on the plants which obtained three levels of foliar applications (6.55) and on plants with one level of foliar application (6.55) whereas a minimum of 5.33 was found on plants without foliar application.

On 30 DAT maximum number of whitefly colony was found on plants with one level of foliar application (9.88) and minimum number of whitefly colony of 7.77 and 7.88 on plants with two and three foliar nutrition levels respectively.

On 45 DAT, highest count of whitefly colony of 12.88 was recorded on plants with one level of foliar nutrition and minimum was found on plants with two foliar nutrition levels (10.55).

The interaction effect of the soil nutrition levels and the foliar nutrition levels (table 24) were discernible on 15, 30 and 45 DAT. On 15 DAT maximum number of whitefly colony was recorded on plants of T_2 (8) which was on par with T_8 (7.33) whereas a minimum number of whitefly colony was recorded on plants of T_5 (4.66).

On 30 days after transplanting, highest count of whitefly colony was recorded in T_2 (13.33) and lowest count of 7 in T_5 and T_{11}. During 45 DAT, maximum number of whitefly colony was found in T_2 and a minimum number of whitefly colony was found in T_5 (10), T_6 (10.66), T_7 (10.33), T_9 (9.33) and T_{10} (9.33).

Table 23. Number of whitefly colonies in different soil and foliar nutrition levels during second field trial

Number of whitefly colonies						
Soil nutrition Levels	**15 DAT**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
P_1	6.33 (2.69)	9.66 (3.24)	14.16 (3.88)	7.5 (2.91)	4.5 (2.33)	1.75 (1.64)
P_2	6 (2.63)	7.83 (2.96)	10.83 (3.43)	6.33 (2.70)	4.25 (2.28)	0.5 (1.19)
P_3	5.91 (2.62)	7.66 (2.94)	10.33 (3.36)	5.16 (2.47)	3.33 (2.07)	0.25 (1.10)
SE(m)	**0.042**	**0.046**	**0.041**	**0.052**	**0.074**	**0.113**
CD	**NS**	**0.135**	**0.12**	**0.152**	**0.153**	**0.234**
Foliar nutrition levels	**Number of whitefly colonies**					
F_0	5.33 (2.51)	8 (2.99)	11.44 (3.50)	5.66 (2.57)	3.44 (2.10)	1 (1.36)
F_1	6.55 (2.74)	9.88 (3.27)	12.88 (3.70)	6.44 (2.57)	3.77 (2.17)	0.88 (1.33)
F_2	5.88 (2.62)	7.77 (2.96)	10.55 (3.39)	6.55 (2.57)	4.55 (2.35)	0.88 (1.33)
F_3	6.55 (2.74)	7.88 (2.97)	12.22 (3.63)	6.66 (2.57)	4.33 (2.29)	0.556 (1.20)
SE(m)	**0.04**	**0.05**	**0.04**	**0.06**	**0.085**	**0.13**
CD	**0.142**	**0.156**	**0.139**	**NS**	**0.176**	**NS**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients; Figures in the parentheses are $\sqrt{x+1}$ transformed values

Table 24. Interaction effect of soil and foliar nutrition levels on the number of whitefly colonies during second field trial

		Number of whitefly colonies					
TREATMENTS		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_1	P_1F_0	5.33 (2.51)	9.33 (3.21)	15 (3.99)	7 (2.82)	3.66 (2.15)	2.33 (1.82)
T_2	P_1F_1	8 (3)	13.33 (3.78)	17 (4.24)	8.33 (3.05)	4.33 (2.30)	1.66 (1.62)
T_3	P_1F_2	6 (2.64)	8.33 (3.05)	11 (3.46)	7 (2.82)	5 (2.44)	1.66 (1.62)
T_4	P_1F_3	6 (2.64)	7.66 (2.93)	13.66 (3.82)	7.66 (2.94)	5 (2.44)	1.33 (1.48)
T_5	P_2F_0	4.66 (2.37)	7 (2.82)	10 (3.31)	5.33 (2.51)	3.33 (2.07)	0.33 (1.13)
T_6	P_2F_1	6 (2.64)	8 (2.99)	10.66 (3.41)	6 (2.64)	4 (2.22)	0.66 (1.24)
T_7	P_2F_2	6 (2.64)	8 (2.99)	10.33 (3.36)	7 (2.82)	4.66 (2.37)	0.66 (1.24)
T_8	P_2F_3	7.33 (2.88)	8.33 (3.05)	12.33 (3.65)	7 (2.82)	5 (2.44)	0.33 (1.13)
T_9	P_3F_0	6 (2.64)	7.66 (2.94)	9.33 (3.21)	4.66 (2.37)	3.33 (2.07)	0.33 (1.13)
T_{10}	P_3F_1	5.66 (2.58)	8.33 (3.05)	11 (3.46)	5 (2.44)	3 (1.98)	0.33 (1.13)
T_{11}	P_3F_2	5.66 (2.58)	7 (2.82)	10.33 (3.36)	5.66 (2.57)	4 (2.23)	0.33 (1.13)
T_{12}	P_3F_3	6.33 (2.70)	7.66 (2.94)	10.66 (3.41)	5.33 (2.50)	3 (1.98)	0 (1)
SE(m)		**0.084**	**0.092**	**0.082**	**0.104**	**0.147**	**0.225**
CD(0.05)		**0.247**	**0.27**	**0.241**	**NS**	**NS**	**NS**

T_1 : P.M + no foliar application (P_1F_1); T_2: P.M+ 1 foliar application (P_1F_2) ; T_3: P.M+ 2 foliar application (P_1F_3); T_4: P.M+ 3 foliar application (P_1F_4); T_5: P.M + NPK with no foliar application (P_2F_1); T_6: P.M +NPK + 1 foliar application (P_2F_2) ; T_7: P.M+ NPK + 2 foliar application (P_2F_3); T_8: P.M +NPK + 3 foliar application (P_2F_4); T_9: P.M + NPK + Ca + Mg with no foliar application (P_3F_1); T_{10}: P.M + NPK + Ca + Mg+ 1 foliar application (P_3F_2); T_{11}: P.M +NPK + Ca + Mg+ 2 foliar application (P_3F_3); T_{12}: P.M +NPK + Ca + Mg+ 3 foliar application(P_3F_4). Figures in the parentheses are $\sqrt{x+1}$ transformed values. n = 12 plants

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Plate 7. Whitefly infestation in plants of T_2 of first field trial

Plate 8. Blackfly infestation in plants of T_2 of first field trial

4.4 BIOMETRIC OBSERVATIONS

Biometric observations such as length of plant, length of fruit and days to flowering of both the field trials are presented in Table 25 and 26.

Table 25. Effect of soil and foliar nutrition levels of mineral nutrition on biometric parameters of chilli

	First field trial			Second field trial		
Soil nutrition Levels	**Height of plant (cm)**	**Length of fruit (cm)**	**Days to flowering**	**Height of plant (cm)**	**Length of fruit (cm)**	**Days to flowering**
P_1	65.33	5.37	88.66	74.16	5.70	80.41
P_2	80.75	6.25	74.33	79.25	6.75	74.66
P_3	76.58	5.91	74.33	80.5	6.38	73.83
SE(m)	**1.735**	**0.188**	**0.502**	**0.748**	**0.112**	**0.828**
CD	**5.095**	**0.552**	**1.475**	**2.198**	**0.329**	**2.43**
Foliar nutrition levels	**First field trial**			**Second field trial**		
F_0	69.55	5.17	79.33	78.55	6.46	76.33
F_1	75.33	5.53	79.33	77.88	6.13	76.77
F_2	72.33	5.77	79	77.33	6.04	75.77
F_3	79.66	5.91	78.77	78.11	6.47	75.77
SE(m)	**2.004**	**0.217**	**0.58**	**0.864**	**0.129**	**0.956**
CD	**5.884**	**NS**	**NS**	**NS**	**NS**	**NS**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients; Figures in the parentheses are $\sqrt{x+1}$ transformed values

4.4.1 Biometric characters of first field trial

4.4.1.1 Length of plant

Soil nutrient levels showed significant difference in length of plant. Highest mean height of plants was recorded in NPK level P_2 with 80.75cm which was on par with plants of P_3 level (76.58cm) and the smallest was recorded in P_1 level. Foliar application of nutrients had significant effect on the length of plant. Maximum mean height was recorded in F_3 (79.66cm) which are on par with mean height of plants of F_1 (75.33cm) and the shortest belonged to F_0 with 69.55cm.

Interaction effect of soil nutrient levels with the foliar nutrition had a significant effect. Tallest plants were observed in treatment T_8 (85.66 cm) which is on par with T_5, T_7, T_9, T_{10} T_{11} and T_{12} and the shortest plant was recorded from treatment T_1 (61.33cm) which is on par with T_2 and T_3. There was no specific trend showed in the treatments.

4.4.1.2 Length of fruit

Significant effect was recorded for the length of fruit in the soil nutrient levels alone. Longest fruit was observed in P_2 whereas shortest was observed in the P_1 (5.37 cm) which is on par with the P_3. Though no significance was observed in the case of foliar nutrition, the fruit length had a linear relation with the levels of foliar nutrition.

Interaction effect of nutrients and the foliar applications did not show significant effect on the length of fruit.

4.4.1.3. Days to first flowering

Soil nutrition levels showed significant difference in days to first flowering. P_2 (74.33 days) and P_3 showed less number of days to flower. Foliar applications of nutrients didn't show significant difference. Interaction of soil nutrient levels and the foliar applications have significant difference and treatment

T9 showed early flowering (73 days) which was on par with T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11} and T_{12}. Late flowering was exhibited by T_1 (90.66) which were on par with T_2 and T_3. Hence from the data, we can conclude that treatments of NPK (P_1) and NPK + Ca + Mg (P_2) levels flowered early in comparison with P_1.

