MAGNESIUM AND BORON NUTRITION FOR YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) IN SOUTHERN LATERITES OF KERALA

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"MAGNESIUM AND BORON NUTRITION FOR YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) IN SOUTHERN LATERITES OF KERALA"** 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 of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"MAGNESIUM AND BORON NUTRITION FOR YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) IN SOUTHERN LATERITES OF KERALA"** is a record of bonafide research work done independently by Ms. Emil Jose (2013-11-209) 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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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
@	At the rate of
^{o}C	Degree Celsius
AEU	Agro Ecological Unit
B	Boron
B:C	Benefit : Cost
cmol kg^{-1}	Centi mol per kilogram
Ca	Calcium
CD	Critical difference
CEC	Cation Exchange Capacity
cm	Centimeter
EC	Electrical conductivity
Fe	Iron
Fig.	Figure
FYM	FarmYard Manure
G	Gram
i.e.	that is
K	Potassium
KAU	Kerala Agricultural University
kg ha^{-1}	Kilogram per hectare
Mg	Milligram
Mn	Manganese
MSL	Mean Sea Level
No.	Number
P	Phosphorus
pH	Negative logarithm of hydrogen ions

POP	Package of practices
Ppm	Parts per million
S	Sulphur
viz.	Namely
Zn	Zinc

Introduction

1. INTRODUCTION

India is a food surplus nation at present with about 260 million tones food grain production per annum. It will require about 7-9 million tones additional food grains each year if the trend in rising population persists. To feed an expanding population of India in future, the only way is to produce more from the same or even lesser land area, because some area will have to be diverted for non-agricultural purposes. The results from several long term fertilizer experiments conducted in different agro ecological regions indicated the effectiveness of balanced plant nutrition by including fertilizers of secondary and micronutrients along with NPK. Thus, additional food grain production has, therefore, to come through efficient, judicious and balanced use of fertilizer.

With the advent of green revolution, farmers started intensive cultivation of early maturing high yielding varieties without paying much attention to soil health. Continuous cultivation without balanced nutrition has resulted in decrease in yield, reduction in crop quality and many environmental problems. The higher crop production per unit area has resulted in greater depletion of soil available secondary and micronutrients because traditional fertilizer practices were designed to meet these needs for only major nutrients (NPK). Eventually, secondary and micronutrient deficiency has become a limiting factor for crop productivity across the country.

Balanced plant nutrition is very essential to meet nutritional needs of the crop and of humankind. Balanced plant nutrition ensures optimum quantitative and qualitative yields, avoid wastefulness of nutrients, nutrient antagonism in soil and plant system and hence plant deficiencies and toxicities and better utilization of NPK, avoids hidden hunger, maximize cost benefit ratio and reduce environmental hazards. Without the adequate supply of secondary and micronutrients, it is impossible to get maximum benefits from the applied N P K fertilizers and cultivation of high yielding varieties (Swarup and Wanjari, 2000).

Indian soils have become deficient not only in major plant nutrients like nitrogen, phosphorus and in some cases, potash but also in secondary nutrients, like sulphur, calcium, and magnesium. Magnesium deficiencies are most frequently found in regions receiving heavy rainfall and in light textured soils. Mg deficiency occurs particularly in plants growing in highly leached acid soils with low cation exchange capacity (Aitken *et al.,* 1999). Many of the cultivated soils are found to be deficient in available magnesium and in many cases, crop growth is found to be limited by magnesium deficiency. The micronutrients deficiency in Indian soils during the last three decades has grown in both, magnitude and extent because of increased use of high analysis fertilizers, use of high yielding crop varieties and increase in cropping intensity. Boron deficiency is found wide spread ranging from 21-68 per cent in few calcareous, sandy, red and laterite acid soils with an average of 33 per cent (Brar *et al.* 2008).

In Kerala, secondary and micronutrients are not regularly applied to soil in the form of fertilizers and their removal from soil has been going on continuously without systematic replacement. The importance of secondary and micronutrients has been realized in the last decade and widespread nutrient deficiencies are observed in the soils of our state.

All soils of Kerala except black soils of Palakkad district showed varying degrees of deficiency in the status of available magnesium (Prema, 1992). Boron deficiency is intense in all southern districts while it is moderate in the central and northern districts of Kerala (Mathew, 2007). Recent studies on soils of Kerala revealed that there is wide spread deficiency of Mg and B throughout the state (Kerala State Planning Board, 2013). The low base saturation of the major soils of Kerala was not taken into account in supplementation of secondary nutrients like Ca and Mg in the fertilizer use practice and use of fertilizers of micronutrients were not included in the package of practices based on the assumption that acid soils are sufficient in available micronutrients. But intense weathering, high rainfall and present fertilizer use pattern have resulted in depletion of micronutrients especially B which is very mobile in soil.

Magnesium is an essential element for chlorophyll molecule structure that regulates photosynthesis process. Also, it acts an activator of many enzyme systems involved in carbohydrate metabolism and synthesis of nucleic acids (Westwood, 1978; Jones *et al.,* 1991). As Aikawa (1981) put it, "wherever there is ATP, there is an obligatory need for magnesium". Boron, a micro-nutrient, is essential for pollen viability and seed production of crops as well as flowering and fruiting and it plays a vital role in nitrogen metabolism, hormonal action and cell division (BARI, 2006). So boron deficient plants may be stunted. Seed and grain production are reduced with low boron supply.

Thus, there is an urgent need for correction of individual nutrient deficiency and for arresting its further spread.

Timing and method of fertilizer application has a significant effect on crop yields. In order to get maximum benefit from fertilizers, they should be applied in proper time and in right manner. Plants need different nutrient amounts and ratios at different growth stages. Proper timing and method of the fertilizer application increases yields, reduces nutrient losses, increases nutrient use efficiency and prevents damage to the environment. Yard long bean is the most popular vegetable crop among farmers of Kerala in view of its marketability and consumer acceptance. Hence the present study on "Magnesium and boron nutrition for yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) in southern laterites of Kerala" was formulated with the following objective.

- To standardize the method and time of application of fertilizers of Mg and B in the Agro Ecological Unit -8 using yard long bean as test crop.

Review of literature

2. REVIEW OF LITERATURE

Due to more concentration and application on primary nutrients (NPK), soils developed deficiency symptoms for secondary and micro-nutrients. The requirements of plant nutrition are high or low, it should not be neglected since *all* essential elements are required for plant growth. This understanding was developed in 1840 by the German chemist, Justus von Liebig, who made a major contribution to the science of agriculture and biological chemistry by proposing the 'Law of the Minimum', which describes the effect of individual nutrients on crops. Liebig's Law of the Minimum, often called Liebig's Law, is a principle developed in agriculture that states that if one of the nutritive elements is deficient or lacking, plant growth will be restricted and not in its full potential even when all the other elements are abundant. Any deficiency of nutrient, no matter how small the amount needed, it will hold back plant development. If the deficient element is supplied, growth will be increased up to the point where the supply of that element is so longer the limiting factor. Increasing the supply beyond this point will not be helpful, as some other elements would then be in minimum supply and become the limiting factor. The increase in cultivation intensity with the increasing demand for higher yields with better quality has resulted in increasing demand for nutrients. Plant productivity has increased along the years due to genetic improvement and selection of high yielding cultivars. These cultivars with intensive cultivation methods were found to remove higher quantities of macro and micro nutrients from the soil, leading to deficiencies occurring in many soils. Hence, ignored elements must be added with the NPK (may be in minor quantity) to get higher yields in crops.

2.1. IMPORTANCE OF SECONDARY AND MICRONUTRIENTS IN AGRICULTURE

Secondary nutrients and micronutrients are essential in managing the concept of balanced plant nutrition and it is agreed and accepted by all. They include calcium, magnesium, sulphur, iron, zinc, copper, boron, manganese, molybdenum and chlorine. They play a vital role in gene expression, biosynthesis of proteins, nucleic acids, growth substances, metabolism of carbohydrates and lipids through their involvement in various plant enzymic systems and other physiologically active molecules (Rangel, 2003).

Though the micronutrients are needed in trace amounts, they are in no way micro in their role; rather they play a major role in enhancing the macronutrient efficiency as micronutrients are highly essential for better utilization of macronutrients. For example, absence of one atom of Zn would impair the biochemical advantages arising from the presence of 3333 atoms of N, 833 atoms of K, 200 atoms of P and 100 atoms of sulphur (Epstien and Bloom, 2005).

Takkar (1996) suggested that in most of the soils entire reserve of Zn will be exhausted in 168 to 384 years followed by Cu (149-630 years), B (266-588 years), Mn (422-711 years) and Mo (419 years) based on the assumption that soil reserves of nutrients will continuously supply those nutrients required by the crops rotation.

Soil fertility maintenance is not only a prerequisite for sustainable increase in crop productivity, but is equally essential for maintaining crop quality in terms of food, fodder and feed quality (Kelly *et al*., 1996; Sahrawat *et al*., 2008a), especially iron (Fe) and Zn in the grain (Sahrawat *et al*., 2008b; Rattan *et al*., 2009). There is a relationship between soil health and food and feed quality which in turn impacts human and animal health.

About 40 mt fertilizer nutrients will have to be used to produce 380 – 400 mt of food grains to feed an estimated population of 1.5 billion by 2050. The stagnation in crop productivity has been found to be due to deficiency of some secondary and micronutrients (Dhane, 2011).

2.2. STATUS OF SECONDARY AND MICRONUTRIENTS IN SOILS OF INDIA

Adoption of high yielding varieties (HYVs) and intensive cropping with use of high analysis NPK fertilizers have caused depletion of secondary and micronutrients in the soils resulting in decline in the productivity of crops (Dangarwala, 1994).

Indian soils have become deficient not only in NPK but also in secondary nutrients, like sulphur, calcium, and magnesium. The micronutrients deficiency in Indian soils during the last three decades has grown in both, magnitude and extent because of increased use of high analysis fertilizers, use of high yielding crop varieties and increase in cropping intensity. The deficiency of calcium in acid soils and sulphur in pulse growing areas has been increasing due to continued mining by crops and use of sulphur free fertilizers (Singh *et al.,* 2014)

Based on the analysis of three lakhs soil samples, Singh and Behera (2011) reported that 49 per cent are deficient in Zn, 12 per cent in Fe, 5 per cent in Mn, 3 per cent in Cu, 33 per cent in B and 11 per cent in molybdenum. In acid soils of India, most of the soil samples indicated an adequate supply of Cu, Fe and Mn, low deficiencies of Zn (30%) and higher deficiencies of B (46 %) and Mo (50%). A reverse trend was recorded in non-acidic soils. Soils of arid and semiarid regions are more affected by Zn and Fe deficiencies.

2.3. STATUS OF SECONDARY AND MICRONUTRIENTS IN SOILS OF KERALA

Now problems due to secondary and micronutrient deficiencies have been reported from many parts of Kerala. A State- wide project on “Soil based nutrient management plan” coordinated by the Kerala State Planning Board (2013) has revealed a severe deficiency of available magnesium and boron in soils of Kerala.

As per the survey report, 40 per cent of the soil samples were calcium deficient. Calcium deficiency was very pronounced in Onattukara sands (AEU 3) and the Wayanadu plateau (AEU 20 and AEU 21). Its deficiency was negligible in Kumily Hills (AEU 16), Marayur Hills (AEU 17), Attappady (AEU 18 and 19), Central Palakkad (AEU 22) and eastern Palakkad (AEU 23).

Magnesium was deficient in 75 per cent of the composite samples drawn from the state and tested, pointing to the widespread deficiency of the nutrient. The only exception to the general trend was soils of Attapadi and Central eastern Palakkad.

Deficiency of sulphur in soils of Kerala is to the tune of 30 per cent. Extensive deficiency of the nutrient was recorded for Onattukara sands (AEU 3), Kumily Hills (AEU 16) and Wayanad plateau (AEU 20 and 21) only.

Deficiency of the micronutrient, zinc is negligible, except in soils of eastern Wayanad plateau. Zinc deficiency was observed only in 12 per cent of soil samples. The nutrient need to be applied on the basis of soil test result only.

The deficiency of the micronutrient, copper also is negligible in soils of Kerala. The deficiency were observed in 15 per cent of the soil samples.

The current study confirmed wide spread deficiency of boron, with nearly 66% of the samples testing inadequate levels. The deficiency was not pronounced in coastal low lands subjected to sea water inundation (AEU 4,5,6 and 7) and the drier Attapady hills (AEU 18 and 19).

Deficiency of iron seldom occurs in acidic lateritic environment. Iron deficiency is only noticed in Onattukara and Coastal sandy tract in Kerala. A small scale of iron deficiency was observed soils of southern laterites, AEU 8 (Mathew, 2007).

The supplementation of secondary and micronutrients under such situation becomes more important to provide balanced nutrition to crops.

2.4. MAGNESIUM

Magnesium (Mg) is an essential nutrient for plant growth and plays an important role in many plant physiological processes such as photosynthesis (Mg is the central element of the chlorophyll molecule), sugar synthesis, starch translocation, formation of plant oils and fats, control of nutrient uptake, increase iron utilization and aid nitrogen fixation in legume nodules. The importance of Mg in crop production was underestimated in the last decades (Cakmak and Yazici, 2010). Indeed, compared to other nutrients little attention has been paid on this mineral nutrient by agronomists and other scientists. Therefore, the term 'the forgotten element' was introduced and used (Cakmak and Yazici, 2010). Increasing incidence of magnesium deficiency are observed mainly as a result of the use of Mg-free fertilizers. The total Mg content range from 0.1 per cent in sandy soils to about 4 per cent in fine textured soils (Tisdale *et al.,* 1995). Plants contain about 0.1 to 0.4 per cent Mg. Many of the cultivated soils are found to be deficient in available magnesium and in many cases, crop growth is also found to be limited by magnesium deficiency (Prema, 1992).

2.4.1. Magnesium deficiency in plants

The Mg deficiency in plants is most common in acid sandy soils especially following periods of excessive rainfall. Low yield of crop under acid soil conditions is due to low Mg availability (Christemen *et al*., 1973). Several studies have indicated that soils having exchangeable soil Mg contents below four to ten cmol kg^{-1} are deficient for a number of crops.

Typical early response of plants to Mg deficiency is reduced root growth (Cakmak *et al*., 1994), even though this effect obviously does not appear in all crops.

Mg plays a fundamental role in phloem export of photosynthates so that a deficiency of Mg restricts the partitioning of dry matter between roots and shoots to result in excessive sugar, starch and amino acid accumulation in leaves (source tissues), chlorophyll breakdown, an over - reduction in the photosynthetic electron transport chain and the generation of highly reactive oxygen species (ROS) because of impairment in photosynthetic CO_2 fixation (Cakmak and Kirby, 2008; Hermans *et al.*, 2005).

Magnesium deficiency symptoms are typically associated with interveinal chlorosis particularly on older leaves as Mg is readily phloem-mobile and, therefore, retranslocated (White and Broadley, 2008). In more severe cases, the whole leaf may turn yellow or other brilliant colours. Necrosis may develop interveinally or along margins or tips of leaves and some plant leaves curl. Premature defoliation occurs.

2.4.2. Factors affecting magnesium availability in soils

Low pH of soil tended to promote Mg deficiency. Prohaszka (1980) reported a positive correlation between Mg uptake and pH. Similarly Simpson (1983) also observed that the low pH promoted Mg deficiency in plants.

Magnesium deficiency is more in coarse textured soils than in heavy textured soils (Bolton, 1973). A deficiency of Mg can be induced in calcarious soils by competing Ca^{2+} ions, in acid soils by NH^{4+} and $Al^{3+,}$ Na^{+} in saline soils (Mengel and Kirkby, 2001).

Bolton (1973) observed that exchangeable Mg content was more in clay fractions of soil. Chu and Johnson (1985) reported that sand and silt but not clay was the important source of exchangeable Mg.

Small amounts of Mg are adsorbed to soil organic matter. Increasing soil organic matter concentrations increases the cation exchange capacity and improves the Mg supply available for plant uptake. The organically complexed Mg is an important source of Mg in some soils (Mathan and Rao, 1982).

A positive relationship was observed between exchangeable Mg and CEC. Kirkby and Mengel (1976) reported that exchangeable Mg constituted 4 to 20 per cent of the CEC.

Soils formed from granites, sandstone and most shales are relatively low in total Mg. Soils formed from mafic igneous rocks contain substantial amounts of ferromagnesian minerals. Without severe weathering and leaching, soils derived from mafic igneous materials will have large amounts of available Mg (Ellis, 1979).

2.4.3. Role of magnesium in plant nutrition

Russell (1975) reported that Mg plays an important role in the transportation of phosphate in the plant leading to higher yields. According to Rai (1981), various enzymatic reactions are influenced by Mg ions e.g. hexose phosphorylating enzymes, kinases, phosphorases, phosphomutases etc.

Magnesium is involved in stabilizing conformational structures of the nucleic acids needed for proper functionality. Nucleic acid-synthesizing polymerases and degrading nucleases require Mg as well. Protein biosynthesis is strongly reduced under Mg deficiency leading to increased concentrations of the precursor amino acids (Klein *et al.,* 1982).

Magnesium is vital to photosynthesis because every molecule of chlorophyll contains a magnesium ion at the core of its complex structure. The magnesium content of different crops are alfalfa 3.55g, red clover 2.70g, soybean 3.88g, corn 0.86g, oats 0.98g, and wheat 0.87g per 1000g dry plant material (Marschner, 1995).

Beale (1999) reported that plants require magnesium to harvest solar energy and to drive photochemistry. Mg has an important regulatory effect on the activity of enzymes in the Calvin cycle (Pakrasi *et al*., 2001). In addition to its catalytic role, Mg acts as an allosteric activator of protein complexes (Cowan, 2002).

Mg also plays an important role in the cell energy balance, interacting with the pyrophosphate structure of nucleotide tri and di-phosphates. The energy-rich compounds Mg-ATP and Mg-ADP represent the main complexed Mg pools in the cytosol, which balance with the free Mg^{2+} pool under the control of adenylate kinase (Igamberdiev and Kleczkowski, 2003).

An insufficient level of magnesium in plants reduces chlorophyll and carotenoid content, leaf stomatal conductance and photosynthesis rate (Cakmak and Kirkby, 2008).

Mg is required for the preservation of ribosome structure and integrity, associated with rapid growth, active mitosis, high protein levels, carbohydrate metabolism, and oxidative phosphorylation and it is involved in energy transfer reactions, respiration, the formation of DNA and RNA, and serves as a cofactor for many enzymes (Marschner, 2011).

2.4.4. Effect of magnesium on nutrient availability in soil

2.4.4.1. Primary nutrients

Due to the greater solublization of phosphorus and the carrier effect on phosphorus, magnesium application increases phosphorus availability (Jacob, 1958). Adams (1980) also reported a positive correlation and interactions between P and Mg concentrations in soil.

Mg generally has a greater effect on K translocation in soil. Mg and K interactions are extremely important in maintaining soil health, production and quality of leaf vegetables. The presence of low Mg may decrease the available K in soil (Hannaway *et al.,* 1982 ; Ohno and Grunes, 1985).

The application of fertilizer and compound magnesium with fertilizer was useful in adjusting soil nutrition and improving the nutrition of N, P, K and Mg (Sun *et al.,* 2006).

2.4.4.2. Secondary and micronutrients

Kene *et al*. (1990) discovered that high concentration of magnesium in the soil reduced the calcium absorption by plants and plants grown under such conditions may soon deal with calcium deficiency. Barber (1995) also reported that a negative interaction exists between Ca and Mg. This may be due to Ca-Mg concentrations balance the ions in soils (cation-anion balance).

Magnesium fertilizers such as magnesium carbonate, calcined magnesium carbonate and magnesium oxide increases the available magnesium in soil (Heming and Hollis, 1995). Wild (1988) found that Mg fertilization significantly increased Mg concentration in soil solutions. Hardter *et al*. (2003) found that magnesium content in soil was increased after the application of magnesium to soil in different rates.

Havlin *et al.* (2004) suggested that application of magnesium sulphate increase the S content in different soils. Soils release variable amounts of SO_4^- in the mineralization process.

Goss *et al.* (1992) observed synergistic effect exists between Mg and Mn. Disch *et al.* (1994) observed an increase in Fe content in soil with the application of Mg. Malcova *et al*. (2002) found that the toxic effect of excess Mn can be alleviated by adding Mg.

2.4.5. Effect of magnesium on nutrient content in plants

2.4.5.1. Primary nutrients

Kumar *et al.* (1981) reported that the uptake of N increased at low Mg and decreased as the Mg addition increased. At low magnesium application rates, the uptake of phosphorus was not affected and at high magnesium, there was a decrease in phosphorus uptake.

El-Moniem *et al*. (2002) reported a reduction in K content in the leaves of banana due to magnesium application. Mg fertilization showed a positive effect on N and Mg content in leaves of banana (Mostafa *et al*., 2007).

Salama *et al.* (2014) reported that magnesium fertilizers (chelate and sulphate) produced positive effect on leaf nitrogen, phosphorus and potassium content of "Hayany" date palm as compared with the control.

2.4.5.2. Secondary and micronutrients

Excess Mg over Ca decrease the productivity of crops, roots become unhealthy with excess Mg and loose turgidity (Bolton, 1973). Nanaya *et al.* (1985) found that magnesium had a beneficial effect in increasing leaf zinc concentration of coorg mandarin.

Foliar application of the magnesium salt solutions significantly increased leaf Mg content, in spite of a sufficient content, as it seems, of this metal in the leaves of the control plants (Hailes *et al.,* 1997).

The concentration of Mg in mustard seed improved significantly with Mg application (Gupta and Singh, 1990). Singh and Singh (1990) also reported similar results in linseed. Khan *et al.* (1997) found that leaf Mg concentration had a higher positive correlation with Cu concentration in leaves**.**

Persson and Olsson (2000) reported that high levels of Mg inhibit the uptake of Mn, and Ca. Application of higher levels of magnesium deducted the calcium content of plants (Mirzapor *et al.*, 2003). The sulphur content in leaves increased with application of Mg as magnesium sulphate. A significant increase from 0.34 per cent to 0.40 per cent S was observed after application of magnesium sulphate. These results were suggested by Lopez (2010).

2.4.6. Effect of magnesium on yield and yield attributes

Mandy and Kiss (1977) observed a favorable effect on ear weight and grain number in wheat by the application of magnesium. Kiss (1977) revealed that use of magnesium sulphate as a seed dressing and a leaf spray increased plant height, pods per plant, seeds per pod, thousand seed weight and fresh seed weight per plant in pea.

Al'shevskii and Derebon (1982) reported that $MgSO_4$ application increased the thousand grain weight in wheat. Kulkarni *et al.* (1989) observed that soil application of magnesium caused increased plant growth, which might have led to better nodulation in groundnut. Mani and Halder (1996) noted that application of dolomite (Mg containing mineral) increased dry matter yield of shoot and root of green gram (*Vigna radiata* L).

Revathi *et al.* (1996) observed that pod yield of groundnut was highest with two foliar applications of a chelated mixture of trace elements and Mg. Ying (1998) observed that application of Mg fertilizer to soybean increased leaf-N and K-content, photosynthesis, plant dry weight and seed quality.

Jayn *et al.* (1999) reported that consumption of magnesium increased sesame yield. Saad *et al*. (2000) observed higher number of branches per plant, leaf dry weight, photosynthetic pigment content, 100-seed weight, harvest index, and seed, straw and biological yields in soybean while applying the Mg as magnesium sulphate. Saad and El-Kholy (2000) stated that foliar application with magnesium sulphate increase net assimilation rates, seed yield and crude protein content of plants.

Khanam *et al.* (2000) observed that the application of Mg and B is necessary for improving yield potentials of chickpea and lentil in Bangladesh. Increased yield of potato (21.00 to 41.60%) has been reported by Sarkar and Singh (2003) by the application of magnesium. Gangadharan (2003) had speculated on the improvement in the development of quantitative yield in kacholam by the application of $MgSO_4$ one month after planting.

Riga and Anza (2003) reported that under Mg-deficiency, pepper plants showed a decrease in their relative growth rate, total dry weight and total leaf area. Ashoub *et al.* (2003) found that foliar application of 1% magnesium sulfate in sunflower had the highest yield, yield components and chemical composition like oil protein and carbohydrate. Kassab (2005) indicated that foliar application of Mg significantly increased growth parameters, yield and its components of mungbean plants.

The foliar application of Mg had a positive effect on growth parameters, yield and yield components of mungbean (Thalooth *et al.,* 2006).

Application of 200-150-200 kg N-P_2O_5-K_2O ha^{-1} plus 100 kg Mg ha^{-1} and 1 kg B ha^{-1} to guinea grass, along with a state recommended dose of 88-57-112 kg N-P_2O_5-K_2O ha^{-1} to coconut recorded the highest yields of green fodder and coconut (Lakshmi *et al.,* 2007).

Mostafa *et al.* (2007) indicated that fertilizing "Grand Naine" banana with 100 g/plant magnesium chelate as soil application plus foliar spray of 2 per cent magnesium sulphate improved growth parameters, yield and fruit quality.

It was observed that magnesium fertilizer in the form of $MgSO_4.7H_20$ increased the dry matter yield of guinea grass, the crude protein content, and the magnesium uptake of the grass (Fajemilehin *et al.,* 2008). The vegetative growth, green pod yield and pod quality of snap bean were improved by increased levels of Mg fertilizer (Huda *et al.*, 2010). Ahmad *et al.* (2011) reported an increase in foliar weight, plant height and curd yield in cauliflower by applying 0.50 and 0.75 per cent Mg.

Effect of magnesium was found to be more pronounced in respect of plant height, number of branches per plant, width of flower, number of flowers per plant, fresh weight (g) of flower and oil content (%). The growth and yield parameters of *Matricaria* increased with increase in application rate of magnesium (Upadhyay and Patra, 2011).

Ahmed *et al.* (2012) found that foliar application of Mg (137.5 ppm), Cu (97 ppm) and growth regulators (20 ppm 2, 4-D, 30 ppm GA3 or 10 ppm BA) improved growth characters and yield of Washington Navel orange trees.

Babaeian *et al*. (2012) reported that magnesium had significant effect on grain yield, thousand grain weight, spike weight and biological yield in barley.

The plant height and leaf area were increased with spraying of magnesium sulphate 0.5 per cent at vegetative shoot stage in tomato (Qubaie, 2013). Grzebisz (2013) reported that a positive impact of Mg on grain yield of field-grown cereals. Application of $MgSO_4$ @ 200 g/vine significantly increased yield in black pepper (Venkataramana, 2014). Application of 4 per cent Mg to tomato gave better growth and yield (Ilyas *et al.,* 2014).

2.4.7. Effect of magnesium on quality parameters

Klein *et al*. (1982) also found that fertilization with $MgSO_4$ reduced enzymatic discoloration and concentration of phenolics, whereas the crude lipid and phospholipid contents of potato tubers were increased.

Dris *et al*. (1999) found that application of Mg imparts the taste, flavor and increased storage characteristics in apple like titratable acidity (TA), total soluble solid (TSS) concentrations, fruit firmness and starch degradation.

Villarias *et al*. (2000) observed an increase in the sugar beet sugar concentration from 13.6 to 16.9 per cent due to soil application of Mg (0 to 40 kg Mg ha^{-1}).

Ram and Bose (2000) found that foliar application of Mg and micronutrients *viz.* Cu, Zn, Fe and B increased TSS, total sugar, reducing sugars and fruit acidity in mandrain orange.

Moretti (2002) found that foliar application of Mg enhanced shoot length and lignification and increased root number thereby high quality production in grapes.

Shaked-Sachray *et al*. (2002) observed that the degradation of anthocyanins is reduced due to Mg supply. Hao and Papadopoulos (2004) reported that Mg application increased various fruit quality parameters including dry matter and TSS in tomato.

Moustafa and Omran (2006) observed that foliar spray with magnesium sulphate solutions increased the sugar concentration and improved quality parameters. Similar observations were also reported by Osman (2005).

Vrataric *et al*. (2006) reported that application of 5 per cent Mg increased the seed yield, protein and oil concentration in soybean. Ramos *et al*. (2010) found that Mg deficiency does not alter the sensory properties like acidity, total soluble solids, vitamin C, pulp colour in pineapple fruit. Borowski and Michalek (2010) found that foliar nutrition of spinach with inorganic magnesium salts ($MgSO_4$ x $7H_2O$, $Mg(NO_3)_2$ x $6H_2O$ and $MgCl_2$ x $6H_2O$) was an efficient method for supplementing the Mg level during the growing period.

