EVALUATION OF THE EFFECT OF MINERAL NUTRITION IN THE MANAGEMENT OF MAJOR PESTS OF COWPEA

by

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THESIS

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DECLARATION

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

Place: Padannakkad

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Certified that this thesis entitled "EVALUATION OF THE EFFECT OF MINERAL NUTRITION IN THE MANAGEMENT OF MAJOR PESTS OF COWPEA" is a record of research work done independently by Ms. Vishnu Priya. T. A. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Vishnu Priya T.A.

Dedicated to

my beloved

Parents

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Introduction

1. INTRODUCTION

Cowpea, *Vigna unguiculata* belongs to family Leguminosae is one of the major vegetable crops grown widely throughout Kerala. It is rich in nutrients, containing a fairly high percentage of proteins. It can be consumed either as dry peas or as vegetable wherein, fresh green pods used. Due to rich protein content, its leaves and shoots support development of pests, with improved fecundity and longevity (Breukel and Post, 1959). This threatens both quality and quantity of the seed and pod yield. Pest and disease constitute one of the major challenges in present day cowpea production. Among various insect pests, aphids, pod sucking bugs and pod borers are the most potential pests which cause a drastic reduction in yield. Aphids cause considerable damage, either directly by sucking the plant juice or indirectly by acting as vectors for transmitting viral disease. Damage by aphid is due to the consumption of sap from tender parts of plant such as leaves, tender shoots, inflorescence and tender pods thus resulting in malformation, stunting and even drying up of the parts, which leads to reduced vigor and poor yield. The presence of 400 - 550 individual aphids per leaf reduced photosynthesis by 6.4 per cent, compared to uninfested leaves in cotton (Godfrey *et al.*,1997). In general, aphids are difficult to be controlled because of tremendous reproductive ability, mobility and resistance to synthetic pesticides (Jagadish *et al.*, 2011; Van lenteren *et al.*, 1990). Pod bugs cause damage by sucking sap from tender pods and shoots which lead to chaffy pods and the seed damage usually ranges from 40- 85 per cent. *Clavigralla gibbosa, C. tomentosicollis and Riptortus pedestris* are the important pod sucking bugs infesting cowpea. Among borer pests, *Maruca vitrata* is highly damaging to cowpea because of their vast host range and cosmopolitan distribution. It causes damage to the pods, flower buds and flowers resulting in 20 – 88 per cent yield loss (Jayasinghe *et al.*, 2015).

Farmers indiscriminately use hazardous pesticides to control these troublesome pests. These practices eventually affect ground water, soil, environment and consumers health. Moreover, careless or excessive use of pesticides often results in poor control due to their drastic effect on natural enemies and also increases the cost of production. Alternative methods are considered to solve this problem. Among these, the use of mineral nutrients in the suppression of pest population has long been recognized. Evidence of suppression of pest attack by use of mineral nutrients has been 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). The timing, amount, and type of mineral used can suppress or stimulate pest population, depending upon the pest species and the crop concerned. Knowledge about a plant's nutrition combined with dynamics of a pest can often provide an excellent basis for successful pest management (El-zik and Frisbie, 1985)

Even in normally N,P,K fertilized plants, balanced use of mineral nutrients will drastically improve plant health and resistance to insect pests. Some nutrients also have toxic effects for pest (Tomlin, 1994) by loosing a portion of insect body water as result of osmotic pressure or by indirect means in which mineral elements increase the natural plant immunity through improvement of plant nutritional status (Nowosielski *et al.*, 1988). Copper concentration of 9 mg caused lethal effects in the insect species, such as decreased reproduction, induce egg sterility, and brings morphological abnormalities when these insect larvae were fed with copper contaminated food (Habustova *et al.*, 2001). Excess fertilization, mainly with nitrogen, can often encourage succulent and excessive vegetative growth that may increase the reproduction rate of pests with 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).

Elements, when applied in adequate quantities, can impart resistance to pests and diseases (Spann and Schumann, 2010). This can be attributed to the ability of certain nutrients in aiding in the biosynthesis of secondary metabolites like polyphenol, alkaloids, terpenes, lignin, saponins, cyanogenic glucosides etc. Mineral elements particularly Mn, B, Zn, Cu and Fe increases alkaloids in plants (Lovkova, 2005) and protect plants from herbivorous insects.

Developing alternatives to pesticides is critical to maintain agriculture production. This is all the more true for Kasaragod district, which has been declared as an organic district and where synthetic insecticides are no more an option. With this background the present research work is proposed 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 cowpea viz. *Aphis craccivora, Maruca vitrata, Lampides boeticus, Liriomyza trifolii, Clavigralla gibbosa* and *Clavigralla tomentosicollis*

Review of Literature

2. REVIEW OF LITERATURES

2.1. COWPEA

Cowpea, *Vigna unguiculata* is a typical warm seasonal annual herbaceous legume acclimatized to tropics. Cowpea has a worldwide production of 3 million tonnes from 14.5 million hectares (Singh *et al.*, 1997). Two hundred million people consume cowpea on a daily basis. Cowpea is believed to have originated from West Africa (Ogunkanmi *et al.*, 2006). Cowpea thrive in poor dry conditions, growing well in sandy soils upto 85 % sand (Obatolu, 2003)

The crop is used in multiple ways. Dry beans are used as pulse and tender pods as vegetable. Moreover, it is also used as a green manure, cover crop, and fodder crop due to its soil improving properties and nutritive value. Common names for cultivated cowpea include yard long bean, southern pea, black-eye pea, crowder pea and catjang (Timko *et al.*, 2007).

Insect infestation is a major hurdle in the cultivation of cowpea which sometimes causes 90 % loss in the yield (Jackai and Daoust, 1986). Among various cowpea pests, *Maruca vitrata* is highly damaging to cowpea because of their wide host range and cosmopolitan distribution. It causes damage to the pods, flower buds and flowers resulting in a 20–88 per cent yield loss (Jayasinghe *et al.*, 2015). Dreyer *et al.* (1994) reported that Pod sucking bugs (PSB) are the most important pest of cowpea. The PSB causes damage to the seed usually ranging between 40 and 85 per cent, but the seed damage from *M. vitrata* was low though it causes occasional high flower infestations.

Cowpea aphid, (*Aphis craccivora* Koch) is an important pest of cowpea in most tropical areas where cowpea is grown (Obopile and Ositile, 2010). The damage caused by both adults and nymphs is either direct through depleting plant's assimilates through sucking and injection of its toxic saliva to the plant or spreading viral diseases.

2.2. ROLE OF INORGANIC NUTRIENTS IN PEST MANAGEMENT

Hosseini *et al.* (2015) in a study to understand the effect of different nitrogen fertilizer levels on biological parameter of cowpea aphid in globe amaranth, indicated that 100 per cent of recommended nitrogen showed the highest intrinsic rate in natural increase of aphid, but in the absence of aphid, plants' yield improves linearly with increasing nitrogen levels.

Hosseini *et al.* (2010) conducted an experiment in green house to investigate the performance and population growth rate of cotton aphid in relation to varying nitrogen levels (90, 110, 150 and 190 ppm) in cucumber plant. Among the different treatment tested, aphids from plants which received 190 ppm had significantly shorter development time and produced more progenies per capita than aphids grown up in lower nutrient concentrations.

Abou-Awad (1980) conducted a field study to find out the effect of nitrogen and manganese fertilization on the Tetranychid mite in cotton reported that two applications of manganese sulfate at 30 or 20 ppm along with ammonium sulfate decreased populations of *Tetranychus urticae* and increased the yield.

Huelsman *et al.* (2000) reports that the incidence of total insect pests and sucking pests in Jamaican sweet potato was higher in soils with high nitrate and phosphorus level and also exist a significant negative correlation with nitrate level and predator population. Moreover, there is a positive correlation between phosphorous and chewing insect population.

A study was conducted with the three fertilization levels of nutrients (33, 50, and 100 per cent of recommended fertilizer of phosphorous, potassium, calcium, and magnesium) and with three different methods of spider mite control *Tetranychus urticae* in rose plant. They reported that the population of *T. urticae* was double on roses fertilized with 100 per cent in comparison to 33 or 50 per cent of the recommended levels (Chow *et al.*, 2009)

Zehnder and Hunter (2009) conducted a study to examine the impacts of phosphorus and nitrogen additions on population growth rates of *Aphis nerii* on milk weed plant phloem-feeding insect herbivore. They reported that addition of nitrogen and phosphorous @ 10 g/m^2 increases foliar nitrogen levels and causes a reduction in aphid performance, indicating that excessive nutrient levels can limit herbivore population growth rates. Nonetheless, phosphorus concentration on leaf has no direct effect on insect performance.

Park *et al.* (2009) conducted a study on the influence of different concentrations of nitrogen fertilization on the cultivar preference, honey dew production and development by greenhouse whiteflies *Trialeurodus vaporariorum* in two cherry tomato cultivars. The result indicated that the developmental times of nymphs and eggs reduced as nitrogen concentration increased on both cultivars. Within each plant, upper plant stratum was most preferred for egg laying and the honeydew production of nymphs increased with decreasing nitrogen concentration.

Jauset *et al.* (1998) studied the effect of different doses of nitrogen (308 ppm, 140 ppm and 84 ppm) on oviposition and feeding site selection by greenhouse whitefly adults, *Trialeurodes vaporariorum*. The result shows that the number of adults and oviposition was high on the plants fertilized with high nitrogen dose and within plants; upper leaf surface was preferred for feeding.

Poinsettia, *Euphorbia pulcherrima* fertilized with ammonium nitrate showed more acceptability and suitability to the sweet potato whitefly, *Bemisia tabaci* than unfertilized plants. Higher oviposition on treated plants indicated that the acceptability of a plant by the whitefly is in response to plant cues (Bentz *et al.*, 1995).

Wermelinger *et al.* (1985) reported that the female *Tetranychus urticae* reared on the apple leaf disc which is fertilized with low concentration of nitrogen produces increased pre-imaginal development time, pre- oviposition period, and decreased female weight, fecundity and oviposition rate of the mites.

Miller *et al.* (1960) reported that silica depositions on wheat plant tissue impart resistance to certain varieties against Hessian fly attack and resistant varieties have more uniform and complete distribution of silica deposits on their surface than those of susceptible varieties.

Keeping and Meyer (2002) reported that calcium silicate @10000 kg/ha and 5000 kg/ha can impart higher rate of resistance to sugarcane against the stalk borer *Eldana saccharina* than unfertilsed plants and that 19.8 per cent and 24.4 per cent reduction in borer mass and stalk damage was found at 10,000Kg/ ha.

Plants treated with NPK fertilizers showed largest leaf damage (31 per cent) compared to control (11 per cent) with pests such as *Plutella xylostella, Brevicoryne brassicae, Hellula undalis* and *Pieris rapae* in cabbage (Mochiah *et al.*, 2011)

Application of K fertilizer is useful in the recovery of damage caused by larvae of the rice stem borer and contributed larger volume of yield and reduced the environmental pollution (Sarwar, 2011).

Improved morphological characters such as plant height, number of leaves and stem thickness induced by application of 40 and 60 kg/ha of phosphatic fertilizer imparted host plant resistance against insect pests such as Aphid, Jassid, Whitefly and Thrips of cowpea (Khairnar and Patel, 2015)

Geddes (2010) reported that application of potassium recorded the highest density of mite eggs *Eotetranychus willamettei* (60.0 ± 18.0 mite eggs per leaf) followed by nitrogen (42.5 ± 13.4 mite eggs per leaf) in grapes.

2.3. ROLE OF ORGANIC NUTRIENTS ON PEST MANAGEMENT

Trials done by Chatterjee *et al.* (2013) indicated that 75 per cent of the recommended dose of inorganic fertilizer (N: P: K-75:45:45) along with 4 t/ha of vermicompost inoculated with azophos biofertilizer gave maximum reduction in whitefly population in tomato cultivation. Maximum incidence of whitefly was recorded with 100 per cent inorganic fertilizers. A combination of lower level of inorganic fertilizer and higher level of organic fertilizer gave maximum reduction in whitefly incidence in tomato.

Rice plants treated with N P K (100:30:40) displayed maximum stem borer infestation (4.03 per cent) in comparison with the plants grown in organic manure @ 10 T/ha (0.733 per cent) and chicken and hog manure (2.03 per cent). Brown plant hopper and leafhopper population showed 30 per cent and 60 per cent reduction in organic manure compared to NPK (Chau and Heong, 2005)

Vermicompost at the rate of 20 per cent and 40 per cent concentration incorporated with Metro-Mix 360 , which is a soilless plant growth medium used in green house containers, significantly suppressed the populations of both aphids and mealy bugs on peppers and mealy bugs on tomatoes. This also decreased loss of leaf area of cabbage seedlings by cabbage white caterpiller (Arancon *et al.*, 2005)

2.4. EFFICACY OF MICRONUTRIENTS IN PEST MANAGEMENT

Habashy *et al.* (2010) made a comparative study on the effect of two rates of micronutrients in the management of aphids (*Aphis gossypi*) on strawberry plants. Nutrients like boric acid, borax, copper oxide, magnesium sulphate at 0.5 per cent concentration rather than 1 per cent showed maximum reduction in the population density of aphids.

A study was conducted to test the efficacy of different non-chemicals like detergents, plant growth promoters and micronutrients like Zn, Mn, Fe, Cu each at 12 percent and liquid Boron 6 percent in two different seasons on cotton. The micronutrient mix treated plants showed a significant drop in the population of Aphids, *Aphis gossypi* (40, 29 per leaf) over control (71, 44 per leaf)(Ebaid and Mansour, 2006)

Ghallab *et al.*(2014) made a comparative study on the effect of mineral nutrients in the management of sucking pests on bean plants. A mixture of primary nutrients showed maximum reduction in the population density of sucking pests (*Tetranychus urticae, T. cucurbitacearum, Bemisia tabaci* and *Thrips tabaci)* followed by micro-nutrients (Zn, Mn, Fe, Cu, B and Mo) and primary nutrients individually.

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 *Bemisia tabaci* in Bt-cotton. They reported that 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.

A study conducted to understand the effect of silicon on the nymphal mortality and longevity of males and females of spittle bug, *Mahanarva frimbiolata* which is a secondary pest of sugarcane. Spittlebug 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 the shortest female longevity (Korndorfer *et al.*, 2011).

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

Growth and developmental performances of three soya bean pests viz. Soybean looper (*Pseudoplusia includens*), mexican bean beetle (*Epilachna varivestis* Mulsant), velvet bean caterpillar (*Anticarsia gemmatalis* Hubner) fed with plants grown in hydroponic solution containing different proportions of boron, iron, zinc were evaluated. All three species displayed highest developmental performance (days to pupation, survival, fresh and dry pupal weight) when fed with plants grown in solutions without boron. (Beanland *et al.,* 2003).

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

Application of zinc at 30 kg/ha markedly decreased the infestation of stem borer in rice, while application at 20-25 kg/ha showed slightly more white head and dead heart incidence, but differed significantly from unfertilized plot. (Shu *et al.*, 2009)

Dash *et al.* (2011) reported that nutrient level 60: 30: 30 kg NPK/ha with ZnS04 recorded minimum rice borer incidence irrespective of rice varieties and insecticidal treatment.

Tollett *et al.* (2008) studied the toxicity of cadmium, lead, and copper on dragonfly larvae and reported that the high concentration of lead and cadmium has no significant effect in decreasing survival rate of dragonfly larvae. In contrast, an exposure to copper has shown significant decrease in the survival of larvae.

2.5. ALKALOIDS AND THEIR ROLE IN PEST MANAGEMENT

Hemming and Lindroth (2000) reported that phenolic glycosides reduced the performance of Gypsy moth larvae and Forest tent caterpillar in terms of increased developmental time and decreased growth rates. Activity of β-glucosidase, which is a midgut metabolic enzyme declined for both insects reared on diets containing phenolic glycosides.

Frah *et al,* (2013) reported that a three percentage increase in the mortality of *Aphis craccivora* was observed when they were reared on diet containing 100 ppm of flavonoids and 2.25 percent and 1.25 percent mortality on 150 and 200 ppm respectively.

According to Atalah *et al.* (2014), the pea aphid (*Acyrthosiphon pisum*) showed low LC50 value (79 μg/mL) for Orysata which is a mannose binding lectin on a bioaasy, indicate that lectin has a strong negative effect on pea aphid. The larvae of *Spodoptera exigua* fed on the transformed plant which contains mannose specific lectin showed reduced weight, larval mortality and extension of larval period

Williams *et al.* 2002 reported that the infestation of Hessian flies on resistant wheat plants produced higher levels of *Hfr-1* transcripts (Hessian fly responsive), which promotes the expression of a high mannose N-glycan-specific jacalin-like lectin. These lectin accumulated at the larval feeding site so that the larval attempt to establish feeding site failed.

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

Endogenous flavonoids (Quercetin, Kaempferol and Isorhamnetin) in cowpea had an *in-vitro* inhibitory effect on nymph deposition by *Aphis fabae* at a concentration of 0.1 mM. Quercetin was found to be more inhibitory (52 percent) than other two flavonoids, Isorhamnetin (43 percent) and Kaempferol (16 percent) (Lattanzio *et al.*, 2012).

Pods of resistant variety of cowpea contain compounds such as Cyanogenic heteroside, Flavonoids, Tannins and Trypsin inhibitors which imparted resistance against pod bug (Dabire-Binso *et al.,* 2010).

Application of 100 percent recommended nitrogen fertilization in strawberry resulted in a considerable enhancement in the protein content and decreased the production of phenol content. Whereas, with 80 per cent fertilization, the protein content reduced and phenol content increased (Alizade *et al.,* 2016).

Studies have shown that glandular trichomes contain high concentration of phenol and alkaloids which enhanced their biochemical defence against insects (Oghiakhe *et al.,* 1992). In yard long bean, Panicker (2000) reported a non-glandular trichome density range of 1.50 to 7.00/ mm^2 area of pod wall surface.

Defatted meal containing phenolics ranging from 0.01 to 0.05 per cent in six genotypes of cowpea has expressed resistance to insect pests such as *Helicoverpa armigera, Maruca vitrata, Psidia tikora* and bruchids (Prasadi *et al.,* 1996*)*.

Oghiakhe *et al.* (1993) observed that phenol concentration varied between different plant parts of cowpea cultivars at the same growth stage which generally decreased with increase in plant age. The phenol does not play any significant role in cowpea resistance to *Maruca vitrata.* Conversely, Veeranna (1998) recorded a higher phenol in tolerant genotypes of cowpea to *Maruca* than susceptible genotypes. He also reported that biochemical characters that can adversely influence legume pod borer resistance is chlorophyll content of leaves.

2.6. 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 amount 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).

Materials and Methods

3. MATERIALS AND METHODS

The research programme entitled "Evaluation of the effect of mineral nutrition in the management of major pests of cowpea" was undertaken at College of Agriculture, Padannakkad during 2016-2017. The study was carried out in two seasons from August 2016 to October 2016 and January 2017 to April 2017.