4.4.2. Biometric characters of plants in the second field trial

4.4.2.1. Length of plant

Soil nutrient levels showed significant difference in length of plant. Highest mean height of plants was recorded in NPK level P_3 with 80.5cm which is on par with plants of P_2 level (79.25cm) and the smallest was recorded in P_1 level. Foliar application of nutrients did not have significant effect on the length of plant.

Interaction effect of soil nutrition levels with the foliar application had a significant effect. Tallest plants were observed in treatment T_7 (83.33 cm) which was on par with T_5, T_9, T_{10} and T_{12} and the shortest plant was recorded from T_1 (72.66cm) which was on par with T_2 T_3 T_4 T_6 T_8 and T_{11}. There was no specific trend showed in the treatments.

4.4.2.2. Length of fruit

Significant effect was recorded for the length of fruit in the soil nutrition levels. Longest fruit was observed in the NPK nutrient level (6.75 cm) which was on par with P_3 (6.38 cm) whereas shortest was observed in the P_1 (5.70 cm).

Foliar application of nutrients and interaction effect of nutrients and the foliar applications did not have significant effect on the length of fruit.

4.4.2.3. Days to first flowering

Soil nutrition levels showed significant difference in days to first flowering. P_3 (73.83 days) and P_2 (74.66 days) showed less number of days to flower. Foliar applications of nutrients and interaction of soil nutrition levels with the foliar applications didn't show significant difference. The second trial is that as the soil nutritional levels increases, number of days to flowering reduced, which is true for foliar nutrition also, though it was not significant.

Table 26. Interaction effect of soil and foliar nutrient levels on biometric parameters of chilli

		First field trial			Second field trial		
Treatments		Height of plant (cm)	Length of fruit (cm)	Days to flowering	Height of plant (cm)	Length of fruit (cm)	Days to flowering
T_1	P_1F_0	61.33	5.83	90.66	72.66	5.83	80
T_2	P_1F_1	61.33	4.83	90	74.33	5.5	82
T_3	P_1F_2	64	5	88	74.66	5.33	78.66
T_4	P_1F_3	74.66	5.83	86	75	6.16	81
T_5	P_2F_0	83.66	6.7	74.33	81.33	7.16	74.66
T_6	P_2F_1	68.66	5.76	73.66	76.33	6.66	75
T_7	P_2F_2	85	6	74.33	83.33	6.5	74.33
T_8	P_2F_3	85.66	6.56	75	76	6.66	74.667
T_9	P_3F_0	81	6	73	81.66	6.4	74.33
T_{10}	P_3F_1	78.66	6	74.33	83	6.23	73.33
T_{11}	P_3F_2	75.66	6.33	74.66	74	6.3	74.33
T_{12}	P_3F_3	78.66	5.33	75.33	83.33	6.6	73.33
	SE(m)	**3.471**	**0.376**	**1.005**	**1.497**	**0.224**	**1.656**
	CD	**10.191**	**NS**	**2.95**	**4.395**	**NS**	**NS**

4.5. YIELD PARAMETERS

Yield parameters such as total yield, marketable yield and total biomass of both the field trials are presented in table 27 and 28.

4.5.1. Yield parameters of first field trial

4.5.1.1. Fresh weight of fruits

Soil nutrition levels had significant effect on the average fresh weight of fruits of plants. Nutrient level P_3 had maximum fresh weight of fruit of 536.5g and minimum was recorded in P_1 (163.87g). Foliar application of nutrients had significant effect on the fresh weight of fruits of plants. Maximum fresh weight of fruits was recorded in plants of F_1 (422.61g) and minimum in F_0 (305.21g)

Interaction effect of soil nutrient levels and the foliar nutrition levels were found to be significant. Maximum fresh weight of fruits was recorded in T_{10} (636g) whereas minimum fresh weight of fruits was recorded in T_1 (90.65g). When different nutrient level was taken separately maximum fresh weight of fruits was found in treatments of P_3 (NPK + Ca + Mg level) and a little less in P_2 (NPK nutrient level).

4.5.1.2. Marketable yield

When marketable yield is taken into consideration, it followed the same trend of total yield. The maximum yield of 530.3g in P_3 and minimum of 159.11g P_1. Foliar application of nutrients had significant effect on the marketable yield of plants. Maximum yield was recorded in plants of F_1 (412.51g) and minimum in F_0 (302.21g).Interaction effect of soil nutrition levels and the foliar application of nutrient were found to be significant. Maximum yield was recorded in T_{10} (630g) whereas minimum yield was recorded in T_1 (87.23g). At P_1 level increasing foliar nutrition increases marketable yield, at P_2 level the trend is not visible and at P_3 level

4.5.1.3. Plant dry weight

Soil nutrient levels had significant effect on the plant dry weight of plants. Nutrient level P_3 had maximum plant dry weight of 52.66g and minimum plant dry weight was recorded in P_1 (21.75g). It is clear that increase in nutrition has increased the plant dry weight. Foliar application of nutrients had significant effect on the plant dry weight of plants. Maximum plant dry weight was recorded in plants of F_3 (41.88g) and minimum in F_2 and F_0 (39.44g) which is on par with F_1.

Interaction effect of soil and foliar nutrition levels were found to be significant. Maximum plant dry weight was recorded in T_{10} (53.66g) which was on par with T_9, T_{11} and T_{12} whereas minimum plant dry weight was recorded in T_2 and T_3 (21g) which was on par with T_1 and T_4.

4.5.1.4. Number of fruits

Soil nutrition levels had significant effect on the average number of fruits of plants. Nutrient level P_3 had maximum fresh weight of fruit of 268.25 and minimum was recorded in P_1 (81.93). Foliar application of nutrients had significant effect on the fresh weight of fruits of plants. Maximum fresh weight of fruits was recorded in plants of F_1 (422.61) and minimum in F_0 (305.21).

Interaction effect of soil nutrient levels and the foliar nutrition levels were found to be significant. Maximum number of fruits was recorded in T_{10} (318) whereas minimum was recorded in T_1 (45.32). When different nutrient level was taken separately maximum fresh weight of fruits was found in treatments of P_3 (NPK + Ca + Mg level) and a little less in P_2 (NPK nutrient level).

4.5.2. Yield parameters of second field trial

4.5.2.1. Fresh weight of fruits

Soil nutrition levels had significant effect on the average fresh weight of fruits of plants. Nutrient level P_2 had maximum fresh weight of fruits of 408.33g which was on par with P_3 and minimum fresh weight of fruits was recorded in P_1 (152.41g). Foliar application of nutrients had no significant effect on the fresh weight of fruits of plants. Interaction effect of soil nutrition levels and the foliar application of nutrient were found to be not significant. But there was a trend of increase in fresh weight of fruits along the levels of the nutrients.

4.5.2.2. Marketable yield

When marketable yield is taken into consideration, it followed the same trend of total yield with a maximum yield of 401.11g in P_2 which was on par with P_3 and minimum of 149.12g in P_1. Foliar application of nutrients had no significant effect on the yield of plants. Interaction effect of soil nutrition levels and the foliar application of nutrient were found to be not significant.

4.5.2.3. Plant dry weight

Soil nutrition levels had significant effect on the plant dry weight of plants. Nutrient level P_3 had maximum plant dry weight of 55.91g and minimum plant dry weight was recorded in P_1 (37.08g). Foliar application of nutrients had significant effect on the plant dry weight of plants. Maximum plant dry weight was recorded in plants of F_3 (49.55g) which was on par with F_1 and F_2 and minimum in F_0 (43.22g). Interaction effect of soil and foliar nutrition levels were found to be non significant, but increase in soil and foliar nutrition levels increased the plant dry weight.

4.5.2.4. Number of fruits

Soil nutrition levels had significant effect on the number of fruits per plants. Nutrient level P_2 had maximum number of fruits of 204.16 which was on par with P_3 and minimum was recorded in P_1 (76.20). Foliar application of nutrients had no significant effect on the number of fruits of plants. Interaction effect of soil and the foliar nutrition levels were found to be not significant.

Table 27. Effect of soil and foliar nutrition levels on yield parameters of chilli

	First field trial				Second field trial			
Soil nutrition levels	Fresh weight of fruits (g)	Number of fruits	Marketable yield (g)	Plant dry weight(g)	Fresh weight of fruits (g)	Number of fruits	Market able yield (g)	Plant dry weight(g)
P_1	163.87	81.93	159.11	21.75	152.41	76.20	149.12	37.08
P_2	421.66	210.83	412.11	45.16	408.33	204.16	401.11	47.33
P_3	536.5	268.25	530.3	52.66	381.41	190.70	379.30	55.91
SE(m)	**5.257**	**2.628**	**5.20**	**0.563**	**13.56**	**6.78**	**12.60**	**0.896**
CD	**15.43**	**7.717**	**13.20**	**1.65**	**39.81**	**19.907**	**31.20**	**2.63**
				Levels of foliar nutrition				
F_0	305.21	152.60	302.21	39.44	298.11	149.056	286.00	43.22
F_1	422.61	211.30	412.51	38.66	331	165.5	321	46.66
F_2	369.55	184.77	356.22	39.44	297.33	148.667	285.22	47.66
F_3	398.66	199.33	385.33	41.88	329.77	164.889	312.88	49.55
SE(m)	**6.07**	**3.035**	**4.5**	**0.65**	**15.65**	**7.829**	**13.2**	**1.035**
CD	**17.82**	**8.911**	**15.6**	**1.90**	**NS**	**NS**	**NS**	**3.03**

P_1: Potting mixture without NPK ; P_2 : Potting mixture with NPK; P_3: Potting mixture with NPK + Ca + Mg; F_0: No foliar application; F_1: One foliar application; F_2: Two foliar application; F_3: Three foliar application of mineral nutrients

Table 28. Interaction effect of soil and foliar nutrition levels on yield parameters of chilli.