Azizi *et al.* (2011) evaluated the effect of different modes of application of $MgSO_4$ (soil, foliar and seed treatment, and their combinations) and found increased yield and quality of lentil (*Lens culinaris* L.). The highest percentage of crude protein concentrations in the seeds was obtained from foliar application.

2.5. BORON

Boron is unique, not only in its chemical properties, but also in its roles in biology. Since the discovery of boron as an essential plant nutrient, the importance of B element as an agricultural chemical has grown very rapidly and its availability in soil and irrigation water is an important determinant of agricultural production. Boron deficiency is the most common and widespread micronutrient deficiency problem, which impairs plant growth and reduces yield. Normal healthy plant growth requires a continuous supply of B, once it is taken up and used in the plant; it is not translocated from old to new tissue. That is why, deficiency symptoms start with the youngest growing tissues. Therefore, adequate B supply is necessary for obtaining high yields and good quality of agriculture crops.

2.5.1. Factors affecting boron availability in soils

The soil pH is one of the most important factors affecting the availability of B. Boron adsorption on soil constituents is also affected by solution pH. Available B in the soil decreases with increasing pH because of more fixations at high pH values. Maximum B fixation takes place at 6 to 9 pH (Peterson and Newman, 1976). Application of lime increases the soil pH and this may cause B deficiency because pH has negative correlation with B availability (Evans and Sparks, 1983). Gupta (1993) also reported that, with increasing pH B becomes less available to plants.

Boron availability very much depends on soil texture. Coarse textured soils contain less B in comparison to fine textured soils, so it is usual to observe B deficiency in plants growing in sandy soils. Leaching losses B from sandy soils are very high, so these soils are mostly deficient in available B. Silty and clay soils are not usually as B deficient as sandy soils (Fleming, 1980; Zhu *et al.*, 1999).

Low soil water status may depress B uptake, even though its level is high in soil. Low water may cause depressed mineralization of B from organic matter by microorganisms. Low plant transpiration may also induce B deficiency (Fleming, 1980). Drying of soil depresses water uptake therefore decreased the supply of B reaching the plant roots through mass flow (Evans and Sparks, 1983).

Organic matter is an important factor affecting the availability of B. Soil B is positively correlated with organic carbon content (Zhu *et al.,* 1999). Organic matter is a major storehouse of available B for crop use and it also adsorbs B. (Yermiyahu *et al*., 2001).

Due to liming of acid soils, soluble B combines with Ca ions and forms the highly insoluble Ca-metaborate which reduces the availability of B (Goldberg and Chuming, 2007).

2.5.2. Role of boron in plant nutrition

Boron is directly or indirectly involved in several physiological and biochemical processes during plant growth. Boron is an important essential micronutrient which is required in very small amounts for the crop production. Boron has been functional in the transport of carbohydrates and translocation of sugar, is enhanced by the formation of borate-sugar complexes (Marcus-Wyner and Rains, 1982; Katyal and Singh, 1983).

A possible role of boron in pollen tube growth may involve vesicle production, transport, fusion or the subsequent formation of the pollen cell wall. Pollen tube cell-wall precursors are rich in polypeptides, mostly glycoprotein and polysaccharides rich in arabino furanosyl residues (Li and Liskens, 1983).

Lovatt and Dugger (1984) postulated that boron can be involved in a number of metabolic pathways and can act in the regulation of metabolic processes similar to plant hormones.

It plays a vital role in processes such as sugar transport, cell wall synthesis, lignifications, phenol metabolism, carbohydrate metabolism, IAA metabolism, RNA metabolism, root cell elongation, cell division, tissue organization, cell structure, pollen tube growth, pollen germination and seed germination (Oosterhuis, 2001).

The boron requirement is much higher for reproductive growth than for vegetative growth in most plant species. Hence the reproductive stage is known as a sensitive period to low B stress (Uraguchi *et al.,* 2011).

In sugar beet, the sucrose content of the storage roots decreased under B deficient conditions (Tariq *et al.,* 1993).

The role of B in seed production is very important, even under moderate deficiency; plants fail to produce functional flowers and any seed (Gupta, 1993).

Obermeyer *et al*. (1996) suggested that boron stimulates ATP hydrolysis and H^+ transport activity and control membrane voltage charging.

Boron is responsible for better pollination, seed setting, low spike sterility and more grain formation in different varieties of rice (Aslam *et al*., 2002).

Boron is important in pollen germination and pollen tube growth, which is likely to increase fruit set. Therefore, boron fertilization may increase yield, particularly when plants are grown on sandy soil with a low content of available boron, as shown by Wojcik *et al.* (2008). They also reported an increase in total soluble solids as well as total acidity due to soil boron application. This can be attributed to transportation of higher amount of assimilates into fruit tissues.

It was observed an increase in the photosynthesis pigments like chlorophylls and carotenoids by foliar application of boron in sweet cherry (Thurzo *et al.,* 2010).

Boron application at very low rate substantially improved seedling emergence, tillering, chlorophyll, water relations and yield related traits resulting in better yield and grain B contents. Boron application at higher level adversely affected chlorophyll pigments (Rehman *et al*., 2012).

2.5.3. Boron deficiency, sufficiency and toxicity levels in soil

Several studies showed that the ranges between deficiency and toxicity of B are quite narrow and the application of B may prove extremely toxic at concentration just slightly above the optimum (Das 2003). In general, available B of 0.50 ppm has been used by several workers for categorizing low or B deficient soils. However, crop response depends on the nature of crops, soil types and agro-ecological conditions since the critical limit of micronutrients varies with soil types and crops. This emphasized the need for careful appraisal of B status through soil and plant test for judicious use of B fertilizer.

2.5.4. Boron deficiency in plants

Poor fruit set and in turn reduced yield are the first visual signs of boron deficiency, since this nutrient plays a key role in reproductive growth (Loomis and Durst, 1992).

Boron is immobile in plants, so its deficiency symptoms develop firstly, and are more severe, on young leaves with marginal, dull yellow chlorosis at the tip of young leaves. Because B plays an important role in the elongation of stems and leaves, stems of B deficient plants are short and stout. If B deficiency is severe, many tillers can die before maturity, or whole plant may die before producing heads (Bell, 1997).

Root may become thick, twisted and do not develop properly, roots may show excessive branching, root crops often fail to develop edible portions or affected by the presence of dark colored corky areas, cuttings may fail to take root, the dropping of buds or blossom, fruits and seed may also be affected by developing of brown sunken areas on it (Dell and Huang, 1997).

The primary effect of boron deficiency appears to be the disruption of the normal functioning of the apical meristems with changes in membrane structure, cell-wall synthesis, metabolisms of auxin, carbohydrate, ascorbate and RNA, and lignification, phenol accumulation and sucrose transport being secondary effects (Brown *et al.,* 2002).

Boron deficiency is the most common and widespread micronutrient problem. Deficiency symptoms vary between crop species, but generally occur in the growing points or flower and fruiting parts of the plant. It is characterized by abnormal or retarded elongation of apical meristems (Benton, 2003).

Commonly occurring B deficiency symptoms include chlorosis and death of the growing points, distortion thickening and cracking of stems, formation of rosettes, growth of auxiliary buds, bushy growth and multiple branching (Anonymous, 2003).

2.5.5. Effect of boron on nutrient availability in soil

2.5.5.1. Macronutrients

Tariq and Mott (1990) suggested that NH_4-N showed a decreasing trend with decreasing B in the soil. The combined concentration of nitrogen (total inorganic N) resulted in positive correlation with applied B.

The concentration of potassium significantly increased with increased B content in soil solution (Tariq and Mott, 1990). The Ca concentration in soil solution decreases as B in soil decreases and resulted in a close positive correlation (Su *et al*., 1994). Application of boron increases the N and K uptake in rice (Rakshit *et al*., 2002).

Kabir *et al*. (2007) stated that application of B at 2 kg ha^{-1} produced highest straw and grain yield and maximum uptake of N, P and K nutrients by rice plants.

In plants N, K, Ca, Mg and S concentration significantly increased with application of boron (20 ppm) and lime (1/3 LR) (Barman *et al*., 2014).

2.5.5.2. Micronutrients

The iron content was increased in soil solution with increasing application of B (Katyal and Randhawa, 1983).

Curtin and Smillie (1983) reported an increase in the Mn content in soil solution with increasing B.

Decreasing the B concentration in the soil, the concentration of zinc in soil solution significantly decreases, which resulted significantly a positive correlation with soil B. This may be due to the lower pH at higher B and perhaps basic cations were displaced from exchange sites by protons and more zinc was released into solution (Tariq and Mott, 1990).

Tisdale *et al.* (1995) reported a positive relation between B and Cu. The Cu content in soil increased with an increase of B content in the soil solution. There was a synergistic relation between B and Cu.

2.5.6. Effect of boron on nutrient content in crop plants

2.5.6.1. Macronutrients

Pollard *et al.* (1977) reported that B deficiency in corn and broad beans reduced the capacity for the absorption of phosphate, due to the reduced ATPase activity, which could be rapidly restored by the addition of B.

There was positive relationship between the boron and potassium (Bowen, 1981). Muralidharan (1992) reported an increase in uptake and utilization of nitrogen by the application of boron in rice crop.

Boron had a positive effect on Ca translocation and accumulation, as reported by Neumann and Davidov (1993).This is due to the stabilizing of the cell wall by both nutrients. Bonilla *et al*. (1995) reported a synergetic relationship between B and Ca. Boron tends to keep Ca in a soluble form within the plant. B deficiency has a specific effect on Ca translocation and incorporation into an insoluble form i.e. as cell wall components (Romon *et al*., 1990).

Foliar application of boric acid and zinc sulphate had significant effect on the concentration of nitrogen, phosphorus and potassium in leaves and fruits of olive cultivar Zard as reported by Taheri and Talaie (2001). There was positive relation between boron and nitrogen metabolism (Lopez-Lefebre *et al.,* 2002). These results support the hypothesis of a positive effect of B on N uptake and metabolism. He found a positive effect between B and Mg also. K concentration was the highest in shoot and leaf tissue when plants were treated with B (Jeanine *et al.,* 2003).

Hosseini *et al.* (2007) reported a significant increase in shoot total N, P and K concentration with increasing B levels. Kabir *et al*. (2007) stated that application of B at 2 kg ha^{-1} produced highest straw and grain yield and maximum uptake of N, P and K nutrients by rice plants.

Nacer (2011) reported that foliar application of B at both flowering and seed fill stages induced nitrogen assimilation and nitrogen fixation, suggesting a close relationship between B nutrition and nitrogen metabolism.

Jasrotia *et al.* (2014) reported that leaf potassium, calcium and magnesium were increased in olive by the application of boric acid.

2.5.6.2. Micronutrients

Leece (1978) reported that B deficiency rendered Zn inactive in maize plant, possibly due to the accumulation of IAA. Pelipenko and Solovieva (1979) also observed that Zn uptake was decreased in B deficient organs corresponded to the ATPase activity localized in cell walls of roots and stems.

Fe concentration was increased by B treatments. Mozafar (1989) in corn plants, found that the foliar Fe concentration was unaffected by the presence of B in the culture medium.

2.5.7. Effect of boron on yield and yield attributes

Schon and Blevins (1990) observed that foliar application of boron resulted increase in the number of pods per branches, increased the number of seeds per plant and seed yield per plant in pea.

Singh and Singh (1990) showed that the application of boron @ 1.0 kg ha^{-1} in combination with phosphorus induced early flowering, fruiting and produced additional green pod yield of 7.38 q ha^{-1} in French bean.

The yield and yield attributes of cowpea, which is a good source of vegetable protein in Indian diet, are significantly benefited by the application of boron during rabi season (Dwivedi *et al.,* 1993).

Kalyani *et al*. (1993) observed that boron applied as boric acid increased the plant height, relative growth rate, net assimilation rate and leaf area index in pigeon pea.

Application of borax @ 7.5 kg ha^{-1} was ideal for cardamom (Srinivasan *et al.,* 1993). The response of chick pea to boron application varied from 167 to 182 kg ha^{-1} with 2 kg B ha^{-1} (Sakal *et al*., 1995). Talashikar and Chavan (1996) observed that pod production of groundnut was enhanced significantly with the addition of B by 44 per cent.

Srivastava *et al.* (1999) observed that the average grain yield of chickpea and other legume crops was 0.1 t ha^{-1} where B was not applied while the yield was 1.4 t ha^{-1} where 0.5 kg ha^{1} B was applied. Meerabai (2001) reported increase in ginger yield by the application of B @ 2 kg ha^{-1} and increase in turmeric yield, oil content and curcumin content by applying B @ 4 kg ha^{-1}. Vairavan *et al.* (2002) revealed that application of micronutrients such as Zn, B and Mo along with recommended dose of NPKS recorded significantly higher yield and yield attributes in red gram than the control.

Rashid and Yasim (2002) found that the yield of Basmathi rice was increased 25 per cent over control due to the application of boron. Devi and Savithri (2003) suggested that soil application of boron @ 2.0 kg ha^{-1} increased oil content and oil yield by 8.1 and 22.3 per cent respectively over control in sunflower.

Singh *et al*. (2004) observed that application of 1.0 kg B ha^{-1} alone or 0.5 kg B ha^{-1} along with 250 kg lime ha^{-1}, was optimal for maximum (10.56 q ha^{-1}, 81.4% increase over control) production of gram in acid soils of Jharkhand.

Pal *et al.* (2004) found that foliar application of 1000 ppm boron increased physical attributes whereas 2000 ppm boron enhanced the quality traits in bell pepper *(Capsicum annuum* L.) when sprayed thrice at 10 day intervals commencing from 50 days after transplanting.

Kumar *et al*. (2006) reported increased plant high, fruiting and pod yield when seeds were primed in 0.5 % boron solution with a concomitant reduction in days to 50 % flowering in on pea (*Pisum sativum* L).

Fageria *et al.* (2007) found that boron application significantly increased common bean yield.

In pigeon pea, boron application through seed treatment (4 g / kg seed) was more effective and economical in increasing seed yield by 10.53 % compared with the control. In another study soil application (10 kg ha^{-1}) increased yield by 5.26 % (Malla *et al.*, 2007).

Application o f B @ 1.5 kg ha^{-1} significantly increased fruit yield and quality in tomato (Jyolsna and Mathew, 2008).

Uddin *et al.* (2008) showed that application of boron @ 2 kg B ha^{-1} increased spikelets per spike, grains per spike, tillers per plant, spike length, straw and grain yield of wheat.

There was an increase in number of tillers $plant^{-1}$, plant height, panicle length, number of grain per panicle, 1000 grain weight in rice by the application of boron @ 1 kg ha^{-1} (Ahmad and Irshad, 2011). Shafiq and Maqssod (2010) observed that application of boron at different levels increased panicle weight, 1000 grain weight and yield in Rice.

Application of B fertilizer @ 5 kg ha^{-1} increased the yield and B concentration in leaves and fruits in banana (Moreira and Fageria, 2011). Application of B either through soil or foliar spray has been found beneficial for increasing the yield of soybean (Sentimela *et al.,* 2012).

Hussain *et al.* (2012) reported that soil applied boron (1.5 kg ha^{-1}) and foliar applied (1.5 % B) at different stages substantially improved the rice growth and yield. However, soil application was better in improving the number of grains per panicle, 1000-grain weight, grain yield and harvest index.

Budadeb (2012) showed that spike length, spikelets per spike, number of grains per spike, chaffy grain (%), thousand grain weight and harvest index are the characters which had contributed significantly in increasing the yield per plant while applying boron in wheat.

Muntaz *et al*. (2012) reported that B fertilization increased fruit set and yield in apple in sandy soil with low boron content.

Razaul *et al.* (2013) found that application of B increased nutrient availability to the crop during the growing season which leads to greater utilization of assimilates into the pods and ultimately increases the pod yield in alfalfa.

Application of boron resulted in increase in grain number and reduced the number of unfilled spikelets in rice. Application of 0.4 ppm boron resulted in significant increase in grain yield (Rao *et al.,* 2013).

Foliar spraying of boron, (50 ppm) had a positive significant effect on growth traits and the chemical composition of green seeds in pea (Moghazy *et al.,* 2014).

Nagula (2014) reported foliar application of borax @ 0.5 per cent increased grain yield, plant height, number of tillers in rice.

Application of 1.5 mg B kg^{-1} soil was ideal for cowpea crop to obtain optimum yield in the acid soils of Arunachal Pradesh. The critical limit of available B in soil and leaves of cowpea plants was 0.48 and 24.5 ppm, respectively, which can be used for acidic Alfisols under high rainfall regions (Debnath *et al.,* 2015).

Suganiya and Harris (2015) observed that foliar application of boron (H_3BO_3) at 150 ppm increased the number of flower buds/plant (70%), number of flowers/cluster (141%), number of flower clusters/plant (48%), total number of flowers/plant (122%), percentage of flower set (30%), percentage of fruit set (46%), number of fruits/plant (216%) and fresh weight of fruits/plant (88 %) than that of control in brinjal.

2.5.8. Effect of boron on quality parameters

Dixon *et al*. (1973) reported that cracking in apple was entirely eliminated by spraying boron. This may be due to the effects of B on membranes and cell walls. Hooda *et al*. (1975) recorded that the combination of urea and boron brought about a decrease in acidity, increase in TSS and total and reducing sugars in fruits. Ravel and Leela (1975) observed that Zn was effective in improving the total sugars, acidity and ascorbic acid content in litchi fruits. Sankaran *et al.* (1977) reported that oil content in groundnut increased by application of boron. Ghosh (1986) stated that boron and zinc increased TSS and total sugars in the fruit of guava. Zinc and boron also reduced the fruit acidity.

Dassanayaka and Thantirige (1993) found that bumpy fruit disorder in papaya is associated with boron unavailability and it can be overcome by application of borax.

Samuilov and Yunusov (2000) stated that sugar content in sugar beet was increased by 38 per cent after seed treatment with Ca, B and Mn chelates. Foliar and soil applied B increased shelf life and reduced the incidence of fruit cracking in tomato (Jeanine *et al*., 2003).

Xuan *et al.* (2003) concluded that pre-harvest boron application had a substantial effect on several physiological parameters and on the storability of pear fruit, i.e. boron may improve the ability of fruit tissue to better resist impaired storage conditions with the result of avoiding typical browning disorders.

Singh *et al.* (2006) observed that boron spray reduces fruit malformation, albinism as well as grey mould percentage in strawberry.

It was reported that application of B as soil and foliar decreased the incidence of internal necrosis and fruit cracking in mango orchards (Saran and Kumar, 2008).

2.5.9. Effect of boron on disease resistance

Boron increases the disease resistance in plant such as potato scab disease, ergot on barley and damping off on tomato and cabbage (Shorrocks, 1984).

Samuilov and Yunusov (2000) showed that the treatment of sugar beet seeds with succinic acid and Cu, B and Mn chelates when combined with thiram application has reduced the incidence of black rot by 12-24 per cent.

Srinivasamurthy *et al*. (2003) observed that boron is found to be effective in controlling tobacco mosaic virus (TMV) in tomato. They also recorded that increased rates of boron application reduced club rot (*Plasmodiaphora brassicae*) infestation in cabbage, the incidence of *Botrytis* infection in cauliflower and "witches broom" symptom in apple.

Many studies prove the role of secondary and micronutrients in disease management. Dordas and Brown (2005) reported B depressed the symptoms of *Verticillium* wilt in tomato and roots of B supplied plants showed no vascular discolouration.

2.5.10. Effect of mode of application

Touchton and Boswell (1975) reported that band or foliar applied B in corn resulted in greater B uptake in plants than B applied by broadcast.

Janaki *et al*. (2002) reported that the combined application of 20 kg borax ha^{-1} and 0.2 per cent borax foliar spray registered a maximum yield of 24.6 t ha^{-1} in winter and 26.15 t ha^{-1} in summer in grapes.

Application of B either through soil or foliar spray has been found beneficial for increasing the yield of several crops such as black gram (Singh *et al.,* 2002), rice (Debnath and Ghosh, 2011) and soybean (Sentimela and Singh, 2012). Soil applications of B are made through broadcasting or in bands.

Singh *et al.* (2006) observed an increase in marketable fruit yield of strawberry by foliar application of boron.

Dordas *et al*. (2007) reported that spraying 0.5 kg boron ha^{-1} increased concentration of B in vegetative and reproductive organs of sugar beet; in their study, foliar application of boron lead to higher yield and better quality compared to the time using boric acid in soil.

Foliar application of B and Mg resulted in increased number of pods (18%) and branches (44%) in soybean (Reinbott and Blevins, 2008).

Among different methods of B application, the foliar spray at the rate of 0.25 kg ha^{-1} along with basal dose of NPK (12:15:20) significantly increased yield and yield attributes such as leaf area, green leaf yield, cured leaf yield, and grade index as compared to other methods of B application and control in tobacco crop (Tariq *et al.,* 2010).

Dragan *et al*. (2011) reported that foliar application of B increased the number of pods, number of seeds and yield in alfalfa.

2.5.11. Effect of time of application

Early foliar application results in greater absorption of B than when applied at later stages of growth (Gupta and Cutcliffe, 1972).

Wojcik *et al.* (1999) reported that among boron treatments, only foliar boron application after bloom increased fruit yield in apples and spraying with boron before bloom had no effect on fruit set and yield.

Sood and Sharma (2004) reported that foliar application of borax @ 0.5 per cent at flower bud initiation, flowering and fruiting stage was found most effective for mature green fruit yield of bell pepper.

Foliar application of boric acid @ 12 per cent at 60 days after planting registered highest root yield and sucrose concentration in sugar beet (Armin and Asgharipour, 2012).

Materials and methods

3. MATERIALS AND METHODS

The present study entitled "Magnesium and boron nutrition for yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) in southern laterites of Kerala" was carried out at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani during August to December, 2014 to standardize the method and time of application of fertilizers of Mg and B in the Agro Ecological Unit -8 using yard long bean as test crop. The details of the experimental site, season and weather conditions, materials used and methods adopted are presented in this chapter.

3.1. EXPERIMENTAL SITE

3.1.1. Location

The experiment was conducted in the D block of the Instructional Farm attached to the College of Agriculture, Vellayani. The farm is situated at 8^{o} $5^{'}$ N latitude and 77^{o} $1^{'}$ E longitude at an altitude of 29 m above mean sea level.

3.1.2. Soil

Initial soil samples were collected from the experimental area before application of treatments, air dried and sieved through 2 mm sieve and analysed for pH, electrical conductivity, cation exchange capacity, texture, organic carbon, available nutrients such as N, P, K, Ca, Mg, S, Fe, Cu, Mn, Zn, and B following standard procedures given in Table 1.

3.1.3. Season

The experiment was conducted during August to December 2014.

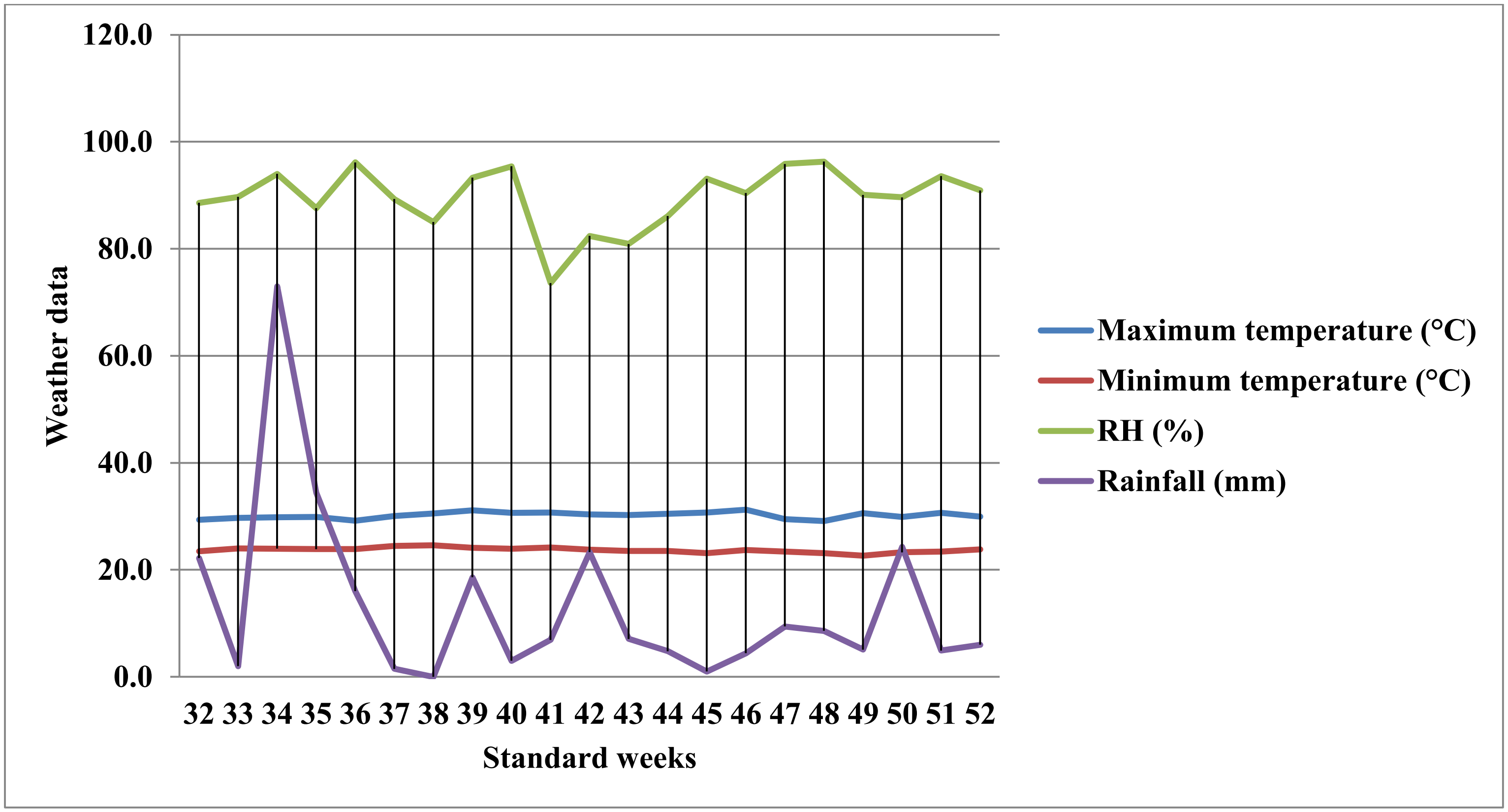
3.1.4. Weather conditions

The data on weather parameters (monthly rainfall, maximum temperature, minimum temperature and relative humidity) during the crop period are presented in Fig.1.

Table 1. Standard Analytical methods followed for soil analysis

Sl No.	Parameters	Method	Reference
1	pH	pH meter (Soil:Water-1:2.5)	Jackson (1973)
2	Electrical conductivity	Conductivity meter	Jackson (1973)
3	Cation Exchange Capacity	Ammonium saturation using neutral normal ammonium acetate	Jackson (1973)
4	Textural analysis	International pipette method	Piper (1967)
5	Organic carbon	Walkley and Black rapid titration method	Walkley and Black (1934)
6	Available nitrogen	Alkaline potassium permanganate method	Subbiah and Asija (1956)
7	Bray No.1 extractable phosphorous	Bray and Kurtz extraction method, chlorostannous – reduced molybdo phosphoric blue colour method in HCl system and estimation by spectrophotometry.	Jackson (1973)
8	Neutral normal ammonium acetate extractable K	Flame photometry	Jackson (1973)
9	Neutral normal ammonium acetate extractable Ca and Mg	Versanate titration method	Hesse (1971)
10	0.01 *N* $Ca(PO_4)_2$ extractable sulphur	Turbidimetry	Chesnin and Yien (1950)
11	0.5 *N* HCl extractable Fe, Mn, Zn and Cu	Atomic Absorption Spectrophotometer Model: Analytic Gene Nova 300	O'Connor (1988)
12	Boron	Hot water extraction and colorimetry using Azomethine-H	Hesse (1971)

Fig. 1. Weather data for the cropping period : August-December 2014



3.2. EXPERIMENTAL MATERIALS

3.2.1. Crop and Variety

The experiment was carried out with yard long bean variety Vellayani Jyothika. It is a trailing vegetable type variety. The seeds of the variety Vellayani Jyothika were purchased from the Department of Olericulture, College of Agriculture, Vellayani.

