

**EFFECT OF Ca AND Mg ON THE YIELD AND QUALITY OF
TOMATO (*LYCOPERSICON ESCULENTUM L.*) IN THE SOILS
OF BALH VALLEY OF MANDI DISTRICT, HIMACHAL
PRADESH**

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Soil Science

By

Subhash Kumar

Registration Number: 41400168

Supervised By

**Dr. Raj Kumar (18340)
Agriculture (Professor)
Lovely Professional University**



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2022**

Department of Soil Science and Agriculture Chemistry
School of Agriculture
Lovely Professional University, Phagwara, Punjab

DECLARATION

I hereby declare that the research work presented in the thesis entitled, “**Effect of Ca and Mg on the yield and quality of tomato (*Lycopersicon esculentum L.*) in the soils of Balh valley of Mandi district, Himachal Pradesh**” is my own original. The work has been carried out by me in Krishi Vigyan Kendra, Mandi at Sudernagar, CSK Himachal Pradesh Krishi Vishvavidyalaya Palampur (HP) under the guidance of Dr. Raj Kumar, HOD and Professor (Department of Soil Science and Agriculture Chemistry) of School of Agriculture, Lovely Professional University, Phagwara, Punjab (India), for the award of the degree of **Doctor of Philosophy in Soil Science**.



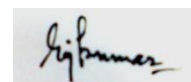
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Place: Phagwara, Punjab (India)

Dr. Raj Kumar

HOD and Professor

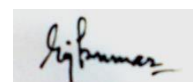
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School of Agriculture
Lovely Professional University, Phagwara, Punjab

CERTIFICATE I

This is to certify that Subhash Kumar (Registration No: 41400168) has personally completed the thesis entitled, **“Effect of Ca and Mg on the yield and quality of tomato (*Lycopersicon esculentum* L.) in the soils of Balh valley of Mandi district, Himachal Pradesh”** under my guidance and supervision. To the best of knowledge and belief, the present work is the results of his original investigation and study. No part of the dissertation has ever submitted for any purpose at any university.

The project report is appropriate for the submission and partial fulfillment of the condition for the evaluation leading to the award of degree of **Doctor of Philosophy in Soil Science.**



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Signature of Supervisor

Place: Phagwara, Punjab (India)

Dr. Raj Kumar

HOD and Professor

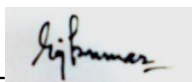
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School of Agriculture
Lovely Professional University, Phagwara, Punjab

CERTIFICATE II

This is to certify that thesis entitled, “**Effect of Ca and Mg on the yield and quality of tomato (*Lycopersicon esculentum* L.) in the soils of Balh valley of Mandi district, Himachal Pradesh**” submitted in partial fulfillment of the requirement for the award of degree **Doctor of Philosophy in Soil Science** to Lovely Professional University, Phagwara (Punjab) is a bonafied research work conducted by Subhash Kumar (Registration No: 41400168) under our guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation have been fully acknowledged.



Major Advisor

Dr. Raj Kumar

External Examiner

Co-advisor

Minor Advisor

Department Nominee

Dean (School of Agriculture)

Dr. Ramesh Kumar Sadarvati

Head of Department

Dr. Raj Kumar.

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Date: 01/08/2022
Place: Phagwara



Subhash Kumar

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variances
B:C	Benefit cost ratio
Ca	Calcium
cm	Centimetre
cv	Cultivar
EC	Electrical conductivity
<i>et al.</i>	Et alii (and others)
FAO	Food and Agriculture Organization
Fig	Figure
FYM	Farm yard manure
G	gram
ha	hectare
HClO ₄	Hydrochloric acid
HNO ₃	Nitric acid
K	Potassium
Kg	Kilogram
KNO ₃	Potassium nitrate
Max.	Maximum
Mg	Magnesium
Min.	Minimum
mm	Milli meter
N	Nitrogen
OC	Organic Carbon
P	Phosphorous
pH	Potential of hydrogen
q	quintal
viz.	Videlicet (namely)

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EFFECT OF CA AND MG ON THE YIELD AND QUALITY OF TOMATO (*Lycopersicon esculentum* L.) IN THE SOILS OF BALH VALLEY OF MANDI DISTRICT, HIMACHAL PRADESH

ABSTRACT

Tomato (*Lycopersicon esculentum* L.) is one of the remunerative cash crops for small and medium scale farmers. Enhancement in the incorporation of primary nutrients (N, P and K) and minimizing the use of secondary (Ca, Mg and S) and micronutrients reduced the yield of the tomato crop. Calcium and magnesium are the secondary nutrients play an important role in development of crops. Calcium supplied in the low quantity results in the appearance of browning and dieback symptoms on the growing tips of leaves. Blossom End Rot (BER) is the deficiency symptom which appears in the tomato crop due to the shortage of calcium. On the other hand, magnesium applied in low quantity results in excess starch, sugar and amino acid accumulation in leaves. Its deficiency also leads to breakdown of chlorophyll and reduction in photosynthetic electron transport chain.

In the present research work the impact of foliar application of calcium and magnesium was studied when applied individually or in combination in the tomato crop. The field experiments were undertaken during 2017 and 2018 in Mandi district of Himachal Pradesh to study the effect of recommended dose of NPK along with two levels of calcium (0.3 and 0.6 %) and three levels of magnesium (0.1, 0.2 and 0.4 %) in the tomato crop. The trials were laid in the randomized block design (RBD) with three replications and fourteen treatments. The calcium chloride and magnesium sulphate were used as the source of secondary nutrients calcium and magnesium.

The significant improvement in growth and yield and its parameters, quality, nutrient content and uptake of both leaves and fruits, economics and correlation in the tomato crop were recorded. The data in the treatment T₁₃ with recommended dose of FYM and NPK along with calcium and magnesium @ 0.6 and 0.2 % in treatment indicated the increase in the growth parameters viz. plant height (123.47 cm) and number of branches (6.72) with the percent increase of 20.65 and 24.21 % over the control. Similarly, for yield parameters the recommended dose of FYM and 100 % NPK along with calcium and magnesium @ 0.6 and 0.2 % significantly enhanced for number of flower clusters per plant, number of fruits per cluster, diameter of the fruit, weight of the tomato fruits and number of fruits per plant to the tune 28.77, 4.85, 4.69 cm, 72.17 g and 61.67 in the mean data of both the years. In comparison, to the control the enhancement was recorded among yield parameters to the tune of 68.84 %, 68.84 %, 19.04 %, 26.90 % and 76.55 % in comparison to the control. The significant improvement was also recorded for the marketable yield (380.72 kg/ha) and the dry matter yield (97.0 q/ha) in the treatment T₁₃ with the percent increase of 26.34 and 19.46 % over the control

treatment. The quality parameters viz. pericarp thickness (10.28 mm), TSS (4.98 °brix), vitamin C (26.0 mg/100 g and titratable acidity (0.78 %) also improved significantly with the percent increase of 9.98 %, 10.40 %, 17.38 % and 47.17 % as compared to the control. The significant increase in the nutrient content in the tomato leaves were recorded with nitrogen (2.91%), phosphorous (0.63%), potassium (3.97 %), calcium (1.32 %) and magnesium (0.82 %) with percent increase of 29.33 %, 186.36 %, 22.91 %, 60.98 % and 65.96 % in the mean data over the control . The uptake of nutrients in the leaves were recorded viz. nitrogen (285.25 kg/ha), phosphorous (61.12 kg/ha), potassium (385.44 kg/ha), calcium (129.20 kg/ha) and magnesium (75.88 kg/ha) in the tomato leaf with the percent increase of 54.48, 241.24, 46.48, 97.95 and 97.35 % in comparison to the control. In tomato fruits, the nutrient content also enhanced with the nitrogen (1.50 %), phosphorous (0.37 %), potash (3.20 %), calcium (0.79 %) and magnesium (0.46%) in the fruit with the percent increase of 36.36, 236.36, 15.94, 71.74 and 65.96 % in comparison to the control T₁. The nutrient uptake of the nitrogen (145.48 kg/ha), phosphorous (35.81 kg/ha), potassium (310.28 kg/ha), calcium (75.45 kg/ha) and magnesium (44.71 kg/ha) with the percent increase of 62.88, 315.43, 38.49, 100.67 and 352.99 % in comparison to the control treatment in the mean data of both the years i.e. 2017 and 2018. The soil properties viz. pH and organic carbon status remained unchanged during the period of study but the N, P and K reported significant improvement in all the treatments over the control. Unlikely the exchangeable calcium and magnesium reported to be non significant in all the soil samples of all the treatments and remained unchanged. The mean net returns and B:C ratio of Rs. 406065/- and 3.46 were recorded with the application of calcium and magnesium @ 0.6 % and 0.2 % with the recommended dose of FYM and 100 % NPK fertilizers. The cost of cultivation ranged from Rs. 146270/- to Rs. 165283/- in the mean data of both the years. The strong and positive correlation of marketable yield of tomato was recorded with the growth parameters, yield parameters, quality parameters and the uptake of the various nutrients during both the years of study.

From the results it can be concluded that incorporation of FYM @ 20 t/ha + 100 % NPK (150:120:55) along with foliar spray Ca and Mg @ 0.6 and 0.2 % in the tomato crop can improve the quality and yield of the crop due to the increase in the nutrient content and the uptake of the primary as well as the secondary nutrients.

INTRODUCTION

Among vegetables, tomato (*Lycopersicon esculentum* L.) is cultivated extensively all over the world in open as well as in the protected (Greenhouse) conditions (Tejashvini and Thippeshappa, 2017). It ranks second after potato (Choudhary *et al* 2013; Paul *et al* 2016) and belongs to solanaceae family. It is popular, nutritious and most commonly grown vegetables in the world (Tejashvini and Thippeshappa 2017).

The total area under tomato cultivation in world is 47.82 M ha with the production of 1370.0 MT. In India, the annual production of 19759.3 thousand MT is obtained from area of 789.2 M ha (Anonymous, 2018). Tomato is grown as a cash crop during season as well as in the off season with annual production of 489.96 thousand MT from an area of 11.08 thousand ha in Himachal Pradesh (Anonymous 2017). The area cultivated under tomatoes has increased by 164 % in 40 years in the world. The consumption of tomato has increased 314 % in these years with an average increase of 3 % annually (Nicola *et al.*, 2009 and Muhammad *et al* 2018). In tomato production, China, among all countries is the largest producer which alone accounted for 31 % of the entire production, with India remaining in the second highest producer and United States in third position in the world. In European Union, the output of tomato cultivation has the share of 23% among production of fresh vegetables in 2014 (Muhammad *et al* 2018).

Tomato is eaten as fresh and in form of processed products throughout the world. It is one of the principal components of the everyday diet in several nations, and is able to provide minerals, vitamin and antioxidants essential for health (Tejashvini and Thippeshappa, 2017) particularly vitamin A, C and E which not only improves livelihood but also alleviates the nutritional status, that are good for body and protect the body against diseases.

The key factors on which the production of tomato crop depends are nutrition, irrigation, plant protection etc. (Choudhary 2016). Soil mining, depletion of mineral elements and imbalanced use of plant nutrients in soils leads to minimal output (Ganeshamurthy and Hegde, 1980; Kasinath *et al.*, 2014). For appropriate development of the crop, most important factors responsible is plant nutrition (Rahi and Choudhary, 2014; 2016; Kumar *et al* 2018). Mining of mineral elements and imbalanced use of plant nutrients is responsible for low productivity of the tomato crop (Ganeshamurthy and Hegde 1980; Kasinath *et al* 2014).

In India, with the enhancement of incorporation of N, P and K fertilizers and minimizing the application of secondary and micronutrients makes the soils deficient in them. Use of N based fertilizers over the years increased deterioration of Ca, Mg and S in the soil (Nambiar and Abrol 1989; Kasinath *et al* 2015). Calcium and magnesium in the secondary nutrients play an important role in development of crops.

Calcium supports the plant membrane stability, cell wall stabilization and cell integrity. It helps plants to develop cell wall and cell membrane. In the middle lamella of the cell wall it also promotes the growth of the calcium pectate. For the neutralization of the organic acids it also provides the base (Hirschi 2004) and is essential for the meristematic activity (Park *et al* 2005 and Tejashvini *et al* 2018). Ca supplied in the low quantity results in the appearance of browning and dieback symptoms on the growing tips of leaves. The curls in the leaves of the plants can be observed and the margins change to brown in colour. The newly developed leaves adhere at the margins whereas the margins of the expanded leaves are shredded. Blossom End Rot (BER) is the deficiency symptom which appears in the tomato crop due to the shortage of calcium (Ho *et al* 1999; Tejashvini and Thippeshappa 2017). It also enhances fruit cracking and breakdown of cell walls and cell membranes in tomato (Simon 1978). The susceptibility to many diseases and problems after harvest of the tomato also increases with low supply of calcium (Tejasvini *et al* 2018). It plays an important role in cell division and in the maintenance of the chromosome structure. It acts as an indispensable co-factor or an activator of the enzymes such as hydrolases. The enzymes such as adenosine tri phosphatase, arginine kinase, amylase and phospholipase are also activated by it (Tejashvini and Thippeshappa 2017). It supports the nitrogen assimilation into organic constituents (proteins especially).

Excessive calcium supplies causes gold specks/gold spot (Ho *et al* 1999; Hao and Papadopoulos 2004), affect the appearance of the fruit and reduces the shelf life (Hao and Papadopoulos, 2004). Foliar spray of calcium enhances resistance to the diseases caused by bacteria and viruses. It also improves firmness of the tomato fruit by improving its quality (Usten *et al* 2006).

Magnesium is the other essential secondary nutrients required for the progress of the crop and for improving the quality of the fruit. In the molecule of chlorophyll it has a role of central atom (Azarmi *et al* 2015). It plays a key role as a cofactor and activator or regulator of many key enzymes in plant physiological processes. Reproductive phase gets delayed by giving inadequate quantity of Mg in the plants (Shaul 2002; Kasinath *et al* 2014). It had negative effects on plant photosynthesis when supplied in low quantity as well as supplied in the excess amount (Shabala and Hariadi 2005), resulting in abnormal growth or by restricting the growth of the plants. Magnesium has a function of transporting photosynthates in phloem of plant. The shortage of magnesium confines the partitioning of dry matter between roots and shoots. Low magnesium availability also results in excess starch, sugar, and amino acid accumulation in leaves. Its deficiency also leads to breakdown of chlorophyll and reduction in photosynthetic electron transport chain (Hermans *et al* 2005, Chakmak and Kirby 2008 and Azarmi *et al* 2015).

Magnesium also has large impact on the quality parameters, when supplied to the plants where magnesium has been supplied in low amount. However, the plants which already have sufficient amount of magnesium do not show any additional response when magnesium is supplied (Cakmak 2013). The increase of magnesium nutrition in magnesium deficit plants improves dry matter as well as total soluble solid (TSS) and titratable acidity (Gerendas and Fuhrs 2013). In tomato

crop magnesium deficiency is a major limitation in achieving required quality and yields (Kasinath *et al* 2015). It not only affects earliness but also improves the quality and uniform maturity in fruits. It has an important role in the formation of fat, vitamins, amino acids and chlorophyll. It is involved in numerous biochemical and physiological processes and other functions required for carbohydrate metabolism such as transport of phosphates and phosphorylating enzyme (Ganeshamurthy and Hegde, 1980; Kasinath *et al* 2015).

Both calcium and magnesium showd antagonism between them. The uptake of one nutrient supresses the uptake of other and vice versa (Sonneveld 1987; Adams and Ho 1995; Paiva *et al* 1998). Magnesium supplied in excess quantity reflects negative effects on fruits in firmness, texture and storability that are mostly observed by its antagonistic relationship with calcium (Malundo *et al* 1995). Knowledge regarding the ratios of calcium and magnesium (Ca: Mg) nutrients concentration in soil as well as in plants in respect of growth and quality parameters is very minimum. The application of one nutrient in large quantity encourages the deficit of the other nutrient.

The fertilizer being an important input not only improves the yield of the crop but also replenishes the soil with the nutrients that have been removed by the crops grown. Basal application of fertilizer in the soil is a method of fertilizer addition plasticized since many decades. Foliar application of nutrition is an important method of fertilization in which the fertilizers are applied directly on the foliage of the plants. In these method the nutrients usually enter into the cuticle or stomata of the leaf, enabling easy and prompt consumption of nutrients.

Due to varied agro-ecological conditions, Himachal Pradesh have an advantage over the other states of the country in growing number of seasonal as well as off season vegetables. This has made vegetable production highly profitable especially in mid and higher hills of the state.

Tomato being one of the highly profitable crops is grown in every part of the state especially, in the mid hill zone and is considered as a major commercial crop in the state. However, as compared to national average, the average productivity of tomato is low in the state (Anonymous 2018)

In modern agriculture the nutrients due to fixation and immobilization of nutrients in soil, losses their efficiency (Dass *et al* 2014). Method in which nutrient is applied in plants has a significant role in providing nutrients. Foliar spray of nutrients is a crop is another method to supply nutrients, in circumstances where the nutrient availability in soil is limited or deficiency is severe (Banyal and Banyal, 2019). Foliar fertilizer application involves minimum fertilizer usage, even distribution of foliar fertilizer, easiest technique of its use and rapid response to the nutrients used (Shabani *et al* 2012). Foliar application of fertilizers generally lessens this insufficiency (Erdal *et al* 2004 and Lanauskas and Kvikliene 2006). The nutrient content in fruiting vegetables also gets enhanced with the foliar application of the nutrients.

Impact of foliar application on various crops had been studied by many workers in their experiments on both macro as well as micronutrients on vegetative growth, quality of the fruit and

yield parameters. The primary nutrients viz. nitrogen, phosphorus and potassium (Banyal and Banyal, 2019) and secondary nutrients viz. calcium and magnesium (Tejashvini *et al* 2018; Hamied and El-Hady 2018) which were significantly effective in ameliorating nutritional level of quality and yield of the fruits of the crop.

The method of foliar spray of nutrients (calcium and magnesium) is very efficacious as compared to soil incorporation and enhances the effectiveness of foliar fertilizers (Tejashvini *et al* 2018). To study the response of Ca, Mg and their combined influence on growth, quality and their parameters, yield and its attributes and soil properties for enhancing mineral level of the tomato crop this research work was planned. Though, lot of study has been ensued on the requirement of major nutrients in tomato (N, P and K) but documentation on individual effect of secondary nutrients (calcium and magnesium) and their interactions effects in tomato is inadequate. Hence, the present research ‘Effect of Ca and Mg on the yield and quality of tomato (*Lycopersicon esculentum* L.) in the soils of Balh valley of Mandi district, Himachal Pradesh’ was taken to study the outcomes of Ca and Mg foliar feeding in tomato hybrid (US-920) with following objectives:

- 1 To study the different physical and chemical properties of the tomato growing soils of Balh valley
- 2 To study the effect and uptake of different levels of calcium and magnesium on quality and yield of tomato
- 3 To work out the best treatment combination for quality, yield and C:B ratio

REVIEW OF LITERATURE

Tomato (*Lycopersicon esculentum* L.) an essential commercial vegetable cultivated over a large area in world. It is a remunerative cash crop for small and medium scale farmers. Aiming only on the usage of the chemical fertilizers containing primary nutrients (N, P and K) reduction in the yield can be observed due to the imbalance of secondary and the micronutrients. In India, constant usage of inadequate quantities of nutrients in an imbalanced proportion in the intensive vegetable cropping systems caused nutrient depletion acutely in soil reserves, leading to multiple nutrient deficiencies and reduction in crop yield (Mahajan and Gupta 2009).

Generally, nutrients supplied in the balanced amounts are essential for the improved quality and yield of tomato. The application of different foliar fertilizers could not only increase tomato yield from 28.6 to 85.7 percent higher than that of the control, but enable the plant to absorb N, P and K through its leaves rapidly, consequently enhancing these nutrient contents in plants (Kumar 2013).

In the formation of cell wall and cell membrane in cells, fruit development and growth in plants and in maintaining the quality of fruits, calcium plays an important role of the key nutrient (Kadir 2004). Increased calcium content in plants controls blossom end rot (BER) in tomato (Sonneveld and Voogt, 2009) and also increases the resistance diseases caused by the bacteria and viruses (Berry *et al* 2006). Increase in the calcium nutrition enhances the resistance in tomato for the diseases like bacterial wilt which is caused by *Ralstonia solanacearum* (Yamazaki 1995) and suppressing other diseases by increase in the calcium content in (Berry *et al* 1988; Chiasson *et al* 2005; Almeida *et al* 2009). Upto 50 % losses in tomato are created by the major physiological disorder called blossom end rot (BER) (Taylor *et al* 2004) which is main cause for the severe economic losses (Hao and Papadopoulos 2003; Taylor and Locascio 2004). However, in the physiological processes the uptake of calcium and its translocation have an indispensable role (Chung *et al* 2010). Calcium is translocated to the leaves when taken from the soil but very little of it reaches in fruits from the leaves (Kadir 2004). Therefore, for proper growth and development of leaf, root and canopy continuous supply of calcium is required for plants (Del and Marcelis, 2003). Calcium uptake through roots by soil application or foliar application through leaves not only enhances uptake of calcium but also enhances the immunity of the plants to the diseases in tomato crop (Eraslan *et al* 2007; Freitas *et al* 2012)

Magnesium being a main component of cell wall plays a vital role in photosynthesis and in the life of the plant (Jones 1999). For many enzymes and the substrate transfer reactions it plays a main role of a cofactor and activator (Ilyas *et al* 2014). Inadequate supply of magnesium in plants show delay in the reproductive phases. However, the deficiency symptoms of magnesium occur

usually on the oldest leaves which hardly attracts any consideration because of the thought that the deficiency in the older leaves have very little impact on yield.

The calcium and magnesium have the antagonistic effect on one another. The magnesium uptake rate in the plants can be suppressed by calcium application and vice versa (Sonneveld 1987; Adams and Ho 1995; Paiva *et al* 1998) In spite of antagonistic effect between calcium and magnesium many investigations on their effects on the quality of the fruit have been done when applied alone or in combinations (Sonneveld and Voogt 1991).

Though, lot of work has been reported on the need of the tomato plants for the primary nutrients, but there is inadequate data on Ca, Mg and S secondary nutrients. This study was initiated by keeping in mind the importance these nutrients and to find out the effect of Ca and Mg collectively, when applied as a foliar feeding on growth and its parameters and yield and its attributes of tomato. Usage of balanced nutrients in correct proportion enhances the yield and improves the quality in different crops such as tomato, cauliflower, capsicum, chilli and brinjal. The literature related with the research problem entitled “Effect of foliar spray of calcium and magnesium on growth, yield and economics of tomato (*Lycopersicon esculentum* L.) in north western Himalayas” has been reviewed under the following heads:

- 2.1 Effect of calcium and magnesium on crop growth, yield and their attributes
- 2.2 Effect of calcium and magnesium on quality and its parameters
- 2.3 Effect of calcium and magnesium on soil properties
- 2.4 Effect of calcium and magnesium in combination
- 2.5 Effect of calcium and magnesium on net returns and benefit: cost ratio (B: C ratio)

2.1 Effect of calcium and magnesium on crop growth, yield and yield attributes:

Calcium:

Gezerel (1985) reported that in a greenhouse trial foliar spray of fertilizer containing calcium @ 0.2 % enhanced the fruit weight of tomatoes due to which the increase in yield of the tomato crop was recorded. In the similar type of study in another greenhouse experiment at Adana, Gezerel (1986) sprayed Wuxal Suspension Type 2 (containing N, Mg, Ca and trace elements) on the leaves of tomato which enhanced the yield and fruit weight in the crop. The nitrogen and calcium content in the leaf was also increased but content of trace elements was not affected in the leaf during the period of study.