Treatments		First field trial				Second field trial			
		Fresh weight of fruits (g)	Number of fruits	Marketable yield (g)	Plant dry weight (g)	Fresh weight of fruits (g)	Number of fruits	Marketable yield (g)	Plant dry weight(g)
T_1	P_1F_0	90.65	45.327	87.23	22	141	70.5	138	33.33
T_2	P_1F_1	133.83	66.917	128.22	21	143.66	71.833	140.2	36.66
T_3	P_1F_2	194	97	189.2	21	159.33	79.667	156.23	38.33
T_4	P_1F_3	237	118.5	227	23	165.66	82.833	162.01	40
T_5	P_2F_0	328	164	325	45.33	397	198.5	381.02	41
T_6	P_2F_1	498	249	490	41.33	383.66	191.833	375.11	47.66
T_7	P_2F_2	443.33	221.667	435	44.33	415.33	207.667	407.22	49
T_8	P_2F_3	417.33	208.667	408	49.66	437.33	218.667	427.33	51.66
T_9	P_3F_0	497	248.5	485	51	356.33	178.167	345.6	55.33
T_{10}	P_3F_1	636	318	630	53.66	465.66	232.833	462.11	55.66
T_{11}	P_3F_2	471.33	235.667	466.33	53	317.33	158.667	310.22	55.66
T_{12}	P_3F_3	541.66	270.833	535.11	53	386.33	193.167	375.22	57
SE(m)		**10.514**	**5.257**	**9.58**	**1.126**	**27.11**	**13.56**	**25.33**	**1.792**
CD		**30.87**	**15.435**	**28.36**	**3.307**	**NS**	**NS**	**NS**	**NS**

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4.6. NUTRIENT CONCENTRATIONS IN SOIL AND PLANT

4.6.1 Nutrient status of soil

Various chemical analyses of soil samples were conducted in order to examine the initial nutrient status of soil. Soil samples for laboratory analysis were collected from 3 soil nutrition levels s. The samples were air dried, ground, sieved with 2mm sieve and stored in air tight container. They were analyzed for available nutrients such as K, Ca, Mg, S, Cu, Zn, B and Si as per the standard procedures as given in the materials and methods. Available nutrient status of soils from two field trials are presented in table 29 and 30.

4.6.2 Nutrient concentration in plant

Various chemical analyses of plant samples were conducted in order to examine the effect of foliar application of mineral nutrients and soil nutrition levels s on plant's nutrient status. The plant samples were collected at harvest stage of the crop and dried in hot air oven, powdered and were analyzed using standard analytical procedures as described in materials and methods. The effect of treatment on total nutrients in plant in two field trials is presented in Table 31, 32, 33 and 34.

The nutrient concentration in plants during first field trial

4.6.2.1 Nitrogen

Soil nutrition levels showed significant difference in nitrogen content of plants. Maximum nitrogen percent in plants was recorded in NPK + Ca + Mg level P_3 with 1.68 percent and the minimum was recorded in P_1 non chemical regime. Foliar nutrition had significant effect on the nitrogen content in plant. Maximum nitrogen percent was recorded in F_3 (1.59 %) which is on par with F_2 and the minimum belonged to F_0. Interaction effect of soil nutrition levels with the foliar nutrition on the nitrogen percent in plants was not significant.

4.6.2.2 Potassium

Soil nutrition levels showed notable difference in potassium content of plants. Maximum potassium percent in plants was recorded in NPK + Ca + Mg level P_3 with 1.468 percent and the minimum was recorded in P_1 non chemical level (1.081 %). Foliar nutrition had significant effect on the potassium content in plants. Maximum potassium percent was recorded in F_3 and F_2 (1.467 %) and the minimum belonged to F_0 (0.987%). Interaction effect of soil nutrition levels with the foliar application on the potassium percent in plants was significant. The highest potassium content was observed in T_{10} (1.707%) which was on par with T_4, T_6 and T_{11}. Lowest potassium percent was recorded in T_1 (0.66) and T_2 (0.66).

4.6.2.3. Calcium

Soil nutrition levels showed notable difference in calcium content of plants. Maximum calcium percent in plants was recorded in NPK + Ca + Mg level P_3 with 0.284 percent and the minimum was recorded in P_1 non chemical level (0.196%). Foliar nutrition had significant effect on the calcium content in plants. Maximum calcium percent was recorded in F_3 (0.272%) which is on par with F_2 (0.237%) and the minimum belonged to F_0 (0.987%). Interaction effect of soil nutrition levels with the foliar application on the calcium percent in plants was not significant.

4.6.2.4. Magnesium

Soil nutrient and foliar nutrition levels and their interaction did not showed notable difference in magnesium content of plants.

4.6.2.5. Sulphur

Soil nutrient and foliar nutrition levels and their interaction did not showed notable difference in sulphur content of plants.

4.6.2.6. Copper

Soil nutrient levels showed significant difference in copper content of plants. Maximum copper percent in plants was recorded in NPK + Ca + Mg level P_3 with 6.757 ppm which is on par with P_2 (6.252 ppm) and the minimum was recorded in P_1 non chemical level(5.672 ppm). Foliar nutrition levels had significant effect on the copper content in plant. Maximum copper percent was recorded in F_3 (7.399 ppm) and the minimum belonged to F_0 (5.398 ppm) which is on par with F_1. Interaction effect of soil nutrient levels with the foliar nutrition on the copper percent in plants was significant. The highest copper content was observed in T_8 (8.243 ppm) which was on par with T_9 and $T_{12.}$ Lowest copper content was recorded in T_1 (3.707 ppm).

4.6.2.7. Zinc

Soil nutrition levels showed significant difference in zinc content of plants. Maximum zinc content in plants was recorded in NPK + Ca + Mg level P_3 with 24.396 ppm which is on par with P_2 (23.493 ppm) and the minimum was recorded in P_1 non chemical level(22.407 ppm). Foliar nutrition had significant effect on the zinc content in plant. Maximum zinc percent was recorded in F_2 (24.836 ppm) which is on par with F_3 and F_1 and the minimum belonged to F_0 (21.746ppm). Interaction effect of soil nutrition levels with the foliar application on the zinc content in plants was not significant.

4.6.2.8. Silicon

Soil nutrition levels and foliar applications and their interaction did not showed notable difference in silicon content of plants.

Table 29: Soil nutrient status of first field trial

Nutrients	Initial soil nutrient status			Final nutrition status		
	Non chemical nutrition level	NPK nutrition level	NPK Ca Mg nutrition level	Non chemical nutrition level	NPK nutrition level	NPK Ca Mg nutrition level
N (Kg/ha)	301.60	425.12	427.02	220.01	303.60	303.1
K (Kg/ha)	220.2	305.2	306.3	160.2	162.1	173.2
Ca (mg/kg)	620.75	628.50	1300.50	286	398	986
Mg (mg/kg)	56	60	150	35.25	34.65	135.55
S (mg/kg)	3.41	3.45	9.25	2.05	2.03	5.65
B (mg/kg)	0.16	0.17	0.18	0.08	0.08	0.09
Cu (mg/kg)	1.52	1.66	1.57	0.82	0.98	1.02
Zn (mg/kg)	3.05	3.08	3.80	2.56	2.74	2.52
Si (mg/kg)	31.14	52.60	55.05	22.3	44.6	56.6

Table 30. Soil nutrient status of second field trial

Nutrients	Initial soil nutrient status			Final nutrition status		
	Non chemical nutrition level	NPK nutrition level	NPK Ca Mg nutrition level	Non chemical nutrition level	NPK nutrition level	NPK Ca Mg nutrition level
N (Kg/ha)	313.60	450.12	451.02	250.01	313.60	300.1
K (Kg/ha)	250.2	325.2	326.3	168.2	172.1	183.2
Ca (mg/kg)	624.75	638.50	1450.00	300	450	1000
Mg (mg/kg)	60	70	240	36.25	37.65	140.55
S (mg/kg)	3.51	3.75	10.25	2.15	2.35	6.5
B (mg/kg)	0.17	0.19	0.19	0.07	0.09	0.08
Cu (mg/kg)	1.65	1.75	1.76	0.72	0.9	1.05
Zn (mg/kg)	3.69	3.88	3.90	2.76	2.84	2.89
Si (mg/kg)	32.14	54.60	56.05	25.3	45.6	57.6

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TABLE 31 : Effect of soil and foliar nutrition levels on nutrient status of plants during first field trial

Soil nutrition levels	Nitrogen in %	Potassium in %	Calcium in %	Magnesium in %	Sulphur in %	Copper in ppm	Zinc in ppm	Silicon in %
P 1	1.456	1.081	0.196	0.165	0.231	5.672	22.407	0.295
P 2	1.568	1.403	0.228	0.166	0.247	6.252	23.493	0.343
P 3	1.68	1.468	0.284	3.035	4.936	6.757	24.396	0.46
SE(m)	0.023	0.018	0.013	1.182	1.937	0.139	0.5	0.006
CD	0.067	0.054	0.04	NS	**NS**	0.409	1.469	NS
Foliar nutrition levels								
F_0	1.278	0.987	0.207	0.151	0.236	5.398	21.746	0.289
F_1	1.503	1.349	0.228	2.02	3.632	5.792	23.416	0.337
F_2	1.542	1.467	0.237	0.16	3.089	6.318	24.836	0.382
F_3	1.59	1.467	0.272	2.157	0.261	7.399	23.731	0.456
SE(m)	0.027	0.021	0.016	1.365	2.236	0.161	0.578	0.006
CD	0.078	0.062	0.046	NS	NS	0.472	1.696	NS