3.2.2. Manures and Fertilizers

Urea (46 per cent N), Factamphos (20 per cent N, 20 per cent P_2O_5), Rock phosphate (20 per cent P_2O_5) MOP (60 per cent K_2O) were used as source of N, P and K respectively. Mg and B were given to the crop through magnesium sulphate (9.8 per cent Mg) and borax (11 per cent B). Farmyard manure @ 20 t ha^{-1} as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 2011) was applied to all treatments.

3.3. DESIGN AND LAYOUT OF THE EXPERIMENT

3.3.1 Experimental Details

Design : RBD

Treatments : 10

Replications : 3

Spacing : 2m x 2m

Plot size : 4m x 4m

3.3.2. Treatments

T_1: Soil test based package of practices recommendation.

T_2: T_1+One time soil application of Mg and B as basal.

T_3: T_1+One time soil application of Mg and B in between basal application and top dressing.

T_4: T_1+One time soil application of Mg and B along with top dressing.

T_5: T_1+Soil application of Mg and B in two equal splits as basal application and top dressing.

T_6: T_1+Soil application of Mg and B at fortnightly intervals in equal splits.

T_7: T_1+Single foliar application of Mg and B at first flowering @ 2 per cent magnesium sulphate and 0.25 per cent borax.

T_8: T_1+Foliar application of 2 per cent magnesium sulphate and 0.25 per cent borax twice at first flowering and active flowering.

T_9: T_1+Foliar application 2 per cent magnesium sulphate and 0.25 per cent borax at fortnightly intervals

T_{10}: T_1+Soil application of half adhoc recommendation of Mg and B as basal and foliar application of 2 per cent magnesium sulphate and 0.25 per cent borax at active flowering.

- The rate of Mg and B used in the experiment for soil application was as per the adhoc recommendations for management of secondary and micronutrients (Crops, 2011) @ 80 kg ha^{-1} magnesium sulphate and 10 kg ha^{-1} borax.
- When all the plants in treatment started flowering, that considered as active flowering stage.

N

Fig 2. Layout of the experimental filed

T_5	T_7	T_9
T_9	T_3	T_2
T_4	T_6	T_5
T_7	T_{10}	T_3
T_1	T_8	T_4
T_3	T_2	T_1
T_8	T_5	T_{10}
T_6	T_1	T_8
T_{10}	T_4	T_7
T_2	T_9	T_6

3.4. FIELD EXPERIMENT

3.4.1. Land preparation

The experimental site was ploughed thoroughly and levelled. Weeds were removed. The field was laid out into three blocks each with ten plots according to the orientation of the land.

3.4.2. Lime, manure and fertilizer application

Doses of lime, manure and fertilizers for cowpea (Crops, 2011) were 250 kg ha^{-1}, 20 t ha^{-1} and N-P-K @ 20-30-10 kg ha^{-1}. Lime and fertilizer were modified based on soil test results. Accordingly lime @ 850 kg ha^{-1}, nitrogen @ 20 kg ha^{-1}, phosphorus @ 18 kg ha^{-1} and potash @ 8 kg ha^{-1} were applied. The entire quantity of lime was applied at the time of land preparation. Full dose of farm yard manure, phosphorus (as factamphos and rockphosphate), and potassium (as muriate of potash) and half the quantity of nitrogen (as factamphos) were applied as basal dose. The remaining quantity of nitrogen was applied 20 days after sowing (as urea).

3.4.3. Sowing

Yard long bean seeds were sown on 25th August 2014, in the respective plots with farm yard manure and required quantity of basal dose of fertilizers as per treatments. Seeds were sown on slightly raised round beds with a spacing of 2m x 2m. Irrigation was carried out at regular intervals.

3.4.4. Plant protection

Ekalux @ 2 ml l^{-1} was applied against *Aphis craccivora* attack when the pest incidence was noticed.

COC @ 3 g l^{-1} was applied against *Fusarium wilt.*

Plate 1. General view of the field experiment

3.5. OBSERVATIONS

3.5.1. Vegetative characters

3.5.1.1. Days to First Flowering

Number of days taken for flowering from sowing was recorded for each plant and mean value was worked out.

3.5.1.2. Leaf Area

The leaf area of observational plant from each plot was measured at flowering stage by graph paper method and expressed in cm^2.

3.5.1.3. Leaf Area Index

Leaf area index was computed using the equation

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Land area}}$$

3.5.1.4. Primary Branches Per Plant

Number of branches per plant was recorded at active flowering.

3.5.2. Yield characters

3.5.2.1. Pod Length

Length of the pods were measured as the distance from pedicel attachment of the pod to the apex using twine and scale. Average of the pod length from observation plants at peak harvesting time was taken and expressed in centimeters.

3.5.2.2. Pod Weight

Average weight of three pods from each harvest from observation plants was recorded and expressed in grams.

3.5.2.3. Number of Harvests

Total number of harvests were recorded for each treatment.

3.5.2.4. Productive Duration

The number of days from first harvest to final harvest of the crop was recorded as productive duration of crop.

3.5.2.5. Crop Duration

Number of days from the date of sowing to the drying of the vines from the observational plants was recorded and the average was taken.

3.5.2.6. Yield Per Plant

Total weight of pods from the observation plant from each plot at each harvest was taken and the average was expressed in grams.

3.5.2.7. Yield Per Plot

Total weight of pods from all plants in each plot at each harvest was taken and the average was expressed in kg.

3.5.2.8. Yield Per Hectare

Total yield from each treatment were calculated and expressed in t ha^{-1}.

3.5.2.9. Bhusa Yield

After the pods were picked, observation plant from each plot was uprooted and weighed and the average weight was expressed in t ha^{-1}.

3.5.2.10. Total Dry Matter Production

The observation plant was uprooted without damaging the roots and separated into leaves, stem and root. These were dried under shade and then oven dried at 70^{o} C till two consecutive weights coincided. The total dry weight of pods and bhusa were added to get the total dry matter production and expressed in t ha^{-1}.

3.5.2.11. Harvest Index

Harvest index of each treatment was calculated by using the formula,

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.5.3. Quality characters

3.5.3.1. Protein Content

Protein content in the fresh sample was estimated by Lowry method (Sadasivam and Manickam,1996).

3.5.3.2. Crude Fibre

Fibre content in the pod was estimated by gravimetric method (Sadasivam and Manickam, 1996).

3.5.3.3. Keeping Quality

The harvested pods were kept under ordinary room condition to study its shelf life. The number of days, up to which the pods remained fresh for consumption without loss of colour and glossiness, were recorded.

3.5.4. Scoring for pests and diseases

Monitored for the incidence of all pests and diseases. Occurrence noted was only for aphids and fusarium wilt.

3.5.4.1. Aphid

Aphid incidence was calculated by using the formula

$$\text{Aphid incidence (\%)} = \frac{\text{Number of affected branches}}{\text{Total number of branches}} \times 100$$

3.5.4.2. Fusarium wilt

For Fusarium wilt, percentage incidence was calculated by using the formula

$$\text{PDI (\%)} = \frac{\text{Number of affected plants}}{\text{Total number of plants}} \times 100$$

3.5.5. Benefit – cost ratio

Benefit – cost ratio was computed by using the formula

$$\text{B:C ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.5.6. Soil analysis

Soil samples were taken at the time of final harvest of pods. The samples were air dried under shade, sieved through 2 mm sieve and used for the analysis of pH, EC, organic carbon and available N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B using standard analytical procedures as presented in Table 1.

3.5.7. Plant analysis

Pod samples were collected at the time of harvest. The samples were oven dried at 70^0C, powdered and used for estimation of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B. Whole plant analysis of these nutrients were also done after final harvest.

3.5.8. Nutrient uptake

Uptake of nutrients calculated by using the formula,

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Concentration of nutrient (\%) x Total dry matter production}}{100}$$

3.5.9. Apparent recovery efficiency

Apparent recovery efficiency was calculated using the following formula,

$$\text{Apparent recovery efficiency (\%)} = \frac{\text{Nutrient taken up (kg)}}{\text{Nutrient applied (kg)}} \text{ x 100}$$

Table 2. Standard analytical methods followed for plant analysis

Sl No.	Parameters	Methods	References
1	Nitrogen	Micro Kjeldhal distillation after digestion in sulphuric acid	Jackson (1973)
2	Phosphorus	Nitric – perchloric acid (9:4) digestion and colorimetry making use of vanado molybdo phosphoric yellow colour method	Jackson (1973)
3	Potassium	Nitric-perchloric acid (9:4) digestion and flame photometry.	Jackson (1973)
4	Calcium and Magnesium	Atomic absorption spectroscopy Model: Analytic Gene Nova 300	Jackson (1958)
5	Sulphur	Nitric-perchloric acid (9:4) digestion and turbidimetry	Chesnin and Yien (1950)
6	Fe, Mn, Zn, Cu	Nitric-perchloric acid (9:4) digestion and atomic absorption spectrophotometry	Jackson (1973)
7	Boron	Dry ashing, extraction in 0.36 N H_2SO_4, filtration and photoelectric colorimetry using Azomethine-H.	Gupta (1967)

3.5.10. Statistical analysis

The experimental data generated from the study were subjected to statistical analysis as described by Cochran and Cox (1965).

Data generated from the field experiment was also subjected to contrast analysis (Rangaswamy, 1995). For that, the treatments were grouped into two: Group 1 (soil application) and Group 2 (foliar application).

Results

4. RESULTS

A field experiment was conducted to standardize the method and time of application of fertilizers of Mg and B in the Agro Ecological Unit -8 (southern laterites) using yard long bean as test crop at College of Agriculture Vellayani. The Southern Laterites agro-ecological unit spread over 24 panchayats in south-western part of Thiruvananthapuram district is delineated to represent the uniqueness of climate and soils. The area with tropical moist, subhumid monsoon climate receives low rainfall compared to the other areas of midland laterites (mean annual temperature 27.1 ^{o}C ; rainfall 1,884 mm). However, the well-distributed rainfall from both SW and NE monsoon restricts the dry period to just three months in a year. The results obtained from the experiment are presented in this chapter.

4.1. SITE CHARACTERIZATION

Basic physico chemical properties (pH, EC, CEC, texture, organic carbon, available N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn and B) of the soil in the experimental site is presented in Table 3. The cation exchange capacity was low (7.35 cmol kg^{-1}). The soil of the experimental site belongs to the family of Loamy Kaolinitic Isothermic Typic Haplustalf of Vellayani series. Results revealed that the soil reaction was extremely acid (pH - 4.4) and electrical conductivity was normal (0.07 dSm^{-1}). Oxidisable organic C and available nitrogen status were in the medium range and belonged to the soil fertility class 3. Available P status (22.5 kg ha^{-1}) was also medium and categorized in the soil fertility class 6. Available K status was also medium and the soil fertility class was 4. Among the secondary nutrients, available Ca and Mg were deficient while available S was sufficient. In the case of availability of micronutrients Fe and Mn were sufficient while available Zn, Cu and B were deficient.

Table 3. Physico-chemical properties of the soil of the experimental site

Sl No.	Physicochemical properties	Status	Rating
Physical properties			
Mechanical Composition			
1	Coarse sand	16.3%	
2	Fine sand	30.50%	
3	Silt	25.80%	
4	Clay	26.10%	
5	Texture	Sandy clay loam	
Chemical properties			
1	pH	4.4	Extremely acid
2	Electrical conductivity	0.07 dS m^{-1}	Normal
3	Cation Exchange Capacity	7.35 cmol kg^{-1}	Low
4	Oxidisable Organic Carbon	0.73 %	Medium
5	Available N	310.4 kg ha^{-1}	Medium
6	Available P	22.5 kg ha^{-1}	Medium
7	Available K	179.2 kg ha^{-1}	Medium
8	Available Ca	150 ppm	Deficient
9	Available Mg	84 ppm	Deficient
10	Available S	5.12 ppm	Sufficient
11	Available Fe	25.4 ppm	Sufficient
12	Available Mn	28.2 ppm	Sufficient
13	Available Zn	0.76 ppm	Deficient
14	Available Cu	0.93 ppm	Deficient
15	Available B	0.06 ppm	Deficient

4.2. VEGETATIVE CHARACTERS OF YARD LONG BEAN AS INFLUENCED BY MODE AND TIME OF APPLICATION OF Mg AND B

4.2.1. Days to first flowering

Data given in Table 4 indicated that the treatments had significant effect on days to first flowering. A significantly lower number of days (35 days) to flowering was noticed for treatments T_2, T_5, T_6 and T_9 and significantly longest duration of 38 days was recorded for the treatment T_1 in which Mg and B were not applied.

4.2.2. Leaf area

As indicated in Table 4, effect of different treatments on leaf area was significant. A significantly highest value of 1.82 m^2 was recorded by T_9 which received soil test based package of practices recommendations and foliar application of 2 per cent magnesium sulphate and 0.25 per cent borax at fortnightly intervals and was on par with T_{10} (1.81 m^2) and T_8 (1.80 m^2). The lowest leaf area was for the treatment T_1 (1.45 m^2). The treatments T_2 and T_3 (1.47 m^2) did not differ significantly from T_1.

4.2.3. Leaf area index

The data presented in Table 4 revealed that the treatments had significant effect on leaf area index. The treatment T_9 (foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations recorded the highest value of 0.46 and it was on par with T_{10} (0.45) and T_8 (0.45). Treatment T_1 recorded the lowest leaf area index (0.36) and it was on par with T_2 and T_3 (0.37).

Table 4. Vegetative characters of yard long bean as influenced by mode and time of application of Mg and B

Treatments	Days to first flowering	Leaf area (m^2)	Leaf area index	No of primary branches
T_1- soil test based package of practices recommendation	38	1.45	0.36	4
T_2- T_1 + soil - Mg and B as basal	35	1.47	0.37	4
T_3- T_1 + soil - Mg and B between basal & top dressing	36	1.47	0.37	4
T_4- T_1 + soil - Mg and B with top dressing	36	1.69	0.42	5
T_5- T_1 + soil - Mg and B in two equal splits as basal & top dressing	35	1.68	0.42	6
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	35	1.75	0.44	5
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	37	1.66	0.42	5
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	37	1.80	0.45	6
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	35	1.82	0.46	6
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	37	1.81	0.45	6
CD (0.05)	0.80	0.035	0.008	0.67

4.2.4. Primary branches

There was significant difference among treatments with respect to the primary branches of plant (Table 4). Significantly highest values were recorded by the treatments T_5, T_8, T_9 and T_{10} *i.e.* 6 branches which was found to be on par with T_4, T_6 and T_7 (5 branches). The lowest value of 4 branches was observed in $T_{1,}$ T_2 and $T_{3.}$

4.3. YIELD CHARACTERS OF YARD LONG BEAN AS INFLUENCED BY MODE AND TIME OF APPLICATION OF Mg AND B

4.3.1. Pod length

Effect of treatments on pod length was significant (Table 5). The mean values ranged from 42.66 to 51.99 cm. Foliar application of 2 per cent magnesium sulphate and 0.25 per cent borax at fortnightly intervals and soil test based package of practices recommendations (T_9) recorded significantly highest pod length and was found to be on par with T_8 (48.89 cm), T_2 (48.55 cm) and T_{10} (48.44 cm). The lowest pod length was observed for T_1 which was on par with $T_{3,}$ $T_{4,}$ $T_{5,}$ T_6 and T_7.

4.3.2. Pod weight

There was significant difference among the treatments with respect to pod weight (Table 5). Significantly highest value was recorded by the treatment T_9 (19.85g) and was on par with T_8 (19.43g), T_{10} (19.29g), T_6 (18.44g), T_2 (17.68g) and T_7 (17.66g). The lowest value of 14.24g was recorded by T_1 which was found to be on par with $T_{3,}$ T_4 and T_5.

4.3.3. Number of harvest

Observations revealed that, the treatments significantly influenced the number of harvest (Table 5). Significantly highest value of 14 harvests was recorded in the Treatments $T_{6,}$ $T_{8,}$ T_9 and $T_{10.}$ The lowest number of harvest was observed in T_1 (11 harvest) which received soil test based package of practices recommendation only

Table 5. Pod length, pod weight, productive duration and number of harvests of yard long bean as influenced by mode and time of application of Mg and B

Treatments	Pod length (cm)	Pod weight (g)	No of harvests	Productive duration (days)
T_1- soil test based package of practices recommendation	42.66	14.24	11	34
T_2- T_1 + soil - Mg and B as basal	48.55	17.68	12	37
T_3- T_1 + soil - Mg and B between basal and top dressing	44.22	16.20	12	37
T_4- T_1 + soil - Mg and B with top dressing	42.77	16.59	12	37
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	44.55	16.34	12	37
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	46.88	18.44	14	41
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	47.10	17.66	13	39
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	48.89	19.43	14	42
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	51.99	19.85	14	42
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	48.44	19.29	14	41
CD (0.05)	3.989	1.987	0.65	1.54

4.3.4. Productive duration

It was observed from Table 5 that the treatments had significant effect on productive duration. Significantly highest value was noticed in the treatments T_8 and T_9 (42 days) and were on par with T_6 and T_{10} (41 days). The lowest productive duration was in T_1 (34 days) in which Mg and B were not included.

4.3.5. Crop duration

The data on crop duration of yard long bean (Table 6) showed that the treatment effect was significant. Foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_9) recorded significantly highest crop duration of 96 days and was on par with T_8 (foliar application of Mg and B twice at first flowering and active flowering and soil test based package of practiced recommendations. The lowest crop duration (84 days) was noticed in $T_{1.}$

4.3.6. Yield per plant

The data given in Table 6 showed that the treatments significantly influenced the pod yield per plant. Foliar application of both the nutrients at fortnightly intervals and soil test based package of practices recommendations (T_9) recorded the highest yield (1569 g) and was on par with T_8 (1550 g). This was followed by T_{10} (1511 g) and T_8 and T_{10} were on par. Soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_6) recorded the highest yield among soil application. Lowest yield was recorded by T_1 (1153 g). Increase in yield in ' 53 $_1$ was 36 per cent.

4.3.7. Yield per plot

Treatments had significant effect on yield per plot (Table 6). Significantly highest yield per plot also was recorded by the treatment T_9 (16.08 kg) and was on par

Table 6. Crop duration, yield per plant and yield per plot of yard long bean as influenced by mode and time of application of Mg and B

Treatments	Crop duration	Yield per plant (g)	Yield per plot (kg)
T_1- soil test based package of practices recommendation	84	1153	11.82
T_2- T_1 + soil - Mg and B as basal	85	1265	12.97
T_3- T_1 + soil - Mg and B between basal and top dressing	86	1303	13.36
T_4- T_1 + soil - Mg and B with top dressing	86	1289	13.21
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	86	1390	14.25
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	91	1491	15.28
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	89	1400	14.35
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	95	1550	15.89
T_9- T_1 + 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	96	1569	16.08
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	92	1511	15.49
CD (0.05)	1.62	32.672	0.334

with T_8 (15.89 kg). This was followed by T_{10} (15.49 kg). Among soil application treatments, the highest yield of 15.28 kg was noted in T_6 and T_6 and T_{10} were on par. The lowest value was recorded in T_1 (11.82kg).

4.3.8. Yield per hectare

It is revealed from Table 7, that the effect of different treatments had significant effect on pod yield. Significantly highest value of 10.05 t ha^{-1} was observed in T_9 which received Mg and B at fortnightly intervals as foliar spray and soil test based package of practices recommendations. This was on par with T_8 (9.93 t ha^{-1}) in which Mg and B were applied twice at initial flowering and at active flowering as foliar spray and soil test based package of practices recommendation. The lowest value was observed in T_1 (7.39 t ha^{-1}).

4.3.9. Bhusa yield

The treatment effect was significant on bhusa yield of plant (Table 7). The treatment T_9 recorded significantly highest bhusa yield (7.45 t ha^{-1}) and was on par with T_8 (7.44 t ha^{-1}), T_{10} (7.23 t ha^{-1}) and T_6 (7.13 t ha^{-1}). The lowest value was recorded by T_1 (5.80 t ha^{-1}) and it was o 56 th T_2 (6.09 t ha^{-1}).

4.3.10. Total dry matter production

Effect of treatments on total dry matter production was significant (Table 7). The mean values ranged from 1.65 to 2.70 t ha^{-1}. Foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_9) recorded significantly highest total dry matter production and it was on par with T_8 (2.69 t ha^{-1}) and T_{10} (2.64 t ha^{-1}). Among soil application T_6 recorded the highest value of 2.33 t ha^{-1} and it was on par with T_7 (2.33 t ha^{-1}), T_2 (2.23 t ha^{-1}), T_5 (2.20 t ha^{-1}) and T_4 (2.15 t ha^{-1}). The lowest value was recorded by the treatment T_1 where Mg and B were not applied.

Table 7. Bhusa yield, pod yield, total dry matter production and harvest index of yard long bean as influenced by mode and time of application of Mg and B

Treatments	Yield (t ha^{-1})	Bhusa yield (t ha^{-1})	Total dry matter production (t ha^{-1})	Harvest index
T_1- soil test based package of practices recommendation	7.39	5.80	1.65	0.549
T_2- T_1 + soil - Mg and B as basal	8.10	6.09	2.23	0.565
T_3- T_1 + soil - Mg and B between basal and top dressing	8.35	6.38	2.09	0.561
T_4- T_1 + soil - Mg and B with top dressing	8.26	6.15	2.15	0.567
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	8.90	6.89	2.20	0.557
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	9.55	7.13	2.33	0.566
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	8.97	6.82	2.33	0.562
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	9.93	7.44	2.69	0.565
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	10.05	7.45	2.70	0.568
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	9.68	7.23	2.64	0.566
CD (0.05)	0.209	0.272	0.165	0.0080

Table 8. Quality characters of pod as influenced by mode and time of application of Mg and B

Treatments	Protein (per cent)	Fibre (per cent)	Keeping quality (days)
T_1- soil test based package of practices recommendation	4.62	12.15	3
T_2- T_1 + soil - Mg and B as basal	4.92	12.99	4
T_3- T_1 + soil - Mg and B between basal and top dressing	5.48	12.29	3
T_4- T_1 + soil - Mg and B with top dressing	5.49	11.91	3
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	5.13	11.76	3
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	5.32	12.55	3
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	5.15	12.21	4
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	5.55	12.18	4
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	5.60	12.77	4
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	5.65	11.69	4
CD (0.05)	0.407	NS	NS

.4.3.11. Harvest index

Treatments had significant effect on harvest index (Table 7). The mean values ranged from 0.549 to 0.568 with significantly highest value recorded for T_9 and was found to be on par with all the other treatments except $T_{1.}$

4.4. QUALITY CHARACTERS OF POD AS INFLUENCED BY MODE AND TIME OF APPLICATION OF Mg AND B

4.4.1. Protein content

The data given in Table 8 revealed that the different treatments had significant effect on protein content of pod. Half dose of adhoc recommendation of Mg and B as basal followed by foliar at active flowering and soil test based package of practices recommendations (T_{10}) recorded highest value (5.65%) and was on par with T_9 (5.60%), T_8 (5.55%), T_4 (5.49%), T_3 (5.48%) and T_6 (5.32%). The lowest value was recorded by the treatment T_1 (4.62%) where Mg & B were not applied and it was not significantly differ from T_2 (4.92%).

4.4.2. Fibre content

Fibre content of pod was not significantly influenced by the treatments (Table 8). The treatment T_2 recorded the highest value of 12.99 per cent which was followed by T_9 (12.77 %). The lowest value was recorded by the treatment T_{10} (11.69 %).

4.4.3. Keeping quality

Treatments had no significant effect on keeping quality (Table 8) . Treatments $T_{2,}$ $T_{7,}$ $T_{8,}$ T_9 and T_{10} recorded 4 days and remaining recorded the value of 3 days.

4.5. SCORING OF PEST AND DISEASE IN YARD LONG BEAN

Fusarium wilt and aphid incidence were observed during the crop period. The treatments had no significant effect on the pest and disease incidence (Table 9).

Table 9. Scoring of pest and disease in yard long bean, per cent

Treatments	Fusarium wilt	Aphid
T_1- soil test based package of practices recommendation	18.75	7.7
T_2- T_1 + soil - Mg and B as basal	12.5	8.4
T_3- T_1 + soil - Mg and B between basal and top dressing	12.5	9.2
T_4- T_1 + soil - Mg and B with top dressing	12.5	12.6
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	0	9.5
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	12.5	10.4
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	0	9.6
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	12.5	12.8
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	0	9.9
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	0	9.2
CD (0.05)	-	NS

4.6. EFFECT OF TREATMENTS ON BENEFIT COST RATIO

B:C ratio was significantly influenced by the treatments (Table 10). From the analysis of data, T8 registered significantly highest value of 2.27 which received foliar application of Mg and B twice at first flowering and active flowering and soil test based package of practices recommendations. This was followed by T_{10} (soil application of half adhoc recommendation of Mg and B as basal and foliar application of 0.25 per cent borax and 2 per cent magnesium sulphate at active flowering and soil test based package of practices recommendation. The lowest B:C ratio was observed in the treatment T_1 (1.79) where Mg and B not included.

4.7. SOIL FERTILITY PARAMETERS AFTER HARVEST

4.7.1. Soil pH

The pH of the experimental site before the experimental site was 4.4 (Table 2) which was extremely acid and after the experiment it was in the strongly acid range (5.0-5.5) only. However, soil pH was not significantly influenced by the treatments (Table 11).

4.7.2. Available Nitrogen

The results of available N content in soil are presented in Table 11. The available N content in soil ranged from 336.57 (T_7) to 413.94 kg ha^{-1} (T_{10}). Initial available status of N in soil was medium and the status was maintained after the experiment. However, there was no significant difference between the treatmen[illegible]spect to available nitrogen content in soil.

4.7.3. Available Phosphorus

Treatments had no significant effect on available P content in soil (Table 11). The mean values ranged from 48.16 (T_6) to 77.14 kg ha^{-1} (T_3). Available status of P remained high in all treatments which was only medium before the experiment.

Table 10. Effect of treatments on benefit-cost ratio

Treatments	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C Ratio
T_1- soil test based package of practices recommendation	283000	125320	1.79
T_2- T_1 + soil - Mg and B as basal	316250	156947	1.99
T_3- T_1 + soil - Mg and B between basal and top dressing	325938	154385	1.90
T_4- T_1 + soil - Mg and B with top dressing	322291	150739	1.88
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	347500	175947	2.03
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	372708	188905	2.03
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	350000	179686	2.06
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	387500	216623	2.27
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	392292	208038	2.13
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	377917	206702	2.21
CD (0.05)	7419.82	7419.82	0.043

Table 11. pH and available NPK in soil after harvest of yard long bean as influenced by mode and time of application of Mg and B

Treatments	pH	Available N	Available P	Available K
		kg ha^{-1}		
T_1- soil test based package of practices recommendation	5.01	353.32	64.21	198.93
T_2- T_1 + soil - Mg and B as basal	5.09	403.49	72.80	220.26
T_3- T_1 + soil - Mg and B between basal and top dressing	4.98	396.17	77.14	242.66
T_4- T_1 + soil - Mg and B with top dressing	4.97	364.81	66.82	236.26
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	5.18	395.79	65.86	242.66
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	4.97	379.45	48.16	243.73
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	4.98	336.57	67.36	227.73
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	5.32	358.54	70.56	209.46
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	5.13	364.81	59.00	225.06
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	4.99	413.94	54.13	205.33
CD (0.05)	NS	NS	NS	19.463

4.7.4. Available Potassium

The results with respect to available K in soil are presented in Table 11. Soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_6) recorded significantly highest value of 243.73 kg ha^{-1} and was on par with T_3 (242.66 kg ha^{-1}), T_5 (242.66 kg ha^{-1}), T_4 (236.26 kg ha^{-1}), T_7 (227.73 kg ha^{-1}), T_8 (225.06 kg ha^{-1}), and T_2 (220.26 kg ha^{-1}). The lowest value was recorded by the treatment T_1 (198.93 kg ha^{-1}) and the treatments T_2, T_8 and T_{10} did not significantly differ from T_1. Soil fertility class of available K was improved from 4 to 5 and 6. However it remained in the medium range.

4.7.5. Available Calcium

The analytical results of available calcium with respect to various treatments are presented in Table 12. The available Ca content in soil ranged from 233.33 (T_{10}) to 433.33 ppm (T_3). Available Ca was improved in the soil compared to the initial status. Available status of Ca was sufficient in all the treatments except T_{10} which remained deficient before and after the experiment. However there was no significant difference between the treatments with respect to available calcium in soil.