In the state of Karnataka in a field investigation conducted to study the effect of Ca, the highest yields were obtained with the foliar application of Ca along with 50 kg K₂O ha⁻¹ for tomato

cultivar Co.1 when applied as basal and 100 kg K₂O ha⁻¹ for tomato cultivar Co. 3 plus Nitrogen incorporated at 120 kg ha⁻¹ (Subbiah and Rani1986).

In a pot culture study at Karnataka on tomato in which three calcium sources (calcium oxide, calcium chloride and calcium sulphate) were applied at 30th, 45th and 60th days as foliar sprays after transplanting (DAT). It was revealed that the improvement in the yields of tomato and in the concentration of the nutrients were obtained with Ca @ 0.2 percent sprayed from calcium chloride at 30th and 45th days after transplantation as compared to the other sources (Subbiah and Rani 1990)

In a field study in Brazil with various combinations of NPK (4:14:8 t ha⁻¹), dolomite (1.8 t ha⁻¹), boron (2 kg borax ha⁻¹) or foliar application of boric acid (0.2 %) or calcium (foliar application of 0.6 % calcium chloride) revealed that the tomato fruit yields was observed to be superior in plants in which NPK + dolomite and NPK + dolomite + calcium were supplied (Oliveira *et al* 1995)

Saikia *et al* in 1999 in an experiment conducted at Ludhiana reported that of Ca application of (NO₃)₂ in tomato could be used for effective control of Blossom End Rot (BER) with significant increase in fruit yield by 79.9-86.0 per cent over the control. The lower percentage of BER incidence was recorded in the treatment where Ca (NO₃)₂ was sprayed @ 0.5 -1.0 per cent.

Pratima and Dube (2000) in a study in the tomato crop in Uttar Pradesh found that with application of low Ca the reduction in the tomato biomass, fruit yield, concentration of Ca and chlorophyll were recorded. The tomatoes which were deficient in calcium were not only malformed but their quality was also deteriorated.

In the study conducted by Vuthy (1999) on application of with Ca and B in tomato found increase in the yield by 11 per cent as comparison to the method with no spray in two cherry and two fresh market tomatoes crops at Asian Regional Centre, Thailand. Non significant effect on non-marketable fruit weight/plant (0.42 kg), non-marketable yield (8.4 t ha⁻¹) whereas total yield (38.1 t ha⁻¹), fruit crack (8.9 %), and brix (5.61 %) in the micronutrient were significantly improved over the no spray methods.

In a field investigation conducted at Brazil on tomato cv.Debora Max in which the effects of Ca and B fertilizers on yield and its attributes were studied, the significant improvement in the of fruit number, fruits per cluster and yield of the tomato crop were revealed with Ca at 60 g/100 litres⁻¹ (Cardozo *et al* 2001).

Taylor *et al* in 2004 in an trial laid on the impact of Ca sources and reduced K on the prevalence of physiological disorder blossom end rot (BER), fruit yield and leaf Ca content. The blossom end rot (BER) symptoms of Ca deficiency were recorded and these intensified by occurrence of the high rainfall, low evapotranspiration rate, reduced irrigation and low Ca uptake.

Nasrollahzadeh asl *et al* (2015) in Iran during the study of foliar application of urea @ 3 g l⁻¹, calcium nitrate @ 10 g l⁻¹ and boric acid @ 0.5 g l⁻¹ in greenhouse cucumber reported that the treatment with calcium nitrate applied as foliar feeding enhanced the fruit yield and number of fruit of cucumber in polyhouse conditions.

Zoz *et al* (2016) in an experiment conducted in wheat on foliar applications of chelated fertilizer containing calcium reported that Ca @ 125 g l⁻¹ improved the fertilization among the flowers and wheat grain yield and yield attributes enhanced.

The field experiment conducted by Kumara *et al* (2019) in Regional Rice Research Institute, Ambalanthota, Sri Lanka on effect of foliar application of nano calcite (NC) with four different levels viz. 0, 50, 100 and 150 ppm in which the 3 different levels of fertilizers incorporated in soil. The treatment with 100 ppm nano calcite along with recommended fertilizer applied in soil increased the yield upto 1 ton/ha.

Dixit *et al* (2018) in a field experiment revealed that application of calcium significantly increased the growth, flowering and marketable yield in cultivar “Arka Rakshak” as compared to the control.

Sakhonwasee and Phingkasan (2017) in the study conducted in the tomato plants reported that the foliar feeding of CaCl₂ and CaNO₃ produced low hydrogen peroxide and superoxide. It also resulted in decrease in the cell death in treatments where CaCl₂ and CaNO₃ were applied as compared control treatment which is heat stressed.

In a greenhouse pot studies conducted on tomato crop cv. Carmelo grown and reported that Ca applied through drip irrigation improved the yields by 100 percent and reduced blossom end rot incidence by 40 percent as compared with control, respectively (Gavate *et al* 1991).

Bayers *et al* (2001) in an experiment laid where calcium (150 and 300 mg/litre) and magnesium (20, 50, 80 and 110 mg/litre) applied in combinations in tomato crop during 1999. It was found that fruit yield increased significantly where Ca applied @ 300 mg/litre along with magnesium @ 80 mg/litre and occurrence of blossom end rot was also reduced in tomato plants in this treatment combination.

In the experiment conducted by Khalifa *et al* 2009 to study the impact of boron and calcium on Anna apple trees when applied as a foliar spray. The significant increase in the fruit yield and its attributes were recorded. It was also found that physical and chemical properties improved significantly with foliar spray of boric acid and calcium chloride when applied alone or collectively. The nutritional status of apple was also enhanced.

In a poly house experiment carried out with different sources of calcium viz. calcium chloride, Calcium nitrate and CAN when applied at three different concentrations (0.20, 0.50 and

0.80%) in the form of foliar feeding. It was revealed that 0.5 % CAN recorded improvement in average yield to 91.98 t ha⁻¹ due to calcium ammonium nitrate. The yield parameters also enhanced significantly due to CAN (Tejashvini *et al* 2018).

Lolaei (2012) in an experiment conducted with four different concentrations of NaCl (0, 50, 100, and 150 mM) and four concentrations of CaCl₂ (0, 100, 200 and 300 mg/litre) in Gorgan, Iran. The significant improvement in fruit yield was recorded with increasing Ca concentration but the reduction in growth of plants and number of leaves was recorded because of salinity stress.

In a study conducted at Peshawar in tomato by Haleema *et al* (2018) revealed that calcium application @ 0.6 percent significantly increased the growth parameters to the tune of plant height (88.04 cm), number of primary branches (2.63), number of secondary branches (7.15), number of leaves per plant (182) and number of fruits per plant (66.15).

Magnesium:

Mostafa *et al* (2007) in in clay loam soil conditions studied the effect of soil magnesium fertilization as foliar sprays (sulphate or chelate form with or without MgSO₄). The results revealed that foliar sprays @ 2% MgSO₄ with 100 gm Mg chelate displayed a positive result on vegetative growth parameters and improved the yield of a crop as compared to control treatment.

In U.S. Environmental Protection Agency (USEPA) Cole *et al* (2016) conducted experiment on application of magnesium ammonium phosphate (MAP) and calcium sulphate to study its impact on plant growth, fruit yield and different attributes of tomato plants. It was recorded that MAP resulted in better above ground biomass whereas calcium sulphate produced more number and weight of tomato fruits as compared to the MAP.

Asiegbu and Uzo (1983) in a trial conducted in ferrallitic sandy loam soil reported that significant increase in the tomato yield and dry matter accumulation by liming at a pH of 5.2 and soil available Mg (0.64 meq per 100 g) recorded to be suitable for tomato growth.

In a study conducted by Elamin and Wilcox (1985) in tomato crop for two years in a sandy loam soils, in which the four concentrations of Mg were applied. It was found that incorporation of 56 kg Mg/ha with lime corrected Mg deficiency and tomato yield improved significantly with an increase of 27.9 % whereas application of lime recorded the increase of 17.7 % in the yield.

Ekinici *et al* (2015) conducted a study to assess the impact of calcium humate, boron humate and humic acid solutions. It was found that the largest tomato yield of 159,682 kg/ha with the application of 2936 mg/kg Ca humate application, whereas application of Ca humate @ 2910 mg/kg recorded maximum of 172,992 kg/ha of cucumber yield.

Abd El-Hamied and Abd El-Hady (2018) in an experiment on tomato in Egypt revealed that phosphorous @ 14 kg/fed and calcium @ 0.3 % enhanced the productivity of tomato and uptake of nutrients when applied as a foliar feeding.

In an experiment conducted by Singh *et al* (1982) on guava (cv. Allahabad Safeda) to study the response of magnesium application at H.A.U., Hissar. The largest fruit set of 79.44 % and fruit retention of 46.27 % was recorded with 0.4 % magnesium. Likewise, the highest yield of 93.43 kg/tree were taken with foliar application of magnesium @ 0.4%.

Ghosh (1986) observed that, foliar application of Mg @ 0.3% improved fruit length, diameter and weight to the tune of 6.4 cm, 7.7 cm and 173.0 g respectively. Suman *et al* (2017) also in his investigations conducted reported the similar findings on guava crop.

The studies conducted on the tomato crop in Egypt revealed that, treatments where phosphorous was applied @ 14 kg P/fed and calcium @ 0.3 % improved the tomato yield as well as the nutrient uptake when applied as foliar feeding (Abd El Hamied and Abd El Hady 2018).

Ali *et al* (2018) assessed the outcome of drought on the mineral content in leaves of castor plant in different ecotypes in Iran in 2014. It was found that drought improved K, Ca and Na contents whereas the Fe, Cu, Zn, and Mg contents decreased in the tomato plants.

In the investigations conducted by Altarugio *et al* (2017) to assess the impact of magnesium on yield of soybean (*Glycine max*) and corn (*Zea mays*) during 2013-2014 and 2014-2015 in Brazil where magnesium was applied @ 50, 100, 250, 500, 1000 and 1500 g/ha. The foliar spraying of magnesium @ 540 and 890 g/ha increased the yield of soybean and corn (325 and 737 kg/ ha) and increased the 100 grain weight upto 2 % during the reproductive stages of both crops.

2.2 Effect of calcium and magnesium on quality and its parameters

In the field trial laid by Zhu and Shu (1991) in China revealed that the higher yield in the plants treated with K₂O were observed as compared controls which was kept untreated with the percent increase of 15.2 %. However, it was 0.7 % lower than that plants treated with K₂O and CaCl₂. The fruit vitamin C concentrations for treatments K₂O and K₂O + CaCl₂ were 16.5 and 18.1 mg/100 g, which were substantially larger than control (14.9 mg/100 g).

Subbiah in 1994 in an experiment conducted recorded that the of calcium chloride (CaCl₂) @ 0.5 % applied as foliar spray increased firmness index of tomato fruits but it was lowered by addition of increasing levels of N.

Adams and Ho (1995) in the review article reported that, the factors affecting nutrient uptake and nutrient distribution in the tomato shoots and also caused quality problems are caused by calcium deficiency called blossom end rot.

In a study conducted on tomato ripening under hydroponic culture the fruit pectin concentration increased with Ca concentration and calcium treatment also delayed the degradation of water soluble pectin (Heun *et al* 1995)

Hohjo *et al* (1996) in his investigations in hydroponically grown tomato plants. It was revealed that increase in calcium application improved the sugar content in tomato fruits. Likewise, the titratable acidity was also higher in plants where nutrient concentrations were increased.

Wada *et al* (1996) reported reduction of incidence of blossom end rot (BER) of tomato fruits by foliar applications of calcium chloride and calcium nitrate in Japan. It was also revealed that BER incidence of tomato fruits can be reduced by foliar spray of recommended calcium solution containing zinc.

In the studies conducted by Franco *et al* (1998) in field grown tomatoes in Spain that the foliar application of calcium reduced the effect of blossom end rot. It was also reported that the calcium treatments also effected the fruit composition and blossom end rot incidence.

In a trial conducted in tomato plants grown in hydroponics. The tomato fruits were treated with 100 mg Ca litre⁻¹ with low air relative humidity had blossom end rot (BER), although their Ca contents were higher than in those fruits submitted to high air relative humidity. When low Ca doses was supplied to plants, seeds were small, malformed and black and the excessive water loss from fruit tissues might lead to blossom end rot (Paiva *et al* 1998).

Ho *et al* (1999) reported physiological disorders in tomato which were caused due to Ca deficiency. Inadequate supply of Ca in tomato plants is the primary cause of blossom end rot.

Irget *et al* (1999) reported the impact of KNO₃ (3.0 %), Ca (NO₃)₂ (1.5 % and 3.0 %) when applied individually and potassium nitrate @ 2.0 % and calcium nitrate @ 2.0 % in combination as a foliar spray on nutrient content and quality of the fruit in figs. The leaf lamina and petiole were recorded the significantly higher K and Ca content. The enhancement in fruit width, length and shape was also reported.

In a study conducted by Heun and Lee (1999) on the effect of Ca on ripening of mature green tomato fruits. It was reflected that the fruits treated with 8 % CaCl₂ or 2 % Ca (NO₃)₂ shown delay in colour development and ethylene climacteric rise as compared with control fruits whereas treatment with 2 % CaCl₂ or 8 % Ca (NO₃)₂ did not inhibit either the colour development or ethylene climacteric rise

Saikia *et al* in 1999 in the trials conducted reported the low percent of BER incidence with foliar application of Ca (NO₃)₂ (0.5-1.0 %) whereas the plants in which no calcium supplements were applied recorded higher incidence of disease (37.9 %).

Tomato cultivars (OH 8245 and TR 12) grown in Columbus, Ohio (USA) found that that weekly foliar applications of calcium (0, 50 and 150 mM) resulted in significant improvement in the ruptured cuticle on calcium application, but firmness of fresh and stored tomato fruits remained unchanged (Srilatha and Barringer 1999).

Saure (2001) in his investigations found that calcium deficiency caused blossom end rot (BER) in tomato fruits. It was also reported that it depends on the nutrient uptake by the roots of the plants and secondly on the Ca^{2+} transport within fruit and a demand of calcium on the which depend on growth rate of fruits.

In field trial Ehret *et al* (2002) found that the foliar applications of inorganic fertilizers significantly reduced powdery mildew (*Erysiphe orontii*) in greenhouse tomato leaves. The significant reduction in the mildew colony counts was recorded in the combinations where Ca was applied or Ca along with elemental S.

The investigation was conducted on the foliar applications of CaCl_2 with different concentrations of NaCl on calcium, oxalic acid concentration and dry matter in tomato crop. It was revealed that calcium chloride improved calcium content in as a result of foliar application and unlikely reduced oxalic acid (Topcuoglu and Kutuk 2002).

Dong *et al* (2005) in the glasshouse study revealed that the treatments containing Ca excluding the Ca sprayed on three weeks old fruits, the significant enhancement in the Ca content in the fruits was recorded. It can also be inferred that Ca on the young fruits and leaves during anthesis enhanced the Ca concentration and improved the fruit quality.

Fanasca *et al* (2006) reported that fruit production improved and the blossom end rot occurrence reduced due to the higher proportion of Ca in K: Ca: Mg ratio. The antioxidant activity was enhanced due to higher amount of Mg in the tomato fruits.

Research trial was laid in tomato using different modes of application viz. dipping, vacuum infiltration and pressure infiltration in which the CaCl_2 was applied with four different levels @ 0%, 2%, 4% and 6% of the aqueous solutions. It was found that treatment in which the CaCl_2 applied @ 6 % the post-harvest quality of tomatoes enhanced with the improvement of 92 % in the shelf life as compared to the which were untreated when fruits were kept at 28 °C. The application of CaCl_2 also improved fruit firmness significantly (Senevirathna and Daundasekera 2010).

In an experiment conducted to study the shelf life and behaviour of ‘Jonagold’ apples kept at 0-2°C. It was revealed that application calcium improved fruit firmness, total soluble solids, catalase activity and titratable acidity. (Shirzadeh and Kazemi 2011)

In a study conducted by Kazemi (2014) reported that foliar application of CaCl_2 @ 15 mM along with humic acid @ 30 ppm increased TSS, vitamin C, nitrate reductase activity, fruit firmness and fruit lycopene content and the low blossom end rot incidence viz. 5.14 °Brix, 25.14, 6.4, 3.91 kg cm^{-2} , 2.14 and 5 %. The tomato yield improved to 25.36 t ha^{-1} .

In an investigation conducted on the phospho-gypsum (by-product of the P fertilizer and amendment for acidic and sodic soils) in the tomato crop. It was revealed that in shoots P, K, and Mg content decreased whereas in fruits decrease in P and Cu content was recorded. The reduction in the incidence of blossom end rot was recorded when rate of application of phospho-gypsum was highest which also increased calcium content in fruits (Jose *et. al.*, 2014).

In a field trials conducted by Bibi *et al* (2019) in which Ca applied from the two sources viz. CaCl_2 and $\text{Ca}(\text{NO}_3)$. The significant improvement in yield and its parameters were recorded with the percent increase (35.7 % and 50.0 %) fruits per panicle, (125 % and 40 %) fruit retention and fruit (52.5 % and 49.2 %) yield of the mango crop. The quality parameters such as shelf life and TSS improved with the percent increase of (73.3 % and 36.6 %) and (35.1% and 40.6 %), respectively

Magnesium:

Avadh in 2000 in the investigations conducted in orange revealed that the enhancement in the fruit juice was recorded with Mg and micronutrients such as Cu, Zn, Fe and B applied in collectively. The non-significant improvement was recorded in the quality attributes (TSS, total sugar, reducing sugars and acidity) of fruits.

In a trial conducted in tomato crop grown on rockwool, the increase in fruit firmness with increasing concentration of Mg (20, 50, 80 and 110 mg L⁻¹) along with low Ca concentration (150 mg L⁻¹) was recorded when both applied in combination (Hao and Papadopoulos 2003)

In an investigation conducted by Chapagain and Wiesman (2004) in greenhouse tomato (cv. Durinta) on quality in a soilless culture for forty seven days and planted with three different treatments. It was found that treatment with KCl: MgCl_2 (25:75%) + KCl in terms of K supplied) significantly improved firmness of fruits but significantly reduced number of rotten and blotchy fruits. The increase in the foliar application of Mg level improved fruit quality significantly by increasing levels of glucose, Mg and dry matter content in the fruits.

The experiment laid in clay loam soils to study the effect foliar sprays of magnesium in form of sulphate or chelate. From the results it was reported that Mg chelate @ 100 gm along with foliar spray of MgSO_4 @ 2 % showed a improvement in N, Mg and chlorophyll a and b content in leaves as well as in fruits over the control treatment (Mostafa *et al* 2007).

Gerendas and Fuhrs (2013) evaluated the influence of Mg on the quality of the fruit. It was reported that increase in the Mg application on sites deficient in Mg increase the quality of the crops. The quality traits of the plants such as photosynthesis and assimilate translocation depend on Mg. It was also required to induce further improvement to produce quality crop.

Nadeem *et al* (2013) observed CaCl_2 @ 1% along with NAA @ 0.02% improved calcium absorption, enhanced growth of the plant, quality and productivity by enhancing mineral uptake. It lowered blossom end rot and produced quality tomato for longer period in ambient conditions (20-25 °C).

The study conducted in hydroponically grown cucumber (*Cucumis sativus* cv. Nagen 792) in which Mg was applied at different concentrations viz. 0.0, 1.0, 2.0, 3.0 and 4.0 mM were applied. It was revealed that 3.0 mM Mg improved plant growth but it was reduced when the Mg applied @ 4.0 mM. Visible symptoms of interveinal necrosis in middle leaves were developed when Mg applied @ 0.0 mM. The quality parameters of fruit such as fruit dry matter percentage and total soluble solids increased with Mg (3.0 mM), when grown in optimum light intensity (Rasoul *et al* 2015).

Waskela *et al* (2013) revealed that foliar feeding of Magnesium sulphate at 0.75% significantly enhanced growth parameters such as shoot length, leaves per shoot, shoot diameter and leaf area (13.44 cm, 11.65, 0.52 cm and 71.60 cm²). The quality parameters viz. TSS, ascorbic acid, and pectin content also recorded improvement (11.04 °Brix, 158.24 mg/100 g and 0.84%) also improved significantly in guava fruits. The reducing and non-reducing sugar (3.45% and 3.45%) of guava also enhanced.

In a research work undertaken to assess the impact of magnesium and potassium on qualitative parameters of the grapes when applied from MgSO₄ and K₂SO₄ (3.86 kg Mg/ha and 12.44 kg K/ha) individually and in combination (1.93 kg Mg/ha + 6.22 kg K/ha) as a foliar spray. It was reported that in all the treatments the sugar content of grapes lowered non-significantly ranging from 0.5 – 4.3 % as compared to the control which was not treated (Zlamalova *et al* 2015).

In the study conducted to stimulate fruit yield in bell peppers on the feeding of boron and calcium as a foliar spray either individual or along with plant growth regulators collectively. It was revealed that calcium applied as a foliar feeding from the start of flowering improved the fruits firmness (Zanin *et al* 2018).

2.3 Effect of calcium and magnesium on different soil properties.

Helyar and Anderson (1974) in the field study reported that increase in the exchangeable calcium and decrease in the exchangeable aluminium and manganese was recorded with the application of calcium carbonate. It was also revealed that except calcium the application of CaCO₃, decreased the concentration other cations

Sharma *et al* (1976) studied all calcium forms in forty three soils of Himachal Pradesh in Kangra valley, reported that the average exchangeable calcium in the soils of warm and wet mountainous zone, hot and humid shivalik zone and relatively dry foot hill zone was 1.96, 2.93 and 3.42 me/100g. It was also reported that total and exchangeable calcium were positive correlation with pH and clay but negative correlation with organic matter.

In an experiment conducted by Srinivasan and Angayarkanni (2009) investigated the impact of different phosphorus levels and boron on the availability of calcium in soil for groundnut (cv. VRI 2) grown on sandy loam soil. The data showed that the application of phosphorus and boron significantly influenced Ca availability in soil. There was an antagonistic effect on the availability of Ca due to interaction of phosphorus and boron.