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TABLE 32 : Interaction effect of soil and foliar nutrition levels on nutrient status of plants during first field trial

Treatments		Nitrogen in %	Potassium in %	Calcium in %	Magnesium in %	Sulphur in %	Copper in ppm	Zinc in ppm	Silicon in %
T_1	P_1F_0	1.35	0.6	0.173	0.14	0.213	3.707	20.07	0.2
T_2	P_1F_1	1.28	0.66	0.18	0.15	0.22	7.187	21.817	0.267
T_3	P_1F_2	1.35	1.443	0.207	0.183	0.247	5.97	24.087	0.323
T_4	P_1F_3	1.36	1.62	0.223	0.187	0.243	5.823	23.653	0.39
T_5	P_2F_0	1.59	1.06	0.2	0.147	0.227	5.083	22.337	0.3
T_6	P_2F_1	1.57	1.68	0.23	0.177	0.243	5.19	23.21	0.283
T_7	P_2F_2	1.59	1.38	0.21	0.17	0.253	6.49	24.263	0.357
T_8	P_2F_3	1.61	1.49	0.27	0.17	0.263	8.243	24.163	0.43
T_9	P_3F_0	1.65	1.3	0.247	0.167	0.267	7.403	22.83	0.367
T_{10}	P_3F_1	1.67	1.707	0.273	5.733	10.433	5	25.22	0.46
T_{11}	P_3F_2	1.68	1.577	0.293	0.127	8.767	6.493	26.157	0.467
T_{12}	P_3F_3	1.72	1.29	0.323	6.113	0.277	8.13	23.377	0.547
	SE(m)	0.046	0.037	0.027	2.364	3.873	0.278	1.001	0.011
	CD	NS	0.108	NS	NS	NS	0.817	NS	NS

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The nutrient concentration in plants during second field trial

4.6.2.9. Nitrogen

Soil nutrition levels s showed significant difference in nitrogen content of plants. Maximum nitrogen percent in plants was recorded in NPK + Ca + Mg level P_3 with 1.680 percent and the minimum was recorded in P_1 non chemical regime. Foliar nutrition had significant effect on the nitrogen content in plan. Maximum nitrogen percent was recorded in F_3 (1.59 %) which is on par with F_2 and the minimum belonged to F_0. Interaction effect of soil nutrition levels s with the foliar application on the nitrogen percent in plants was not significant.

4.6.2.10. Potassium

Soil nutrition levels s showed notable difference in potassium content of plants. Maximum potassium percent in plants was recorded in NPK + Ca + Mg level P_3 with 1.474 percent which is on par with P_2 and the minimum was recorded in P_1 non chemical level (1.099 %). Foliar nutrition had significant effect on the potassium content in plants. Maximum potassium percent was recorded in F_2 (1.507%) and the minimum belonged to F_0 (1.017%). Interaction effect of soil nutrition levels s with the foliar application on the potassium percent in plants was significant. The highest potassium content was observed in T_{10} (1.693%) which was on par with T_4, T_6 and T_{11}. Lowest potassium percent was recorded in T_1 (0.61) and T_2 (0.69).

4.6.2.11. Calcium

Soil nutrition levels s and foliar applications and their interaction did not showed notable difference in calcium content of plants.

4.6.2.12. Magnesium

Soil nutrition levels s and foliar applications and their interaction did not showed notable difference in magnesium content of plants.

4.6.2.13. Sulphur

Soil nutrition levels s, foliar applications and their interaction did not showed notable difference in sulphur content of plants.

4.6.2.14. Copper

Soil nutrition levels s showed significant difference in copper content of plants. Maximum copper percent in plants was recorded in NPK + Ca + Mg level P_3 with 6.657 ppm which is on par with P_2 (6.52 ppm) and the minimum was recorded in P_1 non chemical level(5.72 ppm). Foliar nutrition had significant effect on the copper content in plant. Maximum copper percent was recorded in F_3 (7.42 ppm) and the minimum belonged to F_0 (5.29 ppm) which is on par with F_1. Interaction effect of soil nutrition levels s with the foliar application on the copper percent in plants was significant. The highest copper content was observed in T_8 (8.14 ppm) which was on par with T_9 and $T_{12.}$ Lowest copper content was recorded in T_1 (3.07 ppm).

4.6.2.15. Zinc

Soil nutrition levels s did not showed significant difference in zinc content of plants. Foliar nutrition had significant effect on the zinc content in plant. Maximum zinc percent was recorded in F_2 (27.836 ppm) which is on par with F_1 and the minimum belonged to F_0 (22.082 ppm). Interaction effect of soil nutrition levels s with the foliar application on the zinc content in plants was significant. The highest copper content was observed in T_{10} (ppm) which was on par with T_3 Lowest potassium percent was recorded in T_1 (22.38ppm).

4.6.2.16. Silicon

Soil nutrition levels s and foliar applications and their interaction did not showed notable difference in silicon content of plants.

TABLE 33 : Effect of soil and foliar nutrition levels on nutrient status of plants during second field trial

	Nitrogen in %	Potassium in %	Calcium in %	Magnesium in %	Sulphur in %	Copper in ppm	Zinc in ppm	Silicon in %
Soil nutrition levels								
P 1	1.456	1.099	0.208	0.163	0.24	5.72	25.3	3.281
P 2	1.568	1.443	0.215	0.155	0.26	6.52	25.77	0.326
P 3	1.680	1.474	3.746	4.412	0.98	6.657	26.028	0.473
SE(m)	0.028	0.018	1.464	1.439	2.452	0.139	0.312	1.982
CD	0.081	0.054	NS	NS	NS	0.391	NS	NS
Foliar nutrition levels								
F_0	1.278	1.017	0.197	0.153	0.24	5.29	22.082	0.281
F_1	1.503	1.354	2.283	2.02	3.608	5.69	26.089	0.328
F_2	1.542	1.507	2.84	2.001	7.076	6.35	27.836	4.348
F_3	1.59	1.477	0.238	2.132	3.062	7.42	24.791	0.482
SE(m)	0.094	0.021	1.69	1.662	2.832	0.161	0.36	1.982
CD	0.032	0.062	NS	NS	NS	0.372	1.057	NS

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TABLE 34: Interaction effect of soil and foliar nutrition levels on nutrient status of plants during second field trial

Treatments		Nitrogen in %	Potassium in %	Calcium in %	Magnesium in %	Sulphur in %	Copper in ppm	Zinc in ppm	Silicon in %
T_1	P_1F_0	1.25	0.61	0.187	0.147	0.24	3.07	22.38	0.19
T_2	P_1F_1	1.26	0.69	0.207	0.157	0.24	7.22	25.3	0.257
T_3	P_1F_2	1.26	1.477	0.223	0.177	0.26	5.87	28.16	0.22
T_4	P_1F_3	1.25	1.62	0.213	0.173	0.25	5.73	25.36	0.457
T_5	P_2F_0	1.31	1.13	0.187	0.143	0.22	5.18	25.3	0.27
T_6	P_2F_1	1.32	1.68	0.23	0.17	0.25	5.17	26.38	0.273
T_7	P_2F_2	1.3	1.47	0.2	0.16	0.3	6.39	26.713	0.337
T_8	P_2F_3	1.32	1.49	0.243	0.147	0.27	8.14	24.687	0.423
T_9	P_3F_0	1.52	1.31	0.217	0.17	0.26	7.34	24.567	0.383
T_{10}	P_3F_1	1.52	1.693	6.413	5.733	0.333	4.9	26.587	0.453
T_{11}	P_3F_2	1.53	1.573	8.097	5.667	0..667	6.39	28.633	0.487
T_{12}	P_3F_3	1.6	1.32	0.257	6.077	0.667	8.03	24.327	0.567
	SE(m)	0.055	0.037	2.928	2.878	4.905	0.278	0.623	3.432
	CD	NS	0.108	NS	NS	NS	0.807	1.831	NS

4.6.3. Correlation of nutrients with the population of mites and whitefly

The relationship between plant nutrient contents and average number of mites and average whitefly colonies of both the field trials were worked out by correlation studies and presented in Table 35.

Nitrogen, potassium, zinc, copper and silicon had positive correlation with the average number of mites during first and second field trials. But it was not statistically significant whereas as calcium, magnesium and sulphur had negative correlation. Nitrogen, potassium, calcium, magnesium, sulphur, copper and silicon had significant negative correlation with the whitefly colonies during both the field trials.

Table 35. Correlation of nutrients with the population of mites and whitefly

Nutrients	Correlation value with average number of mites 1st trial	Correlation value with average number of mites 2nd trial	Correlation value with average number of whitefly colonies 1st trial	Correlation value with average number of whitefly colonies 2nd trial
N	0.123574	0.112386	-0.75292*	-0.84058*
K	0.199981	0.335998	-0.8058*	-0.29735
Ca	-0.13038	-0.01468	-0.82662*	-0.38153*
Mg	-0.22282	-0.01676	-0.47149*	-0.59411*
S	-0.07031	0.193066	-0.49426*	-0.44291*
Zn	0.010354	0.16848	-0.11272	-0.11619
Cu	0.28001	0.281396	-0.68747*	-0.01062
Si	0.003477	0.198442	-0.74649*	-0.48256*

* Significant at 0.05%

DISCUSSION

5. DISCUSSION

5.1 EFFECT OF MINERAL NUTRITION ON MITE POPULATION AND THEIR DAMAGE SYMPTOMS

During both the field trials the population densities and leaf curl indices of mites were significantly influenced by the soil and foliar nutrition levels.