The objective of the study was to assess the effect of mineral nutrients such as potassium, calcium, silicon, boron, zinc, copper and magnesium in the pest management of cowpea. The experiment was carried out by growing cowpea plants in pots under three different nutrient regimes, namely 1) without NPK, 2) with NPK, according to the recommendation of POP, KAU, 2011 and 3) with NPK along with Ca and Mg according to the recommendation of POP, KAU, 2011. Later, the mineral nutrients were applied as foliar spray with 0.8 per cent solution containing Zn, Cu, B, K and Si at different time intervals *viz.* the branching stage, the peak branching stage and the flower bud initiation stage. Different mineral nutrients used include potassium silicate, boric acid, copper sulphate, zinc sulphate, calcium carbonate and magnesium sulphate. Monitoring of pests was done at biweekly intervals and the yield was recorded in the first four harvests. Preliminary soil analysis was conducted to know the status of K, Ca, Mg, S, Cu, B, Zn and Si. The analysis of plant samples were carried out after the crop. The detailed plan of the experiment are given below:

3.1. PREPARATION OF THE FOLIAR SPRAY MIXTURE

The foliar spray solution was prepared with potassium silicate, borax, copper sulphate and zinc sulphate. As the trial spray with 0.8 per cent concentration showed severe toxicity symptoms, the concentration was lowered to 0.2 per cent. Moreover, in order to avoid the immiscibility of borax and potassium silicate, boric acid was fixed as the source of boron and Potassium silicate was given as separate spray. Finally, micronutrient mixture was prepared by mixing 0.2 per cent boric acid, 0.2

per cent copper sulphate and 0.2 per cent zinc sulphate. Each plant required about 75 ml of spray fluid.

3.2. POT CULTURE EXPERIMENT

The experiment was conducted in completely randomized design with 12 treatments and three replications. The plants were raised in seventy two pots under three different nutrient regimes. Each nutrient regime contained twentyfour pots with two plants per pot. Four plants were maintained in each replication so that the total number of plants was 144. Plate 1 showed field view of experimental plots at College of Agriculture, Padannakkad and Figure 1. showed the layout of the experimental plot.

The potting mixture was prepared in two seasons, during August 2016 and January 2017. Laterite soil, sand and cow dung were mixed together in the ratio of 1:1:1 to prepare potting mixture. Later 15 Kg of potting mixture was added to the pots of size 30 cm diameter and 25 cm height. Twenty four pots were maintained as organic nutrient regime (without application of NPK). NPK fertilizers such as Urea, Rajphos and Muriate of potash were added to another 24 pots filled with potting mixture. The quantity of N, P, and K in the above chemical fertilizers was determined based on the number of cowpea plants accommodated in a hectare. About 1.5 times recommended quantity of N, P and K were added. The remaining 24 pots were filled with potting mixture and NPK were incorporated along with calcium carbonate and magnesium sulphate. About 1.5 times of recommended quantity of NPK, Ca, Mg (as per Package of Practices recommendations, KAU (2016) were incorporated to the pot. 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 are as follows:

Urea - 1.74 g

Rajphos	- 5.90 g
Muriate of potash	- 1.80 g
Calcium carbonate	- 10.13 g
Magnesium sulphate	- 3.19 g

3.2.1 Design and Layout

Crop : cowpea

Variety : kanakamony

Design : CRD

Treatments : 12

Replication : 3

3.2.2 Details of treatments

The micronutrient mixture was sprayed at 0.2 per cent concentration. Potassium silicate 0.2 per cent was sprayed separately eight hours after the first spray of the micronutrient mixture.

T_1 - Potting mixture (Absolute control)

T_2 - Potting mixture + One foliar spray

T_3 - Potting mixture + Two foliar spray

T_4 - Potting mixture + three foliar spray

T_5 - Potting mixture+ NPK with no foliar spray (control)

T_6 - Potting mixture +NPK + one foliar spray

T_7- Potting mixture+ NPK + two foliar spray

T_8 - Potting mixture +NPK + three foliar spray

T_9 - Potting mixture+ NPK + Ca + Mg with no foliar spray

T_{10}- Potting mixture+ NPK + Ca + Mg+ one foliar spray

T_{11}- Potting mixture +NPK + Ca + Mg+ two foliar spray

T_{12}- Potting mixture +NPK + Ca + Mg+ three foliar spray

3.2.3. Schedule of foliar spray

Spraying was carried out at 3 different stages of the cowpea namely, branching stage, peak branching stage and flower bud initiation stage.

3.2.4. Observations on damage of pests

The major pests on which observations were taken were Aphids, *Aphis craccivora* Koch. (Hemiptera: Aphididae); Pod borers such as Gram pod borer *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae); Spotted pod borer, *Maruca vitrata* (Fabricius) (Lepidoptera: Crambidae); Blue butterfly, *Lampides boeticus* (L) (Lepidoptera: Lycaenidae); Serpentine leaf miner, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae); Pod bugs, *Clavigralla gibbosa* Spinola (Hemiptera: Coreidae); *Clavigralla tomentosicollis* Stal (Hemiptera: Coreidae).

Damages caused by aphid, *Aphis craccivora* were recorded with number of infested pods, shoots, total number of shoots and scoring of aphid colony based on standard scale as low/medium/high (Kavitha and Reddy, 2012) (Table. 1). Scoring of aphids on leaves was calculated by counting the population of aphids from one leaf from top of each plant. The average of twelve such plants was recorded as the mean of each treatment. The same methodology was followed for estimating aphid score on pods. In case of aphid scoring on stem, population of aphids on the top 15 cm of stem was counted and average of twelve plants was recorded as mean of each treatment.

Table 1. Scoring of aphid population based on standard scale

Sl No:	Standard scale	Aphid population	Stem	Leaf	Inflorescence/ pod
1	0	Nil	0	0	0
2	1	Very low	<10	<10	<10
3	2	Medium	10-20	10-50	10-20
4	3	High	20-100	50-200	20-100
5	4	Very high	>100	>200	>100

Observations on the damage caused by flower borer, *Maruca vitrata* and pod borers, *viz.* gram pod borer, *Helicoverpa armigera* and blue butterfly, *Lampides boeticus* with number of pod borers per plant, and the number of infested pods and flowers were recorded

Observation on the damage due to pod bugs viz. *Clavigralla gibbosa and Clavigralla tomentosicollis* were recorded with number of attacked pods, total number of pods and number of nymphs and adult pod bugs per plant were recorded.

Observation on the damage of serpentine leaf miner, *Liriomyza trifolii* was recorded with number of infested leaves and total number of leaves per plant.

3.2.5. Biometric observations

Biometric observations such as leaf area per plant, number of leaves per plant, height of plant, length of pod and days to flowering were taken. Number of leaves produced and length of the plant were recorded at the end of the crop season. Leaf area was recorded at the time of flower initiation and it is expressed in cm^2. Mean length of the pods were recorded by taking five randomly selected pods from each replication.

3.2.6. Yield parameters

Yield parameters such as fresh yield of pods (g/plant), marketable yield, total seed yield (g/plant), total biomass and benefit –cost ratio 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 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 crop season. The samples were air dried, ground, sieved with 2mm sieve. They were analyzed for available mineral nutrients such as K, Ca, Mg, S, Cu, Zn, B and Si as per the standard procedures given in the Table 3.

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3.2.9. Statistical analysis

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

Table. 2 Analytical methods for plant nutrient analysis

Sl.No	Parameters	Method	Reference
1	Total K	Flame photometry	Jackson (1958)
2	Total Ca	Atomic absorption spectroscopy	Issac and Kerber (1971)

3	Total Mg	Atomic absorption spectroscopy	Issac and Kerber (1971)
4	Total S	Turbidimetric method	Bhargava and Ragupathi (1995)
5	Total Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
6	Total B	Azomethane – H colorimetric method	Bingham (1982)
7	Total Cu	Atomic absorption spectroscopy	Emmel *et al.* (1977)
8	Silicon	Photoelectric colorimetry	Korndorfer *et al.,* 2001

Table 3. Analytical methods followed for soil nutrient analysis

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

Figure1. Layout of experimental plot

T_6R_2	$T_{11}R_1$	T_6R_1	T_6R_1	$T_{11}R_3$	T_3R_2	T_7R_1	T_8R_2
T_6R_2	T_1R_2	$T_{11}R_1$	$T_{11}R_3$	T_3R_2	T_1R_1	T_7R_1	T_8R_2
T_2R_2	T_1R_2	T_2R_3	T_4R_3	T_7R_2	T_1R_1	$T_{12}R_2$	T_9R_3
T_2R_2	$T_{10}R_2$	T_2R_3	T_4R_3	T_7R_2	T_3R_3	T_8R_3	T_9R_3
$T_{11}R_2$	$T_{10}R_2$	T_4R_2	$T_{12}R_3$	$T_{12}R_2$	T_3R_3	T_8R_3	T_5R_2
T_2R_1	T_4R_1	T_4R_2	T_9R_2	T_1R_3	T_9R_1	T_5R1	T_5R_2
T_2R_1	T_4R_1	$T_{11}R_2$	T_9R_2	T_1R_3	T_9R_1	T_5R1	T_5R_3
$T_{10}R_3$	$T_{12}R_3$	$T_{12}R_1$	T_6R_3	T_8R_1	$T_{10}R_1$	T_3R_1	T_5R_3
$T_{10}R_3$	T_3R_1	$T_{12}R_1$	T_6R_3	T_8R_1	$T_{10}R_1$	T_7R_3	T_7R_3

Plate1. Field view of plot - 2 weeks after sowing

Results

4. RESULTS

Studies were undertaken to examine the effect of mineral nutrients in the management of major pests of cowpea. Pot culture experiments were carried out in two seasons to assess the efficacy of various mineral nutrients like potassium, calcium, magnesium, sulphur, copper, zinc, boron and silicon in managing pests of cowpea. The results of the studies are presented in this chapter. Data on various pests observed, biometric and yield parameters and plant and soil analysis values were statistically analyzed and presented.

4.1. THE EFFECT OF MINERAL NUTRIENTS IN THE MANAGEMENT OF APHIDS

4.1.1. Aphid population on leaves

In the pot culture experiment conducted during rainy season, the effect of mineral nutrients in the development of aphid colonies on leaves was evaluated and the results are presented in the Table 4.1. Nutrient sprayings were given in between 21st and 35th day after sowing and the observations were recorded at biweekly interval from 1st week after sowing.

Aphid population in the 7th day after sowing (DAS) revealed that treatments T_1, T_2 and T_3 has recorded a higher aphid population on leaves in comparison with T_4 to T_{12}. T_2 (1.66) exhibited maximum count of aphid population whereas, T_4 and T_6 recorded minimum aphid population. A gradual increase in the population was observed on 21st DAS with maximum population in T_2 (1.75) which was on par with T_3. Minimum aphid population score of 0.75 was recorded on T_5, T_6 and T_8.

Maximum population score of 2.00 was recorded on T_2 on the 35 DAS which was on par with T_1. There was a slight increase in population at 15th DASP (day after spraying) in which maximum population was on T_3 (2.25) which was on par with T_2 whereas, the lowest population was recorded was on T_6 (1.16) which was on par with

T_8 (1.33). A marginal reduction in the population was observed on 30th day after spraying in which maximum population was observed on T_3 (2.08) whereas minimum population was recorded on T_8. On 45th day after spraying, T_3 recorded the highest score (1.17), whereas T_6 recorded the lowest.

The results of the experiment conducted during summer season are presented in the table 4.2.

The aphid population was low when compared to rainy season crop. On the 7th DAS, 3 treatments that were grown in the potting mixture viz. T_2 (0.67), T_1 (0.33) and T_3 (0.33) recorded the higher scoring in the population of aphid. T_4, T_5 and T_7 to T_{12} recorded no infestation. A gradual increase in the population was observed on 21st DAS with maximum population on T_4 (1.25) which was on par with T_2 and T_{11}. T_5 and T_8 were free of infestation. Maximum population score of 1.58 was recorded on T_4 on the 35 DAS and minimum aphid score was recorded by T_5 and T_9.

On 15th DASP (day after spraying), maximum population was recorded on T_4 (1.83) whereas, T_9 was free of aphid infestation. A reduction in the population was observed on 30th day after spraying in which maximum population was observed on T_{12} (1.00). A similar trend was seen from the observation recorded on 45th day after spraying. T_{12} recorded the highest score (0.92).

The establishment and multiplication of aphid colonies on leaves was comparatively faster in T_1, T_2, T_3 and T_4 than in plants fertilized with adequate macronutrients (T_5 to T_{12}). From 21st DAS, aphid colonies established on leaves of majority of the plants irrespective of the treatments. Maximum population was recorded on the 15th DAS. There after a reduction was seen.

Treatments such as T_1, T_2, T_3 and T_4 have shown higher infestation by aphids in both seasons. T_{12} has shown maximum infestation towards the end of the crop in summer season.

Table 4.1 Aphid population on leaves in the rainy season

	DAS			DASP		
Treatments	7	21	35	15	30	45
T_1	1.00	1.50	1.75	2.00	1.75	1.08
T_2	1.66	1.75	2.00	2.08	1.75	1.08
T_3	1.58	1.66	1.66	2.25	2.08	1.17
T_4	0.25	1.50	1.58	1.91	1.58	1.00
T_5	0.75	0.75	1.25	1.50	1.50	0.83
T_6	0.25	0.75	1.25	1.16	1.16	0.00
T_7	0.33	0.91	1.25	1.50	1.16	0.83
T_8	0.33	0.75	1.25	1.33	1.00	0.75
T_9	0.33	1.25	1.50	1.58	1.25	0.83
T_{10}	0.33	1.25	1.50	1.58	1.25	0.75
T_{11}	0.33	1.25	1.41	1.58	1.25	0.83
T_{12}	0.33	1.25	1.50	1.75	1.50	0.83
C.D (0.05%)	0.20	0.10	0.27	0.19	0.14	0.20

DAS -days after sowing.

DASP - days after spraying

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

Table 4.2 Aphid population on leaves in the summer season

	DAS			DASP		
Treatments	7	21	35	15	30	45
T_1	0.33	1.00	1.17	1.58	0.00	0.00
T_2	0.67	1.17	1.25	1.08	0.00	0.00
T_3	0.33	0.75	0.83	0.92	0.67	0.58
T_4	0.00	1.25	1.58	1.83	0.00	0.00
T_5	0.00	0.00	0.00	0.67	0.00	0.00
T_6	0.25	1.08	1.00	1.00	0.00	0.00
T_7	0.00	0.75	0.83	0.75	0.00	0.00
T_8	0.00	0.00	0.67	0.58	0.00	0.00
T_9	0.00	0.50	0.00	0.00	0.00	0.00
T_{10}	0.00	0.75	0.75	0.67	0.00	0.00
T_{11}	0.00	1.17	1.25	1.25	0.58	0.42
T_{12}	0.00	1.08	1.08	1.08	1.00	0.92
C.D (0.05%)	0.12	0.14	0.17	0.23	0.10	0.12

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

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4.1.2. Aphid population on stems

In the pot culture experiment conducted during rainy season, the effect of mineral nutrients in the development of aphid colonies on the stem was evaluated and results are presented in the Table.5.1 Observations were recorded at biweekly interval from 7th day after sowing. Spraying was given in between 21st and 35th day after sowing.

Aphid population on the 21st DAS revealed that treatments T_1 and T_2 have recorded a higher aphid population on the stem in comparison with T_3 to T_{12}. Even though no notable difference was recorded among various treatments, T_2 (1.00) exhibited maximum count of aphids on the stem whereas, T_5, T_7 and T_8 (0.42) recorded minimum aphid population. A gradual increase in the population was observed on the 35th DAS with maximum population on T_2 (1.33) which was on par with T_3 (1.25) and T_1 (1.08). Minimum aphid population was recorded on T_8 (0.33) and T_{12} (0.33).

In the 15th day after spraying, a reduction in the aphid population was observed in T_3, T_4, T_5, T_7 and T_8 with minimum population on T_8 (0.25), whereas the highest population was recorded on T_{12} (1.67). On the 30th day after spraying, T_2, T_6 and T_8 had shown a reduction in the aphid population, whereas the highest population was observed on T_{12} with a score of 1.75 which was on par with T_1, T_2 and T_3.

Results of the experiment conducted during summer season are presented in Table 5.2

Aphid population on the 21st DAS revealed that maximum population was recorded on T_2 (0.58) which was on par with T_4. Minimum aphid population score was recorded on T_9 and T_{10}. Maximum population score of 2.42 was recorded on T_{12} on the 35th DAS and minimum aphid score was recorded by T_3 and T_8.

On 15[th] DASP (day after spraying), maximum population was on T_{12} (1.67) whereas, T_3, T_5 and T_8 were free of infestation (0.00). A reduction in the population was observed on 30[th] day after spraying in which maximum population was observed on T_{12} (0.50). A similar trend was seen from the observation recorded on 45 days after spraying in which T_{12} recorded the highest aphid score of 0.67.

Table. 5.1 Aphid population on stems in rainy season.

	DAS		DASP	
Treatments	21	35	15	30
T_1	0.83	1.08	1.17	1.42
T_2	1.00	1.33	1.50	1.42
T_3	0.50	1.25	0.92	1.42
T_4	0.58	0.58	0.33	0.33
T_5	0.42	0.58	0.50	0.50
T_6	0.50	0.67	0.75	0.67
T_7	0.42	0.67	0.58	0.92
T_8	0.42	0.33	0.25	0.17
T_9	0.50	0.58	0.58	0.92
T_{10}	0.58	0.42	0.50	0.67
T_{11}	0.58	0.58	0.67	0.67
T_{12}	0.58	0.33	1.67	1.75
C.D (0.05%)	NS	0.54	0.41	0.45

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

Table 5.2 Aphid population on stem in summer season.

	DAS		DASP		
Treatments	21	35	15	30	45
T_1	0.17	0.58	0.83	0.00	0.00
T_2	0.58	0.92	1.08	0.33	0.00
T_3	0.08	0.00	0.00	0.00	0.33
T_4	0.50	0.83	0.50	0.00	0.00
T_5	0.17	0.33	0.00	0.00	0.00
T_6	0.08	0.25	0.67	0.00	0.17
T_7	0.17	0.33	0.33	0.00	0.00
T_8	0.17	0.00	0.00	0.00	0.00
T_9	0.00	0.08	0.50	0.00	0.00
T_{10}	0.00	0.17	0.08	0.00	0.00
T_{11}	0.08	1.08	1.08	0.00	0.17
T_{12}	0.08	2.42	1.67	0.50	0.67
C.D (0.05%)	0.20	1.09	0.19	0.07	0.19

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

4.1.3 Aphid population on pods

In the pot culture experiment conducted during rainy season, the effect of mineral nutrients in the development of aphid colonies on pods was evaluated and results are presented in the Table 6. Observations were recorded at biweekly interval from 15th day after sowing. Spraying was given in between 21st and 35th day after sowing.