Study conducted to find the effects of soil properties on degrees Brix on tomato processing in Aegean and south Marmara regions of Turkey. The results revealed the positive correlations between degrees Brix and soil properties (lime, organic matter contents and pH) and on soil nutrients viz. available potassium, calcium and magnesium, the negative correlations were recorded with salt and available Na contents on both locations (Aydin and Yoltas 2004).

Taylor and Locascio (2004) in a study found that in tomato (*Lycopersicon esculentum*) the common physiological disorder is blossom end rot (BER) which occurs in whole world where ever tomato is grown and results up to 50 % losses. To prevent BER in the crops it is necessary to develop an understanding regarding Ca in the soil and knowhow about its uptake and its translocation.

Dal Bo *et al* (1986) described the outcome of different calcium sources on the movement of bases in the soil. The movement of Ca was not detected when the source was CaCO₃. However, CaCl₂ promoted intense base leaching and the solubility of amendments seems to be the main factor responsible for the differential mobility of bases in the soil.

In field trials laid in China by Jiang *et al* (2009) it was found that calcium is used as a soil amendment due to which the ratio of exchangeable Ca and Na is changed. The decrease in the saline soils among pH, EC and total salt contents was recorded over the control treatment where Ca was not added. The increase in the tomato yield was recorded by 18.7% and 20.2 % enhancement in the soluble solid content was observed. The soil physio chemical characteristics in greenhouse were evidently improved.

In an experiment conducted in Ethiopia by Bekele *et al* (2018) where lime was applied in three different rated viz. 2 tons/ha, 4 tons/ha, and 6 tons/ha, vermicompost @ 2.5 tons/ha, 5.0 tons/ha and 7.5 tons/ha and P fertilizers @ 20 kg/ha, 40 kg/ha and 60 kg/ha. The exchangeable Al reduced from 1.70 to 0.09 c mol/kg , organic matter recorded was 4.1 % and 0.29 % of total nitrogen were found from application of lime @ 4 tons/ha and vermicompost @ 7.5 tons/ha. The exchangeable acidity (0.17 c mol/kg) decreased significantly when treated with lime @ 6 t/ha. The exchangeable Ca²⁺ and Mg²⁺ improved with the different treatment combinations.

Colla *et al* (2002) observed the impact of various organic inputs and conventional management practices on productivity, composition of minerals and soil chemical properties for 10 years in tomato crop. It was found that soil total carbon and N, P, K and exchangeable Ca improved with incorporation of manure regularly in soil and use of cover crops for 10 years.

In a study conducted by Martin and Liebhardt (1994) in tomato (cv. Redpak) to determine a high crops requirement of K and a response of potassium chloride or type of lime viz. dolomite, calcite and mixed. It was observed that the increase in the soil pH was observed with dolomite lime as compared to the calcite lime. The soil K saturation was not influenced by any type of lime or the rate it is applied. The soil K saturation increased with increasing K rate but soil Ca decreased with increasing K rate.

To observe the impact of liming and gypsum usage on the chemical properties in a clayey Typic Hapludox in the moderate acidity in Brazil in short term (for 1 year) and the long-term (for 11 years) experiments. The findings revealed that lime and gypsum did not have any synergistic effect on soil chemical properties. In short term, the gypsum was more efficient than lime in raising

exchangeable Ca, however, lime application decreased soil acidity and had a residual effect on exchangeable Ca (Sandra *et al* (2019)).

In a pot experiment by Khan *et al* (2019) to investigate the impact of organic and inorganic fertilizers at Khulna University, Bangladesh. The results indicated that soil chemical properties improved with the application of gypsum in combination with calcium chloride by reducing the electrical conductivity. The reduction in sodium adsorption ratio (SAR) due to calcium chloride and reduction in pH due to gypsum was recorded in all the treatments.

Pivetta *et al* (2019) found that enhancement in soil pH and decline in the aluminium content was documented with phospho gypsum. Without phospho gypsum high organic carbon status was found in the soil, which shows that the incorporation of phospho gypsum enhanced complexed carbon and aluminium.

The laboratory experiments conducted in Vietnamese Mekong Delta in which two kinds of rice husk biochar @ 0 and 50 g/kg were incorporated. These were combined with three levels of calcium oxide viz. 0, 0.5 and 2.0 Mg /ha and were applied in the rice shrimp cropping system. The results reported that application of biochar and calcium oxide was more effective in improving soil properties related to Na leaching and ESP when applied in low doses (Phuong *et al* 2019).

Saqib *et al* (2017) in a field trial laid from 2013 to 2016 to assess usage of organic and inorganic amendments when applied collectively in the soils which were salt affected in the rice-wheat cropping system. It was found that CaCl_2 applied @ 50 % SGR along with biogas slurry @ 10 t/ha is an effective method in reclamation of salinity. The significant decrease in pH, EC and SAR was recorded when gypsum incorporated @ 100% SGR.

In an investigation on the liming potential of biochars in Hawaii and West Java, Indonesia. The results indicated that CaCO_3 in biochar were among the most important properties required for improving productivity and plant growth of acid soils (Berek *et al* 2016).

Tiritan *et al* (2016) determined the results of liming applied @ 0, 2.7 and 5.4 Mg ha⁻¹. It was reported that the highest reactivity of calcium carbonate was observed after six months of liming. The decrease in the level of exchangeable Ca^{2+} and Mg^{2+} to 0.05 m depth and increased Al^{3+} and soil acidity to 0.3 m were recorded at the sampling time. The liming did not increased reactions of the bases in the degraded soil profile therefore, surface liming provided the best alternative to increase the soil pH index at a depth up to 0.3 m.

During investigation of thirteen vertisols of semi-arid tropical (SAT) areas of western Maharashtra it was recorded that the Ca^{2+} and Mg^{2+} together as both can improve soil structure were as Mg^{2+} ions are less efficient than Ca^{2+} ions (Zade *et al* 2017).

In the investigation performed by Singh *et al* in 2016 in five pedons of sodic soils, it was revealed that ranges of electrical conductivity ranged from 0.82 to 2.72 dS/m, pH ranged from 7.7 to 9.5 and exchangeable sodium percentage (ESP) from the 17.81 to 37.24 in different horizons. Range of 1.08 to 4.56 g kg⁻¹ was recorded for organic carbon (OC) in different horizons and with depth the decrease was recorded in all pedons. With increasing soil depth, the CEC decreased from 13.56 to 34.45 c mol (p+)/kg. The bulk density recorded from 1.46 to 1.53 Mg/m³. Na⁺ ion was recorded as a dominating cation followed by Ca²⁺ and Mg²⁺ ion.

In an experiment laid on two blossom end rot susceptible tomato cultivars (Ace 55 and AB2) in a greenhouse in which the calcium deficiency conditions were maintained. It was revealed that application of GA₄ increased BER incidence in both cultivars up to 100 % whereas apogee did not show BER incidence. Apogee application also improved fruit pericarp and calcium concentration whereas GA₄ reduced uptake of calcium in fruits which enhanced incidence of blossom end rot in both cultivars (Freitas *et al* 2012).

Magnesium:

Mogor *et al* (2013) conducted a study to identify changes due to foliar application Mg(OH)₂ or MgCl₂ in chlorophyll and Mg content in leaves of tomato cultivars. It was revealed that the 1.0 ml l⁻¹ and 2.0 ml l⁻¹ of solution prepared viz. 300 g l⁻¹ of Mg as Mg (OH)₂ and the 3.75 ml l⁻¹ of MgCl₂ increased chlorophyll contents which resulted in the absorption and metabolization of Mg. Due to application of 7.5 ml l⁻¹ of MgCl₂, chlorophyll content reduced and Mg content was stimulated in leaves.

In the investigation performed by Grzebisz (2013) reported that extra supply of nitrogen with magnesium increased the yield by improving nitrogen uptake efficiency. This phenomenon can be best described as "magnesium-induced nitrogen uptake".

Liming done at the pH 5.2, 5.7 and above had minor effects on fruit yield and dry matter accumulation. Tomato growth was satisfactory higher when applied with Mg @ 0.64 meq per 100 g soil (Asiegb *et al* 1983).

Mehmet *et al* (2015) revealed that minerals in 2 % of earth's crust has a Mg as a main component. Mg from the soil solution is taken by the plants, which is again refilled by soil reserves.

In a field research by Shete *et al* (2018) during kharif of 2017-18 at Kolhapur. to study the effect of foliar spray after 45 and 60 days. Soil samples taken after post-harvest reported the non-significant difference among available nutrient.

In a trial carried out at Slovenia during 2008-09 to study the impact of Mg and Fe on the K, Mg, Fe and Zn content in the grape vines when incorporated in soil or as a foliar application. It was revealed from results that Mg uptake was decreased due to the fertilization of K almost to half as compared to the untreated plots (Bratasevec *et al* 2013).

The rates and methods which were investigated in field trial in which magnesium sulphate applied as soil application @ 0, 25, 50, 75 and 100 kg/ha and as foliar spray of 0.25 and 0.5 % Mg twice on maize. It was found that the incorporation of Mg substantially encouraged uptake of major nutrients (N, P, K Ca and Mg) and micronutrients (Fe, Mn and Zn) when applied at different rates (El Dissoky *et al* 2017).

Effect of Calcium and Magnesium in combination:

Aghofack Nguemezi and Valere (2010) studied the effect of calcium and magnesium in combination plant development and conservation of tomato fruits at postharvest. It was found that longest shelf-life was acquired on incorporation of nitrogen, phosphorous and potash in soil at the same time along with calcium nitrate @ 200 kg ha⁻¹ and calcium and magnesium as a foliar feeding.

Candilo and Silvestri (1993) in their study evaluated the impact of Ca and Mg on parameters viz. productivity and quality in tomato cultivar Hypeel 244. The results exhibited significant differences in early ripening, total yield and total soluble solids. Leaf treatment with Ca + Mg (420 ppm CaO⁺ 35 g MgO L⁻¹) improved earliness and yield.

In an experiment laid with two concentrations of calcium @150 and 300 mg L⁻¹ on rockwool with four magnesium concentrations viz. 20.0, 50.0, 80.0 and 110.0 mg L⁻¹). The Ca and Mg concentration @ 300.0 and 50.0-80.0 mg L⁻¹ highly improved fruit firmness whereas tomato production was optimum with it (Hao and Papadopoulos, 2003).

Hao and Papadopoulos in 2004 applied Ca @ 150 and 300 mg L⁻¹ in factorial combination with magnesium @ 20.0, 50.0, and 80.0 mg L⁻¹ levels. It was reported that with increase in Mg concentration along with 300 mg L⁻¹ of Ca enhanced fruit yield and stover yield.

In a field studies performed by Mohammad *et al* (2014) in Pakhtunkhwa, Pakistan in which Ca (0.0, 3.0 and 6.0 %) and Mg (0.0, 2.0 and 4.0 %) in different level were applied. It was found that Ca and Mg applied @ 6.0 % and 4.0 % significantly enhanced growth parameters viz. plant height (cm) and branches per plant (no.), yield parameters viz. flowers per cluster (no.), fruits cluster (no.), fruits per plant (no.), fruit weight(gm) and yield (q/ha). It also reduced incidence of blossom end rot.

In an experiment undertaken by Morton *et al* (2008), it was reported that Ca: Mg ratios (7:1) can cause Mg deficiency which can be corrected by soil applied or foliar application of Mg fertilizers.

The study was undertaken on olive groves in Macedonia, Northern Greece in which the soil samples were analysed. It was presented that foliar application of nutrients such as potassium, calcium and magnesium recorded the positive correlation with soil exchangeable K, Ca and Mg in the 40-60 cm depth (Chatzistathis and Papaioannou 2019).

Ajiboye *et al* (2019) determined the soil mineralogical properties and its results on the sustainable management of the fertility by studying nine profile in Alfisols in Nigeria. It was revealed from the results that calcium and magnesium dominated exchangeable bases occupied 75% of the exchange sites.

Nasab *et al* (2019) on Pistachio crops laid an experiment in Sirjan, Iran in soils low in organic matter. The results revealed that cow manure application during the first year of study increased phosphorus and manganese in soil whereas during second year the magnesium content enhanced whereas calcium and iron reduced.

The experiment laid in sandy loam soils in 2016-17. It was revealed from the results that, calcium, magnesium, sulphur and zinc applied at 25 and 45 days after sowing observed the highest dry matter value, yield, haulm yield and nutrient uptake (Ca, Mg, S and zinc) when applied along with recommended dose of fertilizer in comparison to the control in which lowest value was observed (Lakshmi *et al* 2018)

Gonfa *et al* (2018) in a greenhouse experiment in nitisol evaluated the six rates of filter cake and bagasse ash (0, 20, 40, 60, 80, and 100 ton ha⁻¹) separately on utilization and nutrient uptake capacity of wheat. It was observed that uptake and utilization efficiency of N, Na, Ca, K and Mg were increased due to the filter cake.

Aghofack Nguemezi and Valare (2010) studied the impact of calcium and magnesium nutrients on postharvest management of tomato fruits and the growth of plants. It was revealed that the calcium and magnesium main elements in improving the quality of the crop by prolonging the shelf life of the red ripe fruits.

Rajasekar *et al* (2017) reported the improvement in yield as well as the quality due to sulfur, calcium, and magnesium (S, Ca, Mg) in the vegetable crops.

In an experiment carried during summer 2010 at Khyber Pakhtunkhwa, Pakistan to study the effect Ca and Mg levels on tomato (cv. Rio Grand). It was revealed that significant increase in growth and yield parameters was observed because of Ca and Mg and their interaction at @ 6.0 and 4.0 %, respectively (Ilyas *et al* 2014).

Effect of calcium and magnesium on net returns and benefit: cost ratio (B:C ratio)

Khurshid *et al* (2019) in a trial laid on Apple (var. Red Delicious) under temperate conditions of Kashmir. The results revealed the profit of Rs. 4,05,392 / ha with benefit cost ratio 4.36 was obtained with nutrient formulations in comparison to the farmers practice where the net return of Rs. 2,79,685/ha were obtained.

Lakshmi *et al* (2018) in field trials studied the impact of foliar sprays on economics of black gram during rabi 2016-17. It was reported that application of secondary nutrients (Ca, Mg and Sulphur) and zinc at 25 and 45 days as a foliar feeding recorded maximum net returns and B: C ratio when applied with the recommended dose of NPK.

In an investigations during 2010–11 and 2011–12 Kumar *et al* (2014) in rice bean (*Vigna umbellata*) reported lime levels when increased (in the furrow) from 0 to 0.6 t ha⁻¹ enhanced net return (Rs. 27,281 ha⁻¹) and B:C ratio (2.29) significantly.

Kumar *et al* (2017) in an experiment performed revealed that, recommended dose of NPK, soil application of humic acid @ 10 kg ha⁻¹, foliar spray of humic acid @ 0.1% and foliar spray of nutrient mixture (0.2 % Ca + 0.5 % Mg + 0.2 % B + 0.5 % Zn) enhanced cost benefit ratio (4.81).

The field trials were laid by Tripathy *et al* (2018) in kharif 2012 and 2013 at Gambharipali. It was noticed that calcium nitrate as foliar feeding resulted in the highest yield of grains (6.54 t ha⁻¹) due to which obtained Rs.109112 ha⁻¹ as net return and benefit cost ratio of 2.47.

Chaity and Sarkar (2009) in 2005 and 2006 in a field experiment laid during at Baruipur to assess the effect potassium nitrate (KNO₃) and calcium nitrate (Ca (NO₃)₂) in rice (*Oryza sativa L.*) when applied as a foliar spray. It was revealed that Ca (NO₃)₂ (0.40 %) followed by KNO₃ (0.50 %) at 50 % flowering enhanced net returns (Rs 14,733/ha) and benefit cost ratio (1.38).

Biradar *et al* (2014) in an experiment undertaken to study nutrient requirement of vertisols in Dharwad, Karnataka in year 2007 and 2008 in Bt cotton. It was revealed that KNO₃ @ 2.0 % (foliar), MgSO₄ @ 25 kg ha⁻¹ and 1.0 % (soil and foliar) and incorporation of MgSO₄ @ 25 kg ha⁻¹ (soil) improved yield by 25.0 %, 24.4 % and 24.3 % with increase in gross returns, net returns and B:C ratio.

In a study carried out for two consecutive years during rainy season of 2002 and 2003 at Kanpur. The maximum net return of Rs. 50,135 ha⁻¹ and benefit: cost ratio by 1:2.28 were recorded with RDF + 10 t FYM + 250 kg gypsum ha⁻¹ (Singh *et al* 2008).

Reddy *et al* (1998) in an investigation conducted in the year 1993 and 1994 revealed that foliar spray of calcium sulphate @ 2.0 % and zinc sulphate @ 1.0 % at 30 and 45 days after transplanting decreased the disease index with significant enhancement in grain yield. The highest B:C ratio with application of potassium chloride (108.5) was recorded followed by magnesium sulphate (73.22).

Hajong *et al* (2018) studied acceptance and profitability level of summer tomato from randomly selected 90 tomato farmers of Jashore district (Bangladesh). The results revealed the average yield of 50.41 t ha⁻¹ with gross return of 15,42,300 tk ha⁻¹. The benefit cost ratio of 2.64 on full cost basis and 3.04 on cash cost basis was recorded.

MATERIALS AND METHODS

The present study entitled “Effect of Ca and Mg on the yield and quality of tomato (*Lycopersicon esculentum* L.) in the soils of Balh valley of Mandi district of Himachal Pradesh” was undertaken at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Krishi Vigyan Kendra, Sundernagar, (Mandi), Himachal Pradesh during kharif season of 2017 and 2018. The details of field experimentation, soil and crop studies undertaken and methodology adopted have been described as under:

3.1 General description of study area

3.2 Experimental details

3.3 Field observations

3.4 Laboratory studies

3.5 Statistical analysis

3.6 Economic analysis

3.1 General description of study area

3.1.1 Experimental Site and Location

The field experiment was conducted in the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Krishi Vigyan Kendra, Sundernagar, (Mandi), Himachal Pradesh. Geographically, the experimental farm is situated at North latitude $31^{\circ} 13' 20''$ to $32^{\circ} 04' 30''$ and East longitude $76^{\circ} 37' 20''$ to $77^{\circ} 23' 15''$ and at an altitude of 880 m a.m.s.l. The climate is sub humid subtropical of the Balh valley.



Plate 1: Site of experimental trial during 2017 and 2018

3.1.2 Climate and Weather conditions

The location of the experiment site agro-climatically, represents zone II of Himachal Pradesh which is endowed with dry summers, sub humid rainy season and cool winters. The average annual rainfall in the region is low 873 mm per annum and most of it is received during winter and the dry spell can be observed from October to December. The humidity ranges from 29 to 84 %, with minimum in April and maximum observed during rainy season i.e. July and August (Fig. 3.1 and 3.2).