4.7.6. Available Magnesium

Application of Mg and B had a significant influence on available Mg content in soil (Table 12). The available Mg content in soil ranged from 88.00 (T_1) to 202.00 ppm (T_6). Soil application of both the nutrients at fortnightly intervals and soil test based package of practices recommendations recorded significantly highest content of available magnesium in soil which was on par with T_5(180.00 ppm), T_{10}(173.20 ppm), T_2(160.00 ppm) and T_4(160.00 ppm). The lowest value was recorded by the treatment T_1 and was on par with T_3, T_7, T_8 and T_9. Critical level of Mg (more than 120 ppm) for sufficiency in the soil was attained in all soil applicationtreatments

Table 12. Available status of secondary nutrients in soil after harvest of yard long bean as influenced by mode and time of application of Mg and B, ppm

Treatments	Ca	Mg	S
T_1- soil test based package of practices recommendation	373.33	88.00	5.50
T_2- T_1 + soil - Mg and B as basal	390.00	160.00	6.80
T_3- T_1 + soil - Mg and B between basal and top dressing	433.33	126.40	7.33
T_4- T_1 + soil - Mg and B with top dressing	336.66	160.00	6.98
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	396.66	180.00	6.75
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	346.66	202.00	7.40
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	386.66	106.00	5.80
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	350.00	112.80	5.40
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	416.66	112.80	5.53
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	233.33	173.20	6.53
CD (0.05)	NS	40.970	0.729

.4.7.7. Available Sulphur

The results of available S content are furnished in Table 12. Significantly highest value of 7.40 ppm was registered by T_6 which received soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendation and was on par with T_3 (7.33 ppm), T_4 (6.98 ppm), T_2 (6.80 ppm), T_5 (6.75 ppm) and T_{10}(6.53 ppm). The lowest value of 5.50 ppm was recorded by T_1 and it was on par with foliar applied treatments T_9 (5.53 ppm) and T_8 (5.40 ppm). Critical level of sulphur (5-10 ppm) for sufficiency in the soil was maintained in all the treatments.

4.7.8. Available Fe, Mn, Zn, Cu and B

Compared to the initial soil status, the availability of micronutrients in general in soil was increased due to the use of Mg and B.

The iron content of soil was estimated for various treatments and the results are shown in Table 13. The available Fe content was significantly higher in T_6 (45.22 ppm) which was on par with T_5 (42.46 ppm). The lowest value of 29.42 ppm was recorded by T_1 and was on par with all the foliar applied treatments.

The Mn content in soil as influenced by various treatments is presented in Table 13. Soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendation (T_6) recorded the highest value of 41.41 ppm and was on par with T_5 (37.67 ppm). The lowest value of 29.73 ppm was recorded by T_9 and was on par with T_7 (30.74 ppm),T_1(31.22ppm)andT_8(31.79ppm).

As indicated in Table 13, available Zn content in the soil was not significantly influenced by the treatments and the values ranged from 0.78 (T_2 and T_8) to 1.15 ppm (T_6). The critical level of Zn (> 1 ppm) for sufficiency in the soil was achieved by the treatments T_4,T_6andT_{10}only.

Table 13. Available status of micro nutrients in soil after harvest of yard long bean as influenced by mode and time of application of Mg and B, ppm

Treatments	Fe	Mn	Zn	Cu	B
T_1- soil test based package of practices recommendation	29.42	31.22	0.85	1.51	0.07
T_2- T_1 + soil - Mg and B as basal	37.88	35.62	0.78	1.08	0.25
T_3- T_1 + soil - Mg and B between basal and top dressing	36.01	36.20	0.93	1.35	0.23
T_4- T_1 + soil - Mg and B with top dressing	40.73	37.08	1.05	1.65	0.25
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	42.46	37.67	0.98	1.52	0.25
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	45.22	41.41	1.15	1.20	0.26
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	28.79	30.74	0.86	1.32	0.07
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	29.57	31.79	0.78	1.26	0.07
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	28.73	29.73	0.88	1.64	0.07
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	34.68	37.14	1.02	1.45	0.16
CD (0.05)	3.277	3.486	NS	NS	0.052

The results of available Cu content are furnished in Table 13. The available copper content in soil ranged from 1.08 (T_2) to 1.65 ppm (T_4). There was no significant difference between the treatments with respect to available copper content in soil. Critical level of Cu (> 1 ppm) for sufficiency in the soil was attained in all the treatments which was deficient before the experiment.

The results with respect to B content in soil at final harvest is shown in Table 13. It indicates that the treatments significantly influenced the available B content of the soil. Significantly highest available boron content was obtained in T_6 (0.26 ppm) which received soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendations and was on par with T_2, T_4 and T_6 (0.25 ppm) and T3 (0.23 ppm). This was followed by T_{10} (0.16 ppm). The lowest value of 0.07 ppm was oserved in T_1, $T_{7,}$ T_8 and T_9. In the case of B, critical level of sufficiency (more than 0.5 ppm) was not attained either through soil or foliar application.

4.8. EFFECT OF TREATMENTS ON NUTRIENT COMPOSITION OF YARD LONG BEAN POD

4.8.1. Effect of treatments on contents of N, P and K in the pod of yard long bean

The results of contents of N, P and K in the pod of yard long bean are presented in Table 14. Effect of treatments on content of N was significant. The values ranged from 2.44 to 3.85 per cent. Significantly highest N content was observed when Mg and B were applied as basal @ of half of adhoc recommendation in combination with one foliar spray at active flowering and soil test based package of practices recommendations (T_{10}). The lowest was observed in T_1 which was found to be on par with T_2 (2.67 %), T_6 (2.68 %) and T_3 (2.85 %).

Table 14. Effect of treatments on contents of N, P and K in the pod of yard long bean, per cent

Treatments	N	P	K
T_1- soil test based package of practices recommendation	2.44	0.18	3.33
T_2- T_1 + soil - Mg and B as basal	2.67	0.21	3.00
T_3- T_1 + soil - Mg and B between basal and top dressing	2.85	0.22	3.00
T_4- T_1 + soil - Mg and B with top dressing	2.88	0.20	3.16
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	2.98	0.19	3.00
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	2.68	0.26	3.00
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	3.04	0.21	2.93
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	3.23	0.26	3.00
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	3.57	0.24	3.00
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	3.85	0.25	3.23
CD (0.05)	0.377	0.03	NS

On analyzing the results of P content in pod, it was observed that, the effect of treatment was significant. Significantly highest value of 0.26 per cent was observed in T_6 and T_8 and the lowest value was recorded by T_1 (0.18 %).

Data on K content in pod (Table 14) showed that the treatment effect on content of K in the pod was not significant. The highest value of 3.33 per cent was in T_1 and the lowest value of 2.93 per cent was in T_7.

4.8.2. Effect of treatments on contents of Ca, Mg and S in pod of yard long bean

The different treatments had significant effect on Ca content of pod (Table 15). The highest value for pod Ca content was reported for the treatment T_9 (1.95 %) and it was on par with all the other treatments except T_1 (1.09%).

The data given in the Table 15 indicated that the effect of different treatments on content of Mg in the pod was significant. The highest Mg content in the pod of 1.24 per cent was in T_9 (foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations) which was on par with T_8 (1.15 %). The lowest value was noticed in the treatment T_1 (0.72 %). All the treatments were superior to T_1 in which Mg and B were not included.

The effect of the treatments with respect to the content of S in the pod are shown in Table 15. The mean values ranged from 0.19 to 0.29 per cent. The highest S content of pod also was noticed in T_9 with the foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations and it was on par with T_5, T_6, T_8 and T_{10}. The lowest value was observed in T_1 and all the other treatments were significantly superior to T_1.

Table 15. Effect of treatments on contents of Ca, Mg and S in the pod of yard long bean, per cent

Treatments	Ca	Mg	S
T_1- soil test based package of practices recommendation	1.09	0.72	0.19
T_2- T_1 + soil - Mg and B as basal	1.88	1.02	0.23
T_3- T_1 + soil - Mg and B between basal and top dressing	1.82	1.04	0.24
T_4- T_1 + soil - Mg and B with top dressing	1.55	1.07	0.24
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	1.70	1.04	0.26
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	1.83	1.08	0.27
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	1.89	1.03	0.22
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	1.91	1.15	0.27
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	1.95	1.24	0.29
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	1.86	1.09	0.26
CD (0.05)	0.333	0.113	0.028

4.8.3. Effect of treatments on contents of Fe, Mn, Zn, Cu and B in the pod of yard long bean

The data on total Fe content of pod of yard long bean are presented in Table 16. When the effect of the treatments on Fe content in pods were compared, the highest value was noticed in T_2 (198 ppm) which received soil application of Mg and B as basal and soil test based package of practices recommendation and it was on par with T_3 (193ppm) and T_1 (192ppm). the lowest value of 173 ppm was observed in T_6 and T_7.

The data on the total content of Mn in the pod of yard long bean are given in Table 16. Among all treatments the treatment T_5 in which Mg and B were applied in two equal splits as basal and top dressing and soil test based package of practices recommendation recorded the highest Mn content in pod (212 ppm) which was on par with T_7 (209 ppm) and T_8 (200 ppm). T_1 registered the lowest value of 169 ppm.

Table 16 shows the total content of Zn in the pod at harvest stage. There was a significant influence of treatments on content of Zn in pods. The highest concentration of Zn (28.09 ppm) was noticed in T_{10}. This was on par with T_3 (26.54 ppm), T_4 (26.24 ppm) and T_2 (25.98 ppm). The lowest value was recorded by the treatment T_1 (14.00 ppm) and it was on par with T_8 (17.79 ppm).

The data on content of copper in the pod at harvest are furnished in Table 16. In the case of copper content in pods, treatments varied significantly. The highest content was recorded in T_8 (8.58 ppm) which was on par with T_7 (8.41 ppm) and T_9 (7.92 ppm) The lowest value of 5.86 ppm was noticed in T_1.

From table 16, it was found that the B content was significantly influenced by the treatments. The highest content of B (38.33 ppm) in pod of yard long bean was obtained when Mg and B were sprayed twice at initial flowering and active flowering and soil test based package of practices recommendation (T_8). This was on

Table 16. Effect of treatments on contents of Fe, Mn, Zn, Cu and B in the pod of yard long bean, ppm

Treatments	Fe	Mn	Zn	Cu	B
T_1- soil test based package of practices recommendation	192	169	14.00	5.86	16.66
T_2- T_1 + soil - Mg and B as basal	198	183	25.98	7.35	26.66
T_3- T_1 + soil - Mg and B between basal and top dressing	193	184	26.54	6.96	28.33
T_4- T_1 + soil - Mg and B with top dressing	185	180	26.24	6.56	30.00
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	179	212	23.13	5.95	28.33
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	173	198	18.65	6.80	36.66
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	173	209	21.27	8.41	28.33
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	181	200	17.79	8.58	38.33
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	185	180	20.55	7.92	36.66
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	185	181	28.09	6.86	36.66
CD (0.05)	5.529	11.49	3.226	1.344	4.699

par with T_6, T_9 and T_{10} (36.66 ppm). The lowest value was registered by T_1 (16.66 ppm) which received soil test based package of practices recommendation only and it was statistically inferior to all other treatments.

4.9. EFFECT OF TREATMENTS ON NUTRIENT COMPOSITION OF WHOLE PLANT AFTER FINAL HARVEST

4.9.1. Effect of treatments on content of primary nutrients in whole plant after final harvest

The data on total nitrogen content of whole plant after final harvest are presented in Table 17. Soil application of half adhoc recommendation of Mg and B as basal in combination with one foliar spray at active flowering and soil test based package of practices recommendation (T_{10}) recorded the highest value of 2.43 per cent. It was on par with T_9 (2.31 %), T_8 and T_6 (2.21 %).

On analyzing the result of P content of whole plant, it was noted that the mean values ranged from 0.17 per cent to 0.22 per cent and the treatment effect was significant (Table 15). The highest value was observed in T_6 and it was on par with T_8 and T_9 (0.21 %). The lowest value was recorded by T_1.

As indicated in Table 17, total content of K in whole plant was not significantly influenced by the treatments and the values ranged from 2.5 per cent to 2.83 per cent.

4.9.2. Effect of treatments on content of secondary nutrients in whole plant after final harvest

There was a significant influence of treatments on content of Ca in whole plant as shown in Table 18. The highest value of 2.02 per cent was observed when Mg and B were applied as basal @ of half of adhoc recommendation in combination with one foliar spray at active flowering and soil test based package of practices

Table 17. Effect of treatments on content of primary nutrients in whole plant after final harvest, per cent

Treatments	N	P	K
T_1- soil test based package of practices recommendation	1.57	0.17	2.50
T_2- T_1 + soil - Mg and B as basal	1.80	0.19	2.83
T_3- T_1 + soil - Mg and B between basal and top dressing	1.72	0.18	2.83
T_4- T_1 + soil - Mg and B with top dressing	1.78	0.18	2.83
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	1.96	0.19	2.50
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	2.21	0.22	2.66
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	1.98	0.19	2.83
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	2.21	0.21	2.83
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	2.31	0.21	2.83
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	2.43	0.19	2.66
CD (0.05)	0.224	0.019	NS

Table 18. Effect of treatments on content of secondary nutrients in whole plant after final harvest, per cent

Treatments	Ca	Mg	S
T_1- soil test based package of practices recommendation	0.74	0.51	0.18
T_2- T_1 + soil - Mg and B as basal	0.78	0.67	0.27
T_3- T_1 + soil - Mg and B between basal and top dressing	0.82	0.76	0.25
T_4- T_1 + soil - Mg and B with top dressing	0.84	0.64	0.25
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	0.94	0.87	0.27
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	1.28	1.09	0.32
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	1.04	0.61	0.27
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	1.66	0.99	0.33
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	1.90	1.01	0.35
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	2.02	1.11	0.34
CD (0.05)	0.165	0.208	0.023

recommendation (T_{10}). This was on par with T_9 (1.90 %). T_1 recorded the lowest Ca content (0.74 %).

Effect of treatments on content of Mg in whole plant after final harvest was significant (Table 18). The highest Mg content was also recorded in T_{10} (1.11%). This was on par with T_6 (1.09 %), T_9 (1.01 %) and T_8 (0.99 %). The lowest value was observed in T_1 (0.51 %) in which Mg and B were not included.

Treatments had significant effect on S content of whole plant after final harvest (Table 18). Foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_9) recorded highest S content (0.35 %) and it was on par with T_{10} (0.34 %) and T_8 (0.33 %). The lowest value was recorded by the treatment T_1 (0.18 %) where Mg and B were not applied.

4.9.3. Effect of treatments on content of micronutrients in whole plant after final harvest

Effect of treatments on content of micronutrients in whole plant was not significant except in the case of B. The mean values of whole plant Fe content ranged from 86 ppm to 146 ppm (Table 19). The treatment with soil test based package of practices recommendations and Mg and B as basal (T_2) recorded the highest value and T_1 (soil test based package of practices recommendations) recorded the lowest value. The treatment T_5 recorded the highest content of Mn (160 ppm) and T_9 recorded the lowest content of Mn (103 ppm). In the case of Zn, the mean values ranged from 38.41 ppm (T_1) to 43.61 ppm (T_5). In the case of Cu, the highest value of 6.46 ppm and the lowest value of 5.26 ppm were noticed in T_8 and T_5 respectively.

Table 19 clearly indicated that total B content of whole plant after final harvest was significantly influenced by the treatments. The highest value of 38.33 ppm was obtained in the treatment T_9 in which Mg and B were applied at fortnightly

Table 19. Effect of treatments on content of micronutrients in whole plant after final harvest, ppm

Treatments	Fe	Mn	Zn	Cu	B
T_1- soil test based package of practices recommendation	86	130	38.41	5.46	21.66
T_2- T_1 + soil - Mg and B as basal	146	146	40.91	5.33	31.67
T_3- T_1 + soil - Mg and B between basal and top dressing	118	151	38.75	5.53	31.67
T_4- T_1 + soil - Mg and B with top dressing	93	134	40.80	5.86	30.00
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	89	160	43.61	5.26	31.67
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	110	136	39.15	5.86	35.00
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	103	134	39.80	6.16	33.33
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	116	114	39.63	6.46	35.00
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	101	103	39.85	5.73	38.33
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	114	110	39.85	6.13	33.33
CD (0.05)	NS	NS	NS	NS	4.739

intervals as foliar spray and soil test based package of practices recommendation. This was on par with T_6 (35 ppm), T_8 (35 ppm), T_7 (33.33 ppm) and T_{10} (33.33 ppm). The lowest value was recorded by T_1 (21.66 ppm) and it was statistically inferior to all other treatments.

4.10. EFFECT OF TREATMENTS ON UPTAKE OF NUTRIENTS BY YARD LONG BEAN

4.10.1. Effect of treatments on uptake of primary nutrients yard long bean

Data presented in Table 20 revealed that the treatment had significant effect on N uptake. Significantly highest total uptake of N (78.72 kg ha^{-1}) was recorded by treatment T_{10} which received combined application of soil with half of adhoc recommendations of Mg and B as basal and foliar at active flowering and soil test based package of practices recommendations. It was on par with treatment T_9 (75.67 kg ha^{-1}). This was followed by T_8 (70.20 kg ha^{-1}). T_1 recorded the lowest value of 32.71 kg ha^{-1}.

Total uptake of P is presented in Table 20. Uptake of P was the highest in T_8 (6.12 kg ha^{-1}) which received foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendation. It was on par with T_9 (5.94 kg ha^{-1}) and T_{10} (5.82 kg ha^{-1}). The lowest value was recorded by treatment T_1 (2.93 kg ha^{-1}) which received soil test based package of practices recommendation only.

Total uptake of K also was significantly influenced by the treatments (Table 20). The total uptake of K was maximum in T_9 (78.56 kg ha^{-1}) and this was on par with T_8 (77.99 kg ha^{-1}), T_{10} (75.69 kg ha^{-1}), T_7 (67.39 kg ha^{-1}), T_6 (65.38 kg ha^{-1}), T_2 (64.88 kg ha^{-1}) and T_4 (64.45 kg ha^{-1}). The lowest value of 47.51 kg ha^{-1} was recorded by the treatment T_1.

Table 20. Effect of treatments on uptake of primary nutrients by yard long bean, kg ha^{-1}

Treatments	N	P	K
T_1- soil test based package of practices recommendation	32.71	2.93	47.51
T_2- T_1 + soil - Mg and B as basal	47.97	4.41	64.88
T_3- T_1 + soil - Mg and B between basal and top dressing	46.38	4.13	60.13
T_4- T_1 + soil - Mg and B with top dressing	48.60	4.07	64.45
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	52.77	4.14	59.12
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	56.41	5.43	65.38
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	56.80	4.60	67.39
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	70.20	6.12	77.99
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	75.67	5.94	78.56
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	78.72	5.82	75.69
CD (0.05)	5.627	0.559	14.508

4.10.2. Effect of treatments on uptake of secondary nutrients by yard long bean

Uptake of secondary nutrients was significantly influenced by the treatments (table 21).

Ca uptake recorded the highest value in T_9 and it was 51.75 kg ha^{-1} which was found to be on par with T_{10} (51.63 kg ha^{-1}) and T_8 (47.25 kg ha^{-1}). The lowest Ca uptake was observed in T_1 (15.03 kg ha^{-1}) in which Mg and B were not included.

The highest value (29.59 kg ha^{-1}) for Mg uptake was also recorded by T_9 which received foliar application of both Mg and B at fortnightly intervals and soil test based package of practices recommendation. It was on par with T_{10} (29.13 kg ha^{-1}) and T_8 (28.24 kg ha^{-1}). The lowest uptake was recorded by T_1 (10.10 kg ha^{-1}).

Treatment T_9 in which Mg and B were sprayed at fortnightly intervals and soil test based package of practices recommendations recorded the highest uptake of S with a value of 8.76 kg ha^{-1}. It was followed by treatment T_{10} which received soil test based package of practices recommendation and half dose of adhoc recommendation of Mg and B as basal followed by foliar application at active flowering. The lowest uptake of S also was recorded by T_1 (3.04 kg ha^{-1}).

4.10.3. Effect of treatments on uptake of micronutrients by yard long bean

Uptake of all the micronutrients were significantly affected by the treatments (Table 22).

Uptake of Fe was highest in T_8 (0.38 kg ha^{-1}. It was on par with T_2 (0.37 kg ha^{-1}), T_{10} (0.37 kg ha^{-1}) and T_9 (0.36 kg ha^{-1}). The lowest Fe uptake was recorded by T_1 (0.22 kg ha^{-1}) in which Mg and B were not included.

The highest value Mn uptake (0.40 kg ha^{-1}) was observed in T_5 and T_8. This was on par with all the other treatments except T_4 (0.34 kg ha^{-1}) and T_1 (0.25 kg ha^{-1}).

Table 21. Effect of treatments on uptake of secondary nutrients by yard long bean , kg ha^{-1}

Treatments	Ca	Mg	S
T_1- soil test based package of practices recommendation	15.03	10.10	3.04
T_2- T_1 + soil - Mg and B as basal	27.35	18.21	5.25
T_3- T_1 + soil - Mg and B between basal and top dressing	26.46	18.64	5.14
T_4- T_1 + soil - Mg and B with top dressing	24.73	17.76	5.24
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	27.92	20.69	5.84
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	35.58	25.27	6.94
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	32.76	18.42	5.77
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	47.25	28.24	8.16
T_9- T_1 + foliar- 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	51.75	29.59	8.76
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	51.63	29.13	8.19
CD (0.05)	5.41	3.13	0.456

Table 22. Effect of treatments on uptake of micronutrients by yard long bean, kg ha^{-1}

Treatments	Fe	Mn	Zn	Cu	B
T_1- soil test based package of practices recommendation	0.22	0.25	0.044	0.009	0.032
T_2- T_1 + soil - Mg and B as basal	0.37	0.36	0.078	0.013	0.066
T_3- T_1 + soil - Mg and B between basal and top dressing	0.31	0.35	0.069	0.012	0.063
T_4- T_1 + soil - Mg and B with top dressing	0.29	0.34	0.074	0.013	0.066
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	0.28	0.40	0.077	0.012	0.067
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	0.32	0.38	0.070	0.014	0.083
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	0.31	0.39	0.074	0.016	0.075
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	0.38	0.40	0.084	0.019	0.098
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	0.36	0.36	0.087	0.017	0.102
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	0.37	0.36	0.093	0.016	0.092
CD (0.05)	0.046	0.045	0.008	0.0022	0.011

Uptake of Zn was highest in T_{10} (0.093 kg ha^{-1}) and it was on par with T_9 (0.087 kg ha^{-1}). The lowest Zn uptake was recorded by T_1 (0.044 kg ha^{-1}).

Cu uptake recorded the highest value in T_8 (0.019 kg ha^{-1}) in which Mg and B were sprayed twice at first flowering and active flowering and soil test based package of practices recommendation. It was on par with T_6, T_7, T_9 and T_{10}. The lowest value was recorded by T_1 (0.009 kg ha^{-1}).

Highest B uptake was associated with T9 (0.102 kg ha^{-1}) which received foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations and was on par with T_8 (0.098 kg ha^{-1}) and T_{10} (0.092 kg ha^{-1}). The lowest value of 0.032 kg ha^{-1} recorded by T_1 in which Mg and B were not applied and was statistically inferior to all the other treatments.

4.11. APPARENT RECOVERY EFFICIENCY

Application of Mg and B had a significant effect on the apparent recovery efficiency of both the Mg and B (Table 23). Single foliar application of Mg and B at first flowering and soil test based package of practices recommendations recorded the highest apparent recovery efficiency of 89.5 per cent for Mg and 2.9 per cent for B in yard long bean. This was followed by foliar application of Mg and B twice at first flowering and active flowering and soil test based package of practices recommendations (67.9 % for Mg and 1.89 % for B). Application of Mg and B at fortnightly intervals recorded the highest apparent recovery efficiency for Mg and B among soil application. Therefore, the efficiency of foliar application at first flowering was proved to be better than other methods.

4.12. CONTRAST ANALYSIS

The data presented in Table 24 revealed that, foliar application was superior to soil application in terms of leaf area, days to first flowering, pod length, pod

Table 23. Apparent recovery efficiency of Mg and B in yard long bean, per cent

Treatments	Mg	B
T_1- soil test based package of practices recommendation	0	0
T_2- T_1 + soil - Mg and B as basal	22.8 (28.5)	0.70 (4.7)
T_3- T_1 + soil - Mg and B between basal and top dressing	23.3 (28.8)	0.63 (4.6)
T_4- T_1 + soil - Mg and B with top dressing	22.2 (28.1)	0.67 (4.7)
T_5- T_1 + soil - Mg and B in two equal splits as basal and top dressing	25.9 (30.6)	0.67 (4.8)
T_6- T_1 + soil - Mg and B at fortnightly intervals in equal splits	31.5 (34.2)	0.83 (5.2)
T_7- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	89.5 (71.0)	2.90 (9.7)
T_8- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax twice at first flowering and active flowering	67.9 (55.5)	1.89 (7.9)
T_9- T_1 + foliar - 2% $MgSO_4$ and 0.25% borax at fortnightly intervals	30.8 (33.8)	0.85 (5.3)
T_{10}- T_1 + soil - half adhoc recommendation of Mg and B as basal and foliar - 2% $MgSO_4$ and 0.25% borax at active flowering	48.5 (44.2)	1.20 (6.3)
CD (0.05)	4.69	0.011

Values in parenthesis are arcsine transformed

Table 24. Contrast analysis

	Leaf area (m^2)	Days to first flowering	Pod length (cm)	Pod weight (gm)	Yield per plant (g)	Bhusa yield (kg ha^{-1})	Total dry matter (kg ha^{-1})	B:C ratio	Available Mg in soil (ppm)	Available B in soil (ppm)
Group 1	24.2	531	680.94	255.8	20216	91000	33003	29.45	2485	3.7
Group 2	15.85	336	443.93	170.85	13557	66325	23167	19.36	995	0.64
Group 1 Vs Group 2	S	S	S	S	S	S	S	S	S	S

weight, yield per plant, bhusa yield, total dry matter production and benefit cost ratio where as soil application was found to be better than foliar application in terms of available Mg and B.

Discussion

5. DISCUSSION

An experiment entitled "Magnesium and boron nutrition for yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) in southern laterites of Kerala" with the objective of standardizing the method and time of application of fertilizers of Mg and B in the Agro Ecological Unit -8 using yard long bean as test crop was carried out at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani. The results generated from the study are discussed in this chapter.

5.1. VEGETATIVE CHARACTERS OF YARD LONG BEAN AS INFLUENCED BY MODE AND TIME OF APPLICATION OF MAGNESIUM AND BORON

Mg and B had a marked influence on vegetative characters like days to first flowering, leaf area, leaf area index and number of branches per plant.

Mg and B treated plants took less number of days to flower compared to the plants which did not receive both the nutrients. Fig.3 shows that either soil or foliar application of Mg and B equally good in reducing days to flowering. Role of Mg in pollen production (Bergmann, 1992) might have contributed to reduction in number of days to flowering. The results are in accordance with the reports by Sood and Sharma (2004) in bell pepper.