The infestation of aphids on pods started on the 15th DASP. The aphid population ranged from 0.17 to 0.50. Minimum aphid population was observed in T_1 (0.17) and maximum on T_7 (0.50). The population of aphid colonies ranged from 1.08 to 2.33 on the 30th DASP. Maximum aphid population was observed in T_{12} (2.33) which was on par with T_1 and T_{11}. T_8 recorded lowest aphid population with 1.08 which was on par with T_9 and T_{10}.

T_{12} recorded maximum population at 45th DASP which was on par with T_1, T_5 and T_{11}. T_8 (1.17) recorded minimum population of aphid which was statistically on par with T_{10} (1.42).

Results of the experiment conducted during summer season are presented in table 6.

Aphid infestation on pods was started on the 30 DASP. The aphid population ranged from 0.92 to 2.75. Minimum population of aphids was observed on T_8 (0.92) and maximum count was observed on T_{12} (2.75) which was on par with T_{11}.

Population of aphids ranged from 1.08 to 3.00 during 45th DASP. Minimum count was observed on T_8 (1.08) which was on par with T_9 and T_{10}. Maximum aphid colonies were observed on T_{12} (3.00) which was on par with T_{11}.

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Table 6. Aphid population on pods in rainy and summer seasons.

	Rainy season			Summer season	
	DASP			DASP	
Treatments	15	30	45	30	45
T_1	0.17	2.08	2.17	2.00	2.08
T_2	0.42	1.83	1.92	1.83	1.91
T_3	0.33	1.75	1.83	2.00	2.08
T_4	0.33	1.58	1.75	1.83	2.00
T_5	0.42	2.00	2.17	1.83	2.00
T_6	0.42	1.91	2.08	1.75	2.08
T_7	0.50	1.50	1.67	1.42	1.50
T_8	0.25	1.08	1.17	0.92	1.08
T_9	0.33	1.23	1.50	1.08	1.41
T_{10}	0.33	1.33	1.42	1.25	1.41
T_{11}	0.33	2.16	2.25	2.42	2.66
T_{12}	0.42	2.33	2.42	2.75	3.00
C.D (0.05%)	NS	0.32	0.32	0.45	0.40

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

4.1.4. Percentage of shoots infested by aphids

The extent of infestation caused by aphids on shoots was expressed as percentage of shoots infested and the result of the rainy season are presented in Table 7.1.

The observation recorded in the 21st DAS revealed that the infestation was minimum in T_9 (4.63 per cent) which was on par with all other treatments except T_1, T_2 and T_{12}. Maximum percentage of infested shoots was observed in T_{12} (15.76 percent) which was on par with T_1 and T_2.

The observation recorded in the 35th DAS revealed that the infestation was minimum in T_8 (3.92 per cent) which was on par with T_3, T_6, T_7, T_9 and T_{11}. Maximum percentage of shoot infested was recorded in T_{12} (25.56 percent) which was on par with T_1, T_5 and T_{10}. The observation recorded in the 15th DASP revealed that the infestation was minimum in T_8 (4.23 per cent) which was on par with all other treatments except T_1, T_2, T_{11} and T_{12}. Maximum percentage of shoot infested was recorded in T_{12} (35.34 percent) which was on par with T_1, T_2 and T_{11}.

On 30th day after the application of foliar spray the same trend was observed with minimum infestation in T_8 (3.52 per cent) which was on par with all other treatments except T_1, T_4 and T_{12}. Maximum infested shoots recorded in T_{12} (24.58 per cent) which was on par with T_4 (17.67 per cent).

Results of the experiment conducted during summer season are presented in Table 7.2

The observation recorded on the 21th DAS revealed that the infestation was absent in T_5, T_9 and T_{10} (0.00 per cent) which was on par with all other treatments except T_4. Maximum percentage of infested shoots was observed in T_4 (25.22 percent) which was on par with all other treatment except T_5, T_9 and T_{10}. The observation recorded in the 35th DAS revealed that the infestation was minimum in

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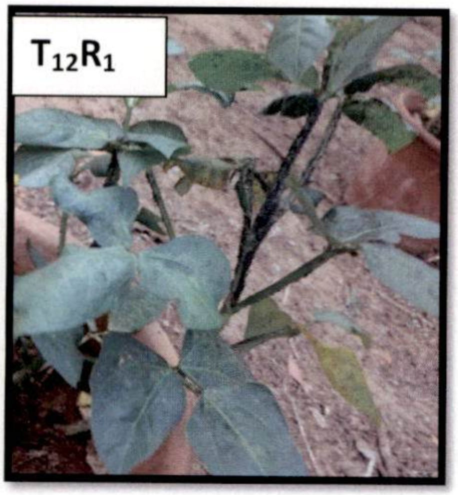
T_7, T_8 and T_{11} (0.00 per cent) which was on par with T_2, T_3, T_4 and T_9. Maximum percentage of shoot infested was recorded in T_{12} (31.54 percent) which was on par with T_1, T_2, T_5, T_6 and T_{10}.

The observation recorded in the 15th DASP revealed that the infestation was minimum in T_3, T_5, T_8 and T_9 (0.00 per cent) which was on par with all other treatments except T_2 and T_{12}. Maximum percentage of shoot infested was recorded in T_2 (28.31 percent).

On 30th day after the application of foliar spray, maximum infestation was observed in T_{12} (30.53 per cent). Infestation was absent in all treatments except T_1, T_2 and T_{12}. The observation recorded on the 45th DASP revealed that the infestation was maximum in T_{12} (35.35 per cent) and all other treatments except T_1, T_3, T_6, T_{11} and T_{12} were free of infestation. Plate 2 shows treatment with highest aphid infestation on pods and shoots and Plate 3 shows treatment with lowest aphid infestation on shoots and pods.



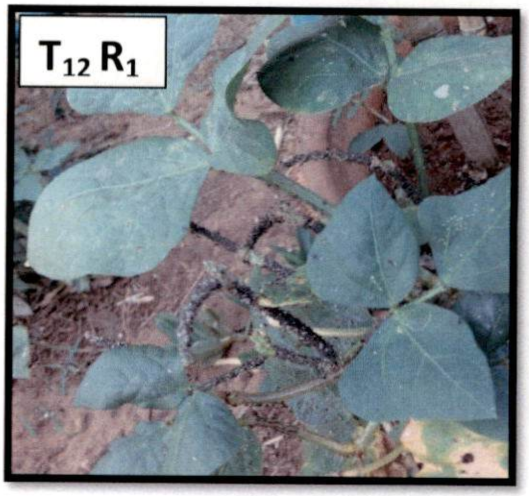


Plate 2 : T_{12}: Treatment with highest aphid infestation on shoots and pods

Plate 3: T_{12}: Treatment with lowest aphid infestation on pods and shoots

Table.7.1 The percentage of shoots infested by aphids in rainy season

	DAS		DASP	
Treatments	21	35	15	30
T_1	15.00	23.39	30.11	14.85
T_2	12.57	14.12	29.94	9.89
T_3	6.13	8.67	8.90	5.18
T_4	9.39	13.69	17.62	17.67
T_5	4.70	17.17	9.79	6.06
T_6	7.59	13.01	12.28	6.22
T_7	7.59	4.76	6.14	4.67
T_8	7.59	3.92	4.23	3.52
T_9	4.63	13.11	14.28	6.35
T_{10}	6.01	21.63	9.11	5.41
T_{11}	6.15	5.83	23.00	4.88
T_{12}	15.76	25.56	35.34	24.58
C.D (0.05%)	6.18	9.53	14.71	7.84

Table.7.2 The percentage of shoots infested by aphids in summer season

	DAS		DASP		
Treatments	21	35	15	30	45
T_1	8.41 (6.06)	30.01 (25.48)	20.47 (18.09)	13.20 (7.69)	12.57 (7.00)
T_2	13.07 (13.33)	14.81 (9.54)	28.31 (23.18)	7.40 (4.76)	0.00 (0.00)
T_3	8.62 (6.35)	6.89 (4.17)	0.00 (0.00)	0.00 (0.00)	6.49 (3.70)
T_4	25.22 (18.18)	10.56 (9.19)	9.99 (8.33)	0.00 (0.00)	0.00 (0.00)
T_5	0.00 (0.00)	23.04 (15.69)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
T_6	8.41 (6.06)	19.15 (16.16)	9.10 (7.02)	0.00 (0.00)	6.14 (3.33)
T_7	8.41 (6.06)	0.00 (0.00)	6.31 (3.51)	0.00 (0.00)	0.00 (0.00)
T_8	6.79 (4.04)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
T_9	0.00 (0.00)	8.41 (6.06)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
T_{10}	0.00 (0.00)	26.68 (20.48)	6.49 (3.71)	0.00 (0.00)	0.00 (0.00)
T_{11}	8.21 (5.79)	0.00 (0.00)	18.24 (14.81)	0.00 (0.00)	6.06 (3.25)
T_{12}	8.21 (5.79)	31.54 (27.58)	25.73 (26.46)	30.53 (25.82)	35.35 (33.63)
C.D	21.87 (0.05%)	18.11	23.26	8.45	10.82

Figures outside parenthesis denote angular transformed values

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

4.1.4. Percentage of pods infested by aphids

The extent of infestation caused by *Aphis craccivora* on pods was expressed as percentage of infested pods and results of the experiment conducted in rainy season are presented in Table 8

Observations recorded on the 15th day after spraying revealed that the infestation was minimum in T_8 (25.47 per cent), which was on par with all other treatments except T_{11} and T_{12} while, it was maximum in T_{12} (55.77 %) which was on par with T_1, T_3, T_5, T_6, T_7, T_9, T_{10} and T_{11}.

A similar trend was observed on 30th DASP also with minimum percentage of infested pods in T_8 (21.76 per cent) which was on par with T_1, T_2, T_3, T_4, T_5, T_6, T_8, T_9, T_{10} and T_{11} while, maximum infested pods were seen in T_7 (49.23 per cent) which was on par with all other treatments except T_8.

A significant difference in the percentage of pods infested by aphids was observed between treatments on the 45th DASP. Maximum percentage of aphid infested pods were recorded in T_{12} (58.97 per cent) which was statistically on par with T_9 and T_{11} while, minimum percentage of infestation was observed in T_8 (19.55 per cent) which was on par with T_4 (20.05 per cent).

Results of the experiment conducted during summer season are presented in Table 8

Observations recorded on 30th day after spraying revealed that the infestation was minimum in T_8 (17.29 per cent) which was on par with T_2, T_3, T_4 and T_{10} while it was maximum in T_{12} (51.13 per cent) which was on par with T_{11} (47.76 per cent).

A similar trend was seen from the observation recorded on 45th day after spraying. T_8 recorded the lowest (11.75 per cent), closely followed by T_4 (12.47 per cent) while, T_{12} recorded the highest (56.58 per cent) pod infestation followed by T_{11}.

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In rainy season lowest percent pod infestation was exhibited by T_4 and T_8 on both 15 and 30 days after spraying. In summer, there was a reduction in the percentage of pod infestation in T_4 and T_8 from 21.38 and 17.29 to 12.47 and 11.75 per cent respectively. Conversely, T_1, T_2, T_3, T_5, T_7, T_9, T_{10}, T_{11} and T_{12} had displayed an increase in the percentage of pod infestation. T_8 that was grown in NPK with 3 foliar sprays recorded minimum percentage of infestation. Whereas, T_{12} that was grown in NPK+ Ca and Mg with 3 foliar spray had shown maximum percentage of pod infestation.

Table 8. Percentage of pods infested by aphids in rainy and summer season.

	Rainy season			Summer season	
	DASP			DASP	
Treatments	15	30	45	30	45
T_1	33.38 (30.47)	35.34 (33.56)	35.02 (33.01)	29.45 (24.20)	29.93 (25.07)
T_2	28.10 (22.21)	33.46 (30.59)	40.20 (41.78)	25.68 (19.00)	32.59 (29.28)
T_3	31.20 (26.86)	39.07 (39.82)	33.74 (30.92)	24.79 (18.61)	28.90 (23.43)
T_4	27.37 (21.91)	31.24 (27.08)	20.05 (11.77)	21.38 (13.63)	12.47 (4.80)
T_5	47.43 (46.48)	36.46 (35.37)	33.54 (31.59)	32.98 (29.66)	33.14 (30.33)
T_6	44.26 (48.77)	31.68 (29.07)	34.97 (32.98)	31.94 (28.03)	31.17 (28.00)

T_7	48.01 (47.22)	49.23 (49.08)	36.71 (35.88)	30.16 (26.78)	31.61 (27.93)
T_8	25.47 (18.85)	21.76 (14.96)	19.55 (11.47)	17.29 (8.87)	11.75 (4.17)
T_9	35.50 (33.81)	39.05 (39.83)	49.40 (57.00)	29.93 (25.70)	30.75 (26.67)
T_{10}	30.29 (25.67)	37.67 (37.84)	31.95 (28.03)	27.04 (21.07)	27.91 (22.40)
T_{11}	54.63 (66.48)	41.29 (43.93)	53.96 (64.96)	47.76 (54.83)	48.84 (56.11)
T_{12}	55.77 (68.37)	45.08 (50.16)	58.97 (73.30)	51.13 (59.97)	56.58 (69.40)
C.D (0.05%)	26.89	21.80	10.61	11.06	12.73

Figures outside parenthesis denote angular transformed values

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

4.2. EFFECT OF MINERAL NUTRITION ON MANAGEMENT OF POD BORERS

4.2.1. The percentage of infested pods by pod borers

During the rainy season, the extent of the infestation caused by pod borers viz. Spotted pod borer, *Maruca vitrata*, Blue butterfly, *Lampides boeticus was* expressed as percentage of pod infested and presented in Table 9.1.

A significant difference was observed in the percentage of infested pods on the 15th DASP. The highest incidence of pod borer was recorded in T_5 (46.27 percent) which was on par with all other treatments except T_4 and T_{12}, while the lowest infestation was recorded in T_{12} which was on par with all other treatments except T_5.

On 30th DASP, maximum infestation was recorded on T_5 (50.69 per cent) which was on par with T_1, T_3 and T_9 with 33.56, 30.59 and 29.97 percent respectively. Minimum infestation was observed on T_{12} with 9.97 percent of infested pods which was on par with all other treatments except T_5 and T_1.

A significant difference in the percentage of infested pods was observed between the treatments on the 45th DASP. The maximum infestation was observed in T_9 (45.34) which was on par with all other treatments except T_7, T_{10}, T_{11} and T_{12}, while the minimum was recorded in T_{12} (16.06 percent).

On the 60th DASP, there was a decrease in the percentage of infested pods in all treatments except T_1, T_2 and T_{11}. The highest percentage of infested pods was observed in T_1 (41.26) which was on par with T_2, T_3, T_5, T_9 and T_{11}, while the lowest infestation was recorded in T_{12} with 9.99 percent of infested pods which was on par with T_3, T_4, T_5, T_6, T_7, T_8 and T_{10}.

Results of the experiment conducted during summer season are presented in Table 9.2

Observations recorded on 15th day after spraying during summer season revealed that the highest incidence of pod borer was on T_5 (74.99 percent) which was on par with T_1. T_3, T_4, T_7, T_8, T_9, T_{10}, T_{11} and T_{12} did not exhibit any infestation.

On 30th DASP, maximum infestation was recorded on T_5 (68.14 per cent) followed by T_1 and T_9 with 28.00 and 10.75 per cent respectively, and T_5 was significantly different from other treatments. Infestation on T_2 and T_6 was reduced to 0.00 percent on 30 DASP. Infestation was absent in T_2, T_3, T_4, T_6, T_7, T_8, T_{10}, T_{11} and T_{12}.

On 45th day after spraying, the same trend was observed with maximum pod infestation on T_5 with 32.25 per cent which was on par with T_1 with 25.98. Infestation was absent in T_2, T_3, T_4, T_6, T_7, T_8, T_{10}, T_{11} and T_{12}.

There was an increase in the infestation on 60th day after spraying. Maximum infestation was exhibited by T_5 (56.74 per cent) followed by T_9 (45.75 percent) and T_1 (41.74 per cent). However, infested treatments were on par with each other. Plate 4 shows treatment with highest pod borer infestation and plate 5 shows treatment with lowest pod borer infestation.

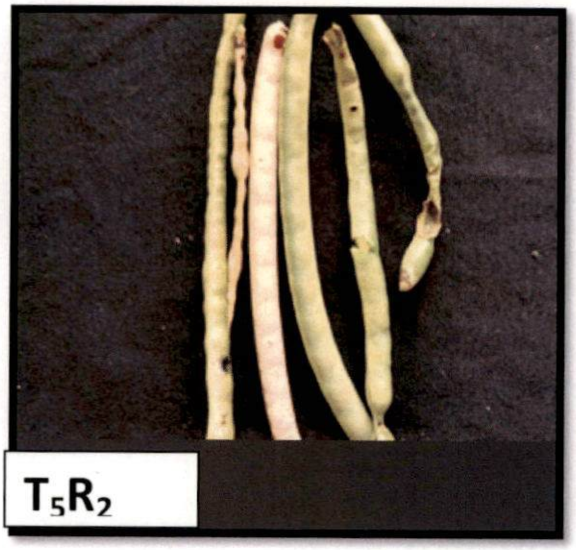

Plate 4: T_5: Treatment with highest pod borer infestation

Plate 5 : T_{12}: Treatment with lowest pod borer infestation

Table 9.1 The percentage of infested pods by pod borers in rainy season

Treatments	15	30	45	60
	DASP			
T_1	33.83	33.56	28.55	41.26
T_2	30.81	19.53	26.48	32.69
T_3	26.88	30.59	26.82	25.73
T_4	17.70	14.99	21.72	16.25
T_5	46.27	50.69	32.26	28.22
T_6	25.75	17.06	23.85	20.69
T_7	21.75	21.14	20.31	15.59
T_8	18.85	11.75	21.44	11.31
T_9	27.37	29.97	45.34	30.33
T_{10}	23.54	16.48	20.38	18.98
T_{11}	33.84	19.18	19.99	36.74
T_{12}	11.75	9.99	16.06	9.99
C.D(0.05%)	27.56	22.29	24.73	18.50

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

Table 9.2 . The percentage of infested pods by pod borers in summer season

Treatments	15	30	45	60
	DASP			
T_1	59.99	28.00	25.98	41.73
T_2	8.03	0.00	0.00	0.00
T_3	0.00	0.00	0.00	0.00
T_4	0.00	0.00	0.00	0.00
T_5	74.99	68.14	32.25	56.74
T_6	14.99	0.00	0.00	0.00
T_7	0.00	0.00	0.00	0.00
T_8	0.00	0.00	0.00	0.00
T_9	0.00	10.75	12.63	45.75
T_{10}	0.00	0.00	0.00	0.00
T_{11}	0.00	0.00	0.00	0.00
T_{12}	0.00	0.00	0.00	0.00
C.D(0.05%)	23.05	10.83	8.57	23.78

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

4.2.2 Pod borers per plant

In the pot culture experiment conducted during rainy season, the effect of mineral nutrients were evaluated against larvae of *Maruca vitrata* and *Lampides boeticus* in cowpea and results are presented in Table 10.