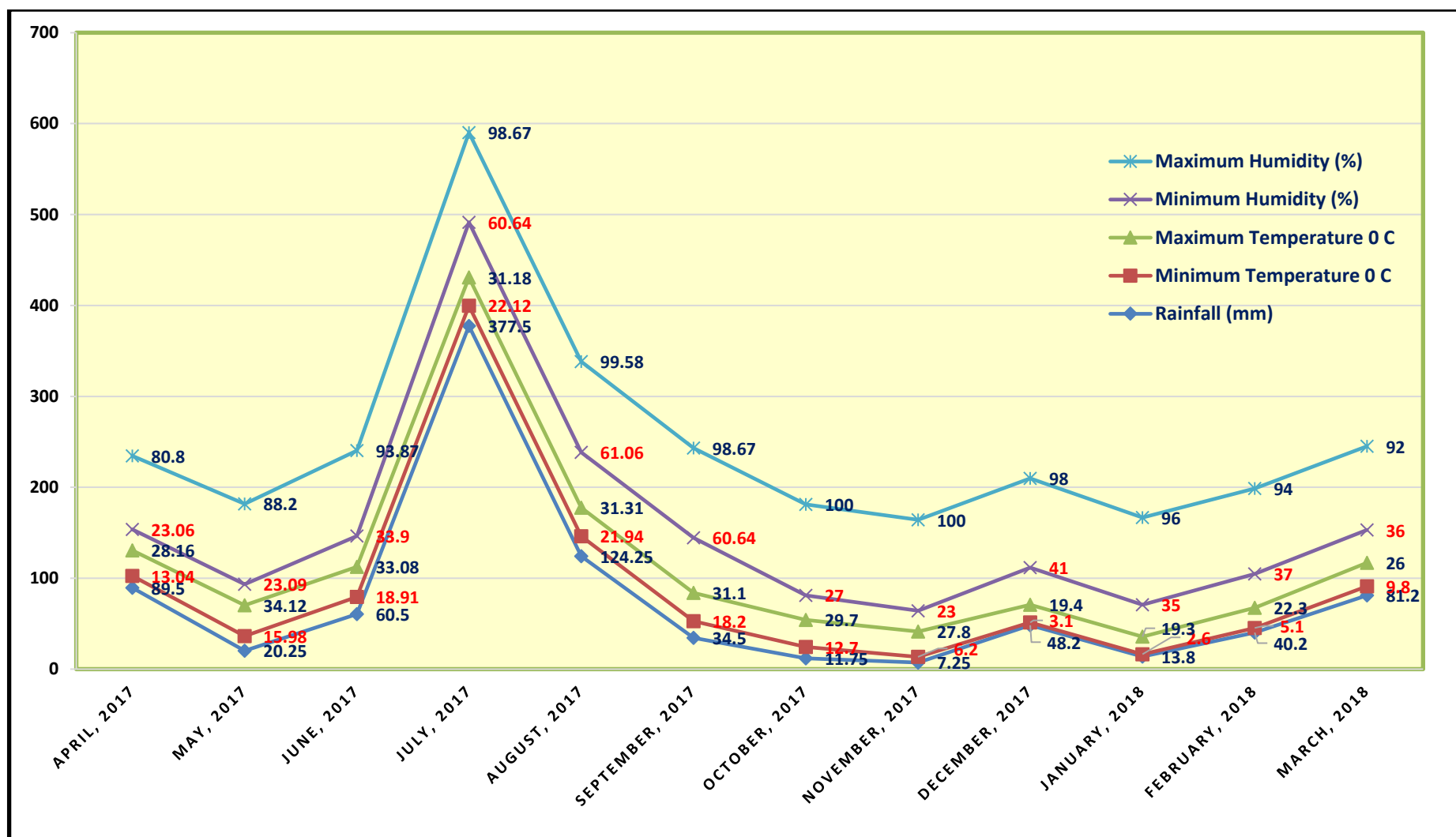


Fig 3.1: Weather data of district Mandi for the year 2017-18

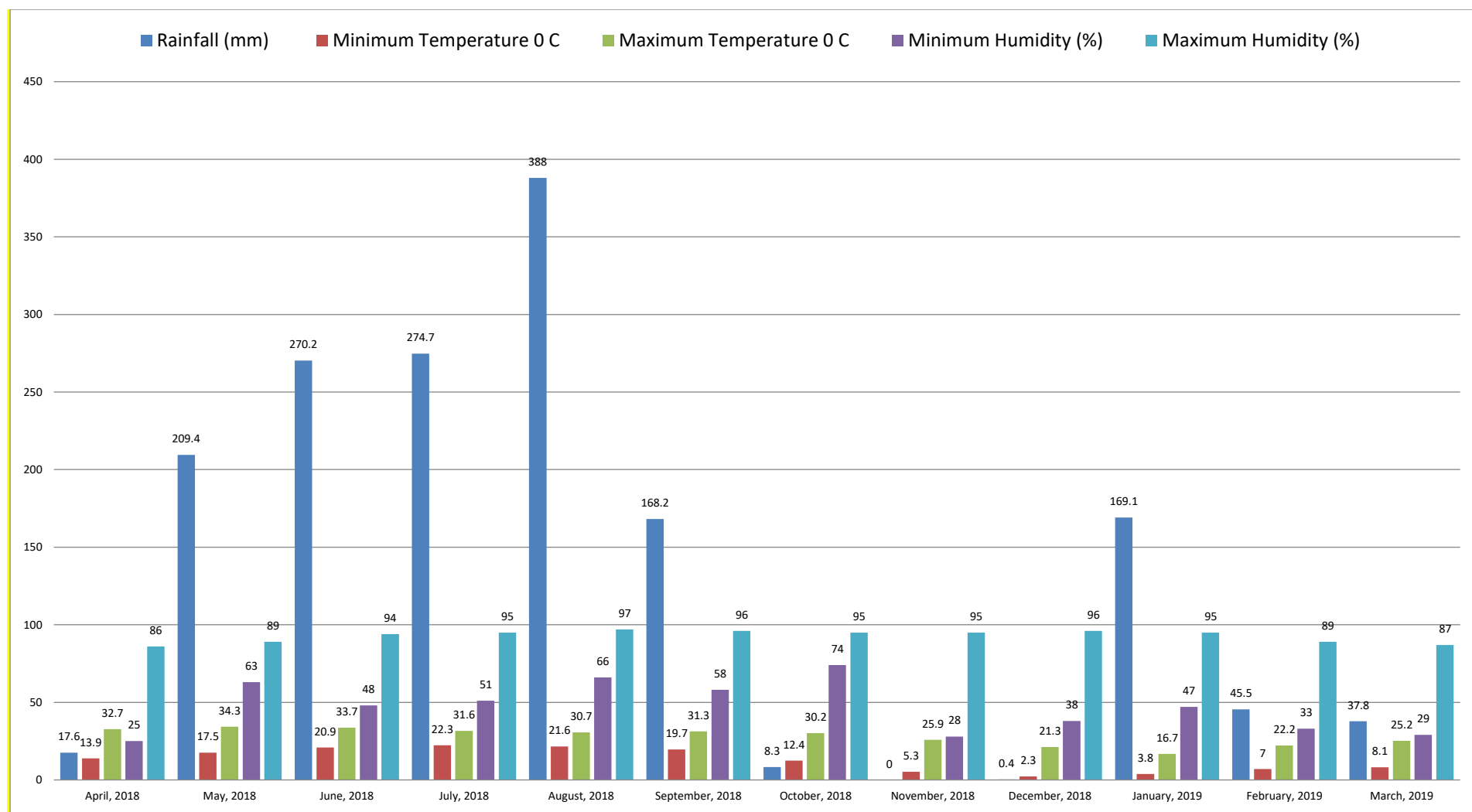


Fig 3.2 Weather data of district Mandi for the year 2018-19

3.1.3 Soils

During initiation of the experiment the soils of the experimental site were neutral in reaction and the organic carbon of the site is high. The texture of the soil is silty loam; available nitrogen and potash are medium whereas available phosphorus in the soil is low to medium. The P-fixation capacity of these soils is low to medium. Some important initial physico-chemical features of the experimental site at the depth of 0-0.15 m are provided in Table 3.1.

Table 3.1 Initial physical, chemical and physico-chemical properties of the experimental soil

S. No.	Property	Value
i.	Mechanical separates (%)	
	Sand	19.4
	Silt (%)	61.5
	Clay (%)	18.6
ii.	Textural class	Silty loam
iii.	pH	6.86
iv.	Organic Carbon (g kg ⁻¹)	8.2
v.	Available Nutrients	
	Available N	211.7
	Available P (kg ha ⁻¹)	15.4
	Available K (kg ha ⁻¹)	174.2
vi.	Exchangeable Ca (c mol (p+) kg ⁻¹)	3.6
vii.	Exchangeable Mg (c mol (p+) kg ⁻¹)	1.9

3.2 Field studies

3.2.1 Experimental details

The experiments were laid in the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Krishi Vigyan Kendra, Sundernagar, (Mandi), Himachal Pradesh during *khari* season of the year 2017 and 2018. The uniform dose of NPK fertilizers (150:120:55) and FYM @ 20 tonnes/ha to tomato crop were applied in each treatment through urea, SSP, and MOP respectively, whereas, calcium and magnesium fertilizers were applied through Calcium chloride (27 % Ca) and Magnesium sulphate (9.8 %). The layout of the experiment is presented in Fig.3.2

3.2.2 Cultivar

The seed of US- 920 hybrid were procured from a local dealer and nursery was raised at, Krishi Vigyan Kendra, Sundernagar (Mandi) Himachal Pradesh. The crop from the nursery was transplanted after 25 days and the seedlings were planted at the row to row distance of 90 cm and plant to plant at 30 cm. The tomato cultivar used in trial was a commercial variety. It was indeterminate in nature, born in clusters, red coloured fruits and excellent fruit setting in summer.



Plate 2: Nursery production of tomato (cv. US 920) for laying experiment

3.2.3 Treatments

A total 14 treatment combinations (Table 3.2) consisting foliar spray of calcium (0 (normal water), 0.3 and 0.6 percent) and four levels of magnesium (0, 0.1, 0.2 and 0.4 percent) were assessed for their relative effect on the different growth, yield, quality parameters and their uptake by tomato fruit and leaves. The details of the treatments are as follows:

Table. 3.2 Details of treatment combination:

Treatment combinations		Method of Application	Time of Application
T₁	FYM (Control)	Basal	Sowing
T₂	100 % NPK (150: 120:60)	Basal	Sowing and N2 split doses
T₃	FYM + 100 % NPK @150: 120:60 (RD)	Basal	30,45 DAT
T₄	RD+ Ca @ 0.3% Foliar application (FA)	Basal, Foliar	45 DAT
T₅	RD + Ca @ 0.6 % (FA)	Basal, Foliar	30,45,60 DAT
T₆	RD + Mg @ 0.1 % (FA)	Basal, Foliar	30,45 DAT
T₇	RD + Mg @ 0.2 % (FA)	Basal, Foliar	60 DAT
T₈	RD + Mg @ 0.4 % (FA)	Basal, Foliar	30,45,60 DAT
T₉	RD + Ca &Mg @ 0.3 & 0.1 % (FA)	Basal, Foliar	45, 60 DAT
T₁₀	RD + Ca &Mg @ 0.3 & 0.2 % (FA)	Basal, Foliar	60 DAT
T₁₁	RD + Ca &Mg @ 0.3 & 0.4 % (FA)	Basal, Foliar	30,45,60 DAT
T₁₂	RD + Ca &Mg @ 0.6 & 0.1 % (FA)	Basal, Foliar	45,60 DAT
T₁₃	RD + Ca &Mg @ 0.6 & 0.2 % (FA)	Basal, Foliar	60 DAT
T₁₄	RD + Ca &Mg @ 0.6 & 0.4 % (FA)	Basal, Foliar	30,45,60 DAT

Nutrients	:	Two (calcium and magnesium)
Method of Application	:	Foliar
Time of Application	:	30, 45 and 60 days after transplanting
A) Calcium (Ca) :		
Source of Calcium	:	Calcium chloride
Calcium levels	:	0.3 and 0.6 percent
B) Magnesium (Mg):		
Source of Magnesium	:	Magnesium Sulphate (AR grade)
Magnesium levels	:	0.1, 0.2 and 0.4 percent

Treatment combinations	:	14
Replication	:	3
Plot Size	:	3.6 × 3.0 m
Spacing	:	90 × 30 cm
No of plants /plot	:	30
Date of transplanting	:	23 rd May 2017 and 25 th May 2018



Plate 3: Preparation of plots for transplanting



Plate 4: Staking of the tomato plants



Plate 5: Flowering in the tomato plants

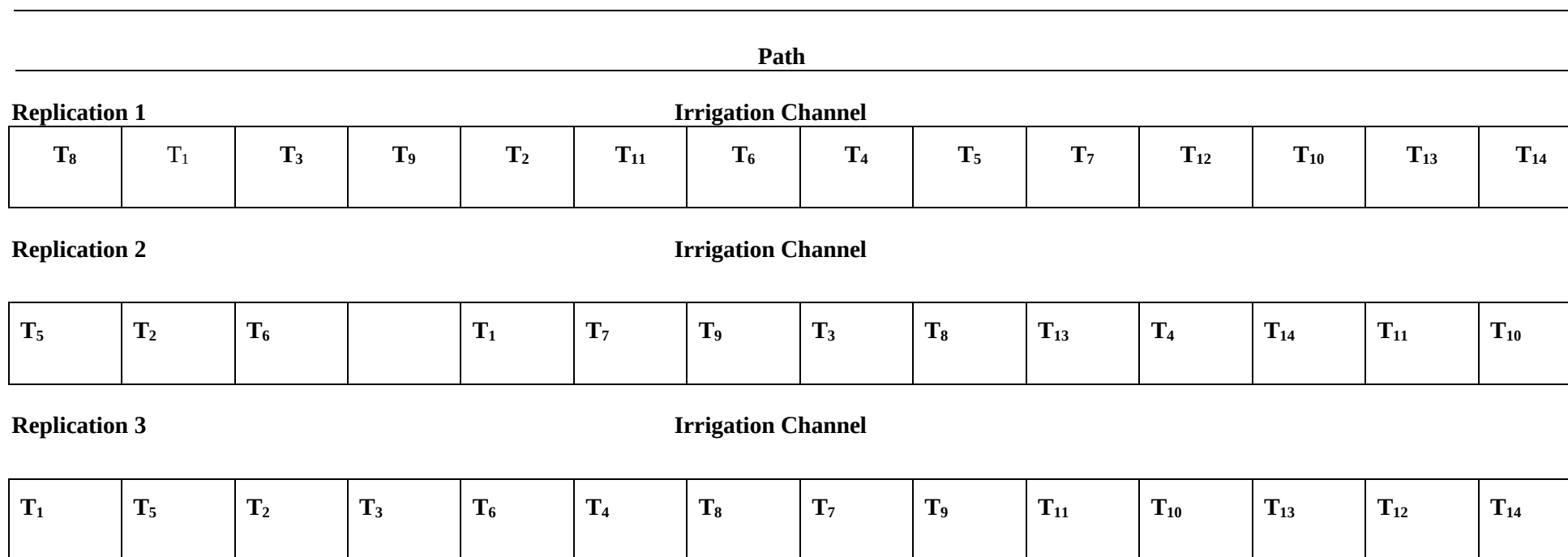
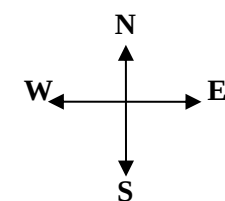


Fig. 3.3 Layout plan of Experimental Farm

Plot size	=10.8 m ²
Design	=Randomized Block Design (RBD)
Total Experimental Units	=42



3.2.4 Sources of fertilizer

Urea	:	46 % (N)
Single Super Phosphate (SSP)	:	16 % P_2O_5
Muriate of Potash (MOP)	:	60 % K_2O
Calcium chloride	:	27 % Ca
Magnesium Sulphate	:	9.8 % Mg

FYM compositions

Moisture = 70 %, Nitrogen = 0.56 %, Phosphorous = 0.22 %, Potash = 0.50 % and Sulphur = 0.30 %)

3.2.5 Recommended fertilizer doses (100 % NPK)

N	:	150 kg ha ⁻¹
P_2O_5	:	100 kg ha ⁻¹
K_2O	:	55 kg ha ⁻¹

The first experiment on tomato was laid during the year 2017. Layout of the field and its preparation were done before sowing of the crop. The tomato cultivar US-920 was transplanted on 23rd May during 2017 in which the nursery was grown at the seed rate of 150.0 g ha⁻¹ with the line to line and plant to plant spacing was 90 cm x 30 cm. Full doses of P_2O_5 and K_2O and half of nitrogen were applied at the time of sowing. Remaining half of the N in two split doses one-fourth each were applied at flowering stage and fruiting stage. The agronomic practices (weeding (manual), earthing up, staking etc.) were followed during the crop growth. The harvest of the crop as fresh was done in the different pickings and weighed plot wise for the calculation of yield per plot which was further converted into yield per hectare. Similarly, non-marketable yield and dry matter yield were also taken plot wise and converted to per hectare.

Similarly, during the year 2018, second crop of tomato was sown on 25th May and harvested fresh in different pickings and weighed plot wise for the calculation of yield per plot which was further converted into yield per hectare. Soil and crop management were same as practiced during the first year.

3.2.6 APPLICATION OF FERTILIZERS

The farm yard manure (FYM) @ 20 t/ha was incorporated at the time of field preparation. The 100 % recommended P, K and 50 % recommended N was applied after 10 days of tomato transplanting. The remaining dose of N was applied in two equal splits at flowering and fruit setting stage. Fertilizers used in the experiment were urea which contains 46 % N, single super phosphate having 16 % P_2O_5 and muriate of potash with 60 % of K_2O .

Foliar spray of calcium chloride and magnesium sulphate were Initiated at 30 days after transplanting and three sprays at 30, 45 and 60 DAT were performed. The treatment T_3 was sprayed with water used in other treatments and in treatment T_2 and T_1 no water were sprayed.

3.2.7 AFTER CARE

The experimental field was visited frequently during the entire field studies. The weeding, earthing up and plant protection against insect pests and diseases were the cultural practices carried during the crop growth periods for healthy crop. A total of seven irrigations were given at different growth stages. The staking of tomato plants was done with metallic wire structure to provide strength.



Plate 6: Harvesting of tomato fruits



Recommended Dose + Ca and Mg @ 0.6 % and 0.2 %

Recommended Dose + Ca and Mg @ 0.6 % and 0.4 %

Plate 7: Production of tomato fruits in different treatments

3.3 Field observations

3.3.1. Height of tomato plants

Five randomly selected tomato plants from each plots were tagged for recording plant height (cm). The height of the plants which were tagged was documented from the ground to the top most leaf tip at flowering stage. The plant height of these plants was taken as the mean plant height.

3.3.2 Number of flower clusters per plant

The numbers of flowers cluster per plant were recorded from the five randomly selected tagged plants which were divided by five counted to calculate the mean. The observations were recorded at flowering state of the tomato crop.

3.3.3 Number of fruits per cluster

The numbers of fruits per cluster were recorded from the five randomly selected and tagged plants which were counted at each picking and mean of the fruits was divided by five counted to calculate the mean. The observations were recorded at fruiting state of the tomato crop.

3.3.4 Fruit weight (g)

Five randomly selected mature fruits picked at every plucking weighed and the total weight recorded was divided by number counted and the mean of the weight of the fruit were calculated in grams.

3.3.5 Fruit diameter (cm)

Five fruits per plant per plot were selected randomly and with the help of vernier calliper diameters were measured which were added and divided by the number of fruits to calculate the mean of the diameter of fruits.

3.3.6 Total soluble solids (⁰B)

At the first picking in freshly harvested tomato fruits, with the help of refractometer the total soluble solid (TSS) were recorded. The fruits which have ripened were crushed and the juice obtained from crushed material was filtered from the double layer of fine meshed cheese cloth. The drop of the filtrate of the juice collected was placed on the hand refractometer and the values were recorded. For this the mean of five fruits was recorded from each plot.

3.3.7 Ascorbic acid content (mg/100g)

For determination of the ascorbic acid content, method described by Ranganna (1986) 2-6 dichlorophenol indophenol visual titration method is used. By macerating freshly harvested fully ripe tomato fruits aliquots were prepared in the presence of 3 % metaphosphoric acid and titrated against

2, 6-dichlorophenol indophenol solution dye. The end point obtained will be the pink colour remaining at least for 15 seconds.

The ascorbic acid contents were calculated by following formula:

$$\text{Vitamin C (mg/100 g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken for titration} \times \text{Weight of sample taken for estimation}} \times 100$$

3.3.7 Pericarp thickness (mm)

Pericarp thickness was measured with the help of ordinary transparent scale by randomly selecting five plants and cutting them transversely into two pieces. The data is recorded in millimetres. The five fruits were taken from each plant to calculate average thickness. On the basis, of average calculated per plant, mean of the pericarp thickness is calculated.

3.3.8 Titratable acidity (TA)

Five grams of tomato juice diluted in 25 ml of distilled water and titrated by 0.1N sodium hydroxide (NaOH) to pH 8.1. The titratable acidity was expressed as g citric acid/kg tomato, according to the following equation:

$$\text{Titratable acidity (g citric acid/kg of tomato)} = (V \times 0.1 \times 1000 \times 0.064)/m$$

0.1 is the normality of NaOH (N), 0.064 is the conversion factor for citric acid, V is the volume of NaOH required (mL) and m is the mass of tomato juice sample used (g) (AOAC 2000).

3.3.9 Tomato fruits and Stover yield

The fruit yield at each harvest was recorded and sum up to obtain total yield per plot, which was expressed as q ha⁻¹. Similarly, the stover yield was recorded after final harvest.

3.4 Laboratory Studies

3.4.1 Soil Studies

Soil samples were collected at the start of the experiment plot wise from individual plots during both the years after harvest from 0-15 cm depth. The soil samples collected initially were analysed for the physical, chemical and physio-chemical properties listed in the table 3.2. The soil samples taken plot wise at the harvest of the crop were dried, sieved and stored for analytic purpose.

At different stages leaf samples of tomato crop were collected (30, 45, 60 DAT). The leaf samples were oven dried at 65⁰ C temperature, grinded and stored in paper bags for further analysis

A. Preparation and analysis of soil samples

The soil samples taken from plots before transplanting and after harvesting of the tomato crop were dried and passed through 2 mm sieve for removing impurities. These soil samples were finally stored in polythene bags to determine the soil properties. The analytical methods used for analysis of the samples are presented in table 3.3.

Table 3.3: Important physio chemical properties of the experimental soil before initiation of the experiment

S.No.	Soil Property	Method Followed
1	Mechanical Analysis	International pipette method (Piper 1966)
2	pH (1:2.5 soil: water ratio)	Using Systronic pH meter (Jackson 1967)
3	Organic carbon (%)	Rapid titration method (Walkley and black 1934)
4	Available N (kg ha ⁻¹)	Alkaline permanganate method (Subbiah and Asija 1956)
5	Available P (kg ha ⁻¹)	0.5 M NaHCO ₃ , pH 8.5 (Olsen <i>et al.</i> 1954)
6	Available K (kg ha ⁻¹)	Neutral ammonium acetate method (Black, 1965)
7	Calcium and Magnesium (C mol (p+) kg ⁻¹)	Extraction using ammonium acetate (Jackson 1967)

B) Preparation and analysis of plant samples

The foliar spray of Ca and Mg was given at 30, 45 and 60 DAT however; leaf samples were collected at flowering and harvest stage from five randomly selected plants. The fruit samples were collected at harvest of tomato. The samples of the plants were collected at various growth stages and were oven dried at 65°C for 3-4 days and stored in paper bags for analysis.

a) Total nitrogen content

Fruit and leaf samples were digested using digestion mixture prepared from concentrated H₂SO₄ and the total nitrogen in fruit and plant samples were determined by the method using Micro-Kjeldahl's (Jackson, 1973).

b) Total phosphorus content

Fruit and leaf samples were digested with the mixture prepared from two acids in the ratio of 4:1 called di-acid (HNO₃ and HClO₄) and definite volume of the extract was made. The vanado-molybdate phosphoric yellow colour method was used to calculate total phosphorus content at the wavelength of 430 nm (Jackson, 1973).

c) Total potassium content

Plant and fruit samples were digested with di-acid mixture to obtain the extract. The flame photometer (Chapman and Brown, 1950) is used to determine the total potassium content in the extract collected.

d) Total calcium and magnesium content

Digestion by Simple dry ashing at 550°C using silica crucibles using flame photometer (Issac and Jhonson 1975)

e) Nutrients uptake

In both fruit and leaves the concentration of nitrogen, phosphorus, potassium, calcium and magnesium were determined. The formula used for the calculation of the uptake was given by (Pomares and Pratt 1987) as follows:

Uptake (kg ha⁻¹) = [concentration of nutrient (%) x yield of crop (fruit or straw q ha⁻¹) on dry weight basis] / 100

3.5 Economic analysis:

The economics of different treatments in the present study was worked out by taking the prevailing prices of inputs used into consideration. The costs for the preparation of the seed bed, input costs, plant protection etc. have been taken into account. The yield of the tomato fruits was taken into account for this purpose. Cost of cultivation, gross returns, net returns and benefit cost ratio tomato crops were calculated year wise. For economic analysis the formulae used is given below:

Gross returns (Rs per ha) = Yield (q/ha) x Price (Rs/kg) x 100

Net returns (Rs per ha) = Gross returns (Rs/ha) – Cost of cultivation Rs/ha

Benefit cost ratio = Net returns (Rs/ha) Cost of cultivation of tomato Rs/ha

3.6 Statistical Analysis:

The analysis of variance was determined for the analysis of the data recorded from this research work statistically in which the procedure drawn to anticipate the causes and it's effect on various parameters (Gomez and Gomez 1984).

3.7 Correlation:

Formula developed by Robinson *et al.* (1951) was used to calculate the correlations.