Similarly leaf area and leaf area index also were significantly influenced by the treatments (Fig.4). The highest leaf area and leaf area index were noticed in the treatment T_9 which received foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendation. It was on par with treatment T_8 where Mg and B were sprayed twice at initial flowering and active flowering and treatment T_{10} in which half adhoc recommendation of Mg and B applied as basal followed by foliar at active flowering. This increase in leaf area may be due to the

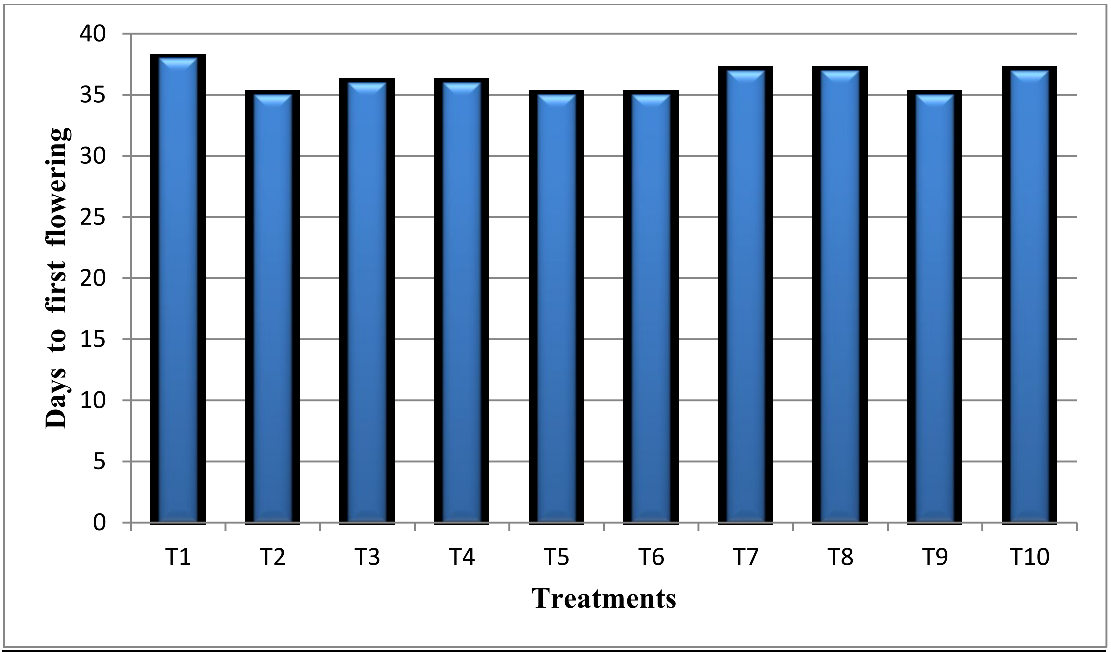


Fig. 3. Effect of application of Mg and B on days to first flowering

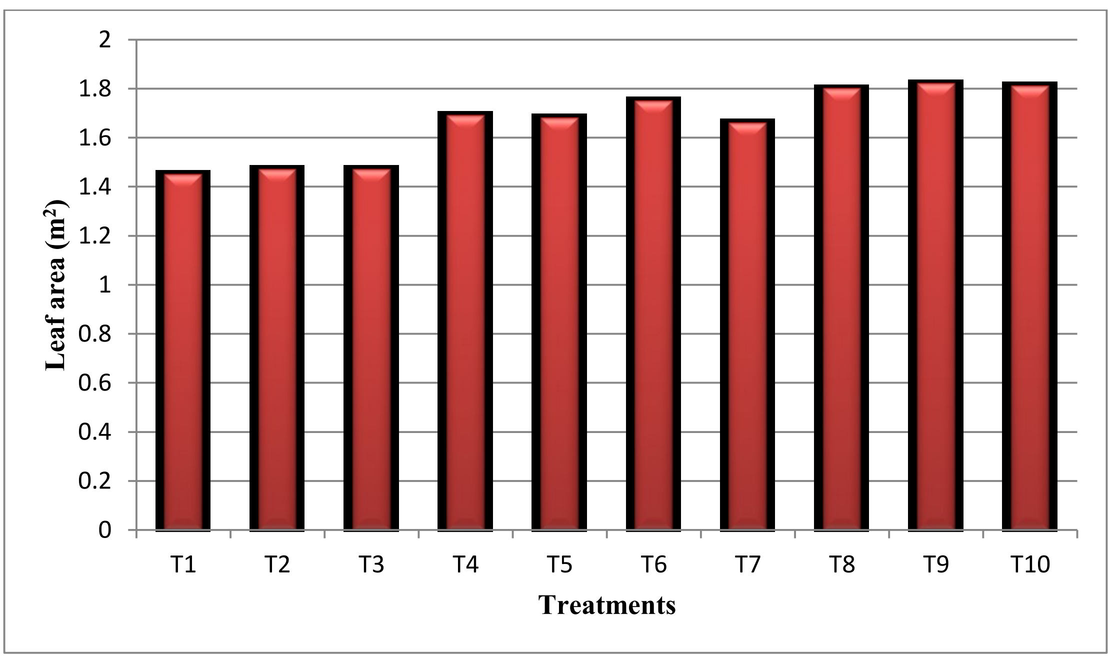


Fig. 4. Effect of application of Mg and B on leaf area

synergistic effect of B on N and P, and Mg on P, which are mostly responsible for initial root development and vegetative growth of plants. Lopez-Lefebre *et al*. (2002) stated that increased B application exerted positive effect on dry material production in the roots and leaves and could be explained by the general improvement in the nutritional state, particularly N and P. Similarly, Ruiz. *et al*. (2001) also reported that increase in foliar biomass in B treatment was due to the stimulation of nitrate (NO_3) assimilation, which resulted in vigorous growth of leaves. Similarly Mg is involved in all phosphorylation processes serving transfer and conversion of energy and ATP production (Aikawa, 1981) which also contributed to enhanced growth.

Mg and B applied plants recorded higher number of primary branches (Fig. 5) also compared to the plants which did not receive Mg and B. Sood and Sharma (2004) reported that boron acts as a catalyst in plant metabolism and ultimately contributes towards the growth of the plant. The increase in number of branches due to boron fertilization was also reported by Schon and Blevins (1990).

The application of magnesium might have increased the chlorophyll content and photosynthetic rate of the plants. This coupled with the influence of boron on the enzyme system and metabolism of the plant might have resulted in more number of leaves, leaf area and branches. The role of Mg and B in cell differentiation and development, translocation of photosynthates and growth regulators from source to sink also contributed to the above parameters. Similar results were reported by Mostafa *et al.* (2007).

5.2. YIELD CHARACTERS OF YARD LONG BEAN AS INFLUENCED BY MODE AND TIME OF APPLICATION OF MAGNESIUM AND BORON

The effect of treatments on yield characters like pod length, pod weight, number of harvest, productive duration, crop duration, yield per plant, yield per plot, bhusa yield, total dry matter production, harvest index were found to be significant.

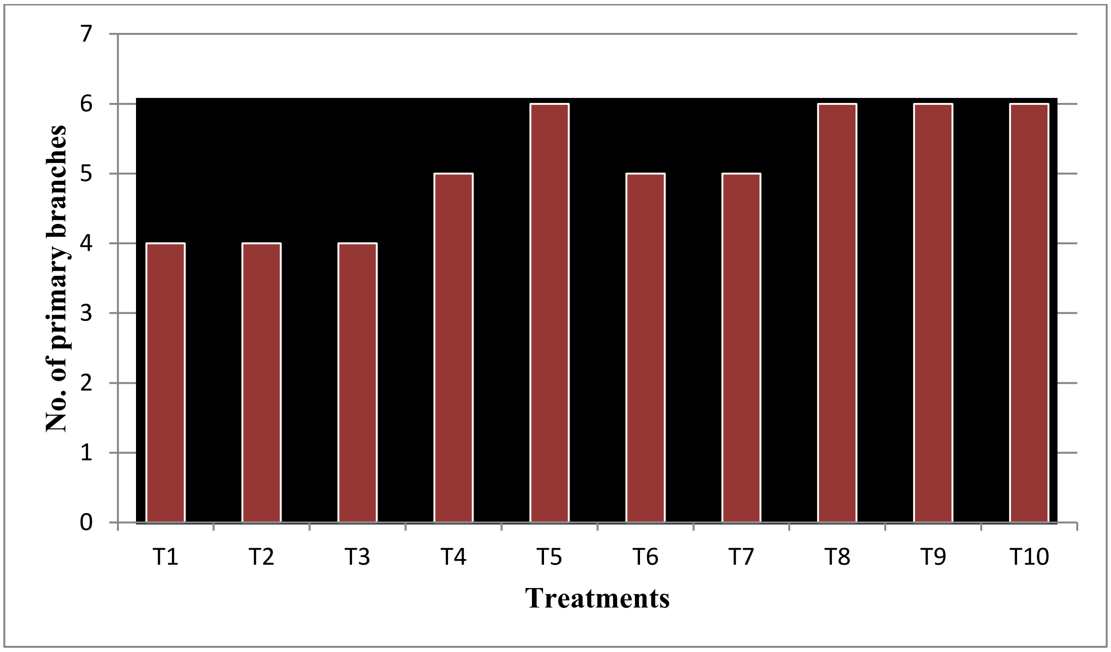


Fig. 5. Effect of application of Mg and B on primary branches

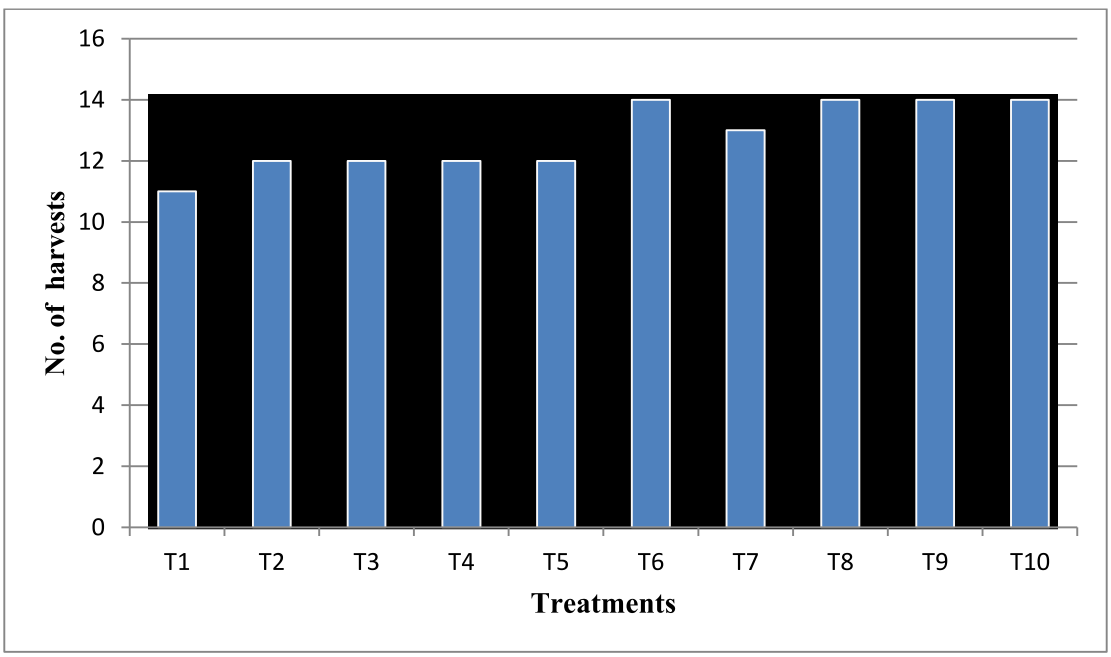


Fig. 6. Effect of application of Mg and B on number of harvests

All the Mg and B treated plants got more number of harvests and productive duration compared to those without Mg and B in T_1 as evidenced from the Fig. 6 and 7. Other characters like pod length, pod weight, pod yield, bhusa yield, total dry matter, harvest index were the highest in T_9 in which Mg and B were applied at fortnightly intervals as foliar spray and soil test based package of practices recommendations (Figs. 8, 9, 10, 11, 12 and 13). The highest pod yield (10052 kg ha^{-1}) shown in Plate. 2 was recorded in T_9 and it was on par with T_8 which received foliar application of Mg and B twice at first flowering and active flowering and soil test based package of practices recommendation.

Involvement of boron in hormone synthesis and translocation, carbohydrate metabolisms and DNA synthesis probably contributed to additional growth and yield (Kalyani *et al*., 1993). Boron increases flower production and retention, pollen tube germination and seed and fruit setting (Oosterhuis, 2001). Boron is also functionally associated with one or more of the processes of calcium utilization, cell division, carbohydrate and nitrogen metabolism (Fageria *et al.,* 2007).

The enhancement in yield and yield characters might also be due to the important role of magnesium on chlorophyll molecule structure that regulates photosynthesis (Jones *et al.,* 1991; Purohit, 2007; Spiegel-Roy and Goldschmidt, 2008). Also, the increase in the amount of magnesium application leads to an increase in leaf total chlorophyll content and consequently photosynthesis level was increased (Bybordi and Shabanov, 2010). So that, the enhancement effect on chlorophyll was reflected in more carbohydrates production through photosynthesis process and increasing vegetative growth and consequently improved fruit set percentage, retained fruit percentage, yield and yield attributes.

The increased photosynthesis due to the application of Mg and B enhanced the total dry matter production and resulted in the uptake of nutrients. If a plant nutrient is involved in improving the vegetative growth it would certainly improve