Range of pod borer per plant varied from 0.08 – 0.67 on 15th day after spraying. Maximum mean pod borer was exhibited in T_1, T_5 and T_{11} and minimum mean pod borer per plant was observed in T_{12}. A significant difference between treatments was observed in mean pod borers per plant on 30th DASP. Maximum mean pod borer was recorded on T_5 (1.25), while minimum infestation was recorded on T_8 (0.08) and T_{12} (0.08) which was on par with all other treatments except T_5 and T_1.

On 45th day after spraying, the same trend was observed with maximum mean pod borer per plant on T_5 (0.83), while minimum mean pod borers per plant was observed in T_{12} (0.17) which was statistically on par with all other treatments except T_1 and T_5. On the 60thdays after spraying, Maximum infestation was exhibited by T_5 (0.50) which was on par with T_1 (0.42), while minimum mean pod borer per plant was recorded in T_{12} which was on par with all other treatments except T_1 and T_5.

Results of the experiment conducted during summer season are presented in Table 10.

Range of pod borer per plant varied from 0.00 – 1.33 on 15th day after spraying. Maximum mean pod borer was exhibited in T_1 (1.33) and T_5 (1.33) followed by T_2 (0.67) and T_6 (0.33). Pod borers were absent in T_3, T_4, T_7, T_8, T_9, T_{10}, T_{11} and T_{12}. However, T_1 and T_5 were significantly different from T_2 and T_6.

On 30th DASP maximum mean pod borer was recorded on T_5 (5.33) followed by T_1 and T_9 with values 1.67 and 0.67 respectively. T_5 and T_1 were significantly different over other treatments. Mean pod borers on T_2 and T_6 were reduced to 0.00 on 30th DASP. On 45th day after spraying, the same trend was observed with maximum mean pod borer on T_5 with 3.33 followed by T_1 and T_9 with 1.67 and 0.67 respectively

On 60[th] day after spraying, maximum infestation was exhibited by T_5 (1.67) followed by T_1 (1.00) and T_9 (1.00). T_5 had shown a significant difference from T_1 and T_9. Treatments T_1 and T_9 were significantly different from rest of the treatments.

Table 10. Pod borers per / plant in rainy and summer season

	Rainy season				Summer season			
	DASP				DASP			
Treatments	15	30	45	60	15	30	45	60
T_1	0.67	0.83	0.50	0.42	1.33	1.67	1.67	1.00
T_2	0.50	0.50	0.33	0.25	0.67	0.00	0.00	0.00
T_3	0.25	0.25	0.33	0.25	0.00	0.00	0.00	0.00
T_4	0.17	0.17	0.25	0.17	0.00	0.00	0.00	0.00
T_5	0.67	1.25	0.83	0.50	1.33	5.33	3.33	1.67
T_6	0.25	0.50	0.33	0.25	0.33	0.00	0.00	0.00
T_7	0.50	0.17	0.33	0.25	0.00	0.00	0.00	0.00
T_8	0.17	0.08	0.25	0.17	0.00	0.00	0.00	0.00
T_9	0.33	0.50	0.33	0.25	0.00	0.67	0.67	1.00
T_{10}	0.58	0.42	0.42	0.25	0.00	0.00	0.00	0.00
T_{11}	0.67	0.33	0.25	0.25	0.00	0.00	0.00	0.00
T_{12}	0.08	0.08	0.17	0.08	0.00	0.00	0.00	0.00
C.D(0.05%)	NS	0.616	0.264	0.187	0.57	0.85	0.85	0.57

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

4.3 POD BUGS

4.3.1. Percentage of infested pods

The results of the effect of mineral nutrient nutrition mentioned in percentage of pods infested by pod bugs in rainy season is given below in Table 11.

The percentage of pods infested by pod bugs was recorded at 30, 45 and 60 days after spraying. On 30th day after spraying, there was significant difference in the percentage of infested pods between the treatments. T_1 recorded maximum percentage of infested pods (50.18 per cent) whereas, T_{11} recorded minimum percentage of infestation (19.18 per cent).

Observations recorded on 45th day after spraying revealed that maximum percentage of infested pods was recorded in T_4 (46.31 per cent) which was on par with T_1, T_2, T_3, T_8, T_9 and T_{12}. Minimum percent of infested pods was observed in T_{10} (28.25 per cent) which was statistically on par with T_3, T_5, T_6, T_7 and T_{11}.

The percentage of pods infested over 60 days after application of treatments, showed T_{10} with lowest infestation (24.30 per cent) which was on par with T_3, T_5, T_6, T_7, T_8, T_9 and T_{11}, while T_4 (46.35 per cent) displayed the highest pod infestation which was on par with T_1, T_2, T_5, T_9 and T_{12}.

The results of the effect of mineral nutrient mixture on percentage of pods infested by pod bugs in summer season are given in Table 11.

Percentage of infested pods by pod bugs was recorded at 30, 45 and 60 days after spraying. On the 30th days after spraying, values ranged from 39.69 per cent to 24.53 per cent. There was significant difference between treatments in the percentage of infested pods. T_1 recorded maximum number of infested pods (39.69 per cent) which was on par with T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9 and T_{12} whereas T_{11} recorded minimum infestation with 24.53 per cent which was statistically on par with T_3 to T_{10}.

Observations recorded at 45 days after spraying follows the same trend as that of on 30thday after spraying. Among different treatments, T_1 recorded maximum (42.65 per cent) infested pods which was on par with T_2, T_3, T_4, T_5, T_6, T_7 and T_{12} whereas minimum percent of infested pods was observed in T_{11} (24.19 per cent) which was statistically on par with T_8, T_9 and T_{10}.

In the observation on percentage of pods infested on 60th day after spraying, T_{11} showed the lowest pod infestation with 18.85 % which was statistically on par with T_8, T_9 and T_{10} while T_1 (48.23 per cent) showed the highest pod infestation which as on par with T_2, T_3, T_4, T_7 and T_{12}.

Table 11. Percentage of infested pods by podbugs in rainy and summer season

	Rainy season			Summer season		
	DASP			DASP		
Treatments	30	45	60	30	45	60
T_1	50.18 (59.02)	42.65 (45.98)	44.98 (50.00)	39.69 (40.95)	42.65 (45.95)	48.23 (55.56)
T_2	42.00 (44.81)	41.74 (44.44)	41.14 (43.33)	39.42 (40.51)	41.74 (44.44)	43.06 (46.67)
T_3	39.82 (41.11)	37.51 (37.30)	29.95 (25.56)	32.51 (28.97)	34.27 (31.75)	44.98 (50.00)
T_4	41.74 (44.44)	46.31 (52.08)	46.35 (52.38)	34.39 (32.08)	38.90 (39.58)	41.05 (43.52)
T_5	32.93 (29.83)	37.07 (36.41)	35.40 (33.61)	34.69 (32.62)	33.86 (31.28)	34.99 (33.33)
T_6	32.11 (28.33)	28.77 (23.33)	32.57 (29.17)	33.83 (31.19)	35.20 (33.33)	35.00 (33.33)
T_7	33.84 (31.67)	33.88 (31.11)	33.02 (30.56)	33.84 (31.67)	34.91 (33.33)	36.74 (36.11)
T_8	29.45 (24.44)	41.59 (44.19)	32.91 (30.32)	29.45 (24.44)	27.48 (21.48)	25.73 (18.89)
T_9	33.06 (30.00)	44.72 (49.63)	35.60 (34.44)	30.29 (26.03)	25.75 (19.17)	27.70 (21.67)
T_{10}	28.22 (22.41)	28.25 (22.74)	24.30 (17.13)	27.30 (21.62)	26.74 (20.52)	26.55 (20.00)
T_{11}	19.18 (10.83)	31.74 (27.78)	29.77 (25.00)	24.53 (18.12)	24.19 (17.04)	18.85 (15.00)
T_{12}	43.06 (46.67)	43.06 (46.67)	44.38 (48.89)	36.74 (36.11)	39.82 (41.11)	39.82 (41.11)
C.D (0.05%)	8.77	10.94	12.01	11.30	9.06	12.80

Figures outside parenthesis denote angular transformed values

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

4.3.2. Number of adults and nymphs of pod bugs

The results of the effect of mineral nutrient mixture on the number of adult and nymph of pod bugs in rainy are given in Table 12.

Population of adult and nymph of pod bugs were recorded at 30th, 45th and 60 days after spraying. On the 30th day after spraying, there was significant difference between treatments in the population of pod bugs. T_{12} recorded maximum population (5.25) which was on par with T_1 (5.16), whereas T_{11} recorded minimum population of pod bugs (1.42) which was on par with all other treatments except T_1, T_4 and T_{12}.

Observations recorded at 45 days after spraying revealed that the highest population of pod bug was recorded in T_1 which was on par with T_{12} and T_4. Minimum population was observed in T_{10} (1.75) which was statistically on par with T_3, T_6, T_7, T_9 and T_{11}. In the observations on the population at 60th day after application of treatments, T_{11} showed the lowest population of pod bugs (1.92) which was statistically on par with T_3, T_6, T_7 and T_{10} while T_1 (5.00) showed the highest population which was on par with T_2, T_4, T_8 and T_{12}.

The result of the experiment conducted during summer season was presented in Table 12.

The population of pod bugs was recorded at 30, 45 and 60 days after spraying. On the 30th day after spraying, there was a notable difference between treatments in the population of pod bugs. T_{12} recorded maximum population (4.08) followed by T_1 (4.00), whereas T_9 and T_{11} recorded minimum population of pod bugs (1.42).

Observations recorded on the 45th day after spraying followed the same trend as that on the 30th day after spraying. Among treatments T_{12} recorded maximum (4.25) which was statistically on par with T_1 (4.17). Minimum population was observed in T_{11} (1.00) which was on par with all other treatments except T_1, T_2, T_4, T_5 and T_{12}.

In the observation on population at 60[th] day after the application of treatments, T_{11} showed the lowest population of pod bugs (1.42) which was statistically on par with T_8, T_{10}, T_7, T_3, T_6 and T_9 whereas, T_{12} (4.58) showed the highest population which was on par with T_1 (4.08). The treatments T_2, T_4 and T_5 were on par with each other.

Plate 6 showed treatment with highest population of podbugs ($T_{12}R_1$) in summer season.

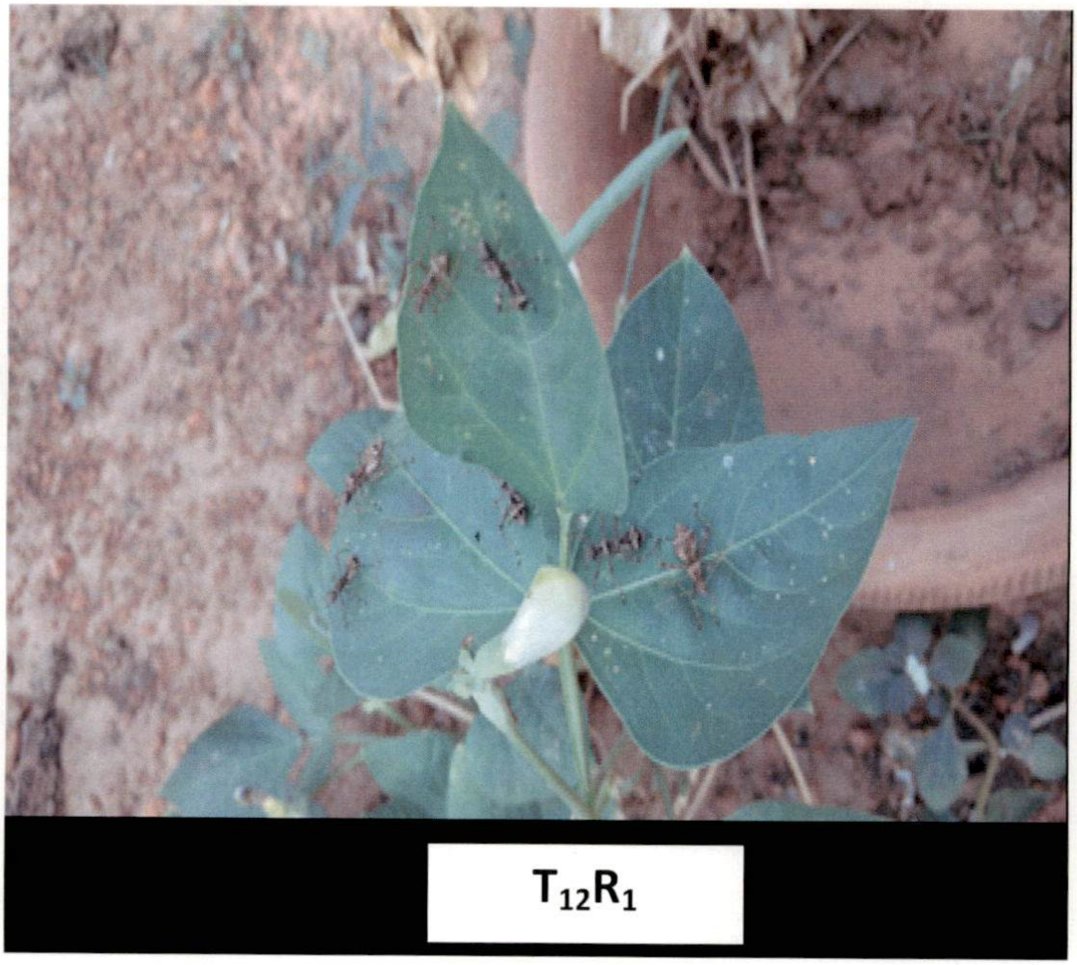

Plate 6: T_{12}: Treatment with highest population of podbugs

Table 12. Number of adult and nymph of pods bug in rainy and summer season

	Rainy season			Summer season		
	DASP			DASP		
Treatments	30	45	60	30	45	60
T_1	5.17	5.83	5.00	4.00	4.17	4.08
T_2	2.50	4.00	4.33	2.00	2.58	2.75
T_3	1.92	1.92	2.25	1.50	1.75	1.83
T_4	3.33	5.00	4.17	2.33	3.00	3.08
T_5	2.17	3.42	3.67	1.67	2.33	2.58
T_6	2.17	2.17	2.67	2.00	2.08	2.08
T_7	1.83	2.17	2.33	1.58	1.67	1.75
T_8	2.25	4.00	4.00	1.50	1.42	1.67
T_9	2.17	2.50	3.17	1.42	1.75	1.83
T_{10}	1.50	1.75	2.17	1.50	1.42	1.75
T_{11}	1.42	1.83	1.92	1.42	1.00	1.42
T_{12}	5.25	5.75	4.58	4.08	4.25	4.58
C.D(0.05%)	1.24	0.92	1.09	1.12	1.12	1.10

T_1: P.M + Absolute control; T_2: P.M+ 1 foliar spray; T_3: P.M+ 2 foliar spray; T_4: P.M+ 3 foliar spray; T_5: P.M + NPK with no spray; T_6: P.M +NPK + 1 foliar spray; T_7: P.M+ NPK + 2 foliar spray; T_8: P.M +NPK + 3 foliar spray; T_9: P.M + NPK + Ca + Mg with no spray; T_{10}: P.M + NPK + Ca + Mg+ 1 foliar spray; T_{11}: P.M +NPK + Ca + Mg+ 2 foliar spray; T_{12}: P.M +NPK + Ca + Mg+ 3 foliar spray

4.4. BIOMETRIC CHARACTERS

4.4.1 The effect of mineral nutrition on leaf area and number of leaves

The influence of treatments on leaf area and numbers of leaves are presented in Table 13

In rainy season, the largest leaf area was recorded in T_{12} (4869.32 cm^2) which was on par with T_7 and T_8 while the lowest leaf area was observed in T_1 (1562.67 cm^2) which was on par with T_2, T_4 and T_{11}. T_5 control recorded 3423.10 cm^2 leaf area.

In summer season, among the treatments T_{12} exhibited the largest leaf area (4971.40 cm^2) which was statistically on par with T_8 (3935.63 cm^2), T_7 (3854.58 cm^2) and T_9 (3703.42 cm^2), whereas absolute control recorded the lowest leaf area (2,013.03 cm^2) which was statistically on par with T_2 (2225.18 cm^2), T_4 (2309.02 cm^2) T_3 (3090.38 cm^2) and T_{11} (3058.15 cm^2).

The number of leaves produced at the end of the crops was recorded and statistically analyzed. In rainy season, maximum number of leaves was recorded in T_{12} (64.70) which was on par with T_9 (60.46), whereas minimum number of leaves was produced by T_1 (absolute control-15.07).

In summer season, there was a significant difference between treatments with respect to the number of leaves produced. Maximum number of leaves was produced in T_{12} (63.60) which were on par with T_{10} (57.27) and T_9 (54.20) while absolute control (without any fertilization) recorded minimum (20.56 leaves).

4.4.2 Height of plant and length of pods

The Height of plant was recorded in the end of the crop and presented in Table 13.

In rainy season, the maximum plant height was observed in T_{12} (218.00 cm), while the minimum plant height was recorded in T_1 (120 cm) which was on par with

T_2 and T_3. Range of height in summer season varied from 120.00 to 203.66 cm. The height of the plant was significantly influenced by the nutrient treatments. Maximum height was observed for T_{12} (203.66cm). The lowest plant height was observed for T_1 which is absolute control.

The data on length of pods was taken at 30 days after spraying and it is presented in Table.13.

In rainy season, maximum pod length was observed in T_3 (17.75 cm) which was on par with T_6, T_8, T_{10} and T_{12} while, minimum pod length was recorded in T_1 which was statistically on par with T_2 (15.70 cm). In summer season, even though there was no significant difference between the treatments, T_{12} and T_{10} recorded maximum length of pods (17.72 cm) and T_1 recorded minimum length of pods (15.41 cm) followed by T_2 (15.92 cm). T_9) recorded 16.06 cm.

4.4.3 Days to flowering

Data on days to flowering were recorded and presented in Table 13.

A noticeable difference between treatments has been exhibited in case of time taken to flowering. In rainy season, minimum days for flowering was observed in T_4 (38.41 days) which was on par with T_6, T_7, T_{10} and T_{11} whereas maximum days to flowering was recorded in T_3 (41.83 days) which was on par with T_2 (41.37 days).

In summer season, maximum days for flowering was recorded in T_2 (40.58 days) and T_5 (40.58 days) which was on par with T_1, T_8, T_9 and T_{12} whereas minimum days to flowering was recorded in T_3 (38.25 days) which was on par with T_4, T_6, T_7 and T_{11}.