RESULTS AND DISCUSSION

The results pertaining to current study entitled ‘Effect of Ca and Mg on the yield and quality of tomato (*Lycopersicon esculentum* L.) in the soils of Balh valley of Mandi district of Himachal Pradesh’ are exhibited under the following headings in this chapter:

4.1 Effect of different treatments on growth and yield attributes

- 4.1.1 Height of the tomato plants
- 4.1.2 Number of branches in tomato plants
- 4.1.3 Number of flower clusters per plant in tomato
- 4.1.4 Number of fruits per cluster in tomato
- 4.1.5 Diameter of the tomato fruit
- 4.1.6 Weight of tomato fruits
- 4.1.7 Number of fruits per plant in tomato

4.2 Effect of different treatments on yield

- 4.2.1 Marketable yield of the tomato crop
- 4.2.2 Non marketable yield of the tomato crop
- 4.2.3 Dry matter yield of the tomato crop

4.3 Effect of different treatments on quality

- 4.3.1 Pericarp thickness of tomato fruit
- 4.3.2 Total soluble solids (TSS) of fresh tomato fruit
- 4.3.3 Vitamin C in tomato fruits
- 4.3.4 Titratable acidity in tomato fruits

4.4 Effect of different treatments on nutrient content and uptake in tomato

- 4.4.1 Nitrogen content and uptake in tomato leaves and fruit
- 4.4.2 Phosphorous content and uptake in tomato leaves and fruit
- 4.4.3 Potassium content and uptake in tomato leaves and fruit
- 4.4.4 Calcium content and uptake in tomato leaves and fruit
- 4.4.5 Magnesium content and uptake in tomato leaves and fruit

4.5 Effect of different treatments on soil properties

- 4.5.1 Soil pH and organic carbon after harvest of the crop
- 4.5.2 Soil available N, P and K after harvest of crop
- 4.5.3 Soil Exchangeable Ca and Mg after harvest

4.6 Effect of different treatments on economics

- 4.6.1 Net returns and B:C ratio in 2017
- 4.6.2 Net returns and B:C ratio in 2018
- 4.6.3 Net returns and B:C ratio in the mean data

4.7 Correlation studies

4.7.1 Correlation studies among different parameters of crop in 2017

4.7.2 Correlation studies among different parameters of crop in 2018

4.7.3 Correlation studies among different parameters of crop in the mean data

4.1 Effect of different treatments on growth and yield attributes

4.1.1 Height of the tomato plants

The data presented in the table 4.1 indicated the significant enhancement in the plant height of tomato crop cv. US-920. The foliar application of calcium and magnesium @ 0.6 and 0.2 % along with FYM and 100 % NPK documented the maximum improvement in the plant height in the treatment T₁₃ (121.83 cm in 2017, 125.11 cm in 2018 and 123.47 cm in the mean data of both the years) over the control treatment T₁ with the plant height of 99.60 cm during 2017, 105.08 cm during 2018 and 102.34 in the mean data of both the years. The percent increase of 22.32 % in 2017, 19.06 % in 2018 and 20.65 % in the mean data was recorded in T₁₃ as compared to the control T₁. The treatment T₁₃ followed by T₁₂ (120.90 cm in 2017, 124.56 cm in 2018 and 122.73 cm in the mean data) where non-significant decrease was recorded in the plant height and remained at par with T₁₃. Similarly, in treatment T₁₄ the plant height decreased non-significantly with increase in the level of magnesium @ 0.4 % (119.56 cm during 2017, 123.88 cm during 2018 and 121.72 cm in the mean data) over the control treatment T₁ with the percent increase of (20.04 % during 2017, 17.89 % during 2018 and 18.94 % in the mean data) which is evident from Table 4.1.

Further study of data in the Table 4.1 revealed that the treatment T₂ where 100 % NPK fertilizers were applied also indicated the percent increase during 2017 (2.03 %), 2018 (3.22 %) and in the mean data (2.64 %). Likewise, the treatment T₃ where recommended dose of FYM and NPK were incorporated also displayed the increase of 5.17 % in 2017, 5.11 % in 2018 and 5.14 % in the mean data of both the years over the control treatment.

The significant improvement in the plant height was also observed when both calcium and magnesium were applied separately (Table 4.1). The calcium applied @ 0.6 % in the treatment T₅ reported the significant improvement in the plant height during 2017 (116.31 cm), 2018 (120.85 cm) and in the mean data (118.58 cm) over the control T₁ with the percent increase of 16.78 % in 2017, 15.01 % in 2018 and 15.87 % in the mean data of both the years as compared to the control treatment T₁ (Table 4.1).

Similarly, the application of magnesium along with the recommended dose of FYM and NPK fertilizers also recorded the significant enhancement in the plant height over the control. The foliar application of magnesium @ 0.4 percent in the treatment T₈ revealed the significant improvement in the plant height 111.33 cm in 2017, 116.27 cm in 2018 and 113.80 cm in the mean data over the control treatment T₁. The percent increase to the tune of 11.78 % in 2017, 10.65 % in 2018 and 11.20 % in the mean data recorded in T₈ over the treatment T₁.

Table 4.1 Effect of foliar application of Ca and Mg on height of tomato plants

Treatments		Plant height after 60 days (cm)		
		2017	2018	Mean
T ₁	FYM (Control)	99.60	105.08	102.34
T ₂	NPK @ 150:120:60	101.62	108.46	105.04
T ₃	FYM + NPK @ 150:120:60 (RD)	104.75	110.45	107.60
T ₄	RD + Ca @ 0.3% Foliar application (FA)	115.55	118.97	117.26
T ₅	RD + Ca @ 0.6 % (FA)	116.31	120.85	118.58
T ₆	RD + Mg @ 0.1 % (FA)	105.86	111.96	108.91
T ₇	RD + Mg @ 0.2 % (FA)	106.65	114.09	110.37
T ₈	RD + Mg @ 0.4 % (FA)	111.33	116.27	113.80
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	116.69	118.63	117.66
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	118.09	119.31	118.70
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	118.22	122.62	120.42
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	120.90	124.56	122.73
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	121.83	125.11	123.47
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	119.56	123.88	121.72
CD (5 %)		3.90	3.22	2.14

Enhancement of the height of the tomato plants may be due to NPK fertilizers applied in the soil which affects physiological processes and vegetative growth of plant due to increase in cell division. Nitrogen being a constituent of chlorophyll, is increased when nitrogen is added which might resulted in augmented synthesis of photosynthates, leading to the better vigour. Meristematic activity of plants increased plant height which resulted due to incorporation of phosphorus which is indispensable constituent of cellular protein and nucleic acid (Fageria *et al* 2009; Ayub *et al* 2002, Maqsood *et al* 2001 and Sepehya *et al* 2012).

The increased plant height is ascribed to calcium application which activates enzymes for cell division and cell mitosis (Marschner 1995 and Mohammad *et al.* 2014; White and Broadley, 2003). The decrease in the mitotic activity due to calcium deficit decreases plant height (Nelson and Niedziela 1998).

The findings are in conformity to the findings of Sharma (1995), Marschner (1995), Dole and Wilkins (2005), White and Broadley (2003) and Mohammad *et al* (2014) and Taylor *et al* (2004) in tomato and Sureshababu (2001) in brinjal.

4.1.2 Number of branches in tomato plants

The data given in Table 4.2 revealed the influence of calcium and magnesium as a foliar feeding on tomato plants, which showed a considerable increase in number of branches. The calcium

and magnesium @ 0.6 % and 0.2 % together in T₁₃ and the FYM and 100 % NPK, lead to enhancement in number of branches in 2017 (6.64), 2018 (6.79) and the mean data (6.72) over the control T₁ with minimum number of branches viz. 5.35 in 2017, 5.46 in 2018 and 5.41 in the mean data of both years. The percent increase of 24.11 % in 2017, 24.36 % in 2018 and 24.21 % in the mean data were recorded over the control T₁. Unlikely, the treatment T₁₂ indicated the non-significant decrease in number of branches but improvement to the tune of 23.55 % in 2017, 22.89 % in 2018 and 23.11 % in the mean data where the calcium and Mg applied @ 0.6 & 0.1 % as a foliar spray over the control T₁. Increasing level of magnesium up to 0.4 % along with calcium @ 0.6 % depicted the decrease in the number of branches in T₁₄ (6.53 in 2017, 6.77 in 2018 and 6.65 in the mean data with the percent increase of 22.06 % in 2017, 23.99 % in 2018 and 22.92 % in the mean data over the control T₁ during the years of study.

The number of branches increased significantly in the treatment T₂ with the percent increase of 3.55 % in 2017, 2.56 % in 2018 and 3.14 % in the mean data over the control. Similarly, treatment T₃ also recorded the significant enhancement in the number of branches with the percent increase of 9.72% in 2017, 8.42 % in 2018 and 9.06 % in the mean data over the control. The performance of spraying calcium and magnesium separately also revealed the improvement in the number of branches of the tomato plants. The application of calcium @ 0.6 % in the treatment T₅ (6.53 in 2017, 6.64 in 2018 and 6.59 in the mean data) revealed the improvement in the number of branches with the percent increase of 22.06 % in 2017, 21.61 % in 2018 and 21.81 % in the mean data of both years over the control T₁ (Table 4.2).

The foliar feeding of magnesium @ 0.4 percent in T₈ along FYM and 100 % NPK (Recommended) also observed significant improvement in the number of branches in T₈ (6.19 in 2017, 6.28 in 2018 and 6.23 in the mean data) with the percent increase of 15.70 % in 2017, 15.02 % in 2018 and 15.16 % in the mean data over the control T₁.

The improvement in number of branches per plant might be due to the importance of Ca and Mg in cell division, cell mitosis, enlargement and metabolism of carbohydrate (Davis *et al.* 2003, Mohammad *et al.* 2014, Rashid 2000 and Ilyas *et al.* 2014). Ca activates enzymes, photosynthesis and carbohydrates metabolism which affects height of the plant, number of branches and leaf area (Bergmann 1992; Hussain *et al.* 2003). Therefore, foliar application of Ca produced taller plants and higher number of branches per plant (Hao and Papadopoulos 2003, Rubio *et al.* 2009 and Shafeek *et al.* 2013). The above findings are in conformity with the findings of Ayyub *et al.* (2012), Mostafa *et al.* (2007) and Ekinici *et al.* (2015) who elucidated that number of branches respond positively to foliar application of Ca.

Table 4.2 Effect of foliar application of Ca and Mg foliar on number of branches

Treatments		Number of Branches (after 45 days)		
		2017	2018	Mean
T ₁	FYM (Control)	5.35	5.46	5.41
T ₂	NPK @ 150:120:60	5.54	5.60	5.58
T ₃	FYM + NPK @ 150:120:60 (RD)	5.87	5.92	5.90
T ₄	RD + Ca @ 0.3% Foliar application (FA)	6.23	6.43	6.33
T ₅	RD + Ca @ 0.6 % (FA)	6.53	6.64	6.59
T ₆	RD + Mg @ 0.1 % (FA)	5.95	5.98	5.96
T ₇	RD + Mg @ 0.2 % (FA)	6.03	6.10	6.06
T ₈	RD + Mg @ 0.4 % (FA)	6.19	6.28	6.23
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	6.22	6.48	6.34
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	6.48	6.51	6.50
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	6.59	6.55	6.57
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	6.61	6.71	6.66
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	6.64	6.79	6.72
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	6.53	6.77	6.65
CD (5 %)		0.05	0.03	0.07

4.1.3 Number of flower clusters per plant in tomato

The data in Table 4.3 indicated that the foliar spray of calcium and magnesium with recommended dose of FYM and NPK fertilizer on tomato plants, displayed considerable progress in the number of flowers clusters per plant. The foliar application of calcium and magnesium @ 0.6 and 0.2 percent in the treatment T₁₃, along with the recommended dose of NPK resulted in the substantial enhancement in number of flowers per cluster (26.80 in 2017, 30.74 in 2018 and 28.77 in the mean data of both the years as compared to the control treatment T₁ (15.10 in 2017, 18.97 in 2018 and 17.04 in the mean data). The percent increase of 70.86 % in 2017, 62.05 % in 2018 and 68.84 % in the mean data of both the years in the T₁₃ was observed over the control T₁. The significant decrease was recorded in T₁₄ with increase in the level of the magnesium and applied both calcium and magnesium @ 0.6 and 0.4 % with FYM and NPK fertilizers, where the number of flowers per cluster recorded as 25.03 in 2017, 31.07 in 2018 and 28.05 in the mean data of both the years with the percent increase of 65.76 % in 2017, 63.78 % in 2018 and 64.61 % in the mean data over the control T₁. Treatment T₂ where only NPK fertilizers were applied recorded the increase of 10.79 % in 2017, 13.60 % in 2018 and 12.32 % in the mean data over the control. The treatment T₃ where FYM along with NPK fertilizers were applied (Recommended dose) also recorded the increase of 19.93 % in 2017, 35.0 % in 2018 and 28.29 % in the mean data of both the years.

Table 4.3 Effect of foliar application of Ca and Mg on number of flower clusters per plant

Treatments		Number of flower clusters per plant		
		2017	2018	Mean
T ₁	FYM (Control)	15.1	18.97	17.04
T ₂	NPK @ 150:120:60	16.73	21.55	19.14
T ₃	FYM + NPK @ 150:120:60 (RD)	18.11	25.61	21.86
T ₄	RD + Ca @ 0.3% Foliar application (FA)	21.33	24.59	22.96
T ₅	RD + Ca @ 0.6 % (FA)	25.07	28.27	26.67
T ₆	RD + Mg @ 0.1 % (FA)	20.93	24.07	22.50
T ₇	RD + Mg @ 0.2 % (FA)	22.73	26.27	24.50
T ₈	RD + Mg @ 0.4 % (FA)	24.97	26.29	25.63
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	25.61	28.07	26.84
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	26.39	28.61	27.50
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	26.40	29.08	27.74
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	26.33	29.53	27.93
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	26.80	30.74	28.77
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	25.03	31.07	28.05
	CD (5 %)	2.50	2.59	2.09

Further, examination of the data in the table 4.3 showed significant impact of calcium and magnesium when applied separately. The considerable improvement in the treatment T₅, was observed when calcium was applied as foliar feeding @ 0.6 % and resulted in the significant rise in number of flowers clusters per plant in 2017 (25.07), 2018 (28.27), and in mean data (26.67) as compared to T₁, with a percent increase of 66.03 % in 2017, 49.02 % in 2018 and 56.51 % in mean data of both the years as compared to the control.

Similarly, the number of flower clusters per plant also recorded the significant growth with magnesium at different levels. The recommended dose of FYM and NPK fertilizer along with the magnesium applied @ 0.4 % recorded the significant improvement in the number of flowers per cluster in the treatment T₈ (24.97 in 2017, 26.29 in 2018 and 25.63 in the mean data) of both the years over the control T₁. The improvement in the number of flowers per cluster was 65.36 % in 2017, 38.59 % in 2018 and 50.41 % in the mean data of both the years over the control treatment T₁ (Table 4.3).

Calcium and magnesium nutrients are able to regulate the duration of flowering in tomato plants. It also has been reported that due to calcium application the Ca²⁺ ion is involved in the photoperiodic flower induction process.

Such findings have been revealed by many researchers and the results given are in conformity with the findings of Hao and Papadopoulos (2003), Tuna *et al* (2007), Mostafa *et al* (2007) and Aghofack Nguemezi and Valere (2010).

4.1.4 Number of fruits per cluster in tomato

In the present investigation the data in the Table 4.4 indicated the effect of foliar application of calcium and magnesium on the tomato plants, which reflects a considerable enhancement in the number of fruits per cluster. The data in the treatment T₁₃ where foliar spray of calcium and magnesium @ 0.6 and 0.2 percent, respectively, along with the recommended dose of FYM and NPK lead to significant increase in number of fruits per cluster (4.61 in 2017, 5.09 in 2018 and 4.85 in the mean data of both the years. The percent increase of 70.86 % in 2017, 62.05 % in 2018 and 68.84 % in the mean data of both the years of both the years (2017 and 2018). Unlikely, with increase in the level of magnesium in treatment T₁₄ where calcium and magnesium applied @ 0.6 and 0.4 % the non-significant decrease in the number of fruits per cluster during 2017 (4.63), 2018 (5.03) and in the mean data (4.83) of both the years as compared to the control were recorded and but found to be at par to the treatment T₁₃. The percent increase of 60.21 % in 2017, 47.08 % in 2018 and 53.33 % in the mean data were recorded in T₁₄ in comparison to the control T₁.

The significant improvement in the number of fruits per cluster were also recorded in the treatment T₂ (3.19 in 2017, 3.65 in 2018 and 3.42 in the mean data) with the percent increase of 10.38 % in 2017, 6.73 % in 2018 and 8.57 % in the mean data over the control. The increase in the number of fruits per cluster were also observed in the treatment T₃ (3.41 in 2017, 3.87 in 2018 and 3.64 in the mean data) with the percent increase of 17.99 % in 2017, 13.16 % in 2018 and 15.56 % in the mean data over the control.

The perusal of the table 4.4 also revealed that, calcium applied as a foliar spray separately also indicated the significant increase in the number of fruits per cluster. Foliar spray of calcium @ 0.6 percent along with the recommended dose of FYM and NPK in the treatment T₅ recorded the growth in the number of fruits per cluster viz. 4.29, 4.89 and 4.59 during 2017, 2018 and in the mean data over the control treatment T₁. The treatment T₅ indicated the increase of 48.44 % in 2017, 42.98 % in 2018 and 45.71 % in the mean data of both the years.

Similarly, the foliar feeding of magnesium separately @ 0.4 % with the recommended dose of FYM and NPK fertilizers enhanced the number of fruits per cluster. The treatment T₈ indicated maximum number of fruits per cluster during 2017, 2018 and in mean data (4.05, 4.47 and 4.26) over the control in the treatment T₁ (2.89 in 2017, 3.42 in 2018 and 3.15 in the mean data). The increase of 40.14 % in 2017, 30.70 % in 2018 and 35.24 % in the mean data was recorded in comparison to the control T₁ (Table 4.4).

Table 4.4 Effect of foliar application of Ca and Mg on number of fruits per cluster

Treatments		Fruits per cluster		
		2017	2018	Mean
T ₁	FYM (Control)	2.89	3.41	3.15
T ₂	NPK @ 150:120:60	3.19	3.65	3.42
T ₃	FYM + NPK @ 150:120:60 (RD)	3.41	3.87	3.64
T ₄	RD + Ca @ 0.3% Foliar application (FA)	3.61	4.15	3.88
T ₅	RD + Ca @ 0.6 % (FA)	4.29	4.89	4.59
T ₆	RD + Mg @ 0.1 % (FA)	3.51	4.03	3.77
T ₇	RD + Mg @ 0.2 % (FA)	3.93	4.37	4.15
T ₈	RD + Mg @ 0.4 % (FA)	4.05	4.47	4.26
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	4.41	4.87	4.64
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	4.47	4.93	4.7
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	4.53	4.99	4.76
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	4.57	5.01	4.79
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	4.61	5.09	4.85
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	4.63	5.03	4.83
	CD (5 %)	0.39	0.57	0.37

Since the development of number of fruits in the plant depend on the number of flower clusters arrived per plant along with nutrients uptake and the amount of the nutrients Ca and Mg supplied. The treatment with the maximum number of flower clusters per plant will have maximum number of fruits per cluster. Ca and Mg play an important role in chlorophyll content, integrity of cell wall and cell membrane, enhancing germination of pollens and growth of activators of enzyme. The deficiency of Ca and Mg might cause abscission of flowers. Therefore, number of fruits might get increased due to sufficient carbohydrate availability (Epstein 1961 and Morarad *et al.* 1999). Calcium and magnesium are the nutrients which have an important role in photosynthesis, enzymes activation and in the metabolism of carbohydrates. The results were in conformity with the findings of Vuthy (1999), Mohammad *et al* (2014), Morarad *et al* (1999) and Haleema *et al* (2018).

4.1.5 Diameter of the tomato fruit

The examination of the data presented in the table 4.5 indicated the effect of foliar feeding of calcium and magnesium on fruit diameter in the tomato plants. The significant increase in the fruit diameter was recorded when calcium and magnesium applied as a foliar spray @ 0.6 % and 0.2 % in the treatment T₁₃ and the diameter recorded was (4.57 cm in 2017, 4.81 cm in 2018 and 4.69 cm in the mean data) as compared to the control treatment T₁ (3.91 cm in 2017, 3.97 cm in 2018 and 3.94 cm in the mean data). The percent increase recorded was 16.88 % in 2017, 21.16 % in 2018 and 19.04 % in

the mean data over the control treatment T₁. Unlikely, with the increase in the level of magnesium the significant decrease in the fruit diameter was recorded in T₁₄ (4.56 cm during 2017, 4.72 cm during 2018 and 4.64 cm in mean data) over the control T₁ with the percent increase of 16.62 % in 2017, 19.19 % in 2018 and 17.77 % in the mean data of both the years over the control T₁.

The application of NPK fertilizers also recorded the increase in the fruit diameter in the treatment T₂ (4.08 cm in 2017, 4.14 cm in 2018 and 4.11 cm in the mean data) with the percent increase of 4.35 % in 2017, 4.55 % in 2018 and 4.31 % in the mean data over the control. Likewise, the application of recommended FYM and NPK fertilizers in T₃ (4.15 cm in 2017, 4.29 cm in 2018 and 4.22 cm in the mean data) also recorded the increase of 6.14 % in 2017, 8.33 % in 2018 and 7.11 % over the control.

The increase in the fruit diameter was also recorded in the treatments where both the nutrients were applied individually. The foliar spray of calcium @ 0.6 % and recommended FYM and NPK fertilizers dose in T₅ observed the increase in the fruit diameter viz. 4.43 cm in 2017, 4.59 cm in 2018 and 4.51 cm in the mean data of the tomato crop over the control T₁. The percent increase in the fruit diameter observed was 13.30 % in 2017, 15.91 % in 2018 and 14.47 % in the mean data of both the years over the control T₁ (Table 4.5).

Table 4.5 Effect of foliar application of Ca and Mg on diameter of the tomato fruits

Treatments		Fruit diameter (cm)		
		2017	2018	Mean
T ₁	FYM (Control)	3.91	3.96	3.94
T ₂	NPK @ 150:120:60	4.08	4.14	4.11
T ₃	FYM + NPK @ 150:120:60 (RD)	4.14	4.29	4.22
T ₄	RD + Ca @ 0.3% Foliar application (FA)	4.28	4.46	4.37
T ₅	RD + Ca @ 0.6 % (FA)	4.43	4.58	4.51
T ₆	RD + Mg @ 0.1 % (FA)	4.22	4.37	4.30
T ₇	RD + Mg @ 0.2 % (FA)	4.26	4.40	4.33
T ₈	RD + Mg @ 0.4 % (FA)	4.32	4.43	4.38
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	4.36	4.48	4.42
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	4.40	4.55	4.48
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	4.47	4.62	4.55
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	4.52	4.67	4.60
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	4.58	4.81	4.69
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	4.51	4.76	4.64
	CD (5 %)	0.22	0.24	0.18

Further, perusal of the data also revealed the increase in the fruit diameter with the increasing level of the foliar application of magnesium. The significant improvement in the fruit diameter was recorded when the magnesium was applied as a foliar feeding @ 0.4 % along with the 100% FYM and NPK fertilizer (4.32 cm in 2017, 4.44 cm in 2018 and 4.38 cm in the mean data) as per the recommendation over the control T₁. The percent increase of 10.49 % in 2017, 12.12 % in 2018 and 11.17 % in the mean data of both the years over the control T₁.

The role of calcium and magnesium can be attributed to functions such as enzyme activation, photosynthesis and metabolism of the carbohydrate. Calcium stimulates the enzyme liable for enhancing mitosis, splitting of the cells as well in increasing the size of the cell and in developing fruits by improving the mobilization of assimilates (Sana *et al.* 2019).