It's evident from the graph that P_2 level had highest and P_1 level had lowest population of mites. The plants of P_2 level had luxuriant vegetative growth which might have resulted in the attraction of mites whereas the plants of first nutrient level were comparatively less vigorous resulting in lowest infestation. The findings are consistent with other studies which have found nitrogen to have a positive influence on the mite density. For example, according to Najafabadi *et al.* (2011) an increase in Nitrogen level enhanced the mite population on bean leaves. In a study by Huelsman *et al.* (2000) in Jamaican sweet potato, they found that at high nitrate and phosphorus levels in soil, the incidence of insect pest increases.

There was a gradual reduction in the mite population throughout the growth phase. This comment goes in line with work of Wilson (1994) who elaborated that as the plant develops and leaves age, nitrogen content within the leaves decline as a result the infestation decreases. The study shows that mites evaluate plant quality and change their behavior accordingly. Third nutrient level NPK + Ca + Mg harbored pests to a minimal number and at the same time produced highest yield. Application of calcium and magnesium might have enhanced the mineralization and uptake of potassium and other nutrients from the soil as a result of which the mite population decreased in the third regime. This was reported in an earlier study of Khairnar and Patel (2015) where the application of potassic fertilizers at the rate of 40 and 60 kg/ha imparted host plant resistance against sucking pests.

Minimum mite population was recorded in the treatments without foliar nutrition and maximum in F_2. There was a positive relation between the number of foliar application and the number of mites up to third level of foliar nutrition and the number decreases. This might be due to the nutrient threshold level above which there would be reduction in the population.

The interaction effect of foliar nutrition and soil nutrient levels on mite population and the visual damages were significant and the graph obtained from the data of 45 DAT, 60 DAT, 75 DAT and 90 DAT revealed that throughout the season the maximum mite population was recorded in T_7 (NPK nutrient level and two levels of foliar nutrition). The increased nutrient application has improved the vegetative growth of plants and might have supported better growth and survival of mites whereas insufficient nutrition in plants of first nutrient level might have made the plant less attractive for the mites. Chow *et al.,* (2008) reported that liquid fertilizer containing NPK at 100 percent of recommended dose showed the highest incidence of mite on different parts of the rose plant when compared to 33 per cent and 50 per cent of the full dose.

From the graph it's evident that T_1, T_2, T_9 and T_{10} showed less mite population but among these treatments T_{10} had greater yield and vegetative growth. Hence considering the magnitude of mite infestation and the economic yield, T_{10} was found to be better treatment as mite population was lesser and had highest yield.

Similar trend was visible in the damage symptoms like leaf curl index, and number of curled leaves since damages is the effect of mite population densities.

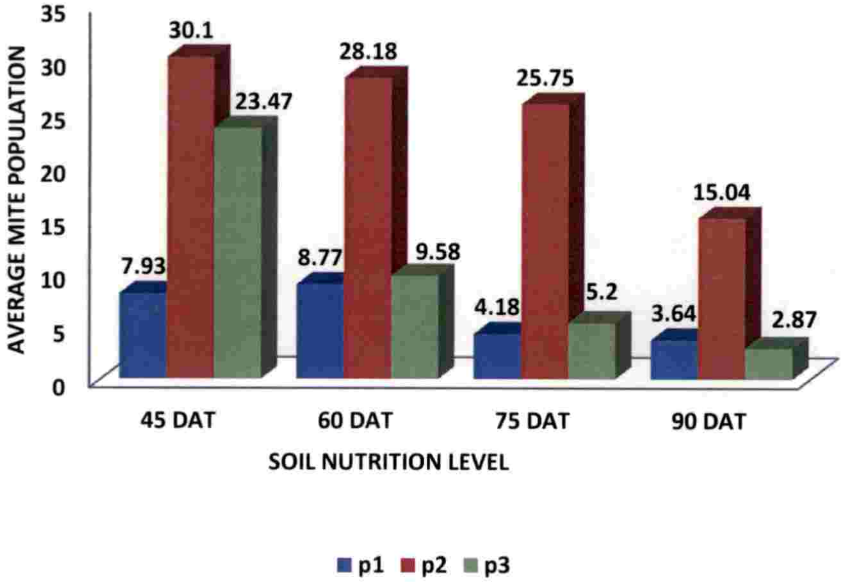

Figure 1: Effect of soil nutrition levels on average mite population of first field trial

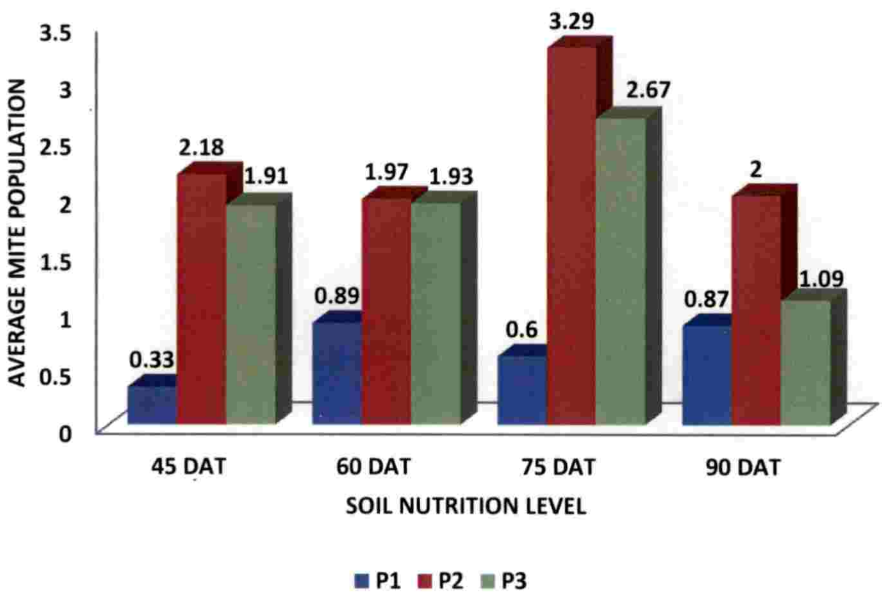

Figure 2: Effect of soil nutrition levels on average mite population of second field trial

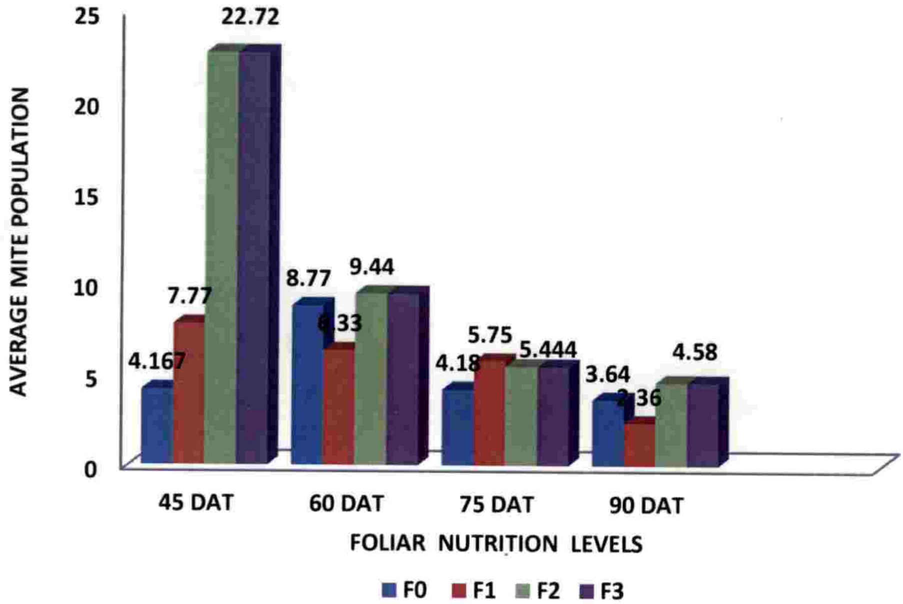

Figure 3: Effect of foliar nutrition levels on average mite population of first field trial

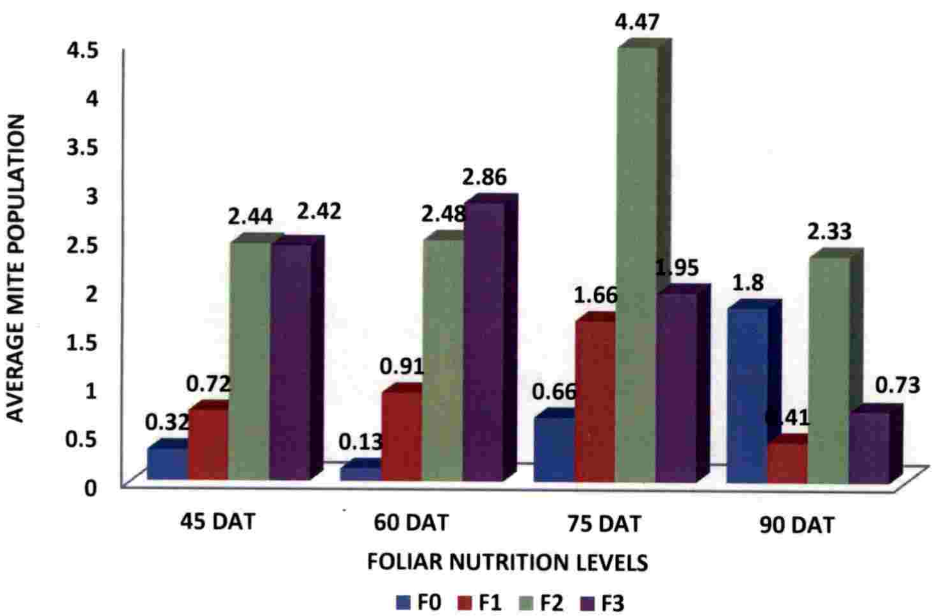

Figure 4: Effect of foliar nutrition levels on average mite population of second field trial

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5.2 EFFECT OF MINERAL NUTRITION ON THRIPS POPULATION AND THEIR DAMAGE SYMPTOMS

Soil and foliar nutrition levels and their interaction effect had a significant effect on thrips population only during 45 and 75 DAT. They didn't exhibit any specific trends. This is because thrips is a low density pest.