Table .13 Foliar application of mineral nutrient mixture on Biometric parameters of cowpea

Treatments	Leaf area (cm^2)		Number of leaves produced		Height of plant (cm)		Length of pods (cm)		Days to flowering	
	Rainy season	Summer season	Rainy season	Summer season	Rainy season	Summer season	Rainy season	Summer season	Rainy season	Summer season
T_1	1,562.67	2,013.03	15.07	20.56	120.00	120.00	15.63	15.41	40.75	40.41
T_2	2,047.02	2,225.18	21.93	32.43	128.13	133.50	15.70	15.92	41.37	40.58
T_3	3,029.82	3,090.38	26.80	38.06	128.60	139.16	17.75	17.29	41.83	38.25
T_4	2,115.96	2,309.02	32.63	36.23	157.70	155.33	16.56	16.60	38.41	38.41
T_5	3,423.10	3,538.38	41.10	47.46	159.50	169.43	16.33	16.11	40.16	40.58
T_6	3,400.55	3,529.31	33.93	37.50	156.06	166.83	17.40	17.46	38.58	38.58
T_7	3,951.97	3,854.58	38.23	31.40	164.43	169.50	17.20	16.51	38.75	39.08
T_8	3,597.57	3,935.63	46.53	25.93	167.26	185.50	17.30	17.27	39.75	39.83
T_9	3,263.25	3,703.42	60.46	54.20	164.50	163.83	16.36	16.06	40.41	40.50
T_{10}	3,368.13	3,499.24	57.20	57.27	154.46	168.16	17.30	17.72	38.66	39.50
T_{11}	2,859.63	3,058.15	38.03	42.63	186.66	176.16	16.60	16.30	38.58	38.58
T_{12}	4,869.32	4,971.40	64.70	63.60	218.00	203.66	17.40	17.72	40.16	40.16
C.D (0.05%)	1,344.92	1,315.72	6.65	11.31	9.95	11.99	0.51	NS	0.912	1.11

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4.5. YIELD CHARACTERS

4.5.1 The Effect of mineral nutrition on the yield parameters of cowpea

Data on seed yield, fresh pod yield, marketable yield and biomass are presented in Table 14.

In rainy season, the highest seed yield was obtained from T_{10} (13.29 g) which was on par with T_4 (11.09 g) and T_6 (12.59 g) while, the lowest yield was recorded for T_{12} with 4.62 g which was statistically on par with T_1 (7.53 g). In summer season, the highest seed yield was obtained from T_{10} (14.02 g) which was on par with T_6 (13.95 g), T_4 (12.32 g) and T_2 (11.96 g) while, the lowest yield was recorded from T_{12} with 5.50 g which was statistically on par with T_1 and T_{11}.

In rainy season, the highest fresh yield was recorded from T_4 (54.40g) and the lowest fresh yield was from T_{12} (22.46g) which was even less than absolute control (28.63 g). In summer season, the highest fresh yield was obtained from T_{10} (54.68 g) which was statistically on par with T_4 (53.45), T_2 (50.26g), T_6 (49.66g) and T_5 (43.33). The lowest fresh yield recorded for T_{12} (26.03 g) which was even less than absolute control.

Marketable yield was found to be highest in T_{10} (44.22g) in rainy season which was on par with T_2, T_4 and T_6. Whereas, the lowest marketable yield was obtained in T_{12} (16.18 g) which was statistically on par with T_1, T_3, T_7 and T_{11}. In summer season, maximum marketable yield was recorded in T_{10} (49.33g) which was on par with T_2 (44.89 g), T_4 (43.21 g) and T_6 (42.56g) while minimum yield was recorded in T_{12} (21.33g) which was on par with T_1 and T_9.

The effect of treatment was found to be significant in case of biomass of plant. In rainy season, the highest plant biomass was recorded in T_{12} (43.94g) which was on par with T_6 (42.02) while, the lowest biomass was observed on absolute control (26.96 g) which was on par with control T_5 (29.88 g) T_4 (30.11 g) and T_{11}.

In summer season, the highest plant biomass was recorded in T_{12} (48.50 g). The Lowest biomass was observed on absolute control (28.08 g) which was on par with T_2 (32.16), T_3 (32.91), T_4 (32.25 g), T_5 (31.125 g), and T_{11} (30.16 g).

Table.14. Foliar application of mineral nutrient mixture on yield parameters of cowpea

Treatments	Seed yield (g)		Fresh yield (g)		Marketable yield (g)		Total biomass (g)	
	rainy season	summer season	Rainy season	summer season	rainy season	summer season	Rainy season	summer season
T_1	7.53	8.21	28.63	32.33	20.88	25.80	26.96	28.08
T_2	10.15	11.96	40.84	50.26	34.52	44.89	31.84	32.16
T_3	8.18	8.60	31.54	39.23	26.33	35.55	32.56	32.91
T_4	11.09	12.32	54.40	53.45	38.22	43.21	30.11	32.25
T_5	8.69	9.65	36.78	43.33	28.65	35.64	29.88	31.12
T_6	12.59	13.95	48.44	49.66	40.56	42.56	42.02	43.00
T_7	8.50	9.31	31.28	38.33	26.50	32.33	36.26	40.91
T_8	8.85	9.17	28.70	35.36	26.90	32.00	33.17	34.58
T_9	8.60	9.93	33.69	37.82	27.50	30.66	35.60	40.08
T_{10}	13.29	14.02	52.01	54.68	44.22	49.33	38.41	40.91
T_{11}	8.14	8.31	30.19	39.66	26.45	35.60	28.96	30.16
T_{12}	4.62	5.50	22.46	26.03	16.18	21.33	43.94	48.50
C.D (0.05%)	3.06	2.95	3.36	13.39	10.49	9.96	4.48	5.26

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4.5.2. Economic analysis

The data on economics of cowpea cultivation are given in Table 15. The treatment T_6 registered the maximum net returns of Rs. 42178.38 and 50937.63 ha^{-1} in rainy and summer season respectively

Cost of inputs

Seed	- Rs. 300
Urea	- Rs. 10 kg^{-1}
Rajphos	- Rs. 10 kg^{-1}
Muriate of potash	- Rs. 20 kg^{-1}
Copper sulphate	- Rs. 1000 kg^{-1}
Zinc sulphate	- Rs. 438 kg^{-1}
Boric acid	- Rs. 438 kg^{-1}
Potassium silicate	- Rs. 503 L^{-1}
Calcium carbonate	- Rs. 366 kg^{-1}
Magnesium sulphate	- Rs. 340 kg^{-1}
Potting mixture	- Rs. 24 / pot

Price of produce

Seed	- Rs. 80/kg

Table 15.1 Foliar application of mineral nutrient mixture on economics of cowpea cultivation in rainy season.

Treatments	Cost of cultivation ($Rs\ ha^{-1}$)	Gross returns ($Rs\ ha^{-1}$)	Net returns ($Rs\ ha^{-1}$)	BCR
T_1	26000.00	44622.17	18622.17	1.71
T_2	28195.63	60148.08	31952.45	2.13
T_3	31079.82	48474.02	17394.2	1.55
T_4	39571.24	65718.45	26147.21	1.66
T_5	29233.32	51496.24	22262.92	1.76
T_6	31428.95	74607.33	42178.38	2.3
T_7	34313.14	50370.32	16057.18	1.46
T_8	42804.56	52444.39	9640.37	1.22
T_9	37211.02	50962.91	13751.89	1.36
T_{10}	39406.65	78755.47	39348.82	1.99
T_{11}	42290.84	48236.98	5946.14	1.14
T_{12}	44782.26	27377.75	-17404.51	0.61

Table 15.2 Foliar application of mineral nutrient mixture on economics of cowpea cultivation in summer season

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	BCR
T_1	26300	48651.80	22351.18	1.84
T_2	28495.63	70874.80	42379.17	2.48
T_3	31379.82	50962.91	19583.09	1.62
T_4	39871.24	73007.33	33136.09	1.83
T_5	29533.32	57185.12	27651.80	1.93
T_6	31728.95	82666.58	50937.63	2.6
T_7	34613.14	55170.31	20557.17	1.59
T_8	43104.02	54340.68	11336.12	1.26
T_9	37511.02	58844.38	21333.36	1.56
T_{10}	39706.65	83031.39	43379.74	2.09
T_{11}	42590.84	49244.39	6653.55	1.15
T_{12}	45082.26	32592.56	-12489.60	0.72

4.6. NUTRIENT CONCENTRATIONS IN PLANT

Various chemical analyses of plant samples were conducted in order to examine the effect of foliar spraying of mineral nutrient mixture on plant's nutrient status. The plant samples were collected at yielding 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 seasons is presented in Table 16.1 and 16.2.

4.6.1. Potassium

In rainy season, the treatments had notable differences in case of K content in cowpea. T_{10} recorded highest K content with 1.72 per cent, whereas control T_1 was found to contain lowest K (0.59 per cent) which was on par with T_2 (0.63 per cent). T_{10} recorded highest K content of 1.87 per cent in summer season which was on par with T_6 (1.79 per cent), T_3 (1.73 per cent) and T_{11}(1.65 per cent), whereas absolute control T_1 was found to have lowest K content (0. 65 per cent).

4.6.2. Calcium

In rainy season, T_{12} recorded highest Ca content with 0.22 per cent. The lowest Ca content was found in absolute control (0.10 per cent) which was on par with T_2 (0.11 per cent). In summer, treatments showed noticeable difference in total Ca content. T_{11} recorded highest Ca content of with 0.24 per cent. The lowest Ca content was found in absolute control (0.14 per cent) which was on par with T_5 (control) and T_4 (0.15 per cent).

4.6.3. Magnesium

In rainy season, a significant difference in Mg content was noticed among the treatments. The highest Mg content was observed in T_{10} and T_4 (0.20 per cent) which was on par with T_3. T_1 was found to have the lowest Mg content of 0.14 per cent

In summer season, the highest Mg content was observed in T_{11} (0.18 per cent). T_1 was found to have lowest Mg content with 0.14 per cent.

4.6.4. Sulphur

Total sulphur content in plant was significantly influenced by treatments in rainy season. The highest S content was found in T_{10} with 0.30 per cent which was on par with T_9 (0.27 per cent) and T_{11} (0.29 per cent). Whereas, the lowest content of S was recorded in T_1 (0.20 per cent) which was on par with T_2, T_5 and T_7.

In summer season, the highest S content in plant was found in T_{10} (0.31 per cent) which was on par with T_3, T_7, T_8, T_9 and $T_{11.}$ Whereas the lowest was recorded in control T_5 (0.22 per cent) which was on par with absolute control (0.24 per cent), T_2, T_3, T_4, T_6, T_8, T_9, T_{11} and T_{12}.

4.6.5. Copper

In rainy season, T_{12} recorded the highest Cu content with 7.95 ppm which was on par with T_2, T_3, T_7, T_8, T_9, T_{11} and T_{12}. The lowest Cu content was obtained for T_1 (3.21 ppm). The plant's Cu content showed a notable difference among the treatments in summer season. T_8 recorded the highest Cu content with 8.91 ppm. The lowest Cu content was found in T_{10} (4.48 ppm).

4.6.6. Zinc

Total Zn in plants was significantly influenced by treatments in which T_{11} recorded the highest Zn content with 25.01 ppm in rainy season. The minimum was found in T_1 (19.07 ppm).

In summer season, T_{11} was recorded highest Zn content (28.45 ppm) which was statistically on par with T_3. The minimum was found in T_1 (22.07 ppm) which was statistically on par with T_{12}.

4.6.7. Boron

Significant differences were found among the treatments in case of boron content in plants. T_4 recorded the highest B content with 58.38 ppm which was on par with T_8, T_{10} and T_{11}. T_1 recorded the lowest B content in plants with 49.15 ppm.

In summer season, T_4 recorded the highest B content with 64.34 ppm which was on par with all other treatments except T_1, T_5, T_7 and T_{12}. T_1 (absolute control) recorded the lowest B content in plants (46.89 ppm), which is on par with T_5, T_7 and T_{12}.

4.6.8. Silicon

Significant differences were found among the treatments in case of silicon content in plants. T_{12} recorded the highest Si content with 0.54 per cent. T_1 recorded the lowest Si content in plants with 0.21 per cent. In summer season, T_{12} recorded the highest Si content with 0.56 per cent. T_1 (absolute control) recorded the lowest Si content in plants (0.18 per cent).

Table 16.1: Data on final plant nutrient analysis in rainy season

Treatments	Potassium in %	Calcium in %	Magnesium in %	Sulphur in %	Copper in ppm	Zinc in ppm	Boron in ppm	Silicon in %
T_1	0.59	0.10	0.14	0.20	3.21	19.07	49.15	0.21
T_2	0.63	0.11	0.15	0.21	7.25	20.25	54.65	0.27
T_3	1.41	0.12	0.19	0.24	6.25	22.26	55.32	0.32
T_4	1.62	0.16	0.20	0.24	5.26	22.96	58.38	0.41
T_5	0.99	0.12	0.15	0.23	5.12	21.28	53.36	0.32
T_6	1.68	0.17	0.18	0.24	5.19	22.28	54.35	0.29
T_7	1.29	0.16	0.18	0.23	6.29	23.36	54.85	0.37
T_8	1.49	0.19	0.18	0.26	7.91	23.98	57.56	0.44
T_9	1.29	0.15	0.17	0.27	7.25	22.32	56.21	0.36
T_{10}	1.72	0. 17	0.20	0.30	5.26	24.64	58.24	0.47
T_{11}	1.58	0.21	0.18	0.29	6.58	25.01	57.36	0.46
T_{12}	1.26	0.22	0.16	0.26	7.95	23.32	54.10	0.54
C.D	0.02	0.01	0.01	0.03	2.20	NS	1.59	0.05

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Table 16.2: Data on final plant nutrient analysis in summer season

Treatments	Potassium in %	Calcium in %	Magnesium in %	Sulphur in %	Copper in ppm	Zinc in ppm	Boron in ppm	Silicon in %
T_1	0.65	0.14	0.14	0.24	4.70	22.07	46.89	0.18
T_2	0.75	0.19	0.15	0.24	7.06	24.95	62.05	0.26
T_3	1.73	0.20	0.17	0.26	5.41	27.74	63.89	0.33
T_4	1.40	0.15	0.16	0.25	6.95	25.04	64.34	0.35
T_5	1.05	0.15	0.14	0.22	5.01	24.45	47.42	0.26
T_6	1.77	0.21	0.17	0.25	5.19	25.07	57.74	0.27
T_7	1.39	0.17	0.15	0.30	6.89	26.07	53.21	0.33
T_8	1.55	0.18	0.15	0.27	8.91	24.53	57.44	0.41
T_9	1.38	0.18	0.16	0.26	7.71	23.85	56.99	0.38
T_{10}	1.87	0. 19	0. 17	0. 31	4.48	26.38	58.10	0.44
T_{11}	1.65	0. 24	0. 18	0. 26	6.32	28.45	60.75	0.48
T_{12}	1.49	0.20	0.17	0.25	8.49	23.49	54.10	0.56
C.D(0.05%)	0.24	0.02	0.01	0.05	0.913	1.744	7.65	0.03

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4.7. NUTRIENT CONCENTRATIONS IN 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 nutrient regimes. 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 seasons are presented in table 17.1 and 17.2

Table. 17.1 Data on initial soil nutrient analysis in rainy season

Nutrients	Potting mixture	Potting mixture + NPK	Potting mixture + NPK +Ca +Mg
K (mg/Kg)	139.28	171.65	171.65
Ca (mg/kg)	357.50	390.00	835.00
Mg (mg/kg)	33.80	35.05	38.30
S (mg/kg)	1.85	2.63	5.04
B (mg/kg)	0.14	0.15	0.17
Cu (mg/kg)	1.20	1.50	1.60
Zn (mg/kg)	2.91	3.22	3.72
Si (mg/kg)	26.18	65.45	99.22

Table 17.2. Data on initial soil nutrient analysis in summer season

Nutrients	Potting mixture	Potting mixture + NPK	Potting mixture + NPK +Ca +Mg
K (mg/Kg)	146.78	167.32	167.32
Ca(mg/kg)	607.50	617.50	1410.00
Mg(mg/kg)	34.15	35.65	39.55
S(mg/kg)	3.42	3.51	9.25
B(mg/kg)	0.15	0.16	0.16
Cu (mg/kg)	1.60	1.70	1.70
Zn(mg/kg)	3.69	3.88	3.90
Si(mg/kg)	34.54	64.6	72.5

Discussion

5. DISCUSSION

5.1 EFFECT OF MINERAL NUTRIENTS ON APHIDS

5.1.1 Aphid population on leaves

Absolute control (T_1) and plants which received foliar spray of mineral nutrients alone without the soil application of macro nutrients (T_2, T_3 and T_4) have developed aphid colonies on leaves comparatively faster than other treatments which received adequate macronutrients like N, P, K, Ca, Mg and S through soil. The soil potassium levels were comparatively medium in the treatments where aphid population was high, i.e.139.28 and 146.78 mg/Kg in rainy and summer season respectively (Table.17.1 and 17.2). Low aphid population is correlated with high K in soil having values 171.65 and 167.32 mg/Kg in rainy and summer season respectively. Plant potassium levels were comparatively low in treatments where higher population was noticed. The values ranged from 0.59 to 1.62 per cent in rainy season and 0.65 to 1.73 per cent in the summer season (Table16.1 and 16.2). This points to the fact that high population might be due to the lower levels of macro nutrients especially potassium which is essential for the growth and development of plants. Deficiency of NPK can make the plant susceptible to pests and diseases, among which potassium has a critical role in imparting resistance to plants against pests and diseases. Results are in line with the report of Amtmann (2008) who stated that the potassium stress can increase the degree of crop damage by insect, mite and fungal infestation. Similar findings have been reported by Marschner (1995) that the high vulnerability of potassium deficient plants to disease and insects is associated with impaired synthesis of high-molecular weight compounds (cellulose, starch and proteins) and accumulation of low-molecular weight organic compounds viz. soluble sugars, organic acids, nitrate and amino acids. Plants grown with inadequate potassium shows physical and metabolic changes which make them susceptible to pests and diseases. So insects will easily establish on such plants.

5.1.2. Aphid population on stem and pods

Treatment which received 0.2 per cent of mineral nutrition as three foliar sprays along with soil application of NPK (T_8) has shown a reduction and lowest aphid score on stem and minimum aphid score on pods. This indicates that three foliar sprays + NPK can attribute resistance to plants and reduce aphid colony formation on stem. 3 nutrient sprays + NPK+ Ca +Mg found to have highest aphid score on stem and pod in both seasons. The luxuriant vegetative growth of plant might have supported faster growth, development and reproduction of aphids. Figure 2 and 3 showed the effect of mineral nutrition on the aphid score on pods in rainy and summer season respectively. This result is in conformity with the report of Habashy *et al.,* (2010) who reported that application of magnesium sulphate, boric acid, borax, and copper oxide at 0.5 per cent concentration given as foliar spray was found to cause reduction in population of adult and nymphs of aphids on strawberry rather than one per cent. 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. The toxic effect of such elements could be attributed to more than one factors 1) Indirect mechanism that foliar fertilizers increase the natural plant immunity through improvement of plant nutritional status (Nowosielski *et al.*, 1988) 2) Toxic elements such as copper, boron etc elements may cause mortality of surviving individuals (Tomlin 1994); boric acid is lethal to insects by acting as a stomach poison and by absorbing the waxes that protect insects from desiccation (Caroline, 2004).

In laboratory studies, Habustova and Weismann (2001) proved that copper caused toxic effects on *Agrotis segetum* and *Mamesia brassicae*, such as morphological abnormalities, decreasing fecundity and egg sterility. Caroline (2004) and Ebaid & Mansour (2006), reported that boron had a toxic effect against pests.