Magnesium enhances activity of enzyme and promotes nutrient transport of and stimulates the growth and increases size. The findings are in agreement with findings of Ilyas *et al* (2014), Ayyub *et al* (2012), Kasinath *et al* (2015), Abdur and Ihsan ul haq (2012), Peter *et al* (1999), Budak and Erdal (2016) and Sana Saleem *et al* (2019).

4.1.6 Weight of tomato fruits

Data pertaining to the fruit weight of tomato fruits has been given in the table 4.6. It was revealed from the study that the foliar spray of calcium and magnesium @ 0.6 and 0.2 % along with 100 % FYM and NPK fertilizers recommended in the treatment T₁₃ indicated a considerable increase in the fruit weight (68.11 g during 2017, 76.23 g during 2018 and 72.17 g in the mean data) in comparison to the control T₁ (53.71 g in 2017, 60.03 g in 2018 and 56.87 g in the mean data). The percent increase of 26.81 % in 2017, 26.99 % in 2018 and 26.90 % in the mean data was observed in T₁₃ over the control. Further, with increase in the level of magnesium in T₁₄ the significant decrease in the tomato weight was recorded viz. 67.95, 75.97 and 71.96 g during 2017, 2018 and in the mean data as compared to the treatment T₁₃ but significantly superior to the treatment T₁ with the percent increase of 26.51 % in 2017, 26.55 % in 2018 and 26.53 % in the mean data. Likewise, incorporation of 100 % NPK fertilizer in the treatment T₂ (58.23 g in 2017, 64.63 g in 2018 and 61.43 g in the mean data) also recorded the increase of 8.42 % in 2017, 7.66 % in 2018 and 8.02 % in the mean data over the control T₁. Perusal of the data further in the treatment T₃ (60.16 g in 2017, 65.16 g in 2018 and 62.66 g in the mean data) also recorded the increase of 12.01 % in 2017, 8.55 % in 2018 and 10.18 % in the mean data over the control T₁ when FYM and NPK fertilizers both were applied.

Further, foliar spray also improved the fruit weight where both the nutrients were applied separately. The foliar feeding of calcium @ 0.6 % along with the 100 % FYM and NPK fertilizers recommended in the treatment T₅ (65.62 g in 2017, 72.36 g in 2018 and 68.99 g in the mean data) of the tomato crop over the control T₁ during the years of study with the percent increase of 22.17 % in 2017, 20.54 % in 2018 and 21.31 % in the mean data over the control.

The foliar spray of magnesium @ 0.4 % along with 100 % FYM and NPK fertilizers recommended also enhanced the fruit weight significantly in the treatment T₈ (61.28 g in 2017, 66.86 g in 2018 and 64.07 g in the mean data) in comparison to the control T₁. The growth in the weight of fruit was observed viz. 14.09 % in 2017, 11.38 % in 2018 and 12.66 % in the mean data over the control.

Both Ca and Mg perform various activities, deficit of both these nutrients may lead to the poor quality of fruit growth and low yields (Davis *et al* 2003). The increase in average weight of tomato shows the positive result of calcium chloride where in the formation of cell wall the Ca plays a role binding agent in the complex polysaccharides and proteins and increases tomato fruit weight with the use of calcium fertilizers (Gezerel 1986, Eraslan *et al* 2007 and Cardozo *et al* 2001). The findings are in conformity with the findings of Gezerel (1985), Rani *et al* (2016) and Dixit *et al* (2018).

Table 4.6 Effect of foliar application of Ca and Mg on weight of tomato fruits

Treatments		Fruit weight (gm)		
		2017	2018	Mean
T ₁	FYM (Control)	53.71	60.03	56.87
T ₂	NPK @ 150:120:60	58.23	64.63	61.43
T ₃	FYM + NPK @ 150:120:60 (RD)	60.16	65.16	62.66
T ₄	RD + Ca @ 0.3% Foliar application (FA)	62.46	68.22	65.34
T ₅	RD + Ca @ 0.6 % (FA)	65.62	72.36	68.99
T ₆	RD + Mg @ 0.1 % (FA)	59.82	65.64	62.73
T ₇	RD + Mg @ 0.2 % (FA)	60.12	66.03	63.08
T ₈	RD + Mg @ 0.4 % (FA)	61.28	66.86	64.07
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	64.19	67.91	66.05
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	65.06	70.18	67.62
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	65.53	71.15	68.34
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	67.19	74.63	70.91
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	68.11	76.23	72.17
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	67.95	75.97	71.96
	CD (5 %)	4.44	3.17	2.62

4.1.7 Number of fruits per plant

The data presented in the table 4.7 pertaining to the number of fruits per plant indicated that the of calcium and magnesium applied as foliar spray @ 0.6 and 0.2 % along with the recommended 100 % FYM and NPK fertilizers recommended in the treatment T₁₃ reflects a considerable increase in the number of fruits per plant (58.73 in 2017, 64.61 during 2018 and 61.67 in the mean data) in

comparison to the control T₁ (32.86 in 2017, 36.99 in 2018 and 34.93 in the mean data). The percent increase of 78.73 % in 2017, 74.67 % in 2018 and 76.55 % in the mean data was recorded over the control. Further, increase in the level of magnesium @ 0.4 % with FYM and NPK fertilizers in T₁₄ non-significantly decreased the number of fruits per plant (57.21 in 2017, 63.33 in 2018 and 60.27 in the mean data) as compared to the treatment T₁₃ but significantly enhanced in comparison to the treatment T₁ with the percent increase of 74.10 % in 2017, 71.21 % in 2018 and 72.55 % in the mean data.

Likewise, 100 % NPK fertilizer incorporated in the treatment T₂ (38.89 in 2017, 44.75 in 2018 and 41.82 in the mean data) also recorded the increase of 18.35 % in 2017, 20.98 % in 2018 and 19.73 % in the mean data over the control. Perusal of the data further also recorded the increase of 28.03 % in 2017, 27.36 % in 2018 and 27.66 % in the mean data in T₃ over the control T₁.

Table 4.7 Effect of foliar application of Ca and Mg on number of fruits per plant

Treatments		Number of fruits per plant		
		2017	2018	Mean
T ₁	FYM (Control)	32.86	36.99	34.93
T ₂	NPK @ 150:120:60	38.89	44.75	41.82
T ₃	FYM + NPK @ 150:120:60 (RD)	42.07	47.11	44.59
T ₄	RD + Ca @ 0.3% Foliar application (FA)	49.13	55.29	52.21
T ₅	RD + Ca @ 0.6 % (FA)	53.52	58.18	55.85
T ₆	RD + Mg @ 0.1 % (FA)	43.87	47.61	45.74
T ₇	RD + Mg @ 0.2 % (FA)	46.64	49.50	48.07
T ₈	RD + Mg @ 0.4 % (FA)	48.45	52.21	50.33
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	51.42	55.32	53.37
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	51.66	56.12	53.89
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	52.14	57.82	54.98
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	55.61	61.33	58.47
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	58.73	64.61	61.67
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	57.21	63.33	60.27
	CD (5 %)	4.62	4.30	2.08

Foliar feeding also improved the number of fruits per plant where both the nutrients were applied alone. The foliar spray of calcium @ 0.6 % along with 100 % FYM and NPK fertilizers recommended in the treatment T₅ indicated the improvement of 53.52 in 2017, 58.18 in 2018 and 55.85 in the mean data of the tomato crop over the control T₁ during the years of study. The percent increase of 62.87 % in 2017, 57.29 % in 2018 and 59.89 % in the mean data over the control.

The foliar spray of magnesium @ 0.4 % along with the 100 % FYM and NPK fertilizers recommended also enhanced the fruit weight significantly in the treatment T₈ (48.45 in 2017, 52.21 in 2018 and 50.33 in the mean data) in comparison to the control T₁. The growth in the fruit weight was recorded to the tune of 47.44 % in 2017, 41.15 % in 2018 and 44.09 % in the mean data over the control.

The reasons for maximum number of fruits in tomato crop is ascribed to increased fruit setting and are retained due to the availability of calcium and magnesium as a foliar spray. Upendra *et al* (2003) and Dixit *et al* (2018) also revealed that increase in the number of fruits per plant is due to the increased mineral nutrition. The Similar finding have been reported by Gezerel (1985), Rani *et al* (2016), Abdur and Ihsan ul haq (2012), Peter *et al* (1999), Budak and Erdal (2016) and Dixit *et al* (2018).

4.2 Effect of different treatments on yield

4.2.1 Marketable yield of the tomato crop

The data related to the impact of foliar spray treatments on fruit yield of tomato is presented in table 4.8. The experimental results indicated that the foliar application calcium and magnesium @ 0.6 % and 0.2 % and incorporation of 100% recommended FYM and NPK fertilizers recorded significant increase of fruit yield in treatment T₁₃ (369.64 q ha⁻¹ in 2017, 391.82 q ha⁻¹ in 2018 and 380.73 q ha⁻¹ the mean data) over the control treatment T₁ (110.94 q ha⁻¹ in 2017, 134.42 q ha⁻¹ in 2018 and 122.68 q ha⁻¹ in the mean data) where only FYM was applied. The increase in the marketable fruit yield of tomato was observed to the tune of 233.19 % in 2017, 191.49 % in 2018 and 210.34 % for mean marketable yield data in comparison to the treatment T₁. With the increase in the level of magnesium in T₁₄ (363.31 q/ha in 2017, 385.77 q/ha in 2018 and 374.54 q/ha in the mean data) the non-significant decrease in the marketable fruit yield was also recorded as compared to the treatment T₁₃ but remained at par with it. The significant increase was recorded over the control T₁ with the per cent increase of 227.48 % in 2017, 186.99 % in 2018 and 205.30 % in the mean data of both the years over the control (Table 4.8).

The significant influence on T₂ (100 % NPK fertilizers) was also revealed with the increase of 89.66 % in 2017, 72.57 % in 2018 and 80.30 % in the mean marketable yield data over the control. Likewise, treatment with FYM and 100 % NPK fertilizers recommended dose in T₃ (252.41 q/ha in 2017, 271.59 q/ha in 2018 and 262.0 q/ha in the mean data) was also recorded with the per cent increase of 127.52 % in 2017, 102.05 % in 2018 and 113.56 % for mean marketable yield data as compared to the control.

The tomato fruit yield was significantly influenced due to foliar sprays performed with both calcium and magnesium separately. The foliar spray of calcium separately @ 0.6 % in T₅ significantly enhanced the marketable fruit yield by 344.18 q ha⁻¹ in 2017, 365.82 q ha⁻¹ in 2018 and 355.0 q ha⁻¹

for mean marketable fruit yield (Table 4.8) over the control with increase of 210.24 % in 2017, 172.15 % in 2018 and 189.37 % in comparison to the control T₁ (Table 4.8).

Further, perusal of data in table 4.8 also indicated the influence of increasing magnesium level on the marketable yield of the tomato crop. The magnesium applied @ 0.4 % individually in T₈ also enhanced the tomato yield during 2017 (273.55 %), 2018 (295.95 %) and in the mean data (284.75 %) in comparison to the control T₁ with the increase of 146.57 % in 2017, 120.17 % in 2018 and 132.11 % in the mean data of both the years.

Table 4.8 Effect of foliar application of Ca and Mg on marketable yield of tomato

Treatments		Marketable yield (q/ha)		
		2017	2018	Mean
T ₁	FYM (Control)	110.94	134.42	122.68
T ₂	NPK @ 150:120:60	210.41	231.97	221.19
T ₃	FYM + NPK @ 150:120:60 (RD)	252.41	271.59	262.0
T ₄	RD + Ca @ 0.3% Foliar application (FA)	304.35	326.33	315.34
T ₅	RD + Ca @ 0.6 % (FA)	344.18	365.82	355.0
T ₆	RD + Mg @ 0.1 % (FA)	261.31	283.49	272.4
T ₇	RD + Mg @ 0.2 % (FA)	268.54	287.22	277.88
T ₈	RD + Mg @ 0.4 % (FA)	273.55	295.95	284.75
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	306.69	329.41	318.05
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	316.14	339.16	327.65
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	318.72	341.5	330.11
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	360.85	381.51	371.18
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	369.64	391.82	380.73
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	363.31	385.77	374.54
CD (5 %)		11.48	11.16	8.92

Talukder *et al* (2009) reported significant effect of Mg on yield of potato. Magnesium is very important constituent of chlorophyll, which has important role in the light reaction of photosynthesis (Taiz and Zeiger 1998). In the studies conducted earlier on the winter tomato crops it was revealed that fruit yield in winter times was reduced significantly due to low Mg content (Hao and Papadopoulos 2003). The similar findings have been reported by Hao and Papadopoulos (2003) and Kasinath *et al* (2014) in tomato. The calcium nitrate improved weight of the tuber, dry matter and tuber size but number of tubers per plant was reduced. The findings are in agreement to the findings of Asiegbo and Uzo (1983), Singh *et al* (1982), Altarugio *et al* (2017) and Ali *et al* (2018).

4.2.2 Non marketable yield of the tomato

The data presented (Table 4.9) indicated the impact of foliar spray of calcium and magnesium on the non marketable yield of tomato. The results revealed that, foliar spray of calcium and magnesium @ 0.6 % and 0.2 % with incorporation of recommended dose of FYM and 100 % NPK fertilizers decreased the non marketable yield of tomato in treatment T₁₃ (42.59 q ha⁻¹ in 2017, 61.27 q ha⁻¹ in 2018 and 51.92 q ha⁻¹ the mean data) over the control treatment T₁ (79.97 q ha⁻¹ in 2017, 92.60 q ha⁻¹ in 2018 and 86.28 q ha⁻¹ in the mean data where only FYM was applied. With the increase in the level of magnesium in T₁₄ to 0.4 % the non marketable fruit yield was recorded to 41.36 q ha⁻¹ in 2017, 65.98 q ha⁻¹ in 2018 and 53.67 q ha⁻¹ in the mean data of both the years as compared to the treatment T₁₃ but remained at par with it but significant decrease was recorded in comparison to the control T₁ where only FYM was applied.

Table 4.9 Effect of foliar application of Ca and Mg on non- Marketable yield of tomato

Treatments		Non- Marketable (q/ha)		
		2017	2018	Mean
T ₁	FYM (Control)	79.97	92.59	86.28
T ₂	NPK @ 150:120:60	61.14	87	74.07
T ₃	FYM + NPK @ 150:120:60 (RD)	58.04	84.18	71.11
T ₄	RD + Ca @ 0.3% Foliar application (FA)	52.77	59.19	55.98
T ₅	RD + Ca @ 0.6 % (FA)	50.12	58.62	54.37
T ₆	RD + Mg @ 0.1 % (FA)	53.31	79.21	66.26
T ₇	RD + Mg @ 0.2 % (FA)	49.25	75.09	62.17
T ₈	RD + Mg @ 0.4 % (FA)	48.12	75.30	61.71
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	44.03	67.47	55.75
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	42.23	69.15	55.69
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	41.62	68.6	55.11
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	41.15	68.27	54.71
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	42.59	61.25	51.92
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	41.36	65.98	53.67
	CD (5 %)	4.39	4.54	2.54

The decrease in the non marketable yield was also revealed in the treatment T₂ (61.14 q ha⁻¹ in 2017, 87.0 q ha⁻¹ in 2018 and 74.07 q ha⁻¹ in the mean data) and T₃ (58.04 q ha⁻¹ in 2017, 84.18 q ha⁻¹ in 2018 and 71.11 q ha⁻¹ in the mean data) as compared to the control treatment T₁.

The foliar feeding in the tomato crop of calcium and magnesium separately along with FYM and 100 % NPK fertilizers recommended also declined non marketable yield. The foliar spray of

calcium separately @ 0.6 % in T₅ significantly decreased the non marketable fruits to 50.12 q ha⁻¹ in 2017, 58.62 q ha⁻¹ in 2018 and 54.37 q ha⁻¹ for mean data of non marketable fruit yield (Table 4.9).

Perusal of the data in the Table 4.9 also indicated the influence of increasing magnesium level on the non marketable yield of the tomato crop. The magnesium applied @ 0.4 % individually in T₈ also declined the non marketable yield of tomato during 2017 (48.12 q ha⁻¹), 2018 (75.30 q ha⁻¹) and in the mean data (61.71 q ha⁻¹) in comparison to the control treatment T₁.

High proportion of Ca and Mg ratio in the nutrient solution may be the reason for improving yield of the tomato fruit and reduction in the blossom-end rot incidence. The high proportion of Mg increased total antioxidant activity in tomato fruits (Fanasca *et al.* 2006). Similar findings have been reported by Fanasca *et al* (2006), Saikia *et al* (1999), Vuthy (1999), Zoz *et al* (2016) and Sakhonwasee and Phingksan (2017)

4.2.2 Stover yield or dry matter yield of the tomato crop

The data presented showed the effect of treatments on tomato stover yield or dry matter yield has been reflected in table 4.10. Significant differences were observed in stover yield when calcium and magnesium applied at different rates along with recommended dose of FYM + NPK fertilizers which had positive effect on this parameter. The results indicated foliar feeding of calcium and magnesium @ 0.6 % and 0.2 % recorded maximum increase in yield (90.89 q ha⁻¹ in 2017, 103.11 q ha⁻¹ in 2018 and 97.0 q ha⁻¹ in the mean data as compared to the control T₁ (75.28 q ha⁻¹ in 2017, 87.12 q ha⁻¹ in 2018 and 81.20 q ha⁻¹ in the mean data of both the years. The percent increase of 20.74 % in 2017, 18.35 % in 2018 and 19.46 % in mean stover yield in T₁₃ was recorded over the control treatment T₁.

With the increase in the level of magnesium in T₁₄ (90.33 q/ha in 2017, 100.01 q/ha in 2018 and 96.17 q/ha in the mean data) the non-significant decrease in the stover yield was recorded as compared to the treatment T₁₃ but remained at par with it. The significant increase was recorded over the control T₁ with the percent increase of 19.99 % in 2017, 14.80 % in 2018 and 18.44 % in the mean data of both the years over the control (Table 4.10).

The significant influence on T₂ (100 % NPK fertilizers) was also revealed with the increase of 5.25 % in 2017, 3.66 % in 2018 and 4.40 % in the mean stover yield data over the control. Likewise, treatment T₃ (Recommended dose of FYM and 100 % NPK fertilizers) was also recorded with the percent increase of 7.84 % in 2017, 5.95 % in 2018 and 6.82 % for stover yield data as compared to the control.

Foliar application of calcium and magnesium separately along with FYM and NPK fertilizers at different concentrations significantly influenced the stover yield of tomato (Table 4.9). The foliar application of calcium @ 0.6 % increased dry matter yield in the treatment T₅ (89.29 q/ha in 2017,

99.35 q/ha in 2018 and 94.32 q/ha in the mean data) with per cent increase of 18.61 % in the year 2017, 14.04 % in 2018 and 16.16 % for mean stover yield over the control T₁.

The further study of data in the Table 4.10 also shows the influence of increasing level of magnesium on the stover yield of the tomato crop. The magnesium applied @ 0.4 % with FYM and NPK fertilizers alone also enhanced the tomato stover yield during 2017 (82.33 q/ha), 2018 (93.41 q/ha and 87.87 q/ha in mean data with the percent increase of 9.37 % in 2017, 7.22 % in 2018 and 8.21 % in the mean data of stover yield over the control in T₁.

Table 4.10 Effect of foliar application of Ca and Mg on dry matter yield of tomato

Treatments		Dry Matter Yield (q/ha)		
		2017	2018	Mean
T ₁	FYM (Control)	75.28	87.12	81.2
T ₂	NPK @ 150:120:60	79.23	90.31	84.77
T ₃	FYM + NPK @ 150:120:60 (RD)	81.18	92.3	86.74
T ₄	RD + Ca @ 0.3% Foliar application (FA)	88.45	97.37	92.91
T ₅	RD + Ca @ 0.6 % (FA)	89.29	99.35	94.32
T ₆	RD + Mg @ 0.1 % (FA)	77.15	88.91	83.03
T ₇	RD + Mg @ 0.2 % (FA)	79.41	90.17	84.79
T ₈	RD + Mg @ 0.4 % (FA)	82.33	93.41	87.87
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	85.15	97.35	91.25
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	85.52	97.76	91.64
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	88.49	99.65	94.07
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	89.78	101.34	95.56
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	90.89	103.11	97
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	90.33	102.01	96.17
CD (5 %)		2.80	2.94	4.62

The improvement in the stover yield of tomato might be the combined application of Ca and Mg that lead to enhancement in leaf yield of tomato crop. The results of the present study are in agreement with the findings of Vishwanath (1996) and Rani *et al.* (2016) who revealed the significant improvement in higher leaf yield in mulberry due to the application of Ca and Mg in combination. Enhancement in the leaf yield by the application of Ca and Mg also reported by Shankar and Shivashankar (1994), Gunther (1981) and Rani *et al* (2016).

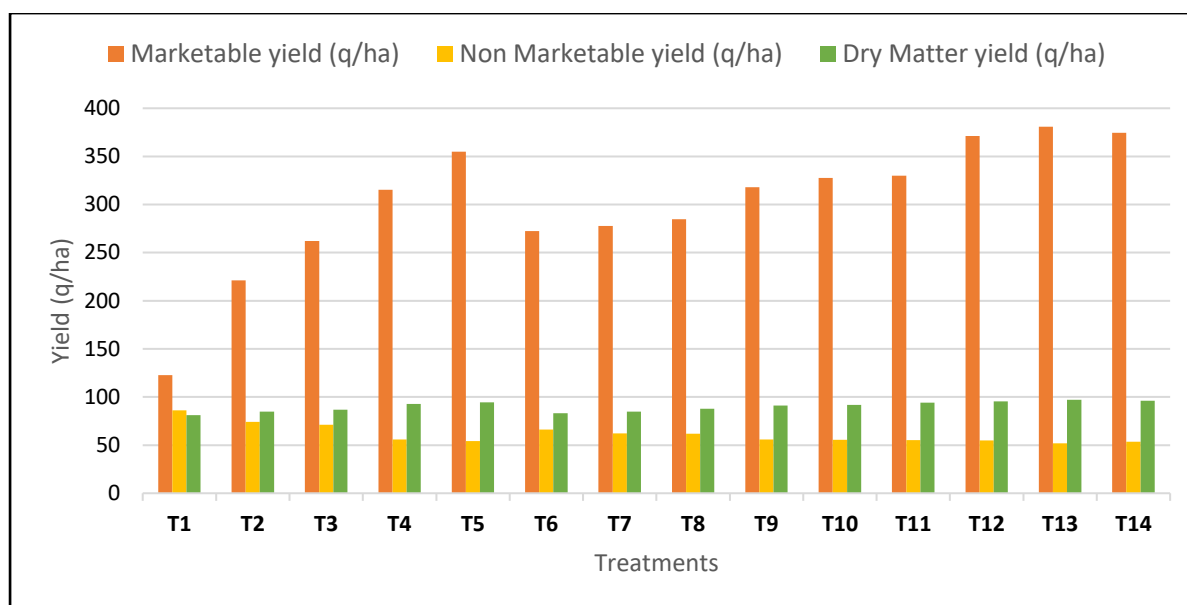


Fig. 4.1 Effect of foliar application of Ca and Mg on mean marketable yield, non-marketable yield and stover yield of tomato

4.3 Effect of different treatments on quality

4.3.3 Pericarp thickness of tomato fruit

The examination of data presented on pericarp thickness in table 4.11 reported that, it was affected by application of calcium and magnesium as a foliar spray of in a tomato crop. The pericarp thickness significantly improved with increasing level of calcium and magnesium when applied in combination and separately. The maximum improvement was recorded in the treatment T₁₃ (4.88 mm in 2017, 5.04 mm in 2018 and 4.96 mm in the mean data) where the calcium and magnesium were applied @ 0.6 and 0.2 % along with recommended dose of FYM and NPK fertilizer with the percent increase of 9.66 % in 2017, 10.28 % in 2018 and 9.98 % in the mean data over the control T₁ (4.45 mm in 2017, 4.57 mm in 2018 and 4.51 mm in the mean data). The significant decrease in the pericarp thickness was recorded with the increasing level of magnesium in the treatment T₁₄ (4.91 mm in 2017, 4.97 mm in 2018 and 4.94 mm in the mean data) in comparison to T₁ but remained at par to T₁₃. The percent increase of 10.34 % in 2017, 8.75 % in 2018 and 9.53 % in the mean data over the control T₁.