Out of the three soil nutrition levels plants of NPK level (P_2) harboured maximum population and minimum in P_1. The highest leaf curl index of 45 and 60 DAT were on P_2 nutrient level whereas at 75 and 90 DAT highest LCI was observed on P_3 *viz* 8.24 and 7.20 ,which were on par with P_2 with 7.80 and 7.06 respectively. This is in line with the findings of Ukey *et al.* (2005) where the application of nitrogen favoured the increase in thrips population and the lowest population was exhibited in plants grown without NPK.

Maximum population of thrips was observed in one application of foliar nutrition and minimum was recorded in two foliar application of nutrition whereas leaf curl index was found maximum in three applications of foliar nutrition and minimum in one or two applications. This is found unusual because in the case of mites, there was a positive relation between the number of foliar application and the number of mites and a similar result was obtained for Priya (2017) where three nutrient sprays + NPK+ Ca +Mg found to have highest aphid score on stem and pod of cowpea.

Interaction effect of soil and foliar nutrition levels on the thrips population didn't exhibit any particular pattern. Throughout the season minimum thrips population and LCI was exhibited by the treatments of first level that is T_1, T_2, T_3, T_4 and maximum in T_8 or T_6 that is NPK nutrient level with three or one levels of foliar nutrition. Hence we can conclude that NPK level with one or three foliar nutrition gives maximum infestation. In a similar study by Huelsman *et al.* (2000)

in Jamaican sweet potato, they found that at high nitrate and phosphorus levels in soil, the incidence of insect pest increases.

Least population of thrips was obtained in treatments of P_1 along with any number of foliar applications. In treatments of P_1 foliar nutrition compensated the nutrient requirement hence positive relation existed between levels of foliar nutrition on the thrips. Lower thrips population was recorded in treatments of P_3 with any number of foliar applications. Number of foliar spray is not specific but one foliar application of nutrients is adequate to reduce the pests because application above one does not have any positive effect due to nutritional homeostasis (Hayden *et al.* 2015).

5.3. INFLUENCE OF MINERAL NUTRIENTS ON THE WHITEFLY COLONIES

Soil and foliar nutrition levels and their interaction effect had a significant effect on the number of whitefly colony. With the increase in soil nutrition levels from P_1 to P_3 there was a gradual decrease in the whitely colonies throughout the growth phase of the crop during both the field trials. Chatterjee *et al.*(2013) reported that the whitefly attacks unhealthy plants first and colonize on them and balanced nutrition has helped in reduction of the whitefly infestation. Similar results were obtained when Park *et al.* (2009) conducted a study to find the influence of different concentrations of nitrogen fertilization on the cultivar preference, honeydew production and development by greenhouse whitefly *Trialeurodus vaporariorum* in two cherry tomato cultivars. The experiment exhibited a negative correlation between the nitrogen concentration and the developmental times of nymphs and eggs on both cultivars. The upper plant stratum was the preferred site for oviposition and the honeydew production of nymphs increased with decreasing nitrogen concentration.

Effect of foliar nutrition didn't show any specific pattern on whitefly colonies during the first field trial. But during the second field trial maximum whitefly colonies was recorded on plants of F_1, F_2 and F_3 whereas minimum in F_0. Hayden *et al.* (2015) reported that nutritional homeostasis might be the reason for the stable nutrient acquisition. Though we provide three foliar applications of nutrients proportional increase in absorption of nutrients might not have taken place because of homeostasis. That is the reason why all the three levels of foliar application showed higher population of whitefly colonies.

Hence one foliar application of nutrients is found to be good for reduction of whitefly infestation. Similar results were also obtained by Ebaid and Mansour, (2006) who reported that plants treated with micronutrients mix which includes twelve per cent each of Zn, Mn, Fe, Cu and liquid Boron 6 per cent in cotton showed a significant drop in the population of aphids (*Aphis gossypi*) (40, 29) over control (71, 44) in two seasons

Among the interaction effects T_{10}, T_{11} and T_{12} exhibited minimum number of whitefly colonies whereas T_2, T_7 and T_8 exhibited maximum throughout the growth phase in both the field trials. Azaizeh *et al*. (2005) reported that balanced NPK Ca Mg nutrition is a very important factor regulating the growth, development and synthesis of secondary metabolites in plants. Moreover, excessive and reduced fertilization with mineral nutrients may be harmful to plants and the proportion of nutrients is as important as that of the concentration of nutrients.

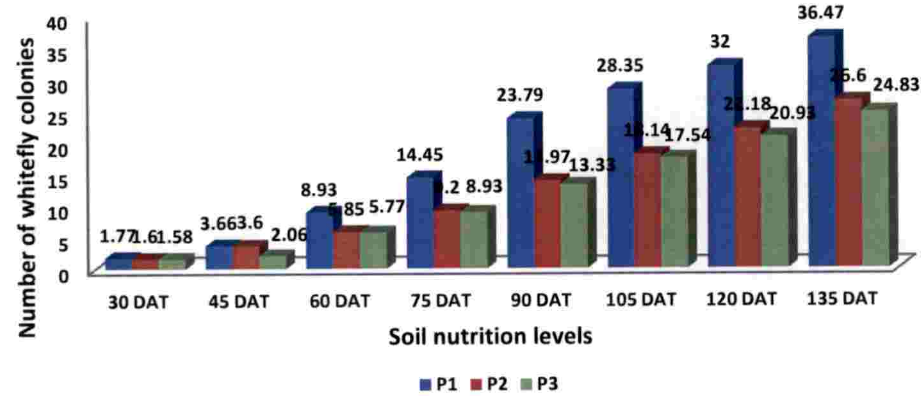

Figure 5: Effect of soil nutrition levels on the number of whitefly colonies during first field trial

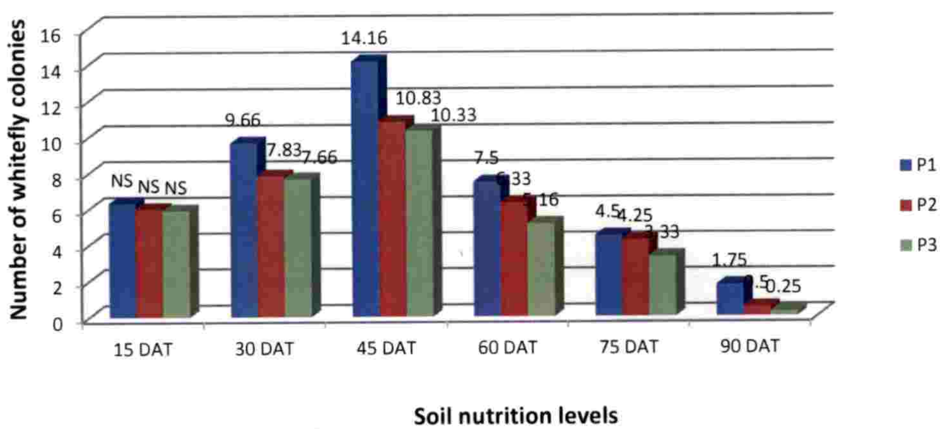

Figure 6: Effect of soil nutrition levels on the number of whitefly colonies during second field trial

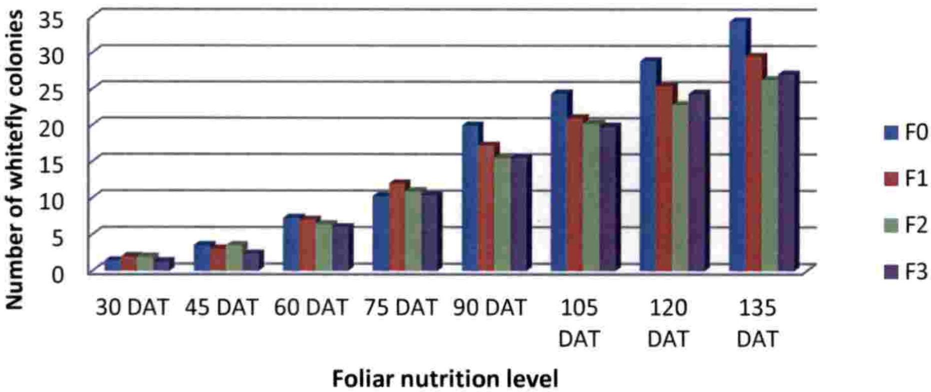

Figure 7: Effect of foliar nutrition levels on the number of whitefly colonies during first field trial