Fig: 2 Aphid population on pods in rainy season

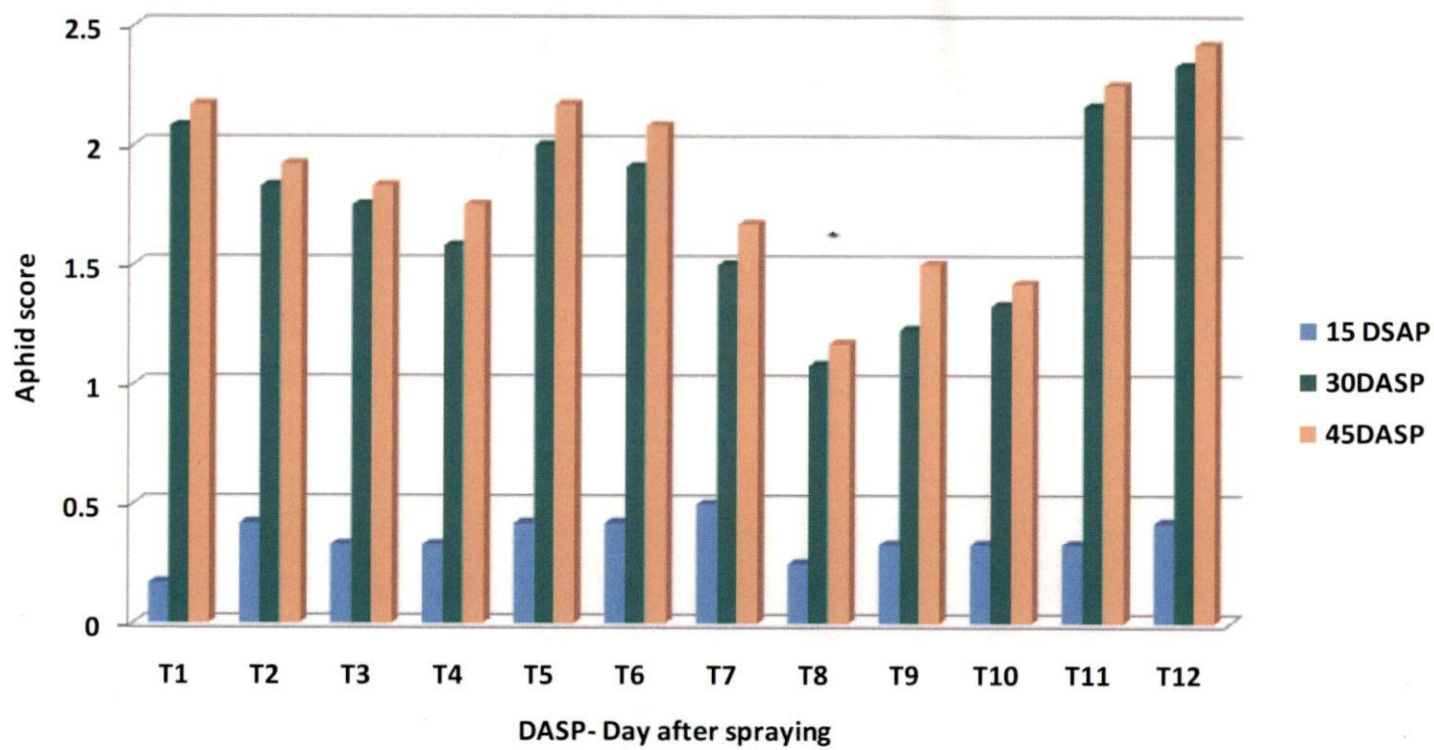
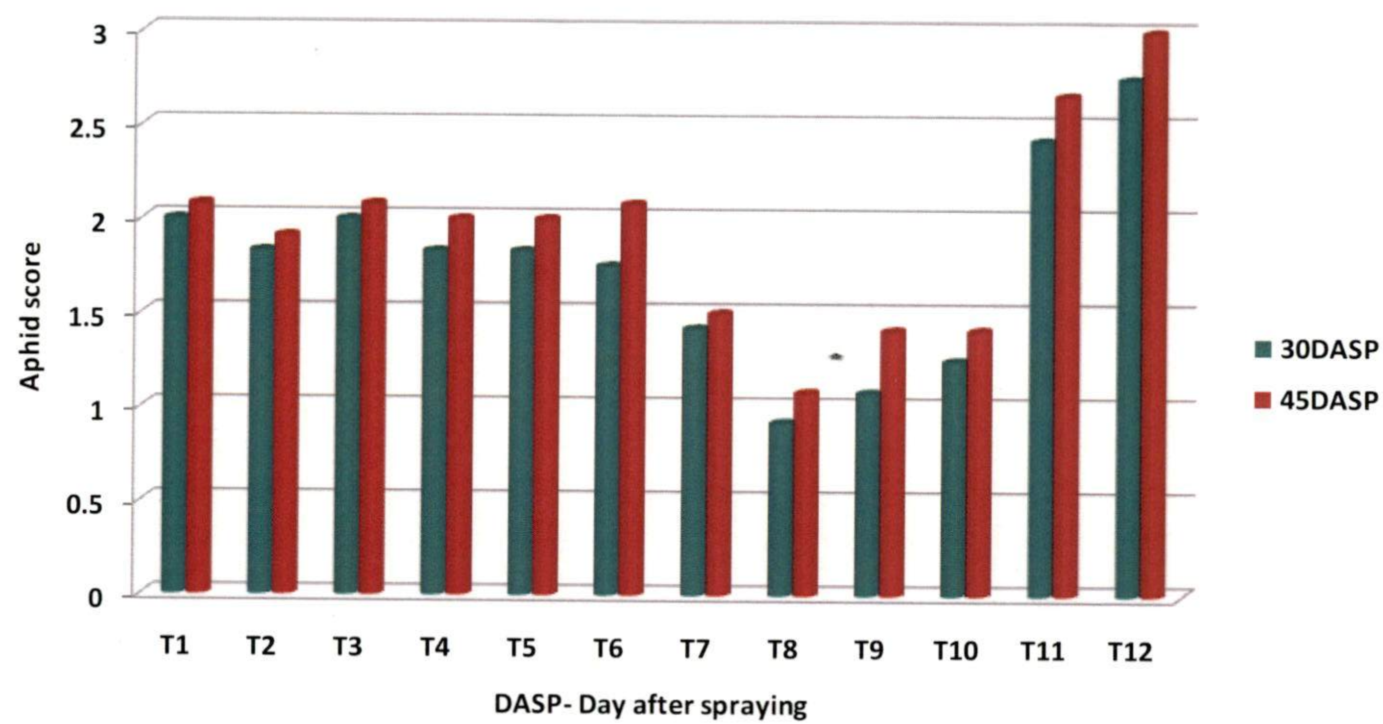


Fig: 3 Aphid population on pods in summer season



In the present study highest population was observed in plants that received with 3 foliar sprays along with soil application of NPK, Ca and Mg. Application of calcium and magnesium might have enhanced the mineralization and uptake of nitrogen and other nutrients from the soil. Moreover, plants have received K through the soil as well as foliar spray in the form of muriate of potash and potassium silicate. With higher plant nutrition, biometric parameters such as fresh weight of plant, number of leaves, length of plant, and number of branches had increased. So better vegetative growth of treated plants might have supported aphid growth, survival and reproduction. This might be the reason for increased infestation by aphids with the addition of Ca and Mg.

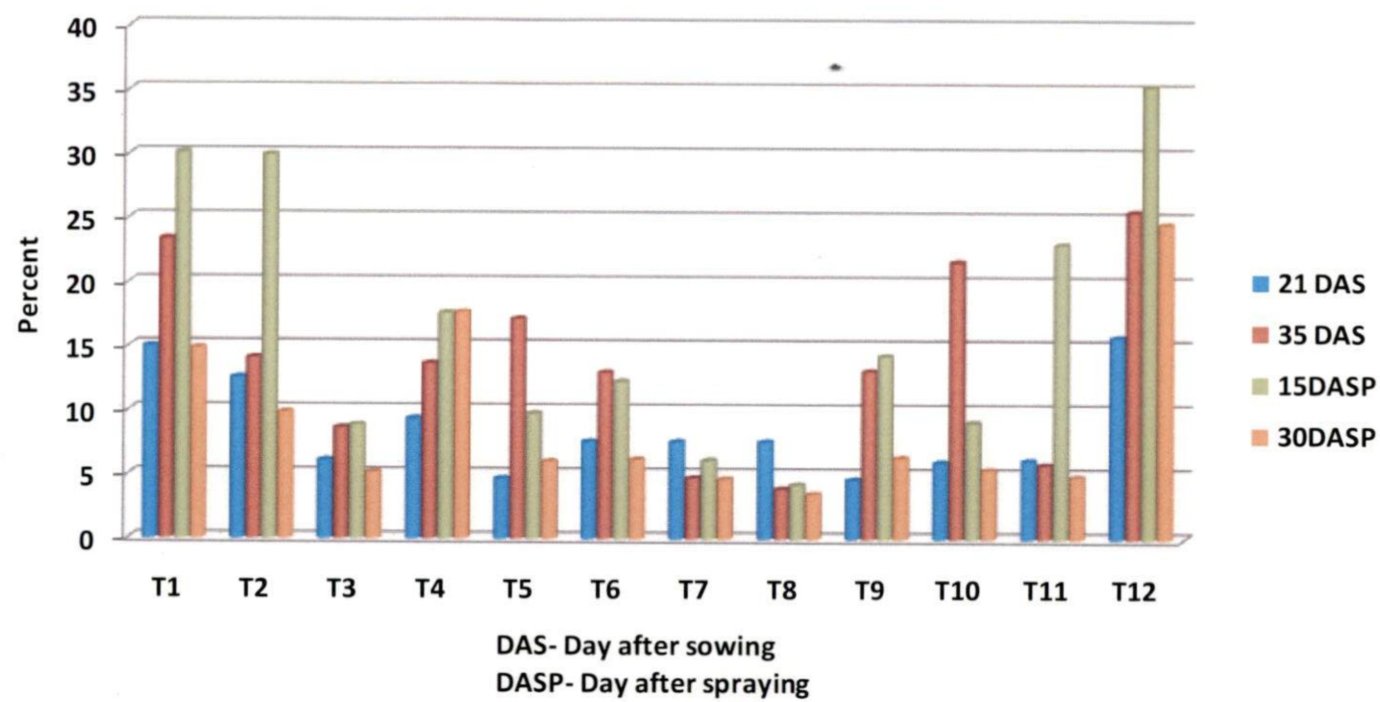
The result is in line with the findings of Chow *et al.*, (2009) who reported that liquid fertilizer containing NPK, Calcium and Magnesium at 100 % of recommended dose showed the highest incidence of mite on different parts of the rose plant when compared to 33 per cent and 50 per cent of the full dose.

5.1.3. Percentage of shoots infested by aphids

Mineral nutrient sprays has shown significant difference in aphid infestation on shoots as shown in Figure 4. Maximum percentage of aphid infested shoots was observed on plants which received 3 foliar sprays + NPK+ Ca + Mg (T_{12}) followed by absolute control. This indicates that plants which received maximum and minimum nutrition have shown the highest aphid infested shoots. The increased nutrient application has improved the vegetative growth of plants and might have supported better growth and survival of aphids whereas insufficient nutrition in absolute control might have made the plant susceptible to aphid attack and the establishment of colonies which is in line with Chow *et al.,* (2009)

Treatment with 3 foliar sprays and NPK has shown minimum infestation (T_8). The optimum nutrient application has been reported to positively correlate with the synthesis of defensive compounds like alkaloids. These alkaloids are helpful to ward

Fig: 4 Effect of mineral nutrition on percentage of shoots infested by aphids in rainy season



off pests, but increased application above optimum level may reduce its synthesis initially. Similar results have been obtained by Lovkova *et al.* (2005) who reported that the optimal concentration of Co, Ni and Zn stimulating alkaloid production was 0.1 mM. Increasing the concentration of Cu, Cr, B, Mo and Fe enhance the accumulation of alkaloids but this process was preceded by a decrease in the amount of alkaloids in plant compared to control.

5.1.4. Percentage of pods infested by aphids

Treatments with foliar application of 0.2 per cent level as three nutrient sprays and which had soil application of NPK, Ca and Mg recorded highest percentage of pods infested. However, treatments which received same nutrition without Ca and Mg recorded minimum per cent of infested pods. This reveals that fertilization with Ca and Mg had made some changes in the physiology of the plants and enhanced pest infestation. Amendments will improve the physical and chemical nature of soil which in turn promotes greater absorption of nutrients thereby growth of the plant which supports the growth and survival of aphids. This is in conformity with findings of Chow *et al.* (2009) who reported that application of a liquid fertilizer containing NPK Ca and Mg at 100 per cent of the recommended rate has increased population of spider mite *Tetranychus urticae* in rose plant in comparison with 50 or 33 per cent of the full dose.

5.2. EFFECT OF MINERAL NUTRITION ON POD BORERS

5.2.1 Percentage of infested pods by pod borers

Results obtained from the experiment conducted in rainy season revealed that per cent of pod borer infestation was maximum in plants at 15^{th} and 30^{th} DASP as shown in Figure 5. Maximum infestation was recorded in plants which were fertilized with NPK followed by absolute control and minimum infested pods in plants which were fertilized with 3 sprays + NPK + Ca + Mg (T_{12}).

Fig: 5 Effect of mineral nutrition in percentage of infested pods by pod borers in rainy season

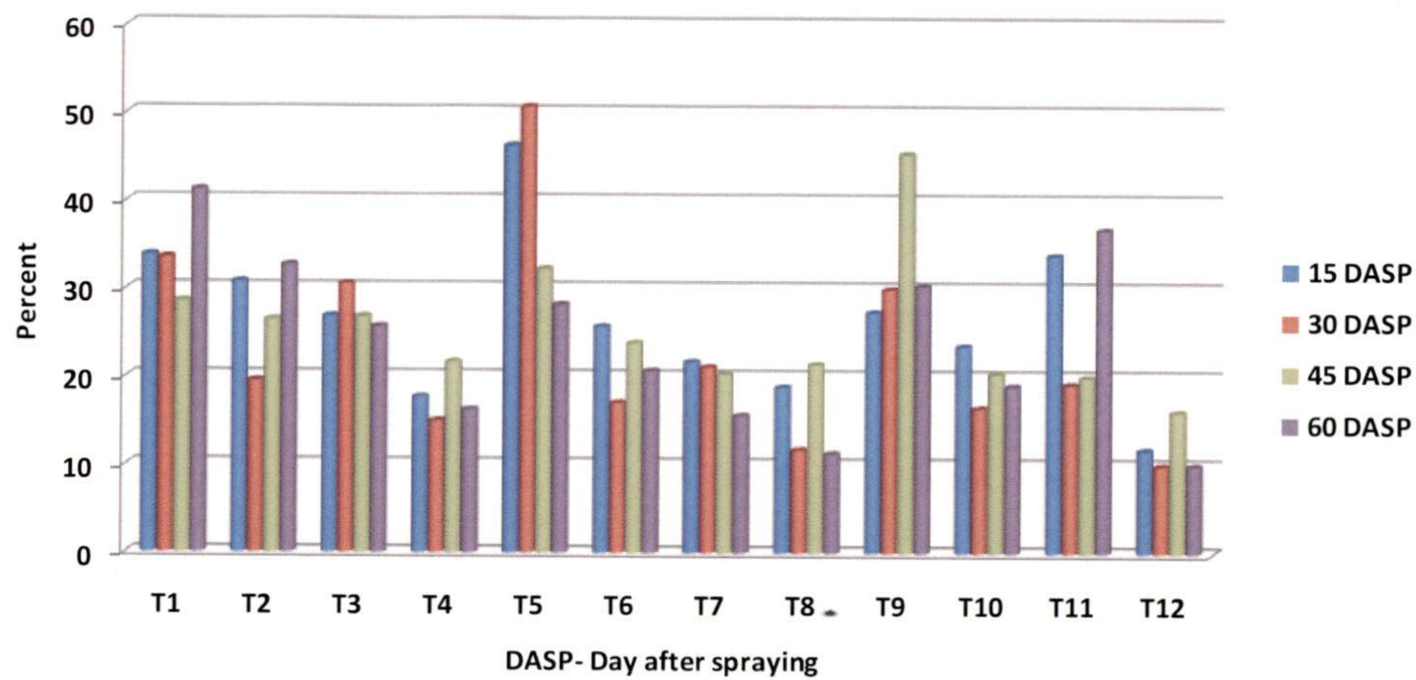
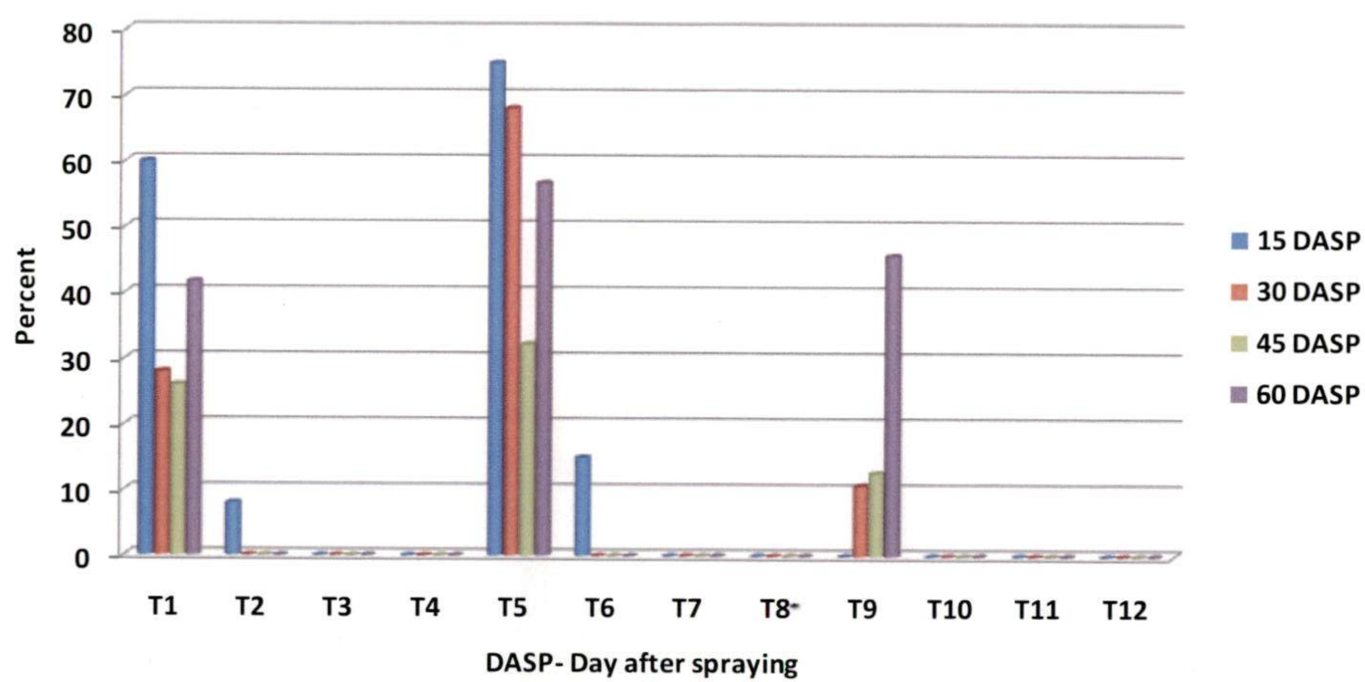


Figure 6 showed the effect of the mineral nutrition in the percentage of infested pods by pod borers in summer season. In the summer season, maximum infestation was found in control (T_5) followed by absolute control and NPK + Ca + Mg. 0.2 per cent foliar nutrition as one spray without and with NPK (T_2 and T_6) has shown some infestation on 15^{th} day after spraying in summer season and it recovered after another 15 days, which is in conformity with the result of Sarwar, (2011) who reported that use of K fertilizer @ 50 kg/ha is useful in the recovery of damage caused by larvae of rice stem borer and contributes larger volume of yield. This indicates that foliar application of mineral nutrients has a significant effect on management of borer pests in cowpea and 2 to 3 times foliar fertilization with mineral nutrients containing Si, B, Zn, K and Cu reduces to borer infestation. The same trend was observed in the case of mean pod borers per plant. The results are in line with the report of Mochiah *et al.* (2011) who observed that plants treated with NPK show highest leaf damage (31%) compared to absolute control (11 %) with pests such as *Plutella xylostella, Brevicoryne brassicae, Hellula undalis and Pieris rapae* in cabbage.