The significant influence on T₂ with 100 % NPK fertilizers was also revealed with the increase of 1.80 % in 2017, 0.88 % in 2018 and 1.33 % in the pericarp thickness over the control. Likewise, treatment T₃ (Recommended dose of FYM and 100 % NPK fertilizers) was also recorded with the per cent increase of 5.17 % in 2017, 4.16 % in 2018 and 4.66 % for pericarp thickness as compared to the control T₁.

Further, perusal of the data (Table 11) also indicated the significant improvement in the pericarp thickness when calcium and magnesium were applied alone. The significant increase in the

pericarp thickness was also recorded when calcium was applied as a foliar feeding in the treatment T₅ @ 0.6 %, which indicated the increase of pericarp thickness during 2017, 2018 and in mean data viz. 4.82, 4.92 and 4.87 mm with the percent increase of 8.31 % during 2017, 7.66 % during 2018 and 7.98 % in the mean data of both the years over the control T₁ (Table 4.11).

Increase in the magnesium level also recorded the significant enhancement in the pericarp thickness. The foliar spray of magnesium @ 0.4 % along with the FYM and 100 % NPK fertilizers in the treatment T₈ (4.72 mm in 2017, 4.80 mm in 2018 and 4.76 mm in the mean data) recorded the percent increase of 6.07 % during 2017, 5.03 % during 2018 and 5.54 % in the mean data of both the years over control T₁.

Table 4.11 Effect of foliar spray of Ca and Mg on pericarp thickness of tomato

Treatments		Pericarp Thickness (mm)		
		2017	2018	Mean
T ₁	FYM (Control)	4.45	4.57	4.51
T ₂	NPK @ 150:120:60	4.53	4.61	4.57
T ₃	FYM + NPK @ 150:120:60 (RD)	4.68	4.76	4.72
T ₄	RD + Ca @ 0.3% Foliar application (FA)	4.75	4.81	4.78
T ₅	RD + Ca @ 0.6 % (FA)	4.82	4.92	4.87
T ₆	RD + Mg @ 0.1 % (FA)	4.69	4.77	4.73
T ₇	RD + Mg @ 0.2 % (FA)	4.71	4.77	4.74
T ₈	RD + Mg @ 0.4 % (FA)	4.72	4.8	4.76
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	4.78	4.84	4.81
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	4.78	4.86	4.82
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	4.79	4.89	4.84
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	4.85	4.97	4.91
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	4.88	5.04	4.96
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	4.91	4.97	4.94
	CD (5 %)	0.07	0.08	0.05

The reason may be that calcium activates the enzyme responsible for increasing cell mitosis. It mobilizes assimilates to developing fruits (Sana *et al* 2019). Improvement in the magnesium is attributed to the availability in adequate level of magnesium element, which enhanced the chlorophyll formation and photosynthesis which produced carbohydrates in leaves and improved fruit size and yield (Ali *et al* 2017).

In addition to that, magnesium sprays had impact on physical and chemical characteristics of fruits (Purohit 2007 and Spiegel Roy and Goldschmidt 2008). The results are in agreement with the

work done by on apricot by Ahmed and Morsy (2001), banana by Mostafa *et al* (2007), on pear by Fawzi *et al* (2010) and on orange by Hanafy *et al* (2012).

4.3.2 Total soluble solids (TSS) in tomato fruits

The data presented in the table 4.12 revealed the result of calcium and magnesium on total soluble solids (TSS) in the tomato fruits. It was recorded that the application of calcium and magnesium as a foliar feeding @ 0.6 and 0.2 % with FYM and 100 % NPK fertilizers enhanced the total soluble solids in the tomato fruit in the treatment T₁₃ (4.91 ° brix in 2017, 5.05 ° brix in 2018 and 4.98 ° brix in the mean data) over the control T₁ (4.48, 4.56 and 4.52 ° brix during 2017, 2018 and in the mean data). The percent increase of 9.60 % in 2017, 10.75 % in 2018 and 10.40 % in the mean data was recorded in T₁₃ as compared to the control T₁. Similarly, non-significant decrease was recorded with the increase in the level of foliar feeding of magnesium to 0.4 % in T₁₄ (4.89, 5.01 and 4.95 ° brix during 2017, 2018 and in the mean data) as compared to the control T₁ with increase of 9.15 % in 2017, 9.87 % in 2018 and 9.51 % in the mean data.

Likewise, the significant impact of 100 % NPK fertilizers in T₂ (4.52, 4.60 and 4.56 ° brix during 2017, 2018 and in the mean data) was also revealed with the increase of 0.89 % in 2017, 0.88 % in 2018 and 0.88 % in the mean data in total soluble solids (T.S.S.) over the control T₁. Likewise, FYM and fertilizers at 100 % NPK in T₃ (4.57, 4.65 and 4.61 ° brix during 2017, 2018 and in the mean data) also recorded the increase in T.S.S. with the per cent increase of 2.01 % in 2017, 1.97 % in 2018 and 1.99 % for the mean of T.S.S. data as compared to the control T₁.

The enhancement in the total soluble solids was also reported due to the foliar feeding when both the secondary nutrients calcium and magnesium were applied alone along with the FYM + NPK fertilizers. The total soluble solids also enhanced when calcium was applied as a foliar spray @ 0.6 % in the treatment T₅ (4.82 ° brix in 2017, 4.88 ° brix in 2018 and 4.85 ° brix in the mean data), which exhibited the percent increase of 7.59 % in 2017, 7.02 % in 2018 and 7.30 % in mean data over the control T₁.

All the treatments with the application of magnesium recorded the significant improvement in the total soluble solids in the tomato fruit. Foliar application of magnesium @ 0.4 % along with FYM and 100 % NPK in T₈ (4.64, 4.76 and 4.70 ° brix during 2017, 2018 and in the mean data) recorded the increase of 3.57 % during 2017, 4.39 % during 2018 and 3.98 % in the mean data of both the years over the control.

Total soluble solids is one of the most important quality parameter attributed to the quality of the fruit, with which texture and composition of the fruit is correlated (Weibel *et al* 2004 and Peck *et al* 2006). TSS depicts the provisional estimation of quantity of sugars and other soluble minerals present in the fruit. In soluble solids sugar is present about 80-85% (Peck *et al* 2006). Due to the application of calcium the TSS might increase. Conversion of polysaccharides into simple sugars at the time of ripening might enhance TSS content. The findings in accordance with the results reported

by Naik *et al* (1993) in the fruits, Rohani *et al* (1997), Cheour *et al* (1991), Cheour *et al* (1990), Peck *et al* (2006) and Shah *et al* (2017) in fruits.

Table 4.12: Effect of foliar spray of Ca and Mg on TSS (°brix) of tomato fruits

Treatments		TSS (° brix)		
		2017	2018	Mean
T ₁	FYM (Control)	4.48	4.56	4.52
T ₂	NPK @ 150:120:60	4.52	4.6	4.56
T ₃	FYM + NPK @ 150:120:60 (RD)	4.57	4.65	4.61
T ₄	RD + Ca @ 0.3% Foliar application (FA)	4.68	4.8	4.74
T ₅	RD + Ca @ 0.6 % (FA)	4.82	4.88	4.85
T ₆	RD + Mg @ 0.1 % (FA)	4.6	4.68	4.64
T ₇	RD + Mg @ 0.2 % (FA)	4.63	4.71	4.67
T ₈	RD + Mg @ 0.4 % (FA)	4.64	4.76	4.7
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	4.7	4.82	4.76
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	4.72	4.84	4.78
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	4.77	4.83	4.8
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	4.84	4.92	4.88
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	4.91	5.05	4.98
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	4.89	5.01	4.95
	CD (5 %)	0.11	0.08	0.04

4.3.3 Vitamin C (mg/100 g) in tomato fruits

The performance of the calcium and magnesium can be seen in the data correlated to effect of the calcium and magnesium (Table 4.13). The examination of the data in the table shows the improvement in the vitamin C content in the tomato crop in the conditions of the Mandi district. The improvement in the vitamin C is visible pertaining to the calcium and magnesium application had significant effect on it which is indicated from the data given. It was revealed that the foliar spray of calcium and magnesium @ 0.6 and 0.2 % with FYM and NPK in T₁₃ (25.59 mg 100g⁻¹ in 2017, 26.41 mg 100g⁻¹ in 2018 and 26.0 mg 100g⁻¹ in the mean data) enhanced the vitamin C content in tomato fruits in comparison to the control T₁ (22.04 mg 100g⁻¹ in 2017, 22.26 mg 100g⁻¹ in 2018 and 22.15 mg 100g⁻¹ in the mean data). The increase of 16.11 % in 2017, 18.64 % in 2018 and 17.38 % in the mean data in vitamin C in T₁₃ was recorded over the control treatment T₁. Unlikely, the significant decrease was recorded in T₁₄ (24.79, 25.23 and 25.01 mg 100g⁻¹ in 2017, 2018 and in the mean data) as compared to the control with the percent increase of 12.48 % in 2017, 13.34 % in 2018 and 12.91 % in the mean data. Similarly, the substantial impact of 100 % NPK fertilizers in T₂ (22.25, 22.85 and 22.55 mg 100g⁻¹ during 2017, 2018 and in the mean data) was also observed with the increase of 0.95

% in 2017, 2.65 % in 2018 and 1.81 % in the mean data of vitamin C was recorded over the control T₁. Likewise, FYM and 100 % NPK fertilizers recommended in T₃ (22.47 mg 100g⁻¹ in 2017, 22.65 mg 100g⁻¹ in 2018 and 22.56 mg 100g⁻¹ in the mean data) also recorded the increase in vitamin C with the per cent increase of 1.95 % in 2017, 1.75 % in 2018 and 1.85 % for the mean data as compared to the control T₁.

The increase in the vitamin C content was also reported due to the foliar feeding when calcium and magnesium applied separately. Perusal of data in the table showed that, when calcium and magnesium were applied alone along with the FYM and 100 % NPK fertilizer the increase in the vitamin C content was also observed. The vitamin C enhanced when calcium was applied as a foliar spray @ 0.6 % along with the recommended dose of FYM and 100 % NPK fertilizers in the treatment T₅ (24.09 mg 100g⁻¹ in 2017, 23.85 mg 100g⁻¹ in 2018 and 23.97 mg 100g⁻¹ in the mean data of both the years) as compared to the control T₁. The percent increase of 9.30 % in 2017, 7.14 % in 2018 and 8.22 % in mean data in vitamin C was recorded over the control T₁.

Table 4.13 Effect of foliar spray of Ca and Mg on Vitamin C of tomato fruits

Treatments		Vitamin C (mg 100g ⁻¹)		
		2017	2018	Mean
T ₁	FYM (Control)	22.04	22.26	22.15
T ₂	NPK @ 150:120:60	22.25	22.85	22.55
T ₃	FYM + NPK @ 150:120:60 (RD)	22.47	22.65	22.56
T ₄	RD + Ca @ 0.3% Foliar application (FA)	23.35	23.21	23.28
T ₅	RD + Ca @ 0.6 % (FA)	24.09	23.85	23.97
T ₆	RD + Mg @ 0.1 % (FA)	22.61	22.83	22.72
T ₇	RD + Mg @ 0.2 % (FA)	22.65	22.87	22.76
T ₈	RD + Mg @ 0.4 % (FA)	22.71	22.93	22.82
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	23.25	23.47	23.36
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	23.41	23.59	23.5
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	23.69	23.63	23.66
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	24.35	24.41	24.38
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	25.59	26.41	26.00
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	24.79	25.23	25.01
CD (5 %)		0.38	0.22	0.16

Further perusal of data showed that all the treatments with the application of magnesium also recorded the significant improvement in the vitamin C content in the tomato fruit. The maximum

improvement among foliar spray of magnesium was @ 0.4 % along with the FYM and 100 % NPK in the treatment T₈ (22.71 mg 100g⁻¹ in 2017, 22.92 mg 100g⁻¹ in 2018 and 22.82 mg 100g⁻¹ in the mean data) with percent increase of 3.04 % in 2017, 3.01 % in 2018 and 3.02 % in the mean data of both the years over the control T₁.

Furthermore, the leaf chlorophyll content and accordingly photosynthesis level increased with increase in the magnesium application. More carbohydrate production through photosynthesis process and enhanced vegetative growth and subsequently improving the percentage fruit set, yield and fruit quality. The similar outcomes had been narrated by Avadh (2000), Waskela *et al* (2013) and Avadh (2000) and El Hadidi *et al* (2017)

4.3.4 Titratable acidity (%) in tomato fruits

The performance of the calcium and magnesium can be seen in the data correlated to effect of the calcium and magnesium (Table 4.14). From the perusal of the data in the table shows the improvement in the titratable acidity in the tomato crop. It was revealed that the foliar application of calcium and magnesium @ 0.6 and 0.2 % with FYM and NPK in T₁₃ (0.75 % in 2017, 0.81 % in 2018 and 0.78 % in in the mean data) enhanced the titratable acidity in the tomato fruit as compared to the control T₁ (0.48 % in 2017, 0.58 % in 2018 and 0.53 % in the mean data). The increase of 56.25 % in 2017, 39.66 % in 2018 and 47.17 % in the mean data in T₁₃ significantly enhanced the titratable acidity over the control treatment T₁. The non significant decrease in the titratable acidity was observed with the increase in the level of magnesium to 0.4 % in T₁₄ (0.73 % in 2017, 0.79 % in 2018 and 0.76 % in the mean data) over the control T₁ with the percent increase of 52.08 % in 2017, 36.21 % in 2018 and 43.40 % in the mean data

Likewise, the increase in the titratable acidity was also recorded with 100 % NPK fertilizers in the treatment T₂ (0.51 % in 2017, 0.67 % in 2018 and 0.59 % in the mean data of both the years with the percent increase of 6.25 % in 2017, 15.52 % in 2018 and 11.32 % in the mean data and in the treatment T₃ (0.58 % in 2017, 0.66 % in 2018 and 0.62 % in the mean data) where recommended FYM and 100 % NPK fertilizers were applied in comparison to the control T₁. The percent increase recorded was 20.83 % in 2017, 13.79 % in 2018 and 16.98 % in the mean data of both the years.

Further, perusal of the data in table 4.14 shows the impact of foliar application of Ca and Mg on the titratable acidity in the tomato plants. It was observed that foliar application of calcium and magnesium alone along with the recommended FYM and NPK fertilizers increased titratable acidity in the tomato fruits. The titratable acidity was significantly enhanced when calcium was applied as a foliar spray @ 0.6 % in the treatment T₅ (0.67 % in 2017, 0.75 % in 2018 and 0.71 % in the mean data) over the control T₁, which indicated the percent increase of 39.58 % in 2017, 29.31 % in 2018 and 39.96 % in mean data as compared to the control T₁.

Table 4.14 Effect of foliar spray of Ca and Mg on titratable acidity of tomato fruits

Treatments		Titratable acidity (%)		
		2017	2018	Mean
T ₁	FYM (Control)	0.48	0.58	0.53
T ₂	NPK @ 150:120:60	0.51	0.67	0.59
T ₃	FYM + NPK @ 150:120:60 (RD)	0.58	0.66	0.62
T ₄	RD + Ca @ 0.3% Foliar application (FA)	0.62	0.68	0.65
T ₅	RD + Ca @ 0.6 % (FA)	0.67	0.75	0.71
T ₆	RD + Mg @ 0.1 % (FA)	0.59	0.67	0.63
T ₇	RD + Mg @ 0.2 % (FA)	0.59	0.69	0.64
T ₈	RD + Mg @ 0.4 % (FA)	0.61	0.71	0.66
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	0.63	0.71	0.67
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	0.65	0.73	0.69
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	0.67	0.75	0.71
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	0.71	0.79	0.75
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	0.75	0.81	0.78
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	0.73	0.79	0.76
	CD (5 %)	0.04	0.05	0.04

Foliar spray of magnesium @ 0.4 % along with the 100 % FYM and NPK in the treatment T₈ recorded titratable acidity of 0.61 % in 2017, 0.71 % in 2018 and 0.66 % in the mean data in comparison to the treatment T₁ with the percent increase of 27.08 % during 2017, 22.41 % during 2018 and 24.53 % in the mean data of both the years.

Titratable acidity is directly related to the concentration of organic acids present in the fruit which are an important parameter in maintaining the quality of fruits. The similar findings had been reported by Avadh (2000), Manganaris *et al* (2005), Zlamalova *et al* 2015 and El Hadidi *et al* (2017)

4.4 Effect of different treatments on nutrient content and uptake in tomato

4.4.1 Nitrogen content and uptake in tomato leaves and fruits

Nitrogen content in leaves of tomato

The examination of data in table 4.15 documented that, application of calcium and magnesium along with the FYM and 100 % NPK registered a significant impact on N content in tomato leaves. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest N content in the treatment T₁₃ (2.87 % in 2017, 2.95 % in 2018 and 2.91 % in the mean data) over the control treatment T₁ (2.23 % in 2017, 2.27 % in 2018 and 2.25 % in the mean data) with the percent increase of 28.70 % in 2017, 29.96 % in 2018 and 29.33 % in the mean data over the control

T₁. With increase in the magnesium @ 0.4 % level in T₁₄ the significant decrease in N content was recorded viz. 2.80 % in 2017, 2.88 % in 2018 and 2.84 % in the mean data) as compared to the T₁₃ but found to be significantly superior to the control T₁ with the per cent increase of 25.56 % in 2017, 26.87 % in 2018 and 26.22 % in the mean data over the control T₁.

Further, data presented in the table 4.15 depicted that foliar application increased N content in the treatment T₂ (2.34 % in 2017, 2.31 % in 2018 and 2.33 % in the mean data) where only NPK fertilizers were applied with the percent increase of 4.93 % in 2017, 1.76 % in 2018 and 3.56 % in the mean data and in the treatment T₃ (2.38 % in 2017, 2.44 % in 2018 and 2.41 % in the mean data of both the years) where the recommended dose of FYM and 100 % NPK fertilizers were applied also reported the percent increase of 6.73 % in 2017, 7.49 % in 2018 and 7.11 % in the mean data in N content over the control T₁.

The data in the table 4.15 revealed that foliar application of the calcium and magnesium when applied individually the positive results were observed. The application of calcium @ 0.6 % improved significantly the N content in the leaf in treatment T₅ (2.72 % in 2017, 2.76 % in 2018 and 2.74% in the mean data) over the control treatment T₁ with the per cent increase of 21.97 % in 2017, 21.59 % in 2018 and 21.78 % in the mean data of both the years.

Table 4.15 Effect of foliar application of Ca and Mg on N content in leaves of tomato

Treatments		N content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	2.23	2.27	2.25
T ₂	NPK @ 150:120:60	2.34	2.31	2.33
T ₃	FYM + NPK @ 150:120:60 (RD)	2.38	2.44	2.41
T ₄	RD + Ca @ 0.3% Foliar application (FA)	2.52	2.64	2.58
T ₅	RD + Ca @ 0.6 % (FA)	2.72	2.76	2.74
T ₆	RD + Mg @ 0.1 % (FA)	2.42	2.49	2.46
T ₇	RD + Mg @ 0.2 % (FA)	2.46	2.52	2.49
T ₈	RD + Mg @ 0.4 % (FA)	2.51	2.57	2.54
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	2.56	2.66	2.61
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	2.62	2.69	2.66
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	2.67	2.75	2.71
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	2.77	2.83	2.80
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	2.87	2.95	2.91
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	2.80	2.88	2.84
	CD (5 %)	0.14	0.09	0.09

Similarly, the foliar feeding of magnesium @ 0.4 % also indicated the increase in the N content of the leaf in T₈ (2.51 % in 2017, 2.57 % in 2018 and 2.54 % in the mean data of both the years) over the control. The per cent increase of 12.56 % in 2017, 13.22 % in 2018 and 12.89 % in the mean data was recorded in comparison to the control, respectively.

Nitrogen uptake in leaves of tomato

The analysis of data in table 4.16 revealed an improvement in N uptake in the tomato leaf. N uptake in the tomato leaf documented a substantial effect with the recommended doses of FYM and NPK and foliar feeding of calcium and magnesium. The maximum N uptake was found when calcium and magnesium were applied as foliar feeding @ 0.6 and 0.2 % along with FYM and 100 % NPK fertilizers, respectively in T₁₃ (260.88 kg ha⁻¹ in 2017, 304.13 kg ha⁻¹ in 2018, and 282.25 kg ha⁻¹ in the mean data) as compared to the control in T₁ (167.97 kg ha⁻¹ in 2017, 197.71 kg ha⁻¹ in 2018 and 182.71 kg ha⁻¹ in the mean data). The per cent increase of 55.31 % in 2017, 53.83 % in 2018 and 54.48 % in the mean data in T₁₃ in comparison to the control T₁. With increase in the level of magnesium to 0.4 % the significant decrease in the N uptake was recorded in T₁₄ (252.92 kg ha⁻¹ in 2017, 293.76 kg ha⁻¹ in 2018 and 273.10 kg ha⁻¹ in the mean data over the treatment T₁₃ but was found to be superior as compared control T₁. The increase of 50.57 % in 2017, 48.58 % in 2018 and 49.47 % in the mean data in T₁₄ was observed as compared to the control T₁.