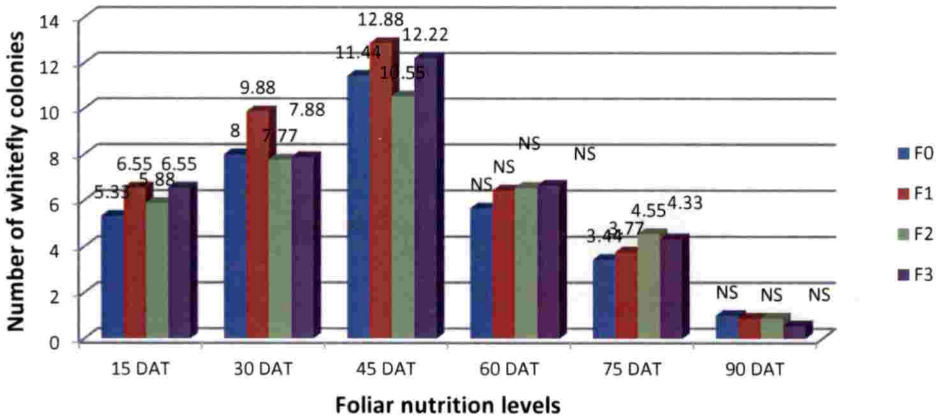

Figure 8: Effect of foliar nutrition levels on the number of whitefly colonies during first field trial

5.4. INFLUENCE OF MINERAL NUTRIENTS ON BIOMETRIC AND YIELD PARAMETERS OF CHILLI

5.4.1. Height of plant

During both the field trials the length of plants were significantly influenced by the nutrient levels and the foliar application of nutrients. Highest mean height of plants was recorded in NPK level P_2 which was on par with plants of P_3 level and the shortest was recorded in P_1 regime. Foliar application of nutrients had significant effect on the length of plant. Maximum mean height was recorded in F_3 which were on par with mean height of plants of F_2 and the shortest belonged to F_0. Interaction effect of soil and foliar nutrition levels had a significant effect. Tallest plants were observed in soil and foliar application and the shortest plant was recorded from treatments of first nutrient level. A significant and positive relation between fertilizer doses and plant height in chilli was also observed by Medhi *et al.* (1990) and Rafiq *et al.* (2010).

These results were in line with the findings of Sharma *et al.*(1996) who reported that application of liquid fertilizers containing NPK, Ca, Mg and micronutrients such as Cu, Mo, B, Fe and Mn significantly improved the growth (height) and number of branches per plant over straight NPK fertilizer.

4.4.1.2 Length of fruit

Significant effect was recorded for the length of fruit in the soil nutrient levels only. Longest fruit was observed in the P_2 (NPK) nutrient level whereas shortest was observed in the P_1 which is on par with the P_3. Foliar applications of nutrients didn't show significant difference. Interaction effect of nutrients and the foliar applications did not show significant effect on the length of fruit. Mirror result was obtained by Barche *et al.*(2011) who reported that the application of

Zn at rate of 3.91 kg/ha and boron at the rate of 1.70 kg/ ha along with soil application macro nutrients like N (130), P 60), K(80), S(20) and Mg (10) kg/ha enhanced plant height and fruit length in chilli.

4.4.1.3. Days to first flowering

Nutrient regimes showed significant difference in days to first flowering. From the graph we can conclude that treatments of P_2 and P_3 level flowered early in comparison with potting mixture regime. According to ManjuNath *et al.*(2009) reason for early flowering might be due to rapid initial plant growth and because of favourable availability of nutrients.

5.5. INFLUENCE OF MINERAL NUTRIENTS ON YIELD PARAMETERS OF CHILLI

5.5.1. Fresh weight of fruits and marketable yield

Nutrient regimes had significant effect on the average fresh weight of fruits and marketable yield of plants during both the field trials. Nutrient level P_3 had maximum yield as well as marketable yield whereas minimum was recorded in P_1. Foliar application of nutrients had significant effect on the yield and marketable yield of plants. Maximum yield was recorded in plants of F_1 and minimum in F_0. The result is in line with work of Priya (2017) where plants treated with one foliar spray + NPK + Ca + Mg exhibited highest seed yield and fresh pod yield in cowpea. These results have been further supported by Jiskani (2005) who reported that significant effect on yield of green chilli was observed when micronutrients were applied in combination with NPK instead of alone.

5.5.2. Plant dry weight

Different levels of nutrient regimes and foliar application of nutrients influenced the plant dry weight in plant. Nutrient level P_3 had maximum dry weight of 52.66g and minimum was recorded in P_1 (21.75g). Foliar application of nutrients had significant effect on the dry weight of plants. Maximum dry weight was recorded in plants of F_3 (41.88g) and minimum in F_1 (39.44g) which was on par with F_0 and F_2. Interaction effect of soil and foliar nutrition levels were found to be significant. Maximum dry weight was recorded in T_{10} (53.66g) which was on par with T_9, T_{11} and T_{12} whereas minimum dry weight was recorded in T_2 and T_3 (21g) which was on par with T_1 and T_4. This is in conformity with the findings of Arun Kumar (2007) who reported that when higher amounts of nutrients were applied there was increased dry matter production through enhanced photosynthetic efficiency in the chilli plant.

5.6. INFLUENCE OF MINERAL NUTRIENTS ON THE NUTRIENT STATUS OF THE PLANT AND THEIR EFFECT ON PESTS OF CHILLI

The result observed in the plant analysis revealed a maximum mineral concentration in the third soil nutrition level and minimum in the first. Foliar nutrition had a strange pattern; variation in the number of foliar nutrition did not affect their concentration in the plants. Maximum concentration of micronutrients was observed in F_3 which was on par F_2 and F_1 and minimum in the F_0 level. Nutritional homeostasis might be the reason for the stable nutrient acquisition (Hayden *et al.* 2015).

Interaction effect of soil and foliar nutrition levels were not significant for most of the nutrients whereas for potassium and copper it was significant. Potassium and copper were found to be maximum in treatments of third soil nutrition level such as T_{10}, T_{11} and T_{12} and also treatments with higher levels of foliar nutrition T_4, T_6 and T_8. Minimum was recorded in the treatments of first soil nutrition level T_1 and T_2. Lime application had a positive influence on absorption of micro and macro nutrients. So third soil nutrition level exhibited maximum concentration of nitrogen, potassium, calcium, copper and zinc which was in line with the findings of Rivero *et al.* (2001).

Silicon concentration in plants was found to be non significant. According to Mitani and Ma (2004) there is a characteristic distribution of Si accumulation in the plant kingdom. In higher plants, only plants in Gramineae and Cyperacea show high Si accumulation. Plants in Cucurbitales, Urticales, and Commelinaceae show intermediate Si accumulation, whereas most other plants species show low Si accumulation. Foliar application of silicon was found to be not effective. According to Liang *et al.* (2015) soil applied silicon leads to significantly more silicon accumulation in plant tissues, than foliar applications and produces much better results against biotic stressors.

The population of mites showed a positive correlation with nutrient content in plants such as nitrogen, potassium, zinc, copper and silicon during both the field trials. According to the study of Geddes (2010) application of potassium and nitrogen resulted in the highest density of mite eggs *Eutetranychus willamettei*) per leaf in grapes. This was due the fact that potassium favoured Willamette spider mites and their survival, by providing a disease free, drought resistant plant. Their feeding presumably does not affect the plants health as quickly as it would without K because of the ability to resist stress and hence mite populations are therefore favored by this macronutrient.

Magnesium and sulphur had negative correlation with the number of mites. This is in line with the findings of work of Abou-Awad (1980) where two applications of ammonium sulfate along with manganese sulfate at 30 or 20 ppm decreased the number of *Tetranychus urticae* in cotton plants during a field study. In this study calcium also had negative correlation (-0.13038) with the number of mites. Similar result was obtained by Keeping and Meyer (2002) where fertilization of sugarcane plant with calcium silicate @ 10,000 kg/ha and 5000 kg/ha could impart a higher rate of resistance against the stalk borer *Eldana saccharina* than unfertilized plants.

Considering the correlation of whitefly colonies with the nutrient content of plants, nutrients such as nitrogen, potassium, calcium, magnesium, sulphur, copper and silicon had significant negative correlation with the whitefly population. This result is supported by the work of Chen *et al.* (2007), the study proved that pest suppression can be done by nutrient management and the macronutrients (N, P, and K) not only improves plant health but reduces the pest population as well.

SUMMARY

6. SUMMARY

The research programme entitled "Role of mineral nutrition in management of pests in chilli" was undertaken at College of Agriculture, Padannakkad with the objective to assess the effect of mineral nutrients such as potassium, calcium, magnesium, sulphur, silicon, boron, zinc and copper in the pest management of chilli. Two trials were carried out on field from August 2017 to February 2018, and November 2017 to May 2018.