The effect of foliar fertilizer could be attributed to factors such as 1) presence of silicon which might have increased the cell wall thickness. Silicon interferes with larval boring and feeding of rice striped borer (Ukwungwu and Odebiyi, 1985). Painter (1951), Takahashi (1996) and Epstein (1999) reported that Si deposited in the epidermal tissue may provide support and protection against pest as a mechanical barrier. Mandibles of larvae of the rice stem borer are damaged when the Si content of rice plants is high (Jones and Handreck, 1967). 2) Zinc fertilization might have induced resistance through antibiosis or feeding inhibition to borer pest. Shu *et al.*,(2009) reported that the application of Zinc has shown markable negative effect on the reproduction of phytophagous insect *Spodoptera litura* when they were reared on a diet containing 300-700 mg/Kg of Zn. Application of zinc at 30 kg/ha markedly decreased the infestation of stem borer of rice, while application at 20-25kg/ha

Fig: 6 Effect of mineral nutrition in percentage of infested pods by pod borers in summer season



showed slightly more white head and dead heart incidence, but differed significantly from unfertilized plot.

From the earlier reports and present study, it is clear that mineral nutrient such as Zn, Si and K are effective in the management of borer pests of cowpea.

5.3 EFFECT OF MINERAL NUTRITION ON POD BUGS

The effect of mineral nutrients on the percentage of pods infested by pod bugs was found to be non significant. Plants raised with 3 foliar sprays (T_4) have shown the highest percent of infested pod on 45th and 60th DASP in the rainy season whereas minimum infestation was observed with NPK+ Ca+ Mg+ 1 spray (T_{10}). In the summer season, maximum percent of infested pods was observed in absolute control whereas minimum infestation was observed in plants raised in the NPK +Ca + Mg + 2 spray (T_{11}).

This shows that mineral nutrients could relatively reduce pod bug infestation in cowpea. This ability of mineral nutrients might be due to their role in the biosynthesis of secondary metabolites which are defensive compounds that ward off insect pests. Cowpea varieties that are resistant to pod sucking bugs found to have antioxidants like flavonoids in their plant parts (Dabire-Binso *et al.,* 2010) and the quantity of antioxidants and their activities in the plants depends on environmental factors like nutrients, water stress, and light intensities. Application of 3 nutrient sprays + NPK + Ca + Mg have accelerated the biosynthesis of flavonoids in cowpea pods. Similar result was obtained for Azaizeh *et al.* (2005) who reported that the supply of N, K, Mg, B, Mo, Zn, Fe and Cu has increased a secondary metabolite in *Leucojum aestivum* and increasing the amount of fertilizer causes a significant concentration dependent increase in antioxidant activity in *Teucrium polium*.

Absolute control exhibited highest population of pod bugs followed by NPK+ Ca +Mg + 3 sprays (T_{12}) in the rainy season. In summer season NPK + Ca +Mg + 3 foliar sprays displayed the highest population of pod bug followed by absolute control. The lowest population was seen in treatments which received 2 sprays with NPK + Ca + Mg (T_{11}). This indicates that under and over fertilization with mineral nutrients will make the plant susceptible to pest. Imbalance in the nutrients in plants results in reduced efficiency in the operation of biochemical pathways leading to the accumulation of structural precursors like free amino acids, simple sugars and peptides which provide an enriched diet for arthropod herbivores (Phelan *et al.*, 1996). Balanced NPK nutrition is a very important factor regulating the growth, development and synthesis of secondary metabolites in plants. Moreover, over fertilization with mineral nutrients may be harmful to plants and the proportion of nutrients is as important as that of the concentration of nutrients (Azaizeh *et al.*, 2005).

5.4 EFFECT OF MINERAL NUTRITION ON YIELD PARAMETERS AND BIOMETRIC CHARACTERS

Foliar application of mineral nutrient mixture significantly improved the plant growth characteristics of cowpea such as plant height, pod length, number of leaves produced, leaf area, days to flowering, seed yield, fresh pod yield and biomass. Enhancement in growth and yield of cowpea after treatment application might be due to the improvement of photosynthetic and other metabolic activities which leads to a rise in various plant metabolites responsible for cell elongation, cell division and assimilation.

5.4.1 Height of plant and length of pods

Increased plant growth characters by the application of micronutrients may be due to their involvement in chlorophyll formation, which might have helped to favour cell division, synthesis of hormones and proteins, enzymes activity, meristematic activity in apical tissue, expansion of cell and formation of new cell wall (Singh and Maurya, 1979; Havlin *et al.,* 2014).

The height of plant was taken at the end of the crop. The final height of the plant can be taken as a critical measure of the effect of moisture stress and nutrients. Foliar spray of 0.2 per cent nutrient mixture as three sprays along with soil application of NPK, Ca and Mg increased the height of plant and length of pods when compared to control and absolute control. In summer, T_3 (2 sprays) recorded highest pod length. The lowest pod length and plant height were recorded for absolute control (potting mixture without nutrient spray). Treatments did not show any notable difference in the length of pods in the summer season. It might be due to fact that length of the pod is a genetically determined character and it will be unique to a particular variety. The increase in the height of the plant and length of the pod with increased nutrition might be due to the reason that foliar sprayed nutrients can be easily absorbed by the leaf and augment the physiological process. 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. The results have been supported by Baloch *et al.* (2008) who reported that foliar spray of nutrient mixture containing various macronutrients (N, P, K, Ca and Mg) and micronutrients (Fe, Mn, B, Cu and Mo) at the concentration of 8 ml/l recorded the highest plant height (68 cm), highest fruit length (4.19 cm) and maximum number of branches (6.93), over straight NPK fertilizers alone with values 63.46, 2.87 cm and 4.20 respectively.

Similar result was obtained by Barche *et al.*(2011) who reported that the application of Zn @3.91 kg/ha and boron @ 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 (Shil *et al.*, 2013). The maximum plant height (80.40 cm) and number of branches per plant (34.7) was recorded with combined application of H_3BO_3, ZnSO4 and $CuSO_4$ each at 250 ppm in tomato .

These results may be due to the effect of these micronutrients in plant physiology; Zn is known to be directly involved in the biosynthesis of IAA hormone which induces cell division and cell elongation (Deb, *et al.,* 2006) and (Bhuiyan *et al.,* 2008). Boron has been reported to play an imperative role in maintaining cell integrity, enhancing respiration rate, increasing uptake of mineral nutrients and metabolic activities

5.4.2 Effect of mineral nutrition on leaf area, number of leaves and plant biomass

The effect of treatment was highly evident in the case of leaf area, number of leaves produced and biomass (dry weight). These results may be due to the effect of foliar mineral application on photosynthetic rates, plant stomatal conductance and transpiration.

Treatments which received 3 sprays + NPK+ Ca+ Mg (T_{12}) exhibited maximum leaf area, number of leaves per plant and plant biomass, while minimum was observed in absolute control.

Similar results were obtained for Datir *et al.* (2010) in okra, Ejaz *et al.* (2011) in tomato, Singh and Rajput (1976) in mango and Ahmad *et al.* (2010) in rose.

El-Azab (2016) reported that foliar application of NPK fertilizers along with micronutrients @ 1.25 per cent (Fe-500ppm, Zn-300ppm and Mn-300 ppm) was found with highest leaf area, number of leaves and biomass when compared to plants treated with NPK alone in cowpea. Kassab *et al.* 2005 and Parvez *et al.* 2009 reported that foliar application significantly increased vegetative growth such as plant height, number of leaves, leaf area, plant fresh weight and plant dry weight

According to Datir *et al.* (2010), application of 2 per cent organically chelated micro nutrient mixture containing Zn, Cu, B and Fe on okra increased plant height, leaf area and yield per plant. In tomato, the foliar spray of a nutrient mixture such as nitrogen 2 per cent, boron 5 per cent and zinc 6 per cent provided substantial results in plant height and number of leaves as compared to control (Ejaz *et al.*, 2011)

These results have been further supported by Singh and Rajput (1976) who found that various combinations of foliar application of Zn (0.1, 0.2 and 0.4 per cent), Fe (0.1, 0.2 and 0.4 per cent) and B (0.1, 0.2 and 0.4 per cent) has increased the length of terminal shoot, plant height, number of leaves and leaf area per shoot of mango tree.

Ahmad *et al.* (2010) revealed that combined application of B and Zn in rose plants resulted in increasing plant height, number of leaves per branch, leaf area, number of flowers per plant, flower stalk length and leaf Zn content.

5.4.3 Days to flowering

Minimum days for flowering was observed in plants treated with 3 sprays of foliar nutrients in first regime in the rainy season and 2 sprays in the summer season. Similar results were obtained by Ali *et al.* (2015) who reported that application of 12.5 ppm of boric acid and zinc sulphate showed minimum days to flowering in tomato.

5.4.4 Effect of mineral nutrients on yield of crop

Foliar spray of mineral nutrients significantly influenced seed yield and fresh yield of crop as shown in Figure 7 and 8. Plants treated with one foliar spray + NPK + Ca + Mg (T_{10}) exhibited highest seed yield and fresh pod yield. In rainy season maximum fresh yield was recorded by plants which received 3 mineral nutrient sprays. Despite the fact that pest infestation was higher in T_{10}, it did not significantly affect the yield, which was due to the phenomena of luxuriant growth and tolerance; as indicated by Huber (1989). Provision of the mineral nutrients might have enhanced the accumulation of assimilates in pods and seeds and resulting in highest pod and seed yield in this treatment. The possible reason for the increase in seed yield by the

Fig: 7 Effect of mineral nutrition on seed yield of cowpea on rainy and summer season

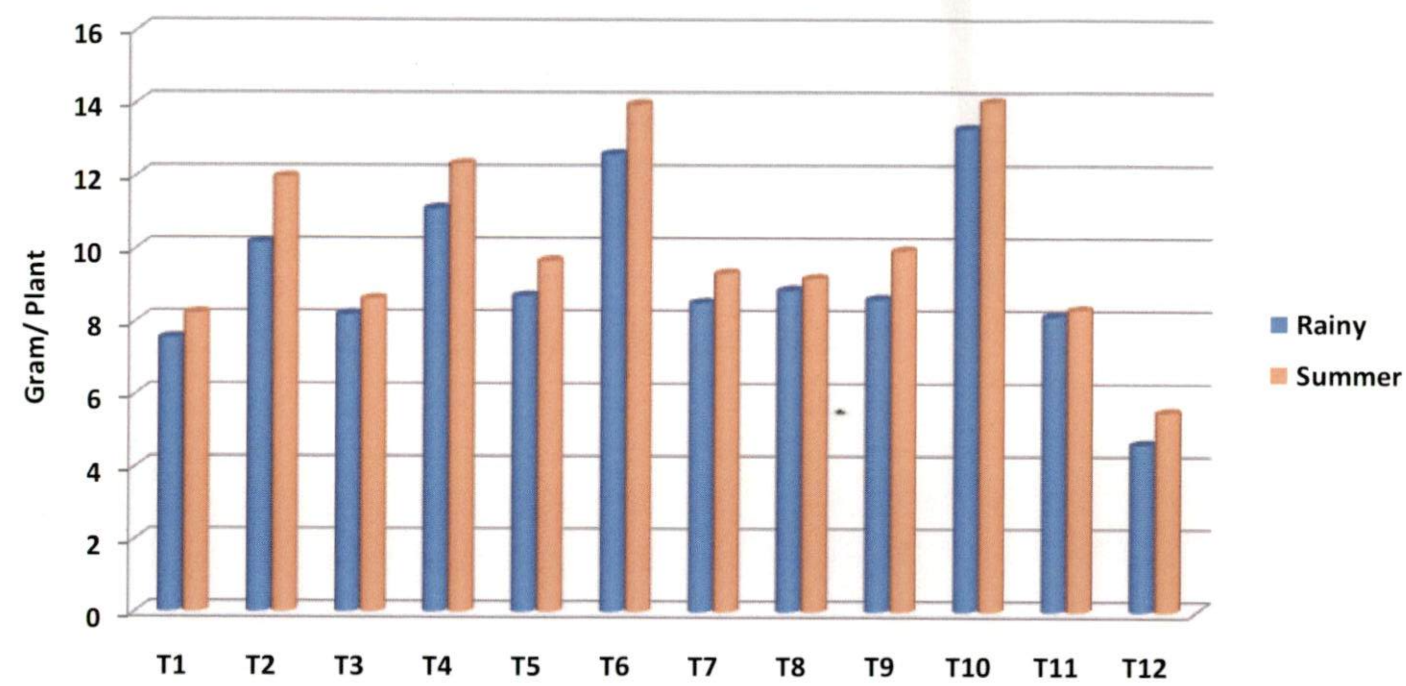
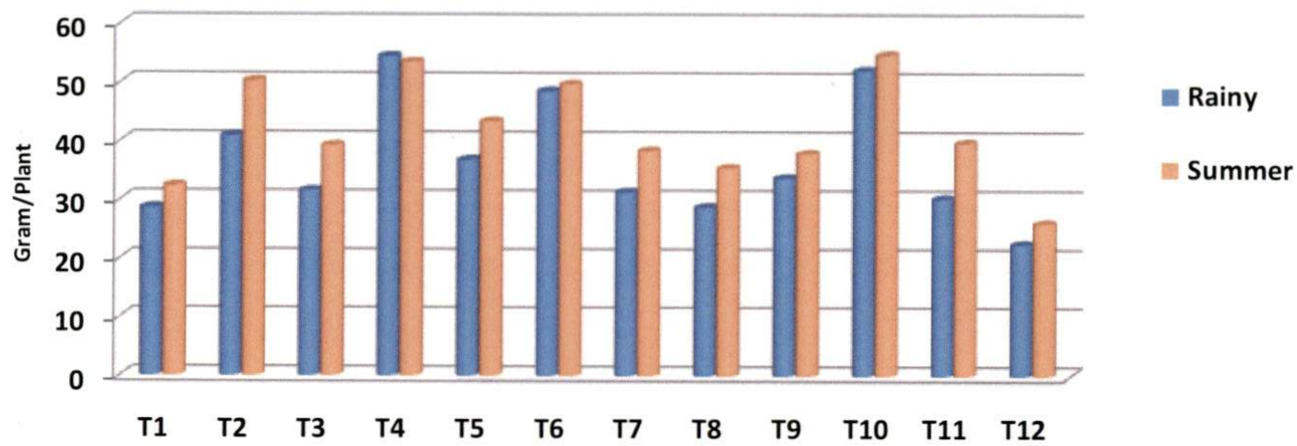


Fig: 8 Effect of mineral nutrition on fresh yield of cowpea on rainy and summer season



mineral nutrients might be due to quicker loading and mobilization of photo-assimilates to storage areas and involvement in cell division and cell expansion which finally resulted in yield in treated plants (Shukla *et al.*, 2009).

Three foliar spraying of mineral nutrients with application of NPK + Ca + Mg showed minimum seed yield and fresh pod yield. This was even lesser than absolute control. Increased nutrition might have caused an inhibitory effect on the development of pods instead promoted vegetative growth. Similar finding was reported by Prasad *et al.* (2012) in peanut where application of ZnO has decreased the seed vigor index and yield at 2000 ppm level while the same nutrient at 1000 ppm enhanced growth and seed vigor index which shows the growth promoting effect of ZnO at optimum concentration and inhibitory effect at higher concentration on pod yield in peanut. 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.

In the present study, foliar application of mineral nutrient mixture on cowpea has shown positive and significant influence in the yield characteristics of the crop. The increase in yield may be attributed to the vital role of mineral nutrients in augmenting photosynthetic activity, cell elongation and division, increased production and accumulation of carbohydrates (Abdel-Kader *et al.,* 1992).

5.5 EFFECT OF TREATMENTS ON PLANT NUTRIENT CONTENTS

The effect of foliar spraying of the mineral nutrient mixture showed significant influence on nutrient contents of cowpea. The increase in macro and micronutrient content of plant might be attributed to the fact that improved physiological processes of the plant led to rapid absorption and utilization of nutrients for primary metabolic processes. The increased uptake of P, K and Zn by various crops was reported by Durgadevi *et al.* (1997) in citrus, Aggarwal *et al.* (1975) in grapes, Lal *et al.* (2000) in guava, Nehete *et al.* (2011) in mango and Afria *et al.* (1999) in pomegranate.