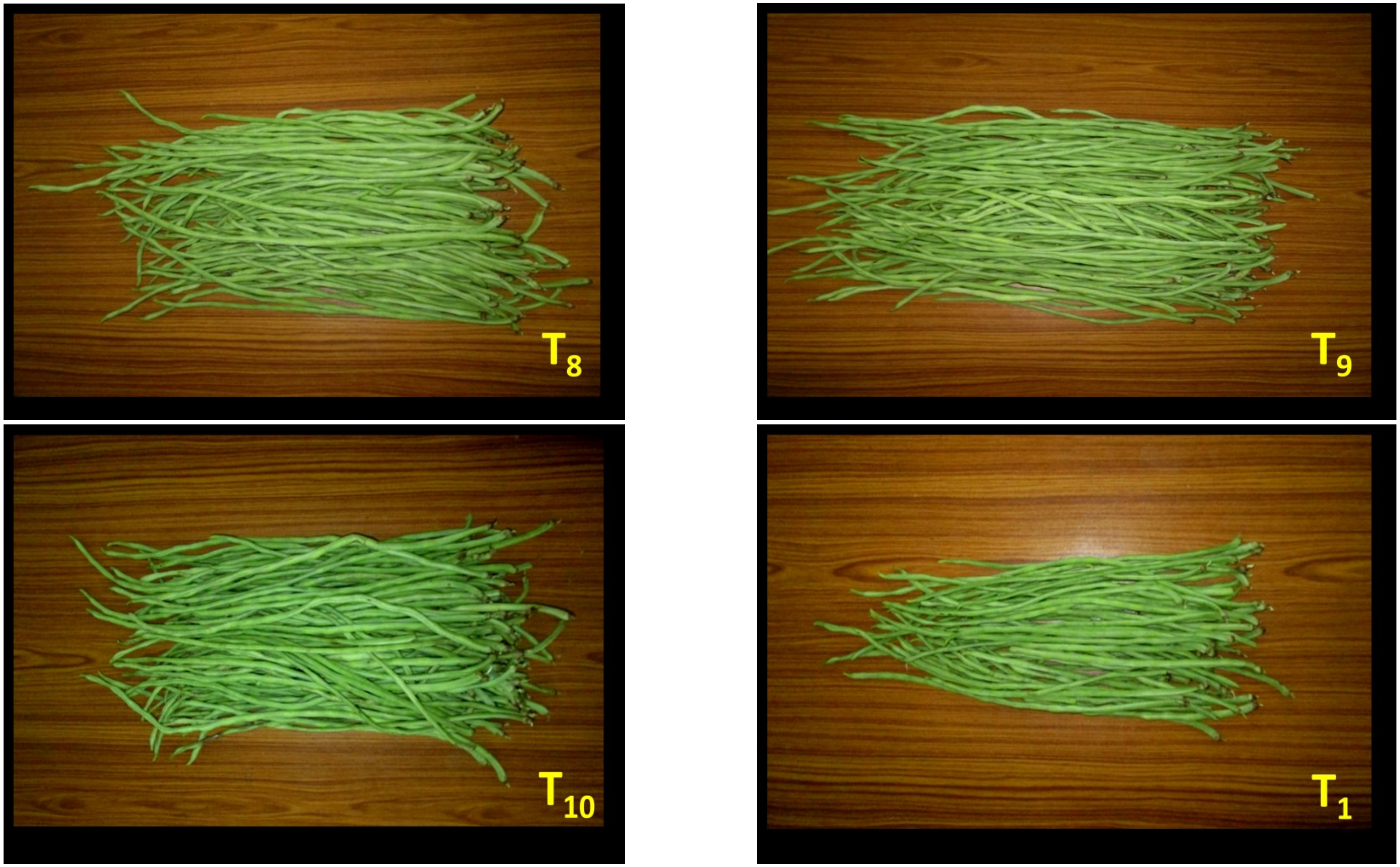


Plate 2. Effect of treatments on pod yield

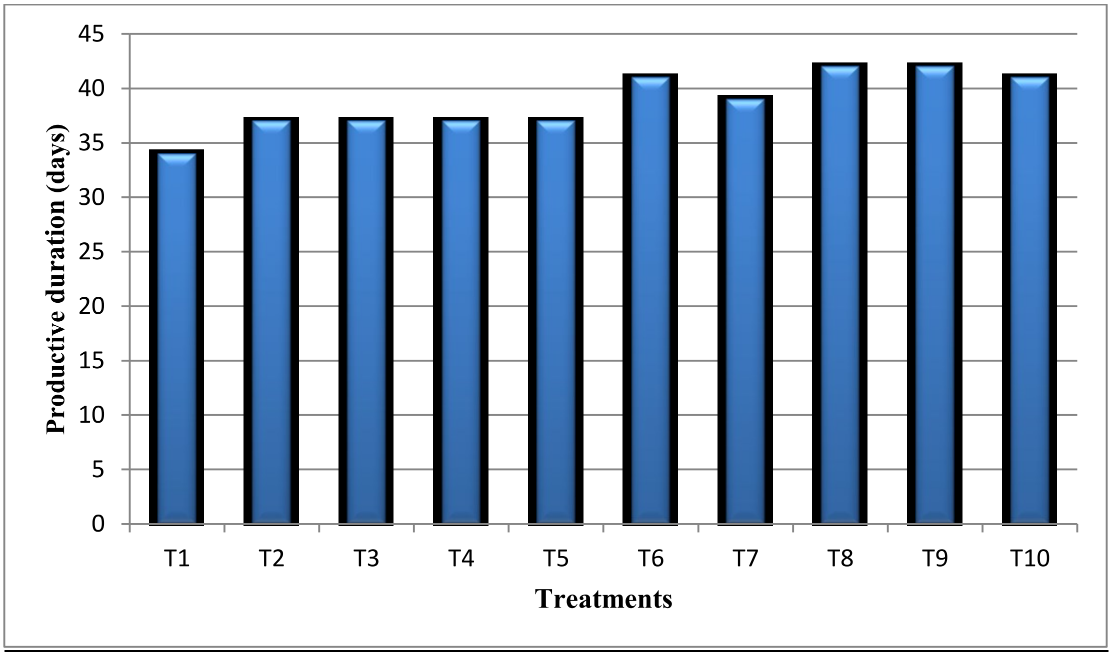


Fig. 7. Effect of application of Mg and B on productive duration

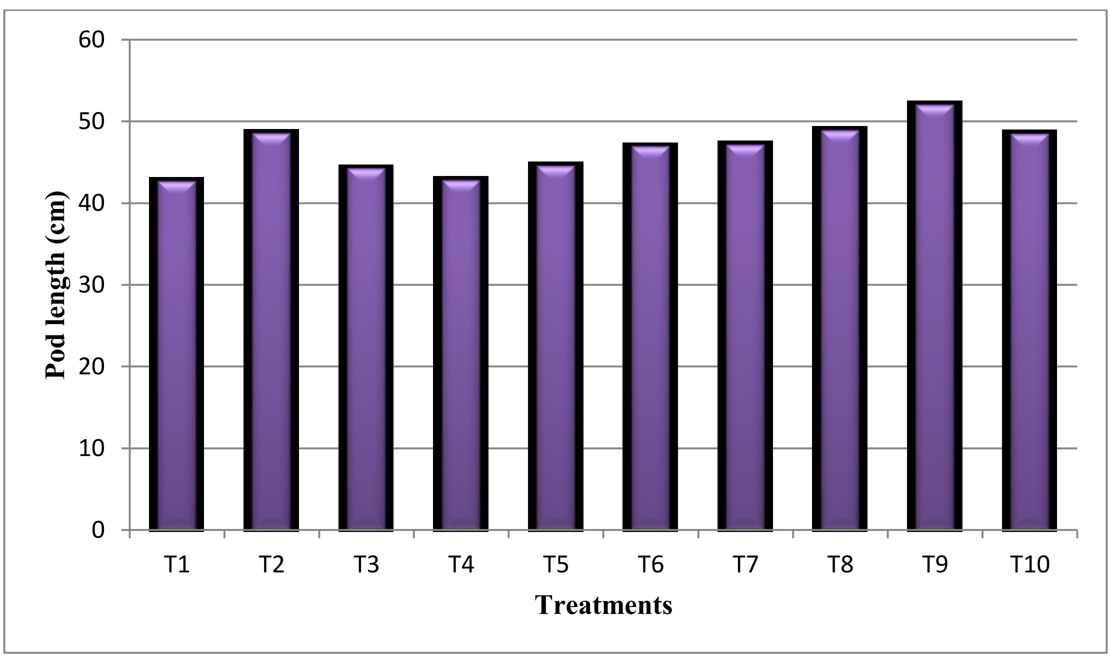


Fig. 8. Effect of application of Mg and B on pod length

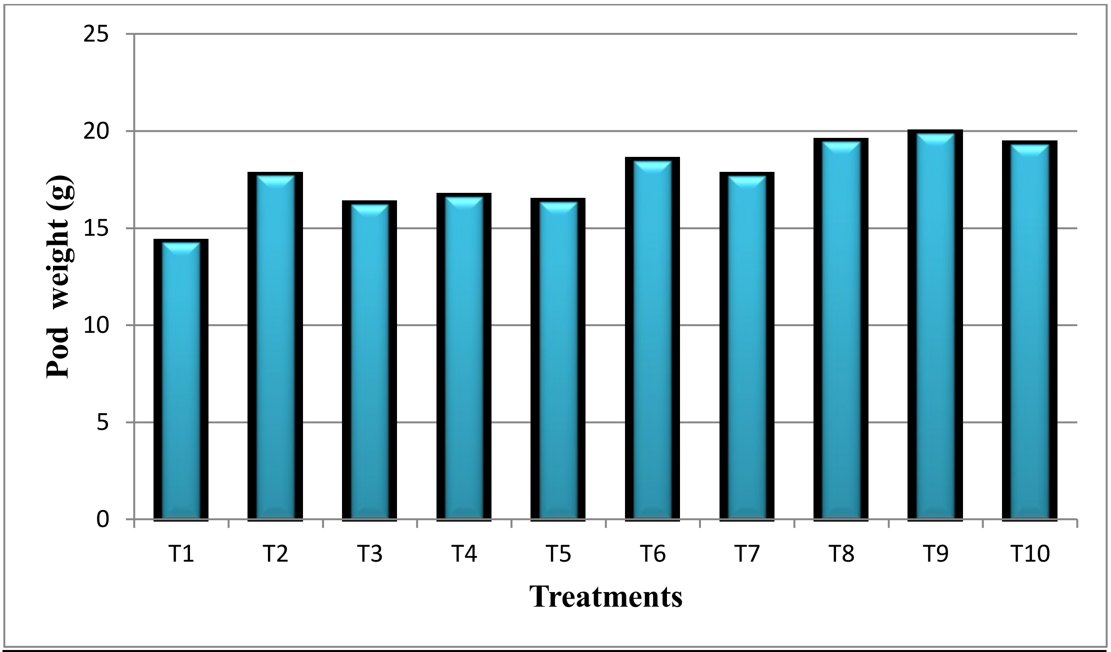


Fig. 9. Effect of application of Mg and B on pod weight

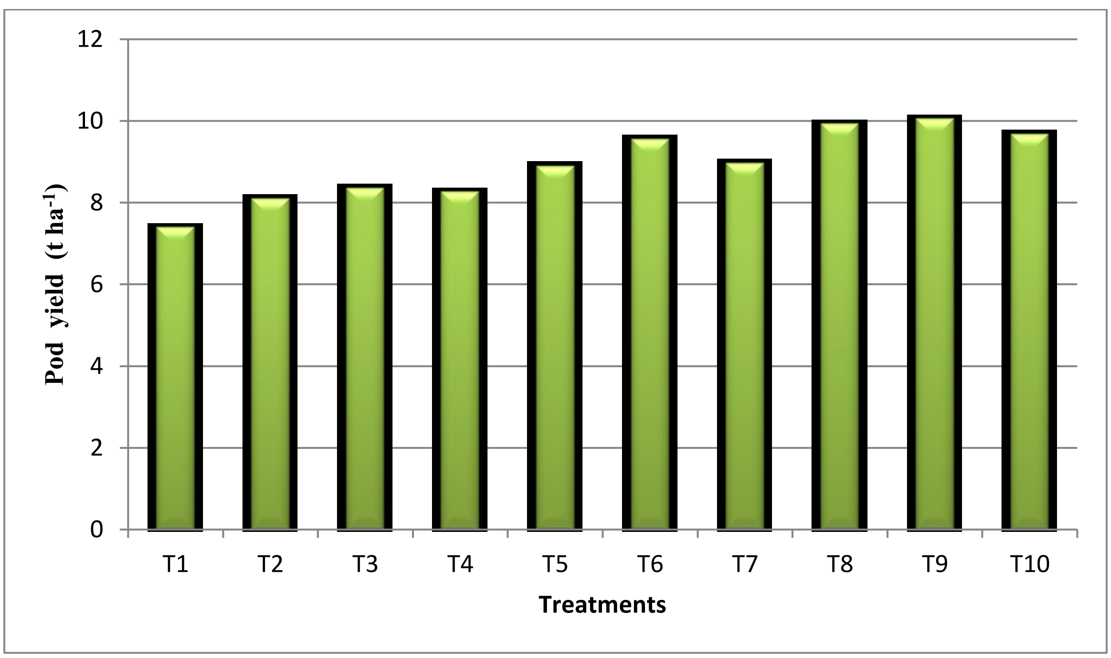


Fig. 10. Effect of application of Mg and B on pod yield of yard long bean

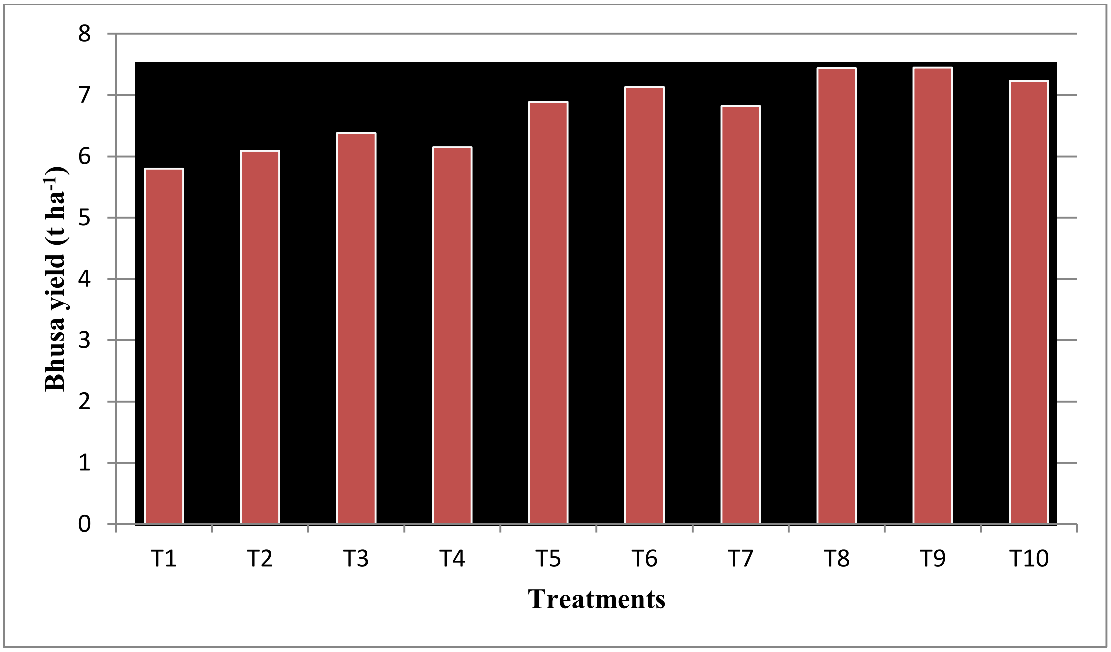


Fig. 11. Effect of application of Mg and B on bhusa yield of yard long bean

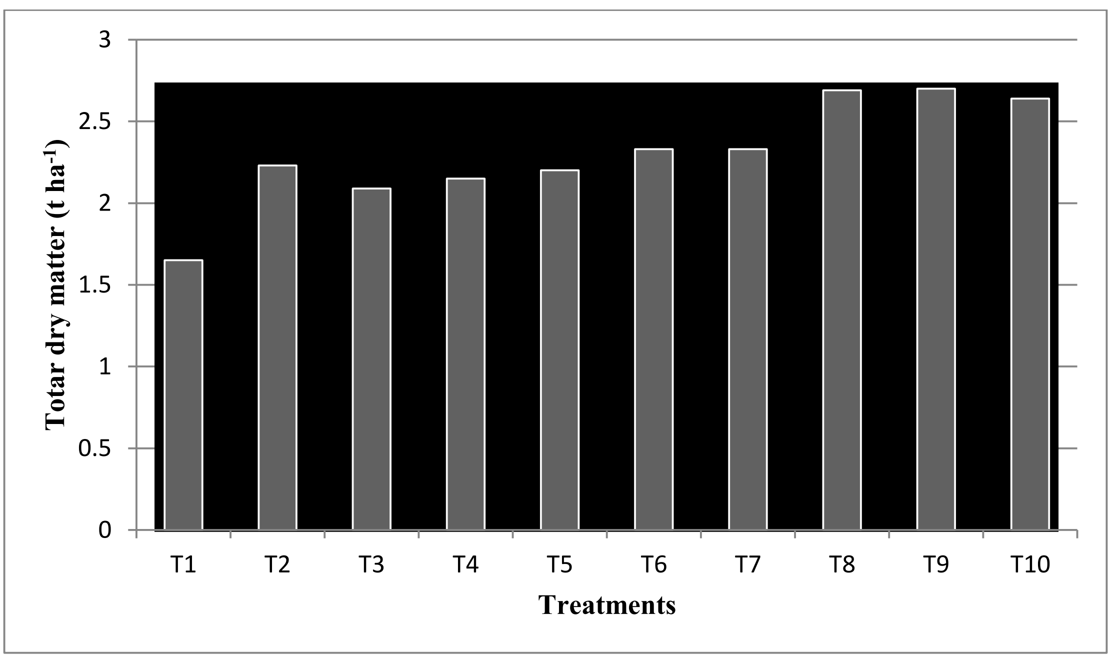


Fig. 12. Effect of application of Mg and B on total dry matter production

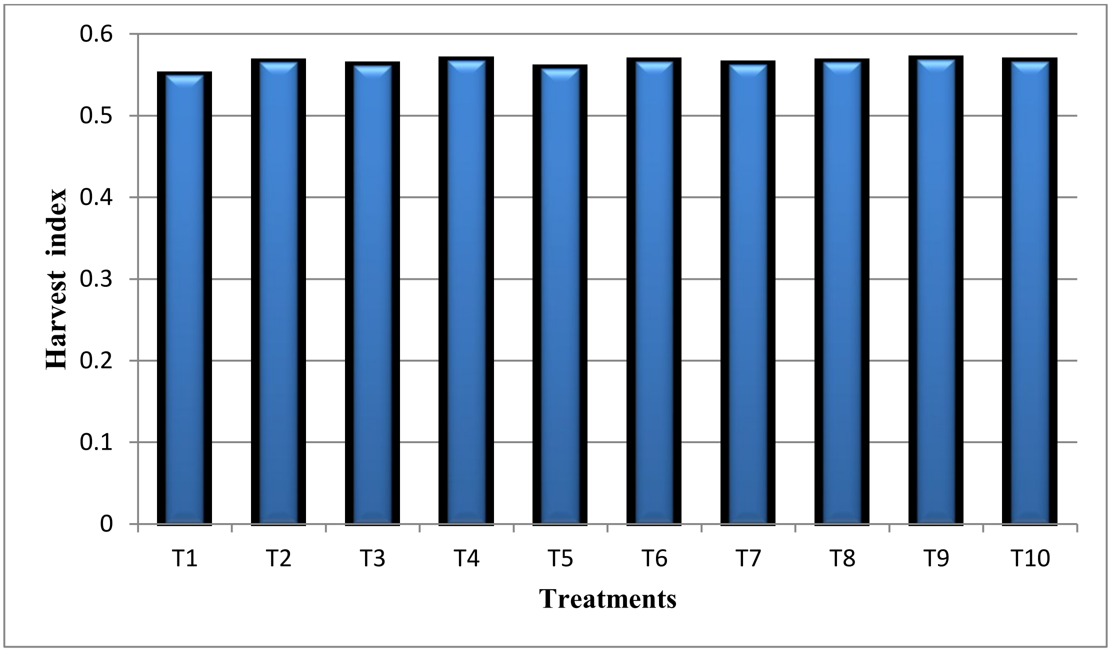


Fig. 13. Effect of application of Mg and B on harvest index

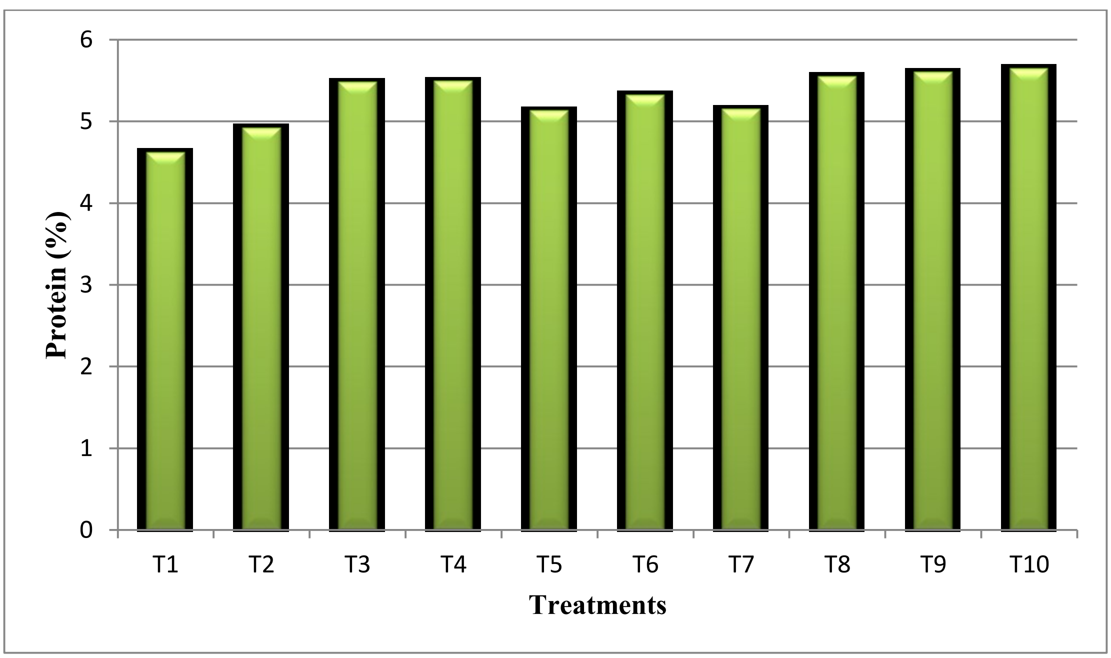


Fig. 14. Effect of application of Mg and B on content of protein in the pod of yard long bean

the uptake of all the nutrients which are required to maintain the growth. Since the application of Mg and B helped to improve the overall growth of the crop, it increased the total uptake although the magnitude of increase depends on the concentration and dry matter accumulation. Similar results were reported by Karthikeyan and Shukla (2008). The positive effect of magnesium fertilization on vegetative growth parameters are in harmony with those obtained by El-Kader *et al*. (1990), Turner and Barkus (1983) and Guiller (1965) on different banana varieties.

5.3. QUALITY CHARACTERS OF YARD LONG BEAN AS INFLUENCED BY MODE AND TIME OF APPLICATION OF MAGNESIUM AND BORON

Treatments had a significant effect on the protein content of pod of yard long bean (Fig. 14). The highest protein content (5.65%) was observed in T_{10} which received half dose of Mg and B as basal followed by foliar at active flowering and soil test based package of practices recommendation and it was on par with T_9 (5.60%), T_8 (5.55%), T_4 (5.49%), T_3 (5.48%) and T_6 (5.32%). This significant rise in protein content is probably due to the vital role that boron plays in protein and nucleic acid metabolism (Debnath and Ghosh, 2011). Similar results have been observed by Ganie *et al*. (2014) in french bean (*Phaseolus vulgaris* L.). Similar findings were also reported by Sauchelli (1969) and Noor *et al*. (1997). This might also be as a result of the mineralization of magnesium sulphate by microorganisms in the soil and its mobilization thus enhancing magnesium and sulphur uptake and translocation of phosphorus all of which, particularly sulphur, play important role in protein synthesis. This reason corroborated the report of Klacan and Berger (1963) that magnesium sulphate fertilizer increased uptake of magnesium, sulphur, translocation of phosphorus and consequently its amino acid profile in canning pea. Mg is a cofactor and activator of many enzymes which facilitate various metabolic activities like biosynthesis of proteins and energy metabolism. 300 enzyme reactions are influenced by Mg^{2+}.

Application of magnesium and boron did not exert any significant effect on fibre content in pod. The reason being that genetic and environmental factors exert so much influence on fibre quality that little effect from boron and magnesium nutrition. Similar reports were observed by Abid *et al*. (2007) in cotton (*Gossypium hirsutum* L.).

5.4. EFFECT OF TREATMENTS ON BENEFIT - COST RATIO

Net return was increased with the application of Mg and B. Significantly higher benefit-cost ratio (2.27) was obtained with the application of soil test based NPK and farm yard manure along with foliar application of 0.25 per cent borax and 2 per cent magnesium sulphate twice at first flowering and active flowering (T_8) and the lowest (1.79) from T_1 in which Mg and B were not included (Fig. 15). This result shows that the application of Mg and B significantly influenced on the yield of yard long bean and ultimately increases the benefit.

5.5. SOIL pH AND AVAILABLE NUTRIENTS IN SOIL AFTER HARVEST OF YARD LONG BEAN AS INFLUENCED BY MODE AND TIME OF APPLICATION ON MAGNESIUM AND BORON

5.5.1. Soil pH

The treatments could not show any significant effect on soil pH. Application of Mg and B increased the pH of soil from extremely acid to strongly acid range (4.4-5.3). This shows a positive but non significant influence of sources of Mg and B on the soil pH.

5.5.2. Primary nutrients

Application of Mg and B did not show any significant effect on available N and P in the soil.

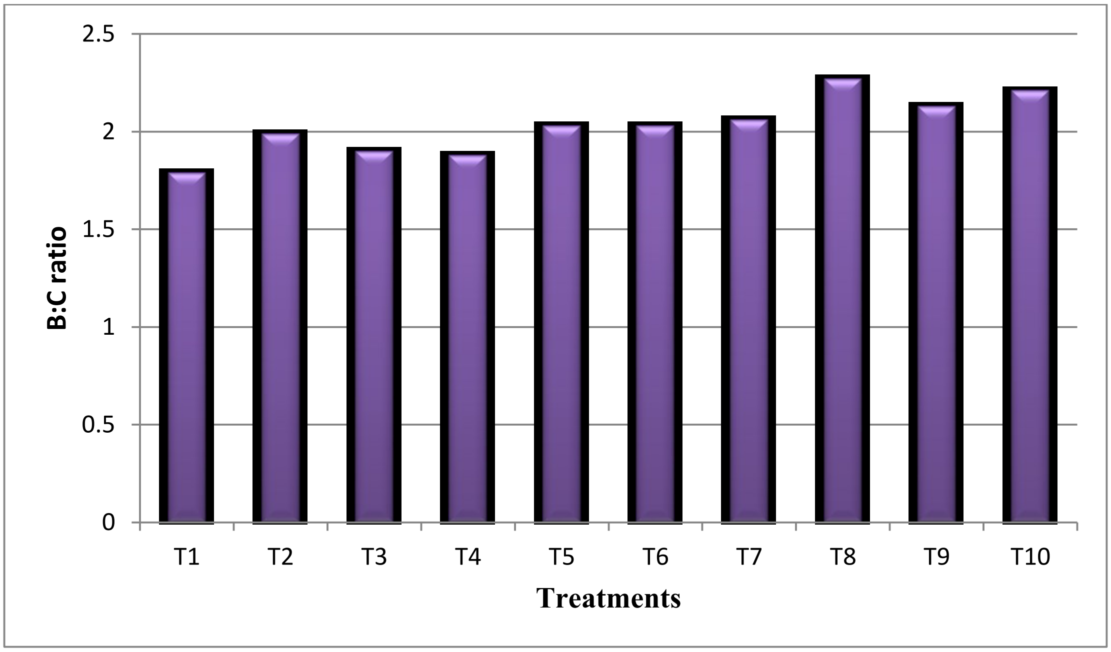


Fig. 15. Effect of application of Mg and B on Benefit: Cost ratio

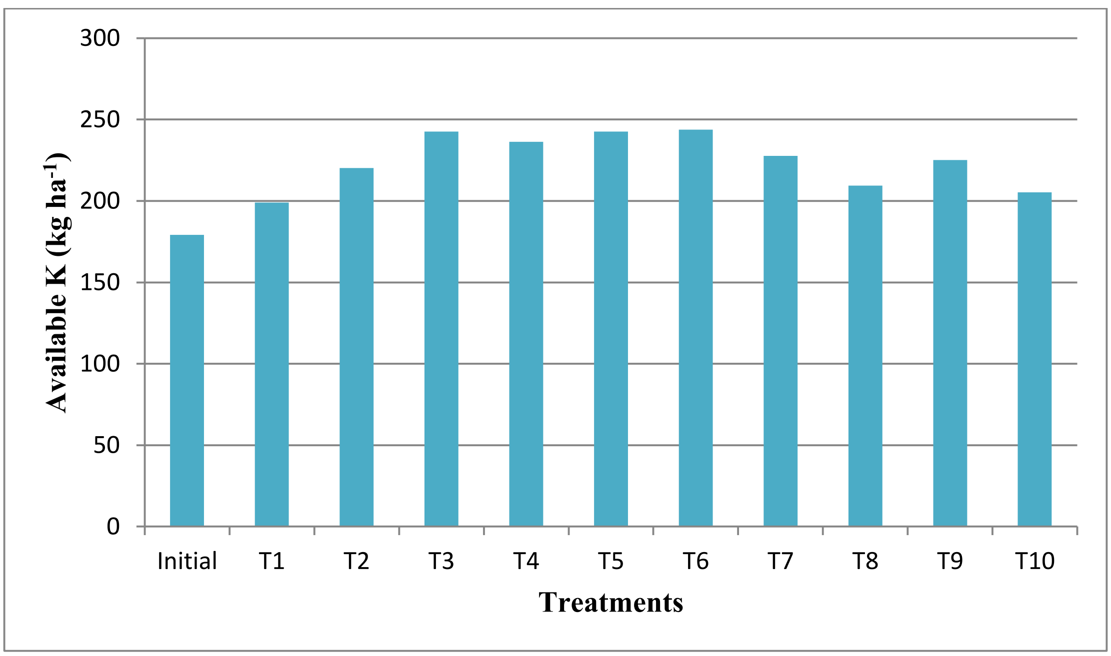


Fig. 16. Available K in soil after harvest of yard long bean as influenced by mode and time of application on Mg and B

The available K in soil was significantly influenced by the application Mg and B (Fig. 16). Soil application of Mg and B at fortnightly intervals recorded the highest available K (243.73 kg ha^{-1}) in soil. This indicates a positive influence of both Mg and B on K availability. Similar results were reported by Barman *et al.* (2014) ; Sun *et al*. (2006) and Hannaway *et al.* (1982).

5.5.3. Secondary nutrients

Available Ca in the soil after the experiment was not significantly influenced by the treatments.

The availability of Mg in soil was significantly influenced by the treatments. Soil application of Mg and B at fortnightly intervals recorded the highest Mg content in soil. Critical level of Mg (more than 120 ppm) for sufficiency in Kerala soil was attained in all soil application treatments (Fig. 17). Therefore after meeting the requirement of the crop, the added Mg might have helped to increase the available Mg status of the soil from the deficiency to sufficiency level for these treatments. These findings are in line with those reported by Hardter *et al.* (2003). The available Mg remained deficient in the treatments which received foliar application of Mg and B and soil test based package of practices recommendations.

The highest available S also was observed in the treatment T_6. This indicates a positive influence of magnesium and boron on the availability of sulphur in the soil (Fig. 18). The application of magnesium and boron might have helped in better mineralization of organic form of sulphur present in the soil which in turn would have contributed to the enhanced available sulphur in the soil. The sulphate from magnesium sulphate applied might have also contributed to the available sulphur. Similar results were also reported by Havlin *et al.* 2004 and Barman *et al*. 2014.

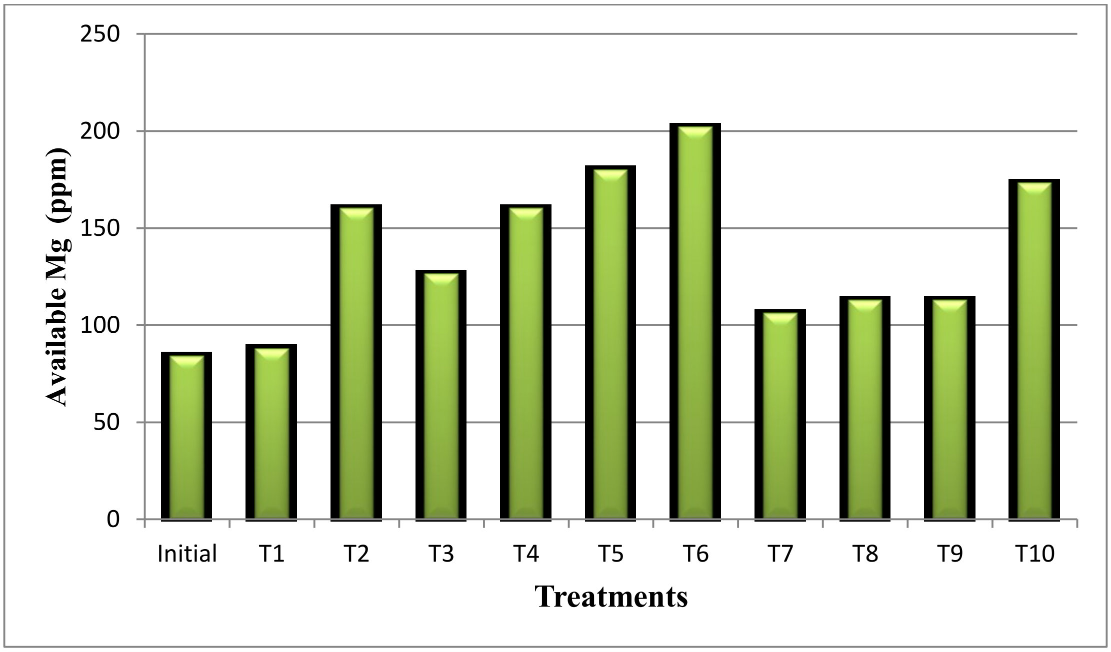


Fig. 17. Available Mg in soil after harvest of yard long bean as influenced by mode and time of application on Mg and B

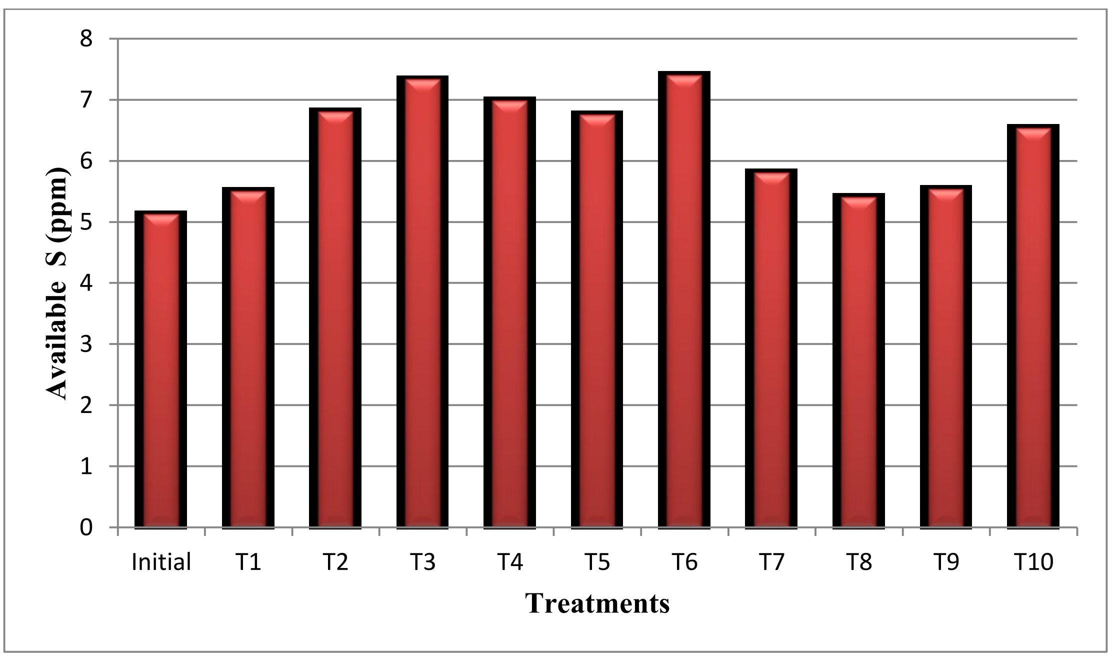


Fig. 18. Available S in soil after harvest of yard long bean as influenced by mode and time of application on Mg and B

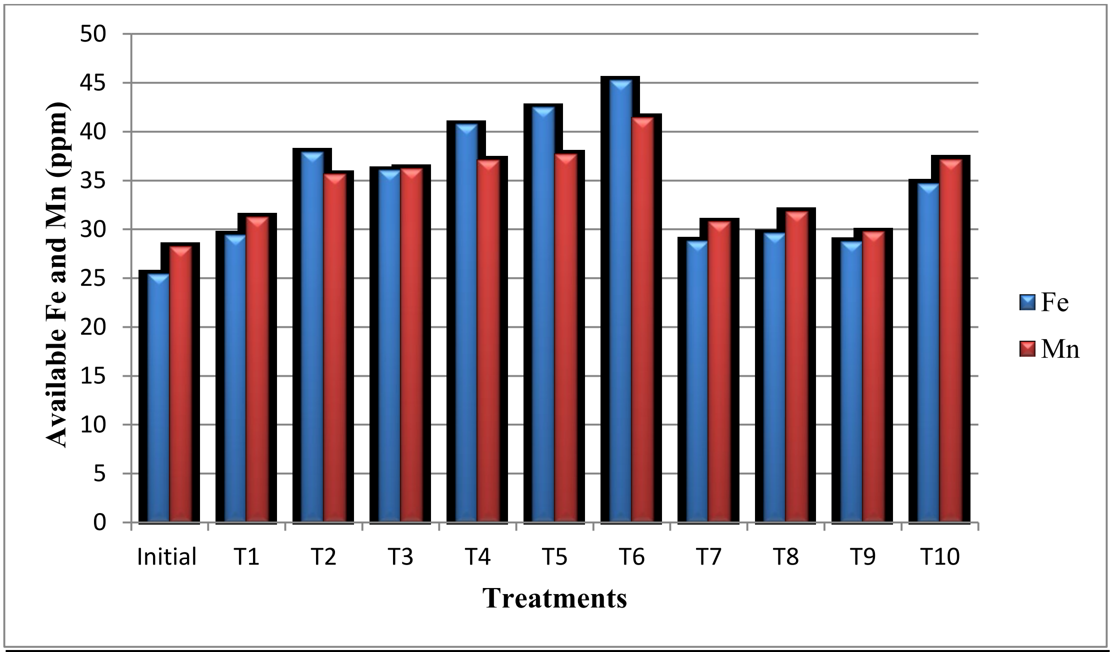


Fig. 19. Available Fe and Mn in soil after harvest of yard long bean as influenced by mode and time of application on Mg and B

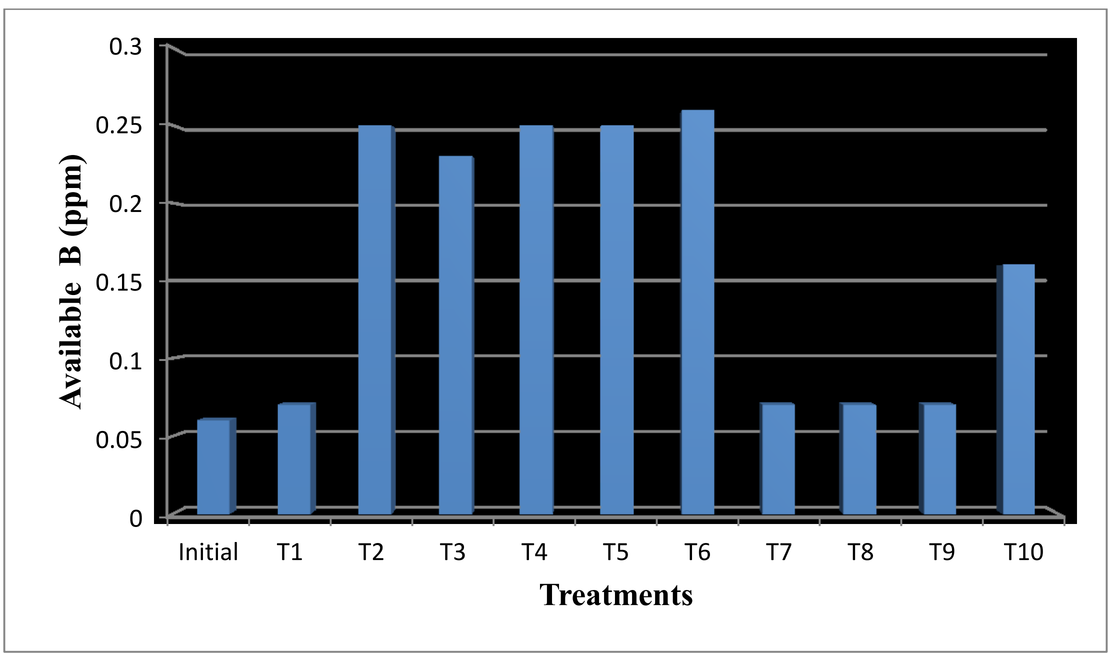


Fig. 20. Available B in soil after harvest of yard long bean as influenced by mode and time of application on Mg and B

5.5.4. Micronutrients

Availability of micronutrients in general in soil was increased after the experiment. Available Fe, Mn, Zn and Cu in the soil did not show a definite pattern of variation among treatments even though the available Fe and Mn were significantly influenced by the treatments (Fig. 19).

Treatments had a significant effect on available B in soil (Fig. 20). Highest B content was observed in the treatment T_6 which received soil application of Mg and B at fortnightly intervals in equal splits and soil test based package of practices recommendations. Critical level of sufficiency (more than 0.5 ppm) was not attained either through soil or foliar application. This is attributed to high rainfall (Fig. 1) during the experimental season which had contributed to leaching loss of B, owing to its mobility in soil. Compared to foliar application, soil application showed more B content soil.