The pot culture experiment was conducted in CRD with two factors at 3 x 4 levels (12 treatments) and three replications each. Plants were raised in pots under three soil nutrient conditions namely: P_1: non chemical nutrient level (potting mixture alone); P_2: NPK nutrient level (potting mixture with NPK); P_3: NPK + Ca + Mg nutrient level (potting mixture with NPK + Ca + Mg). Ca and Mg were given in the form of calcium carbonate and magnesium sulphate respectively. Mineral nutrient mixture of potassium, calcium, silicon, boron, zinc and copper were applied as a foliar spray of 0.8 % at different time intervals. Mineral nutrients mixture for foliar application consist of boric acid – 0.2 %, Copper Sulphate – 0.2 %, and Zinc Suphate – 0.2 %. Potassium Silicate – 0.2 %.The levels of foliar nutrition were F_0: no foliar nutrition, F_1: one foliar nutrition applied, F_2: two foliar nutrition, F_3: three foliar nutrition. First foliar nutrition was done 10 days after transplanting, second application after 30 days of first and third foliar nutrition 30 days after second foliar nutrition. Potassium Silicate was applied separately at an interval of 10 days after the application of the foliar mineral nutrition. Treatment combinations were: T_1 : potting mixture + no foliar application (P_1F_0); T_2: Potting Mixture + 1 foliar application (P_1F_1); T_3: Potting mixture + 2 foliar application (P_1F_2); T_4: Potting Mixture + 3 foliar application (P_1F_3); T_5: Potting Mixture + NPK with no foliar application (P_2F_0); T_6: Potting Mixture + NPK + 1 foliar application (P_2F_1) ; T_7: Potting Mixture + NPK + 2 foliar application (P_2F_2); T_8: Potting Mixture + NPK + 3 foliar application (P_2F_3);

T_9: Potting Mixture + NPK + Ca + Mg with no foliar application (P_3F_0); T_{10}: Potting Mixture + NPK + Ca + Mg+ 1 foliar application (P_3F_1); T_{11}: Potting Mixture + NPK + Ca + Mg+ 2 foliar application (P_3F_2); T_{12}: Potting Mixture + NPK + Ca + Mg+ 3 foliar application(P_3F_3).

The results of the experiment revealed that infestation of mites (*Polyphagotarsonemus latus*), thrips (*Scirtothrips dorsalis*) and whiteflies (*Bemisia tabaci*) along with their damages were significantly influenced by the soil and foliar nutrition levels and their interactions during both the field trials.

In the case of mite population and leaf curl indices (LCI), plants of P_2 level showed maximum values and lowest in P_1 level. Among the levels of foliar nutrition, highest values were observed in F_2 and minimum in F_0. Within the interaction effects, the maximum mite population and leaf curl indices were recorded in T_7 and minimum in T_1, T_2, T_9 and T_{10}. Nitrogen, potassium, zinc, copper and silicon had positive correlation with the average number of mite *viz* 0.123, 0.199, 0.010, 0.280 and 0.003 respectively during both field trials. Calcium, magnesium and sulphur had negative correlation *viz* -0.130, - 0.222 and -0.07 respectively.

With respect to chilli thrips, plants of soil nutrition level P_2 harboured maximum population and minimum in P_1. With regard to foliar nutrition, no specific trend was observed. Throughout the season minimum thrips population and LCI was exhibited by the treatments of first level, which is T_1, T_2, T_3, T_4 and maximum in T_8 and T_6. Second field trial didn't show any infestation of thrips.

Concerning whitefly colonies, with the increase in soil nutrition levels from P_1 to P_3 there was a gradual decrease in the whitefly colonies. Significantly high number of whitefly colonies were recorded on plants of F_1, F_2 and F_3 whereas minimum in F_0. Among the interaction effects, T_{10}, T_{11} and T_{12} exhibited minimum number of whitefly colonies whereas T_2, T_7 and T_8 exhibited maximum throughout the growth phase in both the field trials. Nitrogen, potassium, calcium, magnesium, sulphur, copper and silicon had significant negative correlation with the whitefly colonies *viz* -0.752, -0.805, -0.826, -0.471, -0.494, -0.687 and -0.746 respectively during the first field trials.

The effects of mineral nutrients on biometric and yield characters were influenced significantly in both the trials. Treatments of P_2 and P_3 registered significantly high fruit length, number of leaves, plant height, plant dry weight and also early flowering in comparison with P_1.

The result observed in the plant analysis revealed a maximum mineral concentration in the P_3 level and minimum in P_1. Variation in the number of foliar nutrition did not affect mineral concentration in the plants. Maximum concentration of micronutrients was observed in F_3 which was on par with F_2 and F_1 and minimum in the F_0 level. Interaction effect of soil and foliar nutrition levels were not significant for most of the nutrients except potassium and copper. Potassium and copper were found to be maximum in treatments of third soil nutrition level (P_3) such as T_{10}, T_{11} and T_{12} and also treatments with higher levels of foliar nutrition i.e. T_4, T_6 and T_8. Minimum was recorded in the treatments of first soil nutrition level T_1 and T_2.

Salient findings

- In treatments of P_2 and P_3, the soil nutrition is offsetting the foliar nutrition and hence no positive relation is found between the number of foliar nutrition levels with whitefly population as well as yield attributes.
- In treatments of P_1, foliar nutrition compensated the soil nutrition hence positive relation existed between levels of foliar nutrition on the whitefly colonies and yield attributes.
- No clear correlation existed between the levels of nutrition and the population of mites and thrips.

- Hence soil nutrition with calcium and magnesium supplementation and one foliar application of nutrients is found to be best in minimizing whitefly infestation and is found to be economically benefiting.

This study is a very preliminary study, hence more research is needed. This study suggests that mineral nutrition can influence the management of sucking pests in chilli by providing tolerance and compensating the loss due to pest damage. Understating the nutrient homeostasis in plants and finding the nutrient threshold levels for insects may lead to an better integrated pest management strategy with integrated nutrient management as the basis.

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Role of mineral nutrition in the management of pests in chilli

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ABSTRACT

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ABSTRACT

The research programme entitled "Role of mineral nutrition in management of pests in chilli" was undertaken at College of Agriculture, Padannakkad with the objective to assess the effect of mineral nutrients such as potassium, calcium, magnesium, sulphur, silicon, boron, zinc and copper in the pest management of chilli. Two trials were carried out on field from August 2017 to February 2018, and November 2017 to May 2018.

The pot culture experiment was conducted in CRD with two factors at 3 x 4 levels (12 treatments) and three replications each. Plants were raised in pots under three soil nutrient conditions namely: P_1: non chemical nutrient level (potting mixture alone); P_2: NPK nutrient level (potting mixture with NPK); P_3: NPK + Ca + Mg nutrient level (potting mixture with NPK + Ca + Mg). Ca and Mg were given in the form of calcium carbonate and magnesium sulphate respectively. Mineral nutrient mixture of potassium, calcium, silicon, boron, zinc and copper were applied as a foliar spray of 0.8 % at different time intervals. Mineral nutrients mixture for foliar application consist of boric acid – 0.2 %, Copper Sulphate – 0.2 %, and Zinc Suphate – 0.2 %. Potassium Silicate – 0.2 %. The levels of foliar nutrition were F_0: no foliar nutrition, F_1: one foliar nutrition, F_2: two foliar nutrition, F_3: three foliar nutrition. First foliar nutrition was done 10 days after transplanting, second application after 30 days of first and third foliar nutrition 30 days after second foliar nutrition. Potassium silicate was given as a separate spray at an interval of 10 days after the application of the mineral nutrition.

The results of the experiment revealed that infestation of mites (*Polyphagotarsonemus latus*), thrips (*Scirtothrips dorsalis*) and whiteflies (*Bemisia tabaci*) along with their damages were significantly influenced by the soil and foliar nutrition levels and their interactions during both the field trials. In

case of mite population and leaf curl indices (LCI), plants of P_2 level showed maximum values and lowest in P_1 level. Among the levels of foliar nutrition, highest values were observed in F_2 and minimum in F_0. Within the interaction effects, the maximum mite population and leaf curl indices were recorded in T_7 and minimum in T_1, T_2, T_9 and T_{10}. Nitrogen, potassium, zinc, copper and silicon had positive correlation with the average number of mite *viz* 0.123, 0.199, 0.010, 0.280 and 0.003 respectively during both field trials. Calcium, magnesium and sulphur had negative correlation *viz* -0.130, - 0.222 and -0.07 respectively.

With respect to chilli thrips, plants of soil nutrition level P_2 harboured maximum population and minimum in P_1. With regard to foliar nutrition, no specific trend was observed. Throughout the season minimum thrips population and LCI was exhibited by the treatments of first level that is T_1, T_2, T_3, T_4 and maximum in T_8 and T_6. Second field trial didn't show any infestation of thrips.

Concerning whitefly colonies, with the increase in soil nutrition levels from P_1 to P_3 there was a gradual decrease in the whitefly colonies. Significantly high number of whitefly colonies were recorded on plants of F_1, F_2 and F_3 whereas minimum in F_0. Among the interaction effects, T_{10}, T_{11} and T_{12} exhibited minimum number of whitefly colonies whereas T_2, T_7 and T_8 exhibited maximum throughout the growth phase in both the field trials. Nitrogen, potassium, calcium, magnesium, sulphur, copper and silicon had significant negative correlation with the whitefly colonies *viz* -0.752, -0.805, -0.826, -0.471, -0.494, -0.687 and -0.746 respectively during the first field trials.

The effects of mineral nutrients on biometric and yield characters were influenced significantly in both the trials. Treatments of P_2 and P_3 registered significantly high fruit length, number of leaves, plant height, total biomass and also early flowering in comparison with P_1.

The result observed in the plant analysis revealed a maximum mineral concentration in the P_3 level and minimum in P_1. Variation in the number of foliar nutrition did not affect mineral concentration in the plants. Maximum concentration of micronutrients was observed in F_3 which was on par with F_2 and F_1 and minimum in the F_0 level. Interaction effect of soil and foliar nutrition levels were not significant for most of the nutrients except potassium and copper. Potassium and copper were found to be maximum in treatments of third soil nutrition level (P_3) such as T_{10}, T_{11} and T_{12} and also treatments with higher levels of foliar nutrition i.e. T_4, T_6 and T_8. Minimum was recorded in the treatments of first soil nutrition level T_1 and T_2.

In general soil nutrition with calcium and magnesium supplementation and one foliar application of nutrients is found to be best in minimizing the whitefly infestation. Mites and thrips population did not exhibit a true correlation between the levels of mineral nutrients and their population.