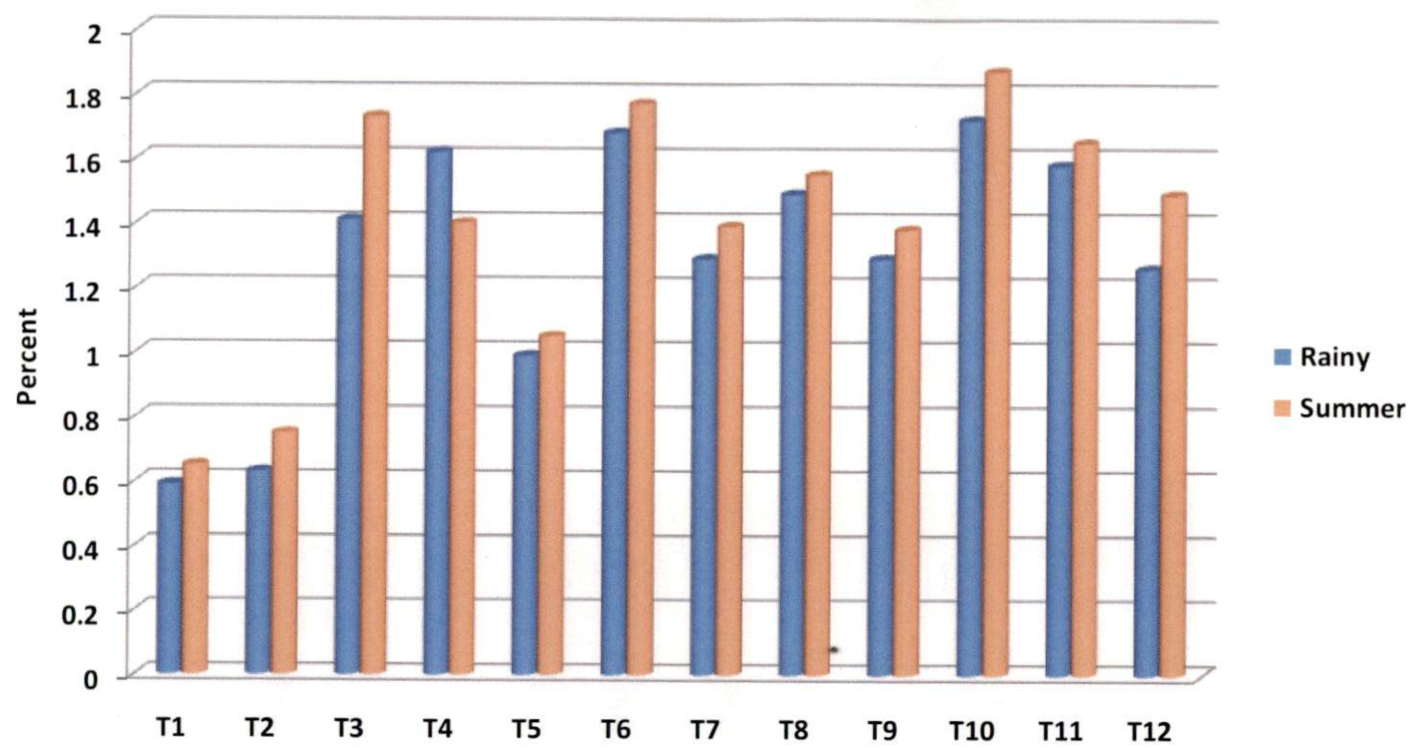
Potassium content of plant showed significant difference with respect to treatments applied (Figure 9). One spray of 0.2 per cent mineral nutrient mixture along with soil application of NPK, Ca and Mg mixture (T_{10}) was found to have highest K content and absolute control had the lowest. This might be due to additional application of potassium through soil as well the role of mineral nutrients especially B in the increased absorption of potassium from soil and plant surface. A similar report was also obtained by Davis *et al.* (2003) in tomato, Sankar *et al.* (2013) in mango cv. Alphonso, Sperry (1995) in tomato.

Plant Ca content showed notable difference among the treatments. In the rainy season, plants treated with 3 sprays along with NPK, Ca and Mg (T_{12}) found to have highest Ca content whereas 2 foliar sprays + NPK+ Ca + Mg (T_{11}) recorded highest Ca content in the summer season. Absolute control recorded lowest in both seasons. Initial soil Ca content was also highest in T_{11} and T_{12}. With the increase in the application of nutrients, Mg content in the plant also increased. Plants treated with one spray along with NPK+ Ca + Mg found to have highest Mg content in the rainy season. In the summer season, two sprays with NPK Ca and Mg recorded highest. Moreover, initial soil Mg content was found highest in these treatments. In both seasons, absolute control recorded lowest Mg content. Boron encourages absorption of Ca and Mg in plants. Boron content in this treatment found to highest.

Sulphur content of plant also increased with application of nutrients (Figure 10). Highest S content was found in plants treated with 1 spray of 0.2% per cent mineral nutrient mixture along with soil application of NPK, Ca and Mg.

The addition of mineral nutrients through foliar spray exerted its effect on plant micro nutrient composition. Application of mineral nutrient mixture brought out significant changes in plant Zn, Cu, B and Si content of cowpea. Similar findings

Fig: 9 Effect of mineral nutrition on potassium content of cowpea in rainy and summer season



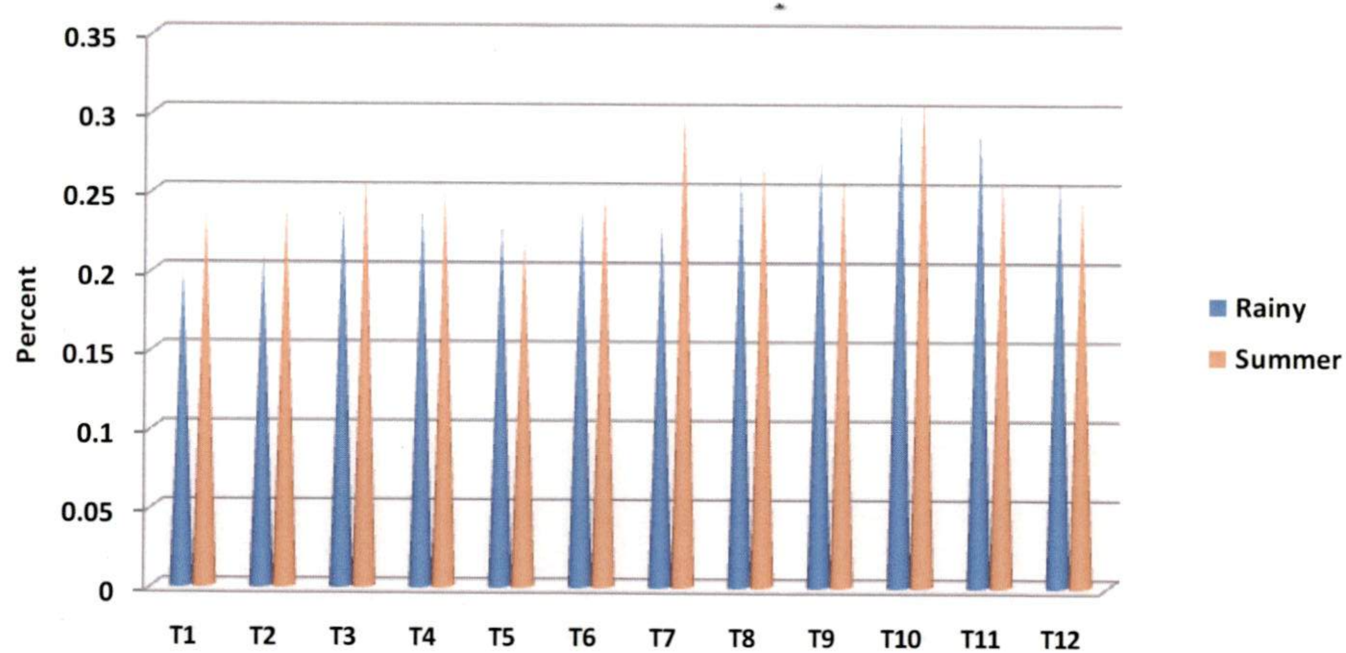


Fig: 10 Effect of mineral nutrition on sulphur content of cowpea in rainy and summer season

were also observed by Bhatt and Srivastava (2005) in tomato, Thiyageshwari and Ramanathan (2001) in soya bean and Prabha and Singaram (1996) in tomato.

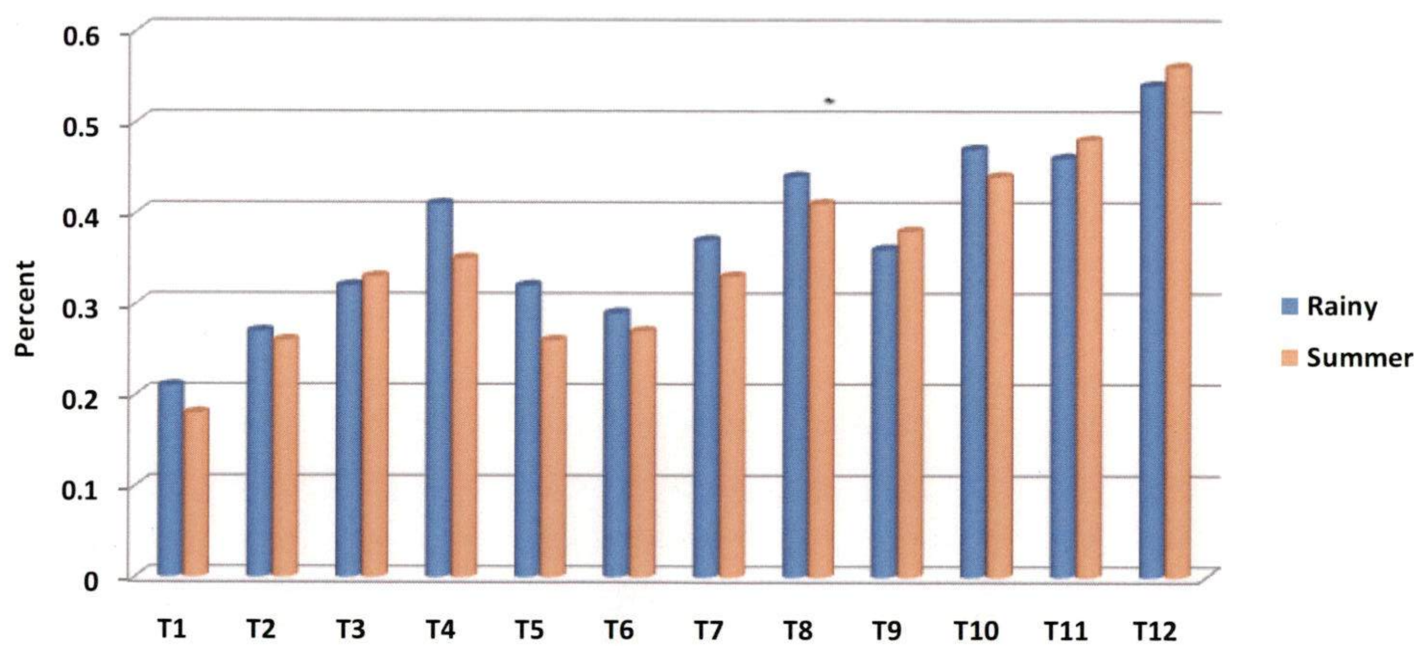
Application of mineral nutrients increased copper content in plant. With increased application of mineral nutrients, the Cu content of the plant also increased. Plants treated with 3 sprays with NPK+ Ca+ Mg shown highest copper content in the rainy season whereas 3 sprays +NPK recorded highest in the summer season. Similar findings were also reported by Lalithya *et al.* (2014) in sapota and Paul and Nair (2015) in banana.

Treatment application significantly influenced the Zn concentration in the plant. With increased application of mineral nutrient Zn content of the plant also increased. The highest Zn content was recorded in plants treated with 2 sprays + NPK + Ca + Mg. Absolute control found to have the lowest Zn content in both seasons. This increase in total Zn content was due to its maximum assimilation from Zn source through foliage. A similar result was also reported by Dalal *et al.* (2011) in Ber and Lalithya *et al.* (2014) in sapota.

Significant differences in B content in plants were noticed with foliar application of mineral nutrient mixture. 3 sprays of the mineral nutrient mixture at 0.2 per cent recorded maximum concentration of boron in the plant. This might be due to the increased uptake of boron by the boron binding compounds present in the cell wall of plants. Similar findings were reported by Abid *et al* in cotton (2007) Brown and Hu (1994) in sunflower.

Significant differences in Si content in plants were noticed with foliar application of mineral nutrient mixture (Figure 11). 3 sprays of the mineral nutrient mixture along with NPK+ Ca + Mg recorded maximum concentration of silicon in the plant whereas, absolute control recorded minimum silicon content. Similar findings was reported by Lalithya *et al* (2014) in sapota.

Fig: 11 Effect of mineral nutrition on silicon content of cowpea in rainy and summer season



Summary

6. SUMMARY

The experiment entitled "Evaluation of the effect of mineral nutrition in the management of major pests of cowpea" was carried out 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 cowpea var. kanakamony. The study was conducted during two seasons *viz.*, rainy and summer season. The data was subjected to statistical analysis to find out the effect of nutrients on management of major pest and biometric and yield parameters of cowpea.

The pot culture experiment was conducted in CRD with 12 treatments including control and absolute control with 3 replications each. The plants were raised in pots in three nutrient regimes namely, potting mixture, potting mixture + NPK and potting mixture + NPK +Ca + Mg. Later, the mineral nutrients were applied as foliar spray with 0.2 per cent concentrated solution at different time intervals *viz.*, the branching stage, the peak branching stage and the flower bud initiation stage. Staking was given at the time of trailing period. The treatments were : T_1 -potting mixture (P.M) (absolute control), T_2 -P.M + one nutrient spray, T_3 -P.M + two nutrient spray, T_4 -P.M + three nutrient spray, T_5 -P.M +NPK (control), T_6 -P.M + NPK + one nutrient spray, T_7 -P.M + NPK + two nutrient spray, T_8 -P.M+NPK+three nutrient spray, T_9 -P.M + NPK + Ca + Mg, T_{10} -P.M + NPK + Ca + Mg + one nutrient spray, T_{11} -P.M + NPK + Ca + Mg + two nutrient spray, T_{12} -P.M + NPK + Ca+ Mg + three nutrient spray. Monitoring of pests was undertaken at biweekly intervals and the yield was recorded in the first four harvests. Before the crop, soil analysis was conducted to know the status of K, Ca, Mg, S, Cu, B, Zn and Si and the analysis of plant samples were carried out after the crop.

The results of the experiment revealed that aphid infestation, pod borer and pod bug infestation were significantly influenced by treatment effects. In case of aphids (*Aphis craccivora)*, treatment T_8 exhibited minimum population score on stem and pods , minimum percentage of pods and shoots infested in both seasons whereas maximum infestation was observed in T_{12}. Treatments which received macro nutrients has shown lowest aphid score on leaves in both seasons.

With respect to pod borers (*Maruca vitrata* and *Lampides boeticus*), T_{12} recorded minimum infestation in both seasons. In summer, pod borer incidence was comparatively low and treatments which received nutrient spray were found free of borer infestation. Pod borers per plant exhibited the same trend as that of percentage of pods infested.

With respect to pod bugs, treatments T_{10} and T_{11} exhibited lowest infestation whereas T_4 and T_1 recorded highest pod bug infested pods in rainy and summer season respectively.

The effect of mineral nutrients on biometric and yield characters were significantly influenced by treatment effects in both seasons. Treatment T_{12} registered the highest leaf area, number of leaves produced, plant height and total biomass whereas T_{10} recorded the highest marketable and seed yield. The effect of mineral nutrients on pod length, days to flowering and fresh yield varied with seasons.

Salient findings

- Aphid scoring on leaves was high in 1st regime as well as in T_{11} and T_{12}, whereas lowest score observed in 2nd regime and T_9 and T_{10} in 3rd regime, which indicate that under and over fertilization is making the plant vulnerable to aphid attack.
- Aphid scoring on stem was high in T_1, T_2, T_3 and T_{12} whereas lowest scoring was observed in T_4, 2nd regime, T_9 and T_{10} in 3rd regime.
- Aphid scoring on pods was high in T_1, T_{11} and T_{12} whereas lower aphid score was recorded in T_7, T_8, T_9 and T_{10}.

- Pod borer- T_1, T_5 and T_9 recorded higher infestation by borers, Si content was found low in these treatments. T_{12} recorded lowest infestation.
- Pod bugs - T_1, T_2, T_4 and T_{12} exhibited higher infestation, whereas T_{10} and T_{11} showed lowest. K and S content recorded maximum in T_{10}, Zn content was high in T_{11}.
- From economic point of view, T_{10} can be recommended with respect to higher B-C ratio, highest marketable seed and pod yield and comparatively lower yield loss.

Although more research is needed, this study suggests that mineral nutrients can influence the relative resistance of cowpea var. kanakamony to insect pests. Understanding how mineral nutrition improves plant health may lead to new and better integrated pest management and integrated soil fertility management designs.

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EVALUATION OF THE EFFECT OF MINERAL NUTRITION IN THE MANAGEMENT OF MAJOR PESTS OF COWPEA

by

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ABSTRACT

The experiment entitled "Evaluation of the effect of mineral nutrition in the management of major pests of cowpea" was carried out 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 cowpea var. kanakamony. The study was conducted during two seasons *viz.*, rainy and summer season. The data was subjected to statistical analysis to find out the effect of nutrients on management of major pest and biometric and yield parameters of cowpea.

The pot culture experiment was conducted in CRD with 12 treatments including control and absolute control with 3 replications each. The plants were raised in pots in three nutrient regimes namely, potting mixture, potting mixture + NPK and potting mixture + NPK +Ca + Mg. Later, the mineral nutrients were applied as foliar spray with 0.2% concentrated solution at different time intervals *viz.*, the branching stage, the peak branching stage and the flower bud initiation stage. The treatments were : T_1 -potting mixture (absolute control), T_2 -P.M + one nutrient spray, T_3 -P.M + two nutrient spray, T_4 -P.M + three nutrient spray, T_5 -P.M +NPK (control), T_6 -P.M + NPK + one nutrient spray, T_7 -P.M + NPK + two nutrient spray, T_8 -P.M+NPK+three nutrient spray, T_9 -P.M + NPK + Ca + Mg, T_{10} -P.M + NPK + Ca + Mg + one nutrient spray, T_{11} -P.M + NPK + Ca + Mg + two nutrient spray, T_{12} -P.M + NPK + Ca+ Mg + three nutrient spray.

The results of the experiment revealed that aphid infestation, pod borer infestation, pod bug infestation were significantly influenced by treatment effects. In case of aphids (*Aphis craccivora)*, treatment T_8 exhibited minimum population score on stem and pods , minimum percentage of pods and shoots infested in both seasons

whereas maximum infestation was observed in T_{12}. Treatments which received macro nutrients has shown lowest aphid score on leaves in both seasons.

With respect to pod borers (*Maruca vitrata* and *Lampides boeticus*), T_{12} recorded minimum infestation in both seasons. In summer, pod borer incidence was comparatively low and treatments which received nutrient spray were found free of borer infestation. Pod borers per plant exhibited the same trend as that of percentage of pods infested.

With respect to pod bugs, treatments T_{10} and T_{11} exhibited lowest infestation whereas T_4 and T_1 recorded highest pod bug infested pods in rainy and summer season respectively.

The effect of mineral nutrients on biometric and yield characters were influenced significantly in both seasons. Treatment T_{12} registered the highest leaf area, number of leaves, plant height and total biomass whereas T_{10} recorded the highest marketable and seed yield. The effect of mineral nutrients on pod length, days to flowering and fresh yield varied with seasons.

The highest K and S contents were recorded by T_{10} and highest Si, B and Zn was recorded by $T_{12,}$ T_4 and T_{11} respectively.

On comparing the infestation caused by pests in two seasons, cowpea grown with recommended macro nutrients with foliar spray of minerals exhibited the lowest aphid (T_8), pod borer (T_{12}) and pod bug incidence ($T_{10,}$ and T_{11}). From economic point of view, T_{10} can be recommended with respect to higher B-C ratio, highest marketable seed and fresh yield and comparatively lower infestation.