5.6. EFFECT OF TREATMENTS ON NUTRIENT CONTENTS IN POD, WHOLE PLANT AND TOTAL UPTAKE

5.6.1. Nitrogen

The content of N in both the pod and whole plant of yard long bean were higher for the treatments received soil and foliar application of Mg and B. The highest content of nitrogen in both the pod and whole plant was observed in T_{10} which received half of adhoc recommendations of Mg and B as basal in combination with one foliar spray at active flowering and soil test based package of practices recommendations (Fig. 21 and Fig. 22). Kumar *et al.* (1981) observed synergistic effect between Mg and N in plants and reported an increase in N content with Mg application. Similarly boron fertilization showed positive effect on nitrogen content in mustard (Hossain *et al*., 2011). There was a positive relation between B and nitrogen metabolism as reported by Lopez *et al.* (2002). The role of Mg in

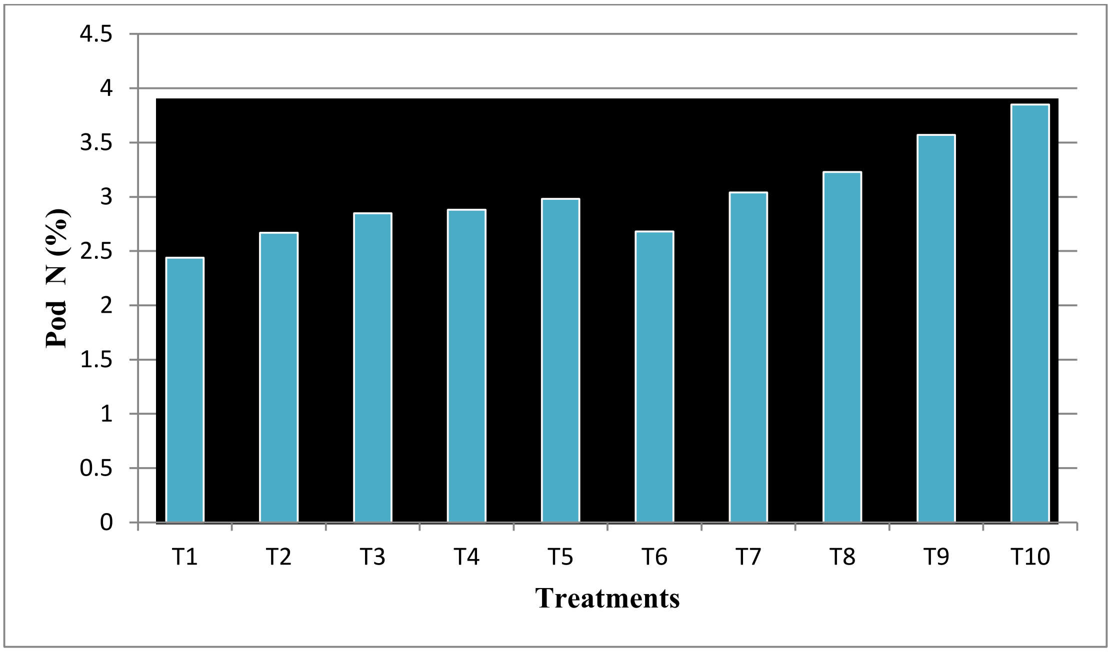


Fig. 21. Effect of treatments on contents of N in pod of yard long bean

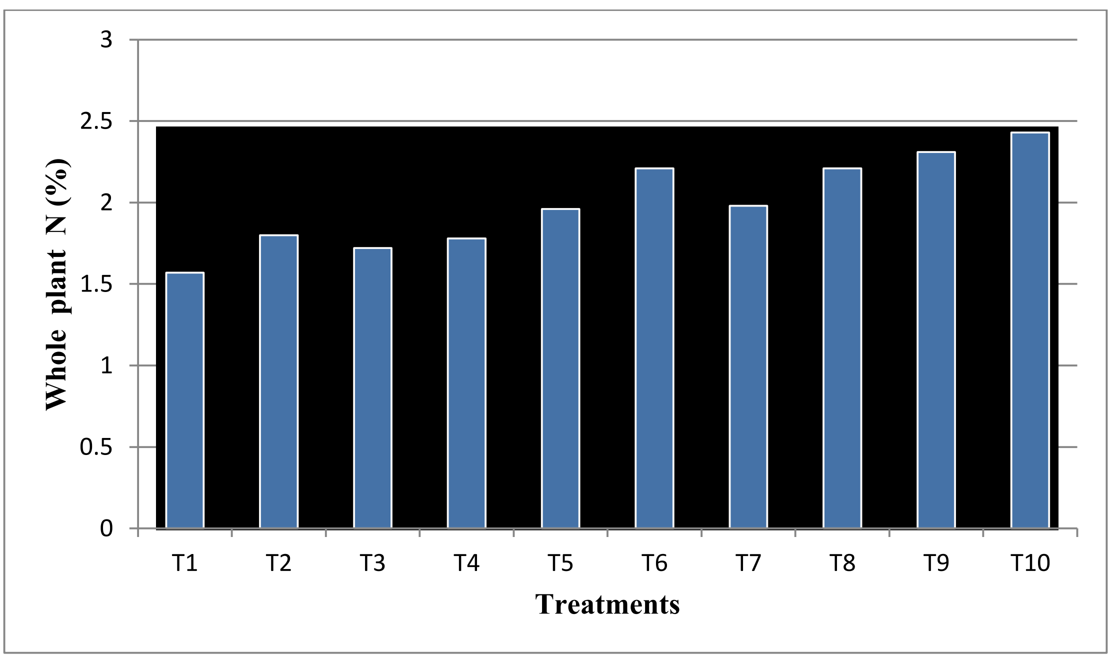


Fig. 22. Effect of treatments on content of N in whole plant after final harvest

chlorophyll formation and higher rates of photosynthesis might have also influenced the development of higher N content in plant. Similar results have also been reported by Dunn *et al.* (2005).

The impact of Mg and B application on nitrogen uptake was significant. The highest nitrogen uptake was recorded by treatment T_{10} (Fig. 25). An increase in nitrogen uptake by the application of Mg was reported by Ananthanarayana and Venkatarao (1982) also. Boron is an essential micronutrient for the development and functioning of nitrogen-fixing root nodules in legumes (Bolanos *et al.*, 1996; Rahman *et al.*, 1999; O'Hara., 2001). Boron and Magnesium are important nutrients for biological nitrogen fixation and it was also reported by Giller (2001), Adjei *et al.* (2002).

5.6.2. Phosphorus

There was a positive synergistic effect with magnesium and boron on the accumulation of phosphorus in pod and whole plant of yard long bean. Soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_6) and foliar application of Mg and B twice at first flowering and active flowering and soil test based package of practices recommendations (T_8) recorded the highest P content in pod (Fig. 23). The highest content of P in whole plant was in T_9 (Fig. 24). Positive interrelationship between P and Mg are expected since Mg is an activator of kinase and activates most reactions involving phosphate transfer and ATP production. These results suggest synergistic effect between Mg and P (Skinner and Mathew, 1990). Pollard *et al.* (1977) found that boron deficiency in corn and broad beans reduced the capacity for the absorption of phosphate, due to the reduced ATPase activity, which could be rapidly restored by the addition of boron. The evidence suggested that B functions in the regulation of plant membranes and that the ATPase is a possible component of transport processes.

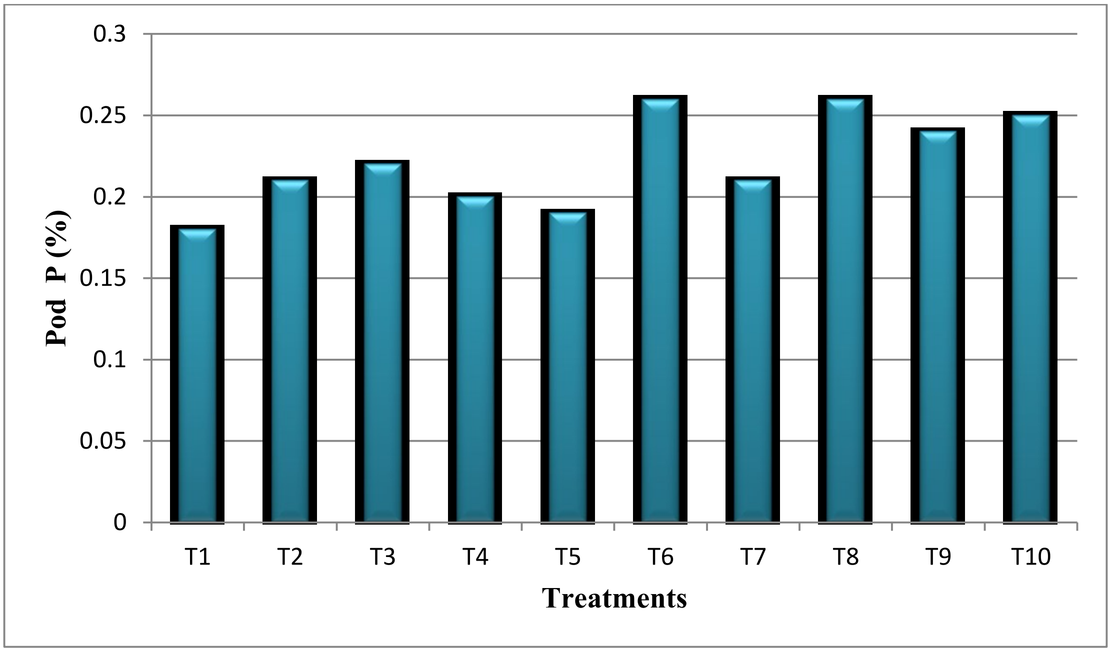


Fig. 23. Effect of treatments on contents of P in pod of yard long bean bean

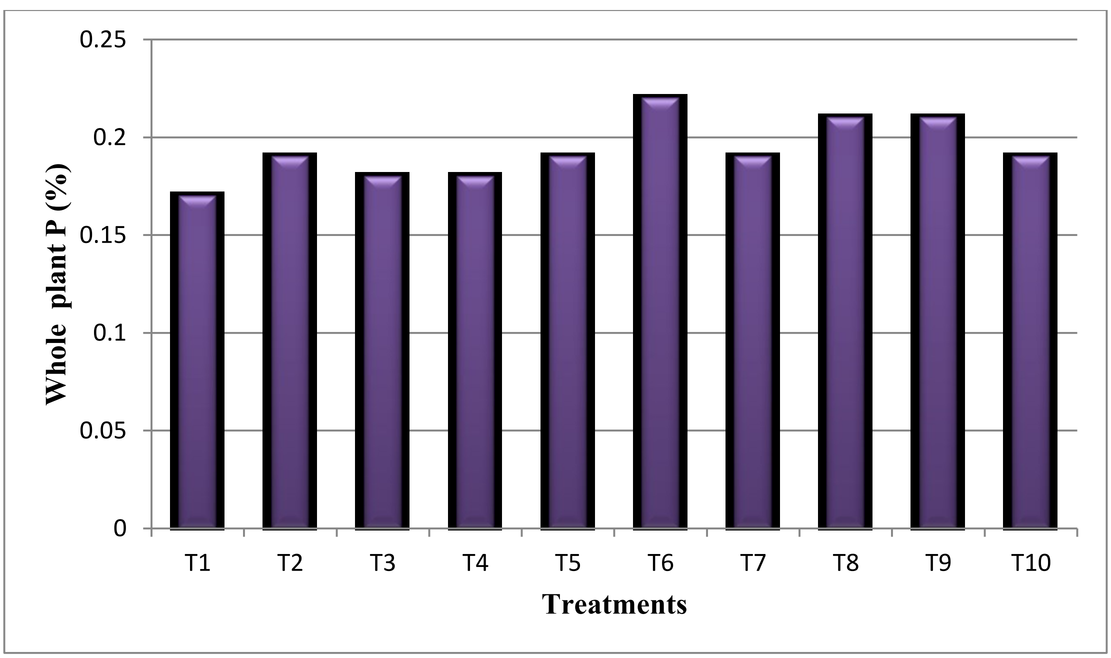


Fig. 24. Effect of treatments on content of P in whole plant after final harvest

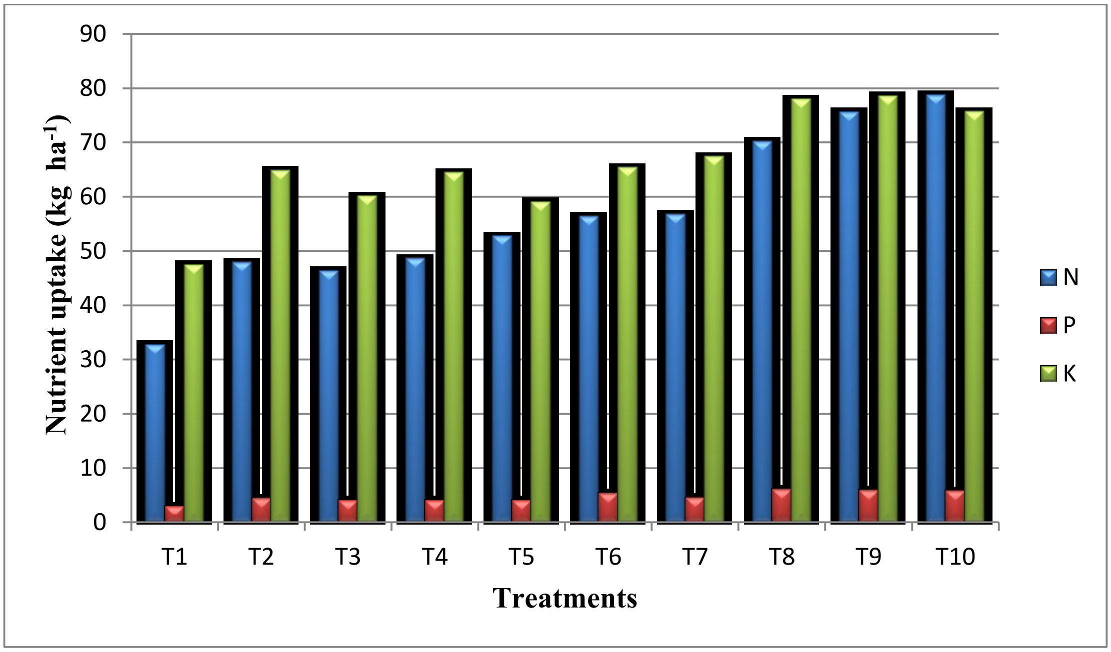


Fig. 25. Effect of treatments on crop uptake of primary nutrients

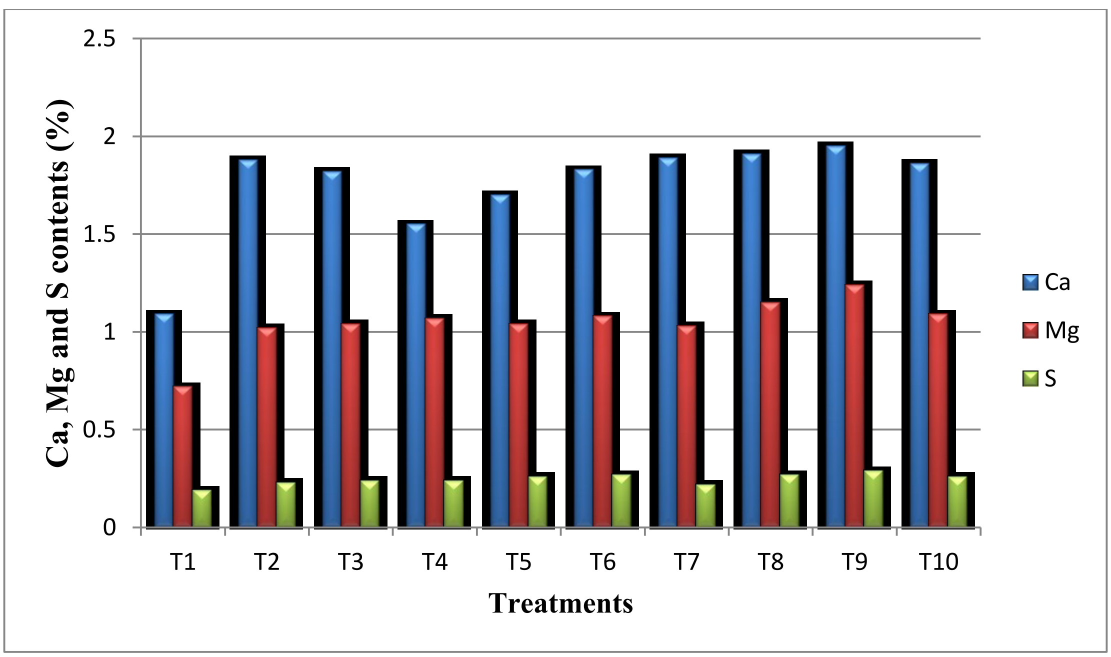


Fig.26. Effect of treatments on contents of Ca, Mg and S in pod of yard long

Application of Mg and B had significant variation in relation to phosphorus uptake by yard long bean. The highest phosphorus uptake (6.12 kg per hectare) was achieved by the application of Mg and B twice at first flowering and active flowering (Fig. 25). Ananthanarayana and Venkatarao (1982) also reported an increase in P uptake with magnesium application The effect of magnesium on phosphorus uptake was significant and a consistent increase in P utilization was recorded with increasing levels of Mg as reported by Biswas *et al.*(1995).

5.6.3. Potassium

There was no significant difference between the treatments in case of K concentration of both the pod and whole plant of yard long bean and it did not show a definite pattern of variation with respect to treatments.

The total uptake of K by yard long bean was significantly influenced by the treatment. Foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_9) recorded the highest K uptake (Fig. 25). Prabhakumari (1998) observed synergistic nutrient interaction between B and K in coconut. Singh *et al.* (2013) reported an increase in K uptake with Mg application in mustard.

The positive interaction of B with the uptake of N, P and K was reported by Rajkumar and Veeraraghavaiah (2002).

5.6.4. Calcium

The application of Mg and B showed highest calcium content in pod and whole plant of yard long bean compared to the plants which did not receive both the nutrients. The highest content of Ca in the pod (1.24 %) was found when Mg and B applied at fortnightly intervals as foliar spray (T_9) as evidenced from the Fig. 26. Soil application of half adhoc recommendation of Mg and B as basal in combination with one foliar spray at active flowering and soil test based package of practices recommendations (T_{10}) recorded the highest value of 2.02 per cent in whole plant (Fig.27). Regarding the similarity of B functions to other plant nutrients, Ca-B relationship is outstanding. Boron tends to keep Ca in a soluble form within the plant: effects are probably on a tissue basis rather than on a cellular basis (Wallace, 1961). The results of Ramon *et al.* (1990) also suggested that B deficiency has a specific effect on Ca translocation and incorporation into an insoluble form ie., as cell wall components. A synergistic relationship was observed between B and Ca by Bonilla *et al.* (1995). Positive effect of B on Ca translocation and accumulation was reported by Neumann and Davidov (1993) also. Application of B to apple trees low in B was shown to increase the mobility of Ca in the plant (Shear and Faust, 1971).

A significant rise in the uptake of Ca by yard long bean crop was also noted due to Mg and B application. The highest Ca uptake (51.75 kg ha^{-1}) recorded by T_9 (Fig. 28).

5.6.5. Magnesium

The concentration of Mg in pod and whole plant of yard long bean increased significantly with magnesium and boron application. The highest magnesium content in pod was recorded by T_9 (Fig. 26) and whole plant was recorded by T_{10} (Fig. 27) . Venkataramana (2014) also reported an increase in Mg content in leaves of black pepper (*Piper nigrum* L.) with the application of magnesium and boron. Gupta and Singh (1985) also reported an increase in Mg content with its application. This clearly indicates positive influence of treatments on magnesium nutrition of cowpea.

Results showed a significant increase Mg uptake in yard long bean in the treatments where Mg and B were applied as soil and foliar spray as compared to the treatment which received soil test based package of practices recommendations only (Fig. 28). Patel *et. al.* (1989) and Singh and Singh (1990) also reported an increase in Mg uptake with its application.

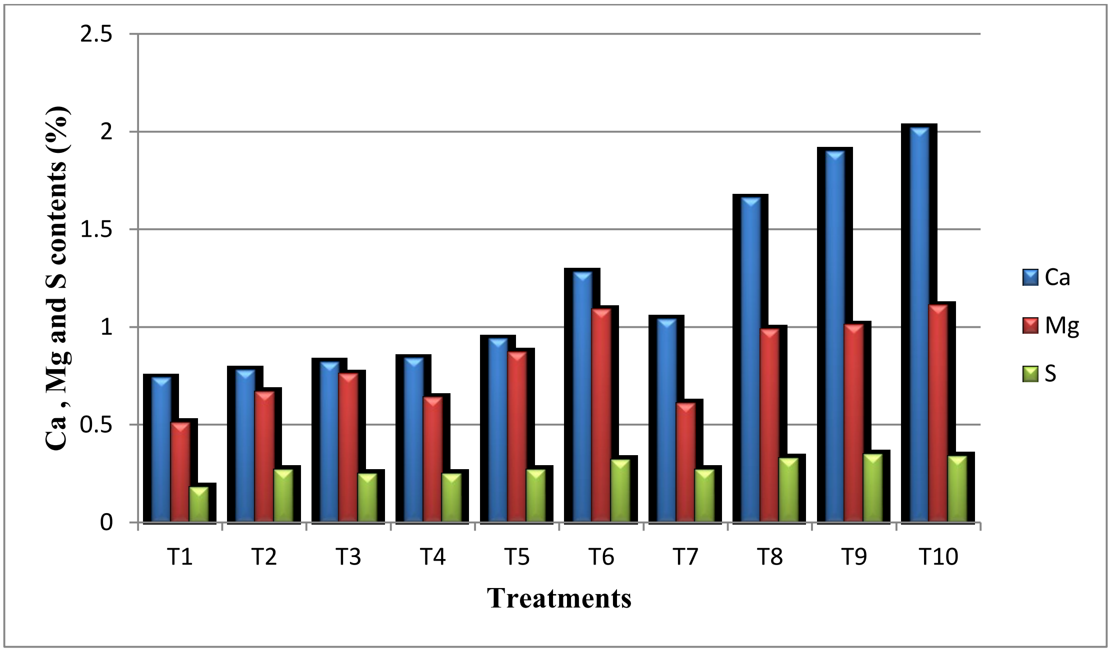


Fig. 27. Effect of treatments on content of Ca, Mg and S in whole plant after final harvest

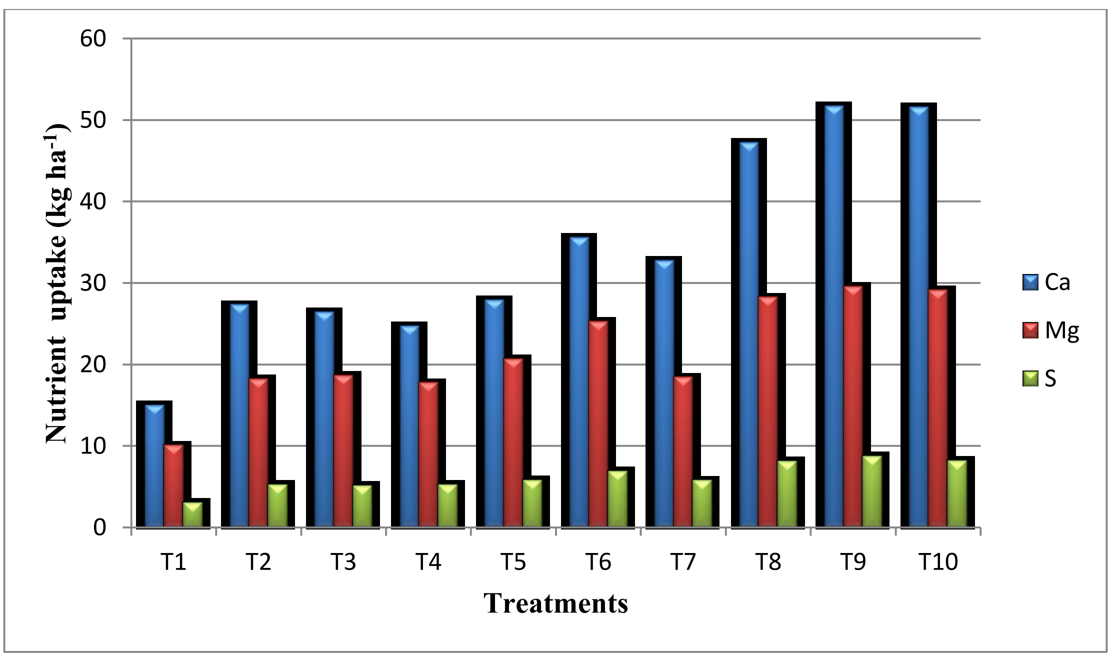


Fig. 28. Effect of treatments on crop uptake of secondary nutrients

5.6.6. Sulphur

The influence of the treatments on sulphur content in pod and whole plant was significant. The highest content of sulphur in both the pod and whole plant was observed in T_9 in which Mg and B were applied at fortnightly intervals as foliar spray and soil test based package of practices recommendation (Fig. 26 and Fig. 27). The availability of sulphur in soil was also high in the treatments which received Mg and B indicating a positive influence of Mg and B on sulphur nutrition. The sulphate present in Mg SO_4 might have also increased the sulphur content in plant as reported by Kirkby and Mengel (1976).

The highest S uptake (8.76 kg ha^{-1}) was found when Mg and B were applied at fortnightly intervals and the lowest from no Mg and B application (Fig. 28).

5.6.7. Fe, Mn, Zn and Cu

The impact of Mg and B application on content of Fe, Mn, Zn and Cu in the pod of Yard long bean were significant. The highest content of Fe was recorded where Mg and B were applied as basal (Fig. 29). Soil application of Mg and B in two equal splits as basal and top dressing recorded the highest content of Mn in the pod (Fig. 29). Application of Mg and B twice at first flowering and active flowering as foliar spray showed highest Cu content in pod of yard long bean (Fig. 31). Shirpurkar *et al.* (2006) also observed positive interaction between B and Fe, Mn, Zn.

The treatments did not show any significant effect on the content of Fe, Mn, Zn and Cu in whole plant. There was no definite pattern of variation in content of Fe, Mn, Zn and Cu with respect to treatments.

The uptake of Fe, Mn, Zn and Cu by yard long bean crop increased over control by the application of Mg and B (Fig. 30 and Fig. 33). Rajaie *et al.* (2009) observed that application of zinc and boron resulted in better plant growth and was

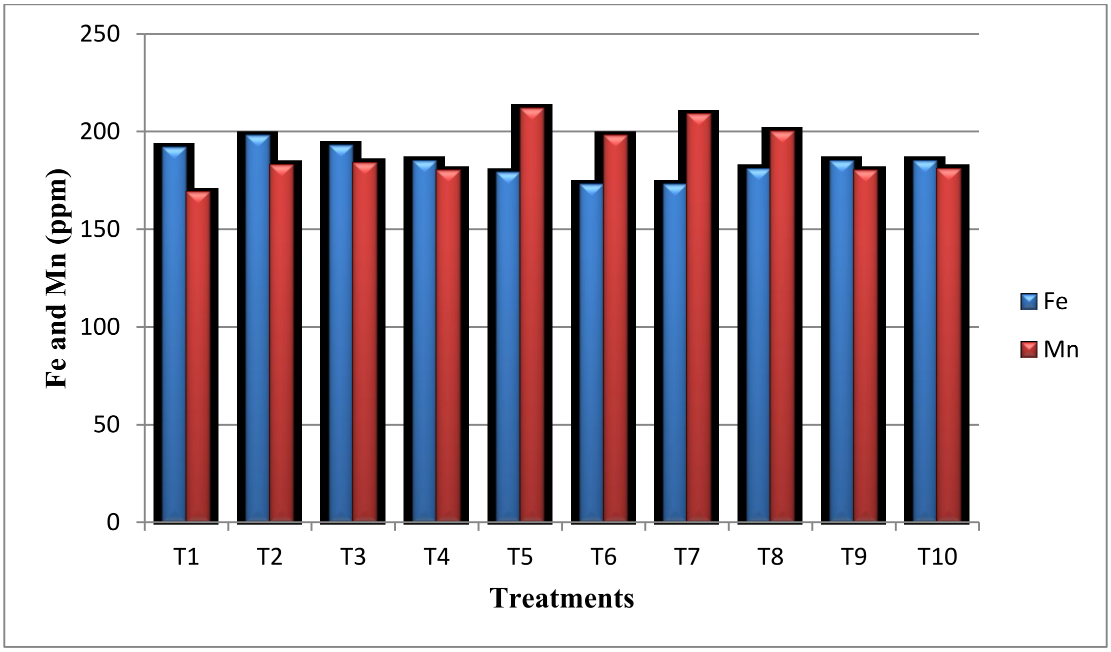


Fig. 29. Effect of treatments on contents of Fe and Mn in pod of yard long bean

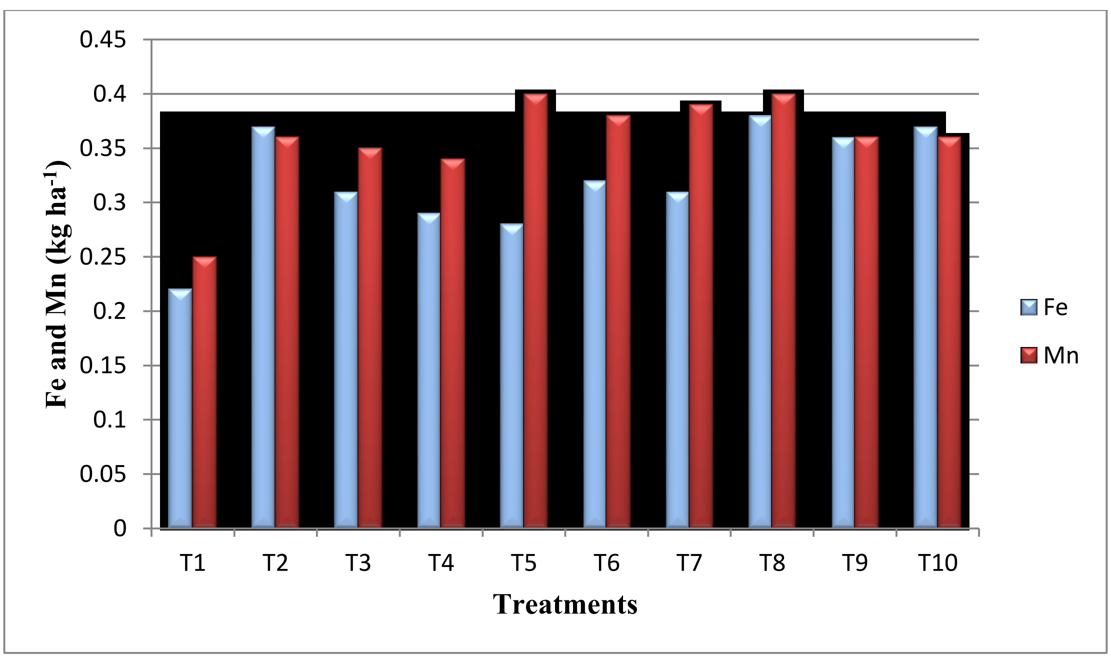


Fig. 30. Effect of treatments on crop uptake of Fe and Mn

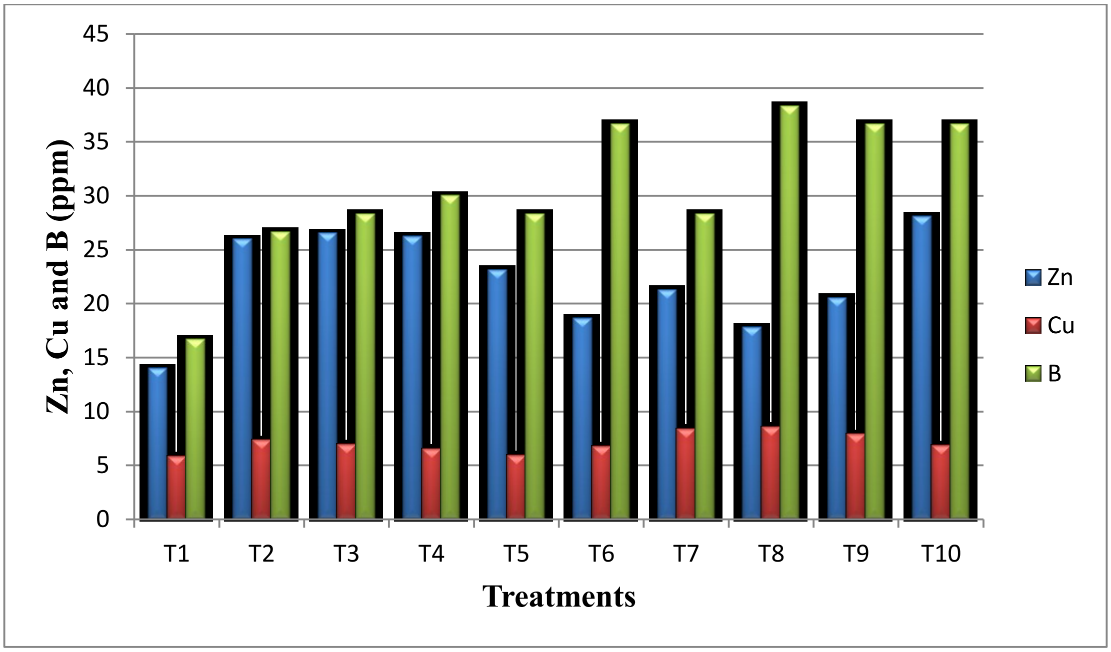


Fig. 31. Effect of treatments on contents of Zn, Cu and B in pod of yard long

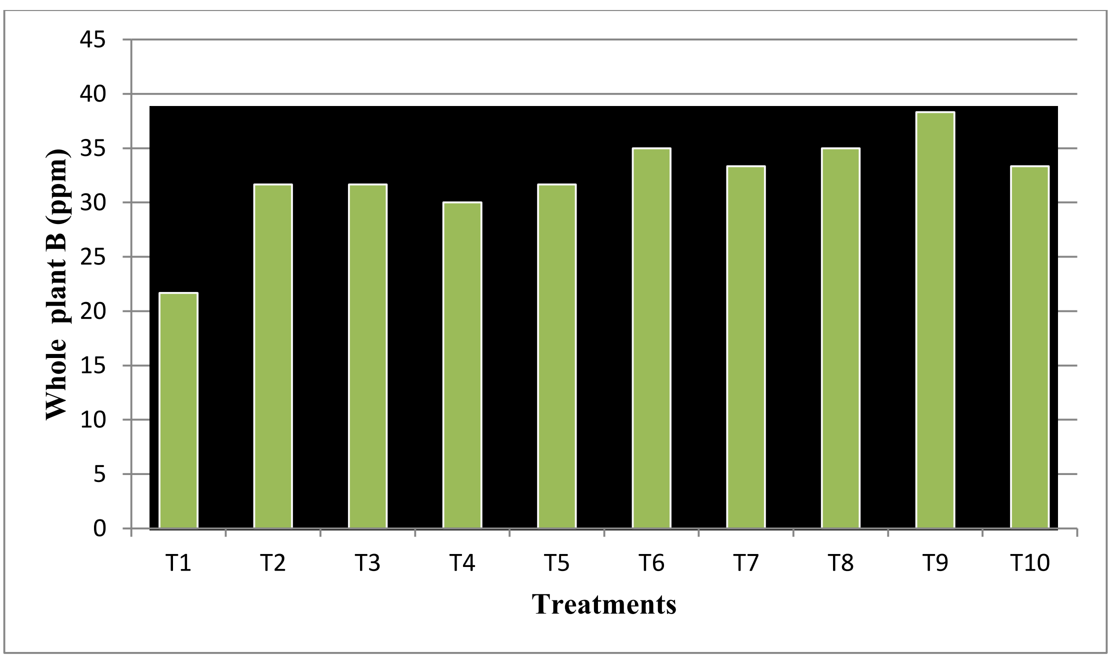


Fig. 32. Effect of treatments on content of B in whole plant after final harvest

associated with highest uptake of Fe, Mn, Zn and Cu in lemon seedlings (*Citrus aurantifolia* L.).

5.6.8. Boron

The treatments that received Mg and B both through soil and foliar application showed significant increase in boron content in pod and whole plant compared to the treatment which did not receive both the nutrients. The highest boron content (38.33 ppm) in the pod was obtained by foliar application of Mg and B twice at first flowering and active flowering (Fig. 31). The treatment T_9 which received Mg and B at fortnightly intervals as foliar spray recorded the highest boron content in whole plant (Fig. 32). Lopez-Lefebre *et al*. (2002), also reported that the concentration of B increased with the application of B as compared to the control in tobacco leaves. In the present study, the greatest B concentration in whole plant was found in the foliar spray treatment, which may be due to the direct absorption of foliar plus root uptake from the soil. Ruiz *et al*. (2001) reported the same idea.

Mg and B application had significant variation in relation to boron uptake by Yard long bean. The highest boron uptake (0.102 kg ha^{-1}) was achieved by the application of Mg and B at fortnightly intervals and the lowest (0.032 kg ha^{-1}) from the treatment which received soil test based package of practices recommendations only (Fig. 33). The results are in concurrent with the findings observed by Kumar *et al*. (1996) who reported that uptake of boron increased due to boron application. Hossain *et al*. (2011) also reported an increase in boron uptake with its application in mustard (*Brassica napus*).

5.7 APPARENT RECOVERY EFFICIENCY

Single foliar application of Mg and B at first flowering (T_7) recorded the highest apparent recovery efficiency for both the Mg and B followed by foliar application of Mg and B twice at first flowering and active flowering (Fig. 34 and

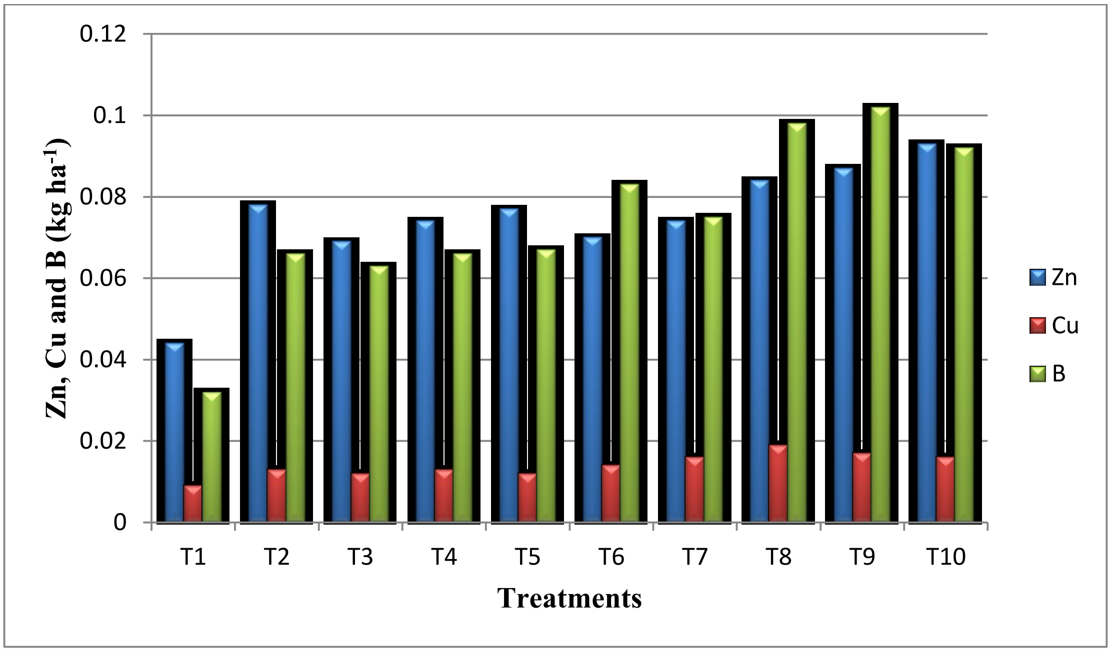


Fig. 33. Effect of treatments on crop uptake of Zn, Cu and B

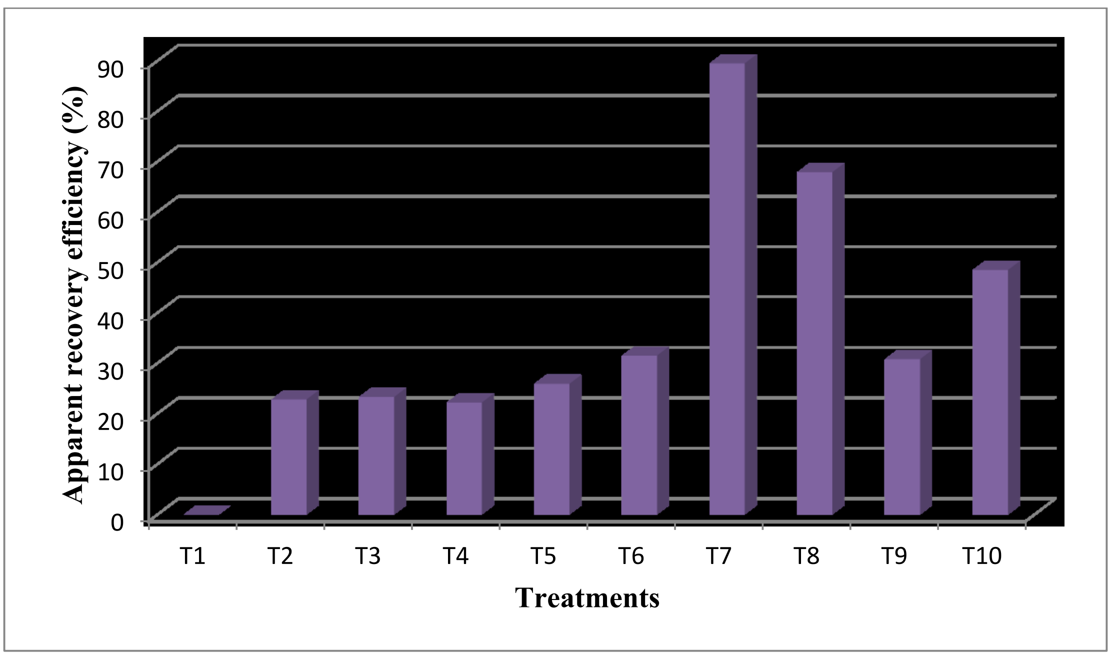


Fig. 34. Apparent recovery efficiency of Mg as influenced by the application of Mg and B

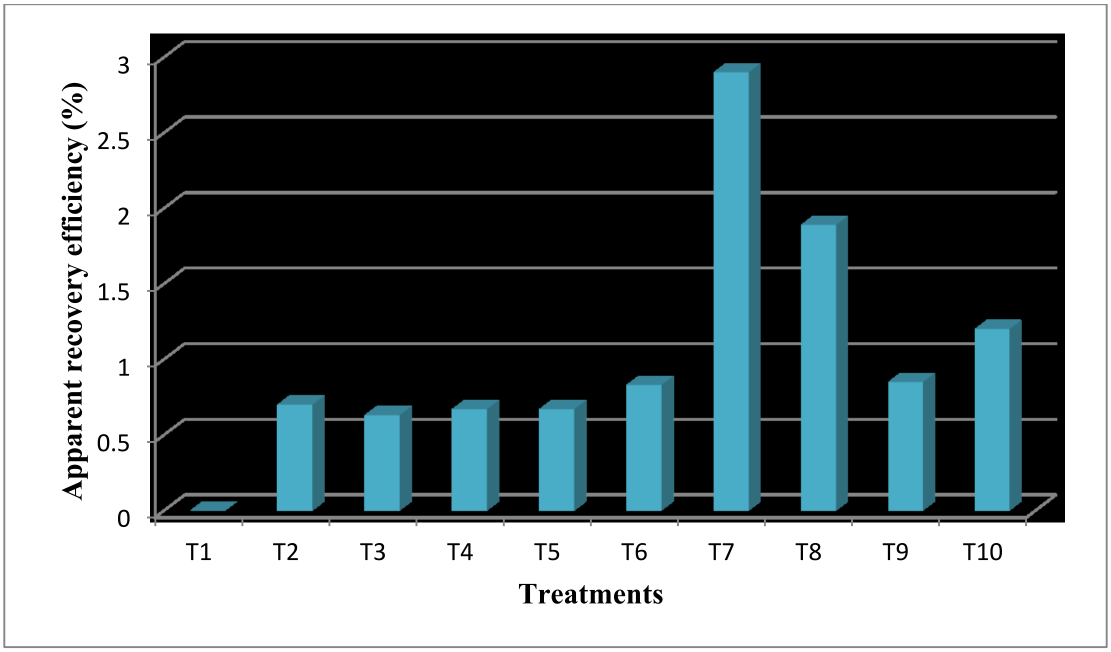


Fig. 35. Apparent recovery efficiency of B as influenced by the application of Mg and B

Fig. 35). The reason is that foliar spray of Mg and B directly absorbed by leaves of the yard long bean, which resulted in better performance. Moreover quantum of fertilizer used is much lesser in foliar than soil application. Nutrients are generally quickly available to the plants by the foliar application than the soil application (Phillips *et al*., 2004 ; Silberbush, 2002). Ruiz *et al.*(2001) drew similar conclusions. From an ecological perspective, foliar fertilization is more acceptable, because the small amounts of nutrients is used for rapid use by plants.

Finally, the foliar spray is more effective, viable, and economical than other methods for applying Mg and B fertilizers in the experimental soil of southern laterites of Kerala. The observations of the present study are in agreement with the findings of Roberts (2008) that nutrient use efficiency can be optimized by best management practices in fertilizer use.

It is concluded that, both the soil and foliar application of Mg and B significantly improved the nutrient uptake, pod yield and yield characteristics of yard long bean. Foliar application of 2 per cent magnesium sulphate and 0.25 per cent borax twice at first flowering and active flowering and soil test based package of practices (T_8) was found to be the best with regard to benefit cost ratio (2.27) compared to other methods and time of application.

Summary

6. SUMMARY

The salient findings drawn from the present study on "Magnesium and boron nutrition for yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) in southern laterites of Kerala" are summarized in this chapter.

A field experiment was conducted in randomized block design with ten treatments and three replications at College of Agriculture, Vellayani to standardize the method and time of application of fertilizers of Mg and B in the Agro Ecological Unit -8 using yard long bean as test crop.

Magnesium sulphate and borax were used as the sources of Mg and B and were applied either in soil or as foliar at different times. Treatments were applied over and above the use of lime and NPK based on soil test and FYM as per package of practices recommendations of Kerala Agricultural University. The treatments include one time soil application as basal, one time soil application between basal and top dressing, one time soil application at top dressing, soil application in two equal splits as basal and top dressing, soil application at fortnightly intervals in equal splits. Foliar application of treatments were done at first flowering, active flowering and fortnightly intervals. Combined application of soil with half of adhoc recommendations of Mg and B as basal and foliar at active flowering was also one of the treatments. The salient results of the study are summarized and listed below.

Initial soil properties of the soil of the experimental site indicated that soil reaction was extremely acid and available status of most of the primary, secondary and micronutrients were in the medium and sufficient range.

On analyzing the effect of application of magnesium and boron on vegetative characters of yard long bean, it was observed that the vegetative characters *viz.,* days to first flowering, leaf area, leaf area index and primary branches were significantly influenced by the treatments. In the case of days to first flowering, the shortest duration of 35 days was observed in the treatments T_2, T_5, T_6 and T_9 indicating that both soil and foliar application of Mg and B enhance flowering. Maximum leaf area and leaf area index were recorded in the T_9 which received 2 per cent magnesium sulphate and 0.25 per cent borax at fortnightly intervals. Primary branches were highest in the treatments T_5, T_8, T_9 and T_{10}.

Treatments had a significant influence on yield and yield characters. Foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_9) recorded the highest pod length and pod weight. Productive duration and number of harvests were high in the treatments which received Mg and B compared to the treatment where Mg and B were not applied. Number of harvests were more when Mg and B were given in split application either through soil or foliar methods indicating that mode and time of application of secondary and micronutrients contribute to significant increase in yield. T_8 and T_9 recorded the highest productive duration. Maximum yield (10.05 t ha^{-1}) was observed in T_9 (foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations) and it was on par with T_8. Increase in yield obtained in T_9 over T_1 was 36 per cent. The highest value for bhusa yield, total dry matter production and harvest index were also noticed in T_9.

As regard to the effect of application of Mg and B on quality characters of yard long bean, it was observed that fibre content and keeping quality of pod were not significantly influenced by the treatments. However protein content of pod was significantly influenced by the treatments. The highest protein content (5.65 %) was noted in T_{10} which received Mg and B through soil and foliar methods basally and active flowering.

Incidence of *Fusarium wilt* and *Aphis craccivora* were noticed during the crop period. But the treatments had no significant influence on them.

The results of economic analysis also showed significant variation due to treatments. The highest B:C ratio of 2.27 was registered by foliar application of Mg and B twice at first flowering and active flowering and soil test based package of practices recommendations (T_8) and was found to be significantly superior to other treatments. The lowest B:C ratio (1.79) was registered by T_1 in which Mg and B were not included and was statistically inferior to other treatments.

On analyzing the soil pH and available primary nutrients at the time of final harvest of yard long bean, it was noticed that the soil pH and available N and P were not significantly influenced by the treatments. However the increase in pH from 4.4 to 5.3 changed the soil reaction from extremely acid to strongly acid. The treatments had significant influence on available K in the soil and soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_6) recorded the highest value for available K.

In the case of availability of secondary nutrients in soil, Mg and S were significantly influenced by the treatments. The availability of both the Mg and S were the highest in the T_6. Critical level of available Mg for sufficiency in soils of Kerala (> 120 ppm) was attained in all soil application treatments while available Mg remained deficient in soil in the treatments which received foliar application.

With respect to available micronutrients in soil, application of Mg and B had significantly influenced the availability on Fe, Mn and B in the soil. Available Fe, Mn and B were the highest for the treatment T_6 (soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendations). Critical level of B (> 0.5 ppm) for sufficiency in soil was not attained either through soil or foliar application.

On analyzing the content of primary nutrients in the pod of yard long bean at harvest, N and P content in the pod were significantly influenced by the treatments. The highest content of N in the pod was obtained from the application of half of adhoc recommendation of Mg and B in soil as basal followed by one foliar spray at active flowering and soil test based package of practices recommendations. The treatments T_6 (soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendations) and T_8 (foliar application of Mg and B twice at first flowering and active flowering and soil test based package of practices recommendations) recorded the highest content of P in the pod.

Application of Mg and B had a significant influence on the content of secondary nutrients in the pod of yard long bean. Foliar application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_9) recorded the highest value for Ca, Mg and S in the pod.

Content of micronutrients in the pod of yard long bean were significantly influenced by the application of Mg and B. The highest value for Fe, Mn and Zn content were noticed with the treatment $T_{2,}$ T_5 and T_{10} respectively. Foliar application of Mg and B twice at first flowering and active flowering and soil test based package of practices recommendations (T_8) recorded the highest value for content of Cu and B in the pod of yard long bean.

On analyzing the content of primary nutrients in the whole plant of yard long bean after final harvest, Combined application of soil with half of adhoc recommendations of Mg and B as basal and foliar at active flowering and soil test based package of practices recommendations (T_{10}) resulted in highest content of N in whole plant. The highest content of P in the whole plant were noticed in T_6 (soil application of Mg and B at fortnightly intervals and soil test based package of practices recommendations). There was no significant influence of application of Mg and B on content of K in the whole plant after final harvest.

Application of Mg and B had a significant influence on the content of secondary nutrients in the whole plant of yard long bean after final harvest. Soil application of half adhoc recommendation of Mg and B as basal followed by one foliar at active flowering and soil test based package of practices recommendations (T_{10}) showed highest content of Ca and Mg and foliar application of Mg and B at fort nightly intervals and soil test based package of practices recommendations (T_9) resulted in highest content of S in the whole plant.

Among the micronutrients, only B content in the whole plant was significantly influenced by the treatment. The treatment that received foliar application of Mg and B at fort nightly intervals and soil test based package of practices recommendations (T_9) showed highest content of B in the whole plant of yard long bean after final harvest.

The treatments had a significant influence on the crop uptake of primary nutrients. The highest value for uptake of N, P and K were noticed in the treatment T_{10}, T_8 and T_9 respectively. The most suitable method and time of application of Mg and B for maximum N uptake was soil as basal and foliar at active flowering combined and those for maximum P and K uptake were foliar at first and active flowering and foliar at fortnightly intervals respectively.

The uptake of secondary nutrients were also significantly influenced by the application of Mg and B. The highest Ca, Mg and S uptake were obtained with the application of Mg and B at fortnightly intervals and soil test based package of practices recommendations (T_9).

Among the micronutrients, the highest Fe uptake was noticed in T_8. While T_5 and T_8 recorded the highest value for uptake of Mn. Uptake of Zn, Cu and B were maximum in T_{10}, T_8 and T_9 respectively.

It is concluded that, foliar application was significantly superior to soil application for yield and yield attributes. The yield was the highest in T_9 which received foliar spray of 2 per cent magnesium sulphate and 0.25 per cent borax at fortnightly intervals and soil test based package of practices recommendations.

However the B:C ratio was higher in T_8 than T_9. This indicates that economic yield was obtained when Mg and B were applied twice at first flowering and active flowering as foliar spray and soil test based package of practices recommendations.

FUTURE LINE OF WORK

Confirmation of this findings in other crops and other ecological units. Increase in yield to the extend of 36 per cent obtained in the present study needs field validation through multi location farm trials. Based on the report on the wide spread deficiency of secondary and micronutrients especially Mg and B reported from all most all the AEU of Kerala underlines the importance formulating crop specific POP recommendations.

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MAGNESIUM AND BORON NUTRITION FOR YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) IN SOUTHERN LATERITES OF KERALA

by

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ABSTRACT

The study entitled "Magnesium and boron nutrition for yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L). Verdcourt) in southern laterites of Kerala" was carried out at College of Agriculture, Vellayani during August to December, 2014 to standardize the method and time of application of fertilizers of Mg and B in the Agro Ecological Unit -8 using yard long bean as test crop.

The experiment was laid out in the Instructional Farm Vellayani in Randomized Block Design with ten treatments and three replications. The treatments included a combination of magnesium as magnesium sulphate and boron as borax and were applied either in soil or as foliar at different times. Treatments were applied over and above the use of lime and NPK based on soil test and FYM as per package of practices recommendations of Kerala Agricultural University, as one time soil application as basal, one time soil application between basal and top dressing, one time soil application at top dressing, soil application in two equal splits as basal and top dressing, soil application at fortnightly intervals in equal splits. Foliar application of treatments were done at first flowering, active flowering and fortnightly intervals. Combined application of soil with half of adhoc recommendations of Mg and B as basal and foliar at active flowering was also one of the treatments.

The study revealed that the use of magnesium and boron in soil and foliar application had a significant effect on the vegetative and yield characters. Foliar application of Mg and B as 2 per cent $MgSO_4$ and 0.25 per cent borax at fortnightly intervals along with soil test based package of practices recommendations of NPK (T_9) recorded the highest yield and it was on par with T_8 which received foliar application of Mg and B twice at first flowering and active flowering along with soil test based package of practices recommendation. The highest cop duration (96 days) was observed in T_9 and the lowest crop duration of 84 days was recorded by T_1. The highest harvest index also was recorded by T_9. The treatment effect was statistically

not significant for the quality characters like fibre content and keeping quality of pod. However the protein content was significantly influenced by the treatment.

The incidence of Fusarium wilt and aphids were noticed during the crop period. But the treatments had no significant influence on them.

The results of the soil analysis before and after the experiment revealed a general increase in available nutrient content and pH as a result of the treatments. The soil application of Mg and B at fortnightly intervals recorded the highest value for available Mg and B. Critical level of Mg (>120 ppm) for sufficiency in soil was attained in all soil application treatments. In the case of B, critical level of sufficiency (> 0.5 ppm) was not attained either through soil or foliar application.

Application of Mg and B as soil and foliar application had a significant effect on the contents of N, P, Ca, Mg, S, Fe, Cu, Zn, Mn and B in the pod of the yard long bean. However the effect of treatments on the content of K in the pod was not significant. Whole plant analysis revealed that, the treatment had significant effect on the contents of N, P, Ca, Mg, S and B. But K, Fe, Cu, Zn, Mn were not significantly influenced by the treatments.

It is concluded that, both the soil and foliar application of Mg and B significantly improved the nutrient uptake, pod yield and yield characteristics of yard long bean. The highest benefit cost ratio was noted in the treatment T_8 which consisted of soil test based NPK and farm yard manure along with foliar application of 0.25 per cent borax and 2 per cent magnesium sulphate twice at first flowering and active flowering.

Appendix

Appendix I

Weather data for the cropping period

(August to December 2014)- Weekly averages of temperature and relative humidity and weekly sum of rain fall.

Standard week	Temperature (ºC)		Relative humidity (%)	Rain fall (mm)
	Maximum	Minimum		
32	29.4	23.5	88.6	22.2
33	29.7	24.0	89.7	2.0
34	29.8	24.0	94.0	73.0
35	29.9	23.9	87.6	34.4
36	29.2	23.9	96.1	16.0
37	30.1	24.5	89.3	1.5
38	30.5	24.6	85.0	0
39	31.1	24.1	93.3	18.6
40	30.7	23.9	95.4	3.0
41	30.7	24.2	73.6	6.9
42	30.3	23.7	82.4	23.3
43	30.2	23.5	80.9	7.1
44	30.5	23.5	86.1	4.8
45	30.7	23.1	93.1	1.0
46	31.2	23.7	90.4	4.4
47	29.4	23.4	95.9	9.4
48	29.1	23.1	96.3	8.6
49	30.6	22.6	90.1	5.1
50	29.9	23.3	89.6	24.3
51	30.6	23.4	93.6	4.9