Table 4.16 Effect of foliar application of Ca and Mg on N uptake in leaves of tomato

Treatments		N Uptake (kg ha ⁻¹)		
		2017	2018	Mean
T ₁	FYM (Control)	167.97	197.71	182.71
T ₂	NPK @ 150:120:60	185.32	208.68	197.09
T ₃	FYM + NPK @ 150:120:60 (RD)	193.24	225.16	209.03
T ₄	RD + Ca @ 0.3% Foliar application (FA)	222.84	257.01	239.70
T ₅	RD + Ca @ 0.6 % (FA)	242.83	274.25	258.41
T ₆	RD + Mg @ 0.1 % (FA)	186.73	221.46	203.86
T ₇	RD + Mg @ 0.2 % (FA)	195.38	227.32	211.14
T ₈	RD + Mg @ 0.4 % (FA)	206.69	240.11	223.20
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	218.02	258.97	238.16
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	224.09	263.04	243.32
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	236.28	274.06	254.92
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	248.71	286.69	267.54
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	260.88	304.13	282.25
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	252.92	293.76	273.10
	CD (5 %)	8.26	9.63	4.90

The further examination of data also reflects an increase in N uptake in T₂ (185.32 kg ha⁻¹ in 2017, 208.68 kg ha⁻¹ in 2018 and 197.09 kg ha⁻¹ in the mean data of both years) where only fertilizers containing NPK were applied. Similarly, the incorporation of FYM and NPK fertilisers in treatment T₃ (193.24 kg ha⁻¹ in 2017, 225.16 kg ha⁻¹ in 2018 and 209.03 kg ha⁻¹ in the mean data of both years) also reported the improvement over the control. The percent increase of 10.33 % in 2017, 5.55 % in 2018 and 7.87 % in the mean data in the treatment T₂ and 15.04 % in 2017, 13.88 % in 2018 and 14.41 % in the mean data of T₃ in N uptake were recorded over the control T₁.

Further, study of table 4.16 revealed that foliar application of calcium and magnesium, when used separately, significantly improved the N uptake of tomato fruit. Foliar feeding of calcium @ 0.6 % significantly increased the N uptake in tomato fruit in T₅ (242.83 kg ha⁻¹ in 2017, 274.25 kg ha⁻¹ in 2018 and 258.41 kg ha⁻¹ in the mean data) in comparison to the control treatment T₁ with the per cent increase of 44.57 % in 2017, 38.71 % in 2018 and 41.43 % in the mean data as compared to the control T₁.

The magnesium applied as a foliar spray at 0.4 % also presented an increase in the N uptake in the tomato leaf in the treatment T₈ (206.69 kg ha⁻¹ in 2017, 240.11 kg ha⁻¹ in 2018 and 223.20 kg ha⁻¹ in the mean data of both years) as compared to the control treatment T₁ with the percent increase of 23.05 % in 2017, 21.45 % in 2018 and 22.16 % in the mean data of both the years.

Nitrogen content in fruits of tomato

Examination of data in Table 4.17 revealed that with the FYM and 100 % NPK along with foliar feeding of calcium and magnesium enhanced the N content in the tomato fruit. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the significant effect on N content in the treatment T₁₃ (1.45 % in 2017, 1.55 % in 2018 and 1.50 % in the mean data) over the control in the treatment T₁ (1.07 % in 2017, 1.13 % in 2018 and 1.10 % in the mean data). The percent increase of 35.51 % in 2017, 37.17 % in 2018 and 36.36 % in the mean data in T₁₃ was documented as over the control.

With increase in the magnesium level @ 0.4 % the significant decrease in N content was recorded in T₁₄ (1.43 % in 2017, 1.49 % in 2018 and 1.46 % in the mean data) in comparison to the T₁₃ but found to be significantly superior to the control T₁ with the per cent increase of 33.64 % in 2017, 31.86 % in 2018 and 32.73 % in the mean data.

The thorough review of data also reflects the increase in the N content in T₂ (1.19 % in 2017, 1.23 % in 2018 and 1.21 % in the mean data) where only fertilizers containing NPK nutrients were applied whereas application of FYM and NPK fertilizers in treatment T₃ (1.21 % in 2017, 1.31 % in 2018 and 1.26 % in the mean data) also reported the significant growth in N content over the control in the tomato fruit. The percent increase of 11.21 % in 2017, 8.85 % in 2018 and 10.0 % in the mean data in

T₂ and 13.08 % in 2017, 15.93 % in 2018 and 14.55 % in the mean data in T₃ were recorded as over the control.

Further, perusal of the data in the table 4.17 revealed that the foliar application of calcium and magnesium when applied separately, significantly improved the N content of the tomato fruit. The spray of calcium @ 0.6 % significantly raised the N content in the fruit of tomato in treatment T₅ (1.39 % in 2017, 1.49 % in 2018 and 1.44 % in the mean data) with the increase of 29.91 % in 2017, 31.86 % in 2018 and 30.91 % in the mean data as compared to the control treatment T₁.

The magnesium applied as foliar spray @ 0.4 % also exhibited the development in the N content of the fruit in T₈ (1.28 % in 2017, 1.37 % in 2018 and 1.33 % in the mean data of both the years) over the control treatment T₁. The percent increase of 19.63 % in 2017, 21.24 % in 2018 and 20.91 % in the mean data was recorded over the control treatment.

Table 4.17 Effect of foliar application of Ca and Mg on N content in fruits of tomato

Treatments		N content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	1.07	1.13	1.1
T ₂	NPK @ 150:120:60	1.19	1.23	1.21
T ₃	FYM + NPK @ 150:120:60 (RD)	1.21	1.31	1.26
T ₄	RD + Ca @ 0.3% Foliar application (FA)	1.30	1.41	1.36
T ₅	RD + Ca @ 0.6 % (FA)	1.39	1.49	1.44
T ₆	RD + Mg @ 0.1 % (FA)	1.23	1.33	1.28
T ₇	RD + Mg @ 0.2 % (FA)	1.25	1.35	1.3
T ₈	RD + Mg @ 0.4 % (FA)	1.28	1.37	1.33
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	1.35	1.41	1.38
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	1.37	1.41	1.39
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	1.39	1.47	1.43
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	1.41	1.49	1.45
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	1.45	1.55	1.5
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	1.43	1.49	1.46
	CD (5 %)	0.07	0.06	0.04

Nitrogen uptake in the fruits of tomato

The study of the data in table 4.18 revealed an increase in N uptake in the tomato leaf. With the recommended doses of FYM and NPK, as well as foliar calcium and magnesium feeding, N uptake in tomato leaves increased significantly in the treatment T₁₃. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest N content in the treatment T₁₃ (131.82 kg ha⁻¹ in 2017, 159.76 kg ha⁻¹ in 2018 and 145.48 kg ha⁻¹ in the mean data) over the control in the treatment

T₁ (80.60 kg ha⁻¹ in 2017, 98.40 kg ha⁻¹ in 2018 and 89.32 kg ha⁻¹ in the mean data) . The percent increase of 63.55 % in 2017, 62.36 % in 2018 and 62.88 % in the mean data over the control. With increase in the level of magnesium to 0.4 % in the treatment T₁₄ (129.16 kg ha⁻¹ in 2017, 151.96 kg ha⁻¹ in 2018 and 140.38 kg ha⁻¹ in the mean data) the percent increase of 60.25 % in 2017, 54.43 % in 2018 and 57.17 % in the mean data were recorded over the control.

The study of data also recorded an increase in N uptake in T₂ (94.29 kg ha⁻¹ in 2017, 111.0 kg ha⁻¹ in 2018 and 102.56 kg ha⁻¹ in the mean data of both years) where only NPK fertilisers were used, whereas in T₃ (98.27 kg ha⁻¹ in 2017, 120.86 kg ha⁻¹ in 2018 and 109.30 kg ha⁻¹ in the mean data) where FYM and NPK fertilisers were used. The percent increase of 16.99 % in 2017, 12.80 % in 2018 and 14.82 % in the mean data in T₂ and 21.92 % in 2017, 22.83 % in 2018 and 22.37 % in the mean data in T₃ over the control T₁.

Table 4.18 Effect of foliar application of Ca and Mg on N uptake in fruits of tomato

Treatments		N uptake (kg ha ⁻¹)		
		2017	2018	Mean
T ₁	FYM (Control)	80.60	98.40	89.32
T ₂	NPK @ 150:120:60	94.29	111.00	102.56
T ₃	FYM + NPK @ 150:120:60 (RD)	98.27	120.86	109.30
T ₄	RD + Ca @ 0.3% Foliar application (FA)	114.90	137.34	125.88
T ₅	RD + Ca @ 0.6 % (FA)	124.10	147.97	135.79
T ₆	RD + Mg @ 0.1 % (FA)	94.91	118.18	106.26
T ₇	RD + Mg @ 0.2 % (FA)	99.26	121.66	110.23
T ₈	RD + Mg @ 0.4 % (FA)	105.41	128.31	114.46
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	114.98	136.19	124.33
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	117.23	137.77	127.37
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	123.05	146.47	134.51
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	126.64	151.03	138.57
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	131.82	159.76	145.48
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	129.16	151.96	140.38
	CD (5 %)	5.40	4.44	9.09

Examination of Table 4.18 further indicated that the calcium and magnesium when applied as a foliar spray separately also improved the N uptake of the tomato fruit. The application of calcium @ 0.6 % significantly increased the N uptake in tomato fruit in T₅ (124.10 kg ha⁻¹ in 2017, 147.97 kg ha⁻¹ in 2018 and 135.79 kg ha⁻¹ in the mean data) with the percent increase of 53.97 % in 2017, 50.38 % in 2018 and 52.03 % in mean data over the control T₁.

The foliar spray of magnesium @ 0.4 percent also exhibited an improvement in the N uptake in the fruit in treatment T₈ (105.41 % in 2017, 128.31 % in 2018, and 114.46 % in the mean data of

both years) with the percent increase 30.78 % in 2017, 30.40 % in 2018 and 28.15 % in the mean data as compared to the control T₁.

4.4.2 Phosphorous content and its uptake in leaves and fruits of tomato

Phosphorous content in leaves of tomato

The analysis of data in table 4.19 indicated that application of calcium and magnesium along with the recommended dose of FYM and NPK registered a significantly affected the P content in tomato leaves. The foliar spray of calcium and magnesium @ 0.6 and 0.2 % recorded the highest P content in T₁₃ (0.60 % in 2017, 0.66 % in 2018 and 0.63 % in the mean data) over the control treatment T₁ (0.20 % in 2017, 0.24 % in 2018 and 0.22 % in the mean data). The percent increase of 200.0 % in 2017, 175.0 % in 2018 and 186.36 % in the mean data of both the years.

The increase in the level of magnesium to 0.4 % in the treatment T₁₄ (0.59 % in 2017, 0.63 % in 2018 and 0.61 % in the mean data) the non significant decrease was recorded as compared to the treatment T₁₃ but the significant enhancement was observed in T₁₄ with the increase of 195.0 % in 2017, 162.50 % in 2018 and 177.27 % in the mean data over the control.

Table 4.19 Effect of foliar application of Ca and Mg on P content in leaves of tomato plant at flowering stage

Treatments		P content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	0.20	0.24	0.22
T ₂	NPK @ 150:120:60	0.28	0.36	0.32
T ₃	FYM + NPK @ 150:120:60 (RD)	0.35	0.39	0.37
T ₄	RD + Ca @ 0.3% Foliar application (FA)	0.44	0.48	0.46
T ₅	RD + Ca @ 0.6 % (FA)	0.54	0.60	0.57
T ₆	RD + Mg @ 0.1 % (FA)	0.37	0.41	0.39
T ₇	RD + Mg @ 0.2 % (FA)	0.38	0.42	0.40
T ₈	RD + Mg @ 0.4 % (FA)	0.40	0.46	0.43
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	0.23	0.27	0.25
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	0.47	0.53	0.50
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	0.51	0.57	0.54
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	0.56	0.60	0.58
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	0.60	0.66	0.63
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	0.59	0.63	0.61
	CD (5 %)	0.03	0.03	0.02

Further examination of the data in the treatment, where NPK fertilizers were incorporated recorded the improvement P content in T₂ (0.28 % in 2017, 0.36 % in 2018 and 0.32 % in the mean data) with the percent increase of 40.0 % in 2017, 50.0 % in 2018 and 45.45 % in the mean data.

Similarly, the treatment T₃ (0.35 % in 2017, 0.39 % in 2018 and 0.37 % in the mean data) where the recommended dose of FYM and NPK fertilizers applied recorded the percent increase of 75.0 % in 2017, 62.50 % in 2018 and 68.18 % in the mean data of both the years in comparison to T₁ the control.

Further, the application of calcium @ 0.6 % improved significantly the P content in the leaf in treatment T₅ (0.54 % in 2017 0.6 % in 2018 and 0.57 % in the pooled data) over the control treatment T₁ (Table 4.19) where the percent increase of 170.0 % in 2017, 150.0 % in 2018 and 159.09 % in the mean data was recorded over the control.

Similarly, the foliar feeding of magnesium @ 0.4 % also indicated the increase in the P content of the leaf in the treatment T₈ (0.40 % in 2017, 0.46 % in 2018 and 0.43 % in the mean data of both the years) with the percent increase of 100.0 % in 2017, 91.67 % in 2018 and 95.45 % in the mean data over the control treatment T₁.

P uptake in the tomato leaves at flowering stage

The data presented in table 4.20 revealed an increase in P uptake in the tomato leaves. The P uptake in the tomato leaf documented a substantial effect with the FYM and 100 % NPK and foliar feeding of calcium and magnesium. The maximum P uptake was observed when calcium and magnesium were applied as foliar feeding @ 0.6 and 0.2 %, in the treatment T₁₃ (54.51 kg ha⁻¹ in 2017, 68.13 kg ha⁻¹ in 2018, and 61.12 kg ha⁻¹ in the mean data) compared to the control treatment T₁ (15.08 kg ha⁻¹ in 2017, 20.86 kg ha⁻¹ in 2018 and 17.97 kg ha⁻¹ in the mean data). The percent increase of 261.47 % in 2017, 226.61 % in 2018 and 241.24 % in the mean data in T₁₃ over the control T₁. Further, increase in the level of foliar spray of magnesium to 0.4 % in recorded enhancement in the P uptake in the treatment T₁₄ (53.3 kg ha⁻¹ in 2017, 64.26 kg ha⁻¹ in 2018, and 58.78 kg ha⁻¹ in the mean data) with percent increase of 253.45 % in 2017, 208.05 % in 2018 and 227.10 % in the mean data over the control.

Further, examination of data also indicated an increase in P uptake in T₂ (22.24 kg ha⁻¹ in 2017, 32.51 kg ha⁻¹ in 2018 and 27.38 kg ha⁻¹ in the mean data) where only NPK fertilisers were incorporated, with the percent increase of 47.48 % in 2017, 55.85 % in 2018 and 52.37 % in the mean data was recorded over the control. Likewise, the improvement in the P uptake was also recorded when FYM and 100 % NPK fertilisers were applied in treatment T₃ (28.33 kg ha⁻¹ in 2017, 36.05 kg ha⁻¹ in 2018 and 32.19 kg ha⁻¹ in the mean data) with the percent increase of 87.86 % in 2017, 72.82 % in 2018 and 79.13 % in the mean data of both years over the control T₁ (Table 4.20)

Examination of data in table 4.20 reported that foliar applications of calcium and magnesium, separately, improved significantly the P uptake of tomato leaf. The spray of calcium @ 0.6 % significantly increased the P uptake in tomato leaf in treatment T₅ (49.06 kg ha⁻¹ in 2017, 58.64 kg ha⁻¹ in 2018, and 53.85 kg ha⁻¹ in the mean data) with the percent increase of 225.33 % in 2017, 181.11 % in 2018, and 199.67 % in the mean data over the control T₁.

The magnesium applied as a foliar spray at 0.4 % along with FYM and 100 % NPK fertilizers also exhibited an increase in the P uptake of the fruits in the treatment T₈ (32.92 kg ha⁻¹ in 2017, 43.94 kg ha⁻¹ in 2018, and 38.43 kg ha⁻¹ in the mean data of both years) as compared to the control treatment T₁ with percent increase of 118.30 % in 2017, 110.64 % in 2018, and 113.86 % in the mean data.

Table 4.20 Effect of Ca and Mg foliar spray on uptake of P in leaves of tomato at flowering stage

Treatments		P uptake (kg ha ⁻¹)		
		2017	2018	Mean
T ₁	FYM (Control)	15.08	20.86	17.97
T ₂	NPK @ 150:120:60	22.24	32.51	27.38
T ₃	FYM + NPK @ 150:120:60 (RD)	28.33	36.05	32.19
T ₄	RD + Ca @ 0.3% Foliar application (FA)	38.87	46.76	42.82
T ₅	RD + Ca @ 0.6 % (FA)	49.06	58.64	53.85
T ₆	RD + Mg @ 0.1 % (FA)	28.51	36.48	32.49
T ₇	RD + Mg @ 0.2 % (FA)	30.10	37.89	33.99
T ₈	RD + Mg @ 0.4 % (FA)	32.92	43.94	38.43
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	19.56	26.24	22.90
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	40.15	51.85	46.00
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	45.09	56.75	50.92
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	50.25	60.78	55.51
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	54.51	68.13	61.32
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	53.30	64.26	58.78
	CD (5 %)	2.67	3.37	4.12

Phosphorous content in fruits of tomato at harvest

The perusal table 4.21 reported that with the recommended dose of FYM and NPK and foliar feeding of calcium and magnesium enhanced the P content in the tomato fruit. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest P content in the treatment T₁₃ (0.34 % in 2017, 0.40 % in 2018 and 0.37 % in the mean data) over the control in the treatment T₁ (0.09 % in 2017, 0.12 % in 2018 and 0.11 % in the mean data). The percent increase of 277.78 % in 2017, 233.33 % in 2018 and 236.36 % in the mean data in T₁₃ was reported over the control T₁. With, increase in the level of magnesium to 0.4 % the non significant decrease was observed in the treatment T₁₄ (0.33 % in 2017, 0.37 % in 2018 and 0.35 % in the mean data) but the increase to the tune of 266.67 % in 2017, 208.33 % in 2018 and 218.18 % in the mean data was observed over the control.

Similarly, the significant enhancement was also recorded in P content in T₂ (0.11 % in 2017, 0.14 % in 2018 and 0.13 % in the mean data of both the years) where only NPK fertilizers was applied whereas application of FYM and NPK fertilizers in treatment T₃ (0.15 % in 2017, 0.17 % in 2018 and 0.16 % in the mean data of both the years) also reported the significant growth in P content over the control in the tomato fruit. The percent increase of 22.22 % in 2017, 16.67 % in 2018 and 18.18 % in the mean data of both the years were recorded in T₂ where the percent increase of 66.67 % in 2017, 41.67 % in 2018 and 45.45 % in the mean data was documented in the treatment T₃ during both the years over the control T₁.

Table 4.21 Effect of foliar application of Ca and Mg on P content in fruits of tomato at harvest

Treatments		P content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	0.09	0.12	0.11
T ₂	NPK @ 150:120:60	0.11	0.14	0.13
T ₃	FYM + NPK @ 150:120:60 (RD)	0.15	0.17	0.16
T ₄	RD + Ca @ 0.3% Foliar application (FA)	0.2	0.25	0.23
T ₅	RD + Ca @ 0.6 % (FA)	0.28	0.31	0.3
T ₆	RD + Mg @ 0.1 % (FA)	0.15	0.2	0.18
T ₇	RD + Mg @ 0.2 % (FA)	0.17	0.21	0.19
T ₈	RD + Mg @ 0.4 % (FA)	0.19	0.23	0.21
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	0.22	0.27	0.25
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	0.26	0.29	0.28
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	0.27	0.31	0.29
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	0.3	0.36	0.33
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	0.34	0.4	0.37
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	0.33	0.37	0.35
	CD (5 %)	0.04	0.04	0.02

The data in the table 4.21 revealed that, the foliar application of the calcium and magnesium when applied separately also improved the P content of the tomato fruit significantly. The spray of calcium @ 0.6 % raised the P content in the fruit of tomato in treatment T₅ (0.28 % in 2017, 0.31 % in 2018 and 0.30 % in the mean data) with the percent increase of 211.11 % in 2017, 158.33 % in 2018 and 172.73 % in the mean data in comparison to the control treatment T₁.

The magnesium applied as foliar spray @ 0.4 % also exhibited the development in the P content of the fruit in the treatment T₈ (0.19 % in 2017, 0.23 % in 2018 and 0.21 % in the mean data of both the years) over the control treatment T₁ with the percent increase of 111.11 % in 2017, 91.67 % in 2018 and 90.91 % in the mean data in over the control.

Phosphorous uptake in the fruits of tomato at harvest

The perusal of table 4.22 reflected an increase in P uptake in the tomato fruit with recommended doses of FYM and NPK, as well as foliar feeding of calcium and magnesium. The P uptake in tomato leaves increased significantly in the treatment T₁₃. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest P uptake in the treatment T₁₃ (34.43 kg ha⁻¹ in 2017, 36.20 kg ha⁻¹ in 2018 and 35.81 kg ha⁻¹ in the mean data) over the control in the treatment T₁ (6.8 kg ha⁻¹ in 2017, 10.43 kg ha⁻¹ in 2018 and 8.62 kg ha⁻¹ in the mean data) with the percent increase of 421.03 % in 2017, 247.08 % in 2018, and 315.43 % in the mean data over the control. With the increase in the level of magnesium the significant improvement was also recorded in T₁₄ (29.81 kg ha⁻¹ in 2017, 37.71 kg ha⁻¹ in 2018 and 33.76 kg ha⁻¹ in the mean data) over the control. The percent increase of 338.38 % in 2017, 261.55 % in 2018, and 291.65 % in the mean data over the T₁ the control. Similarly, the significant increase was also recorded in P uptake in T₂ (8.74 kg ha⁻¹ in 2017, 12.56 kg ha⁻¹ in 2018 and 10.65 kg ha⁻¹ in the mean data) where only 100 % NPK nutrients were applied whereas application of FYM and NPK fertilizers in treatment T₃ (12.14 kg ha⁻¹ in 2017, 15.68 kg ha⁻¹ in 2018 and 13.91 kg ha⁻¹ in the mean data) also reported the significant growth in P uptake over the control treatment T₁ in the tomato fruit. The percent increase of 28.53 % in 2017, 20.42 % in 2018 and 23.55 % in the mean data of both the years were recorded in T₂ whereas the percent increase of 78.53 % in 2017, 50.34 % in 2018 and 61.37 % in the mean data was recorded in the treatment T₃ as compared to the control.

Table 4.22 Effect of foliar application of Ca and Mg on P uptake in fruits of tomato at harvest

Treatments		P uptake (kg ha ⁻¹)		
		2017	2018	Mean
T ₁	FYM (Control)	6.10	11.43	8.71
T ₂	NPK @ 150:120:60	8.74	12.56	10.65
T ₃	FYM + NPK @ 150:120:60 (RD)	12.14	15.68	13.91
T ₄	RD + Ca @ 0.3% Foliar application (FA)	17.72	24.43	21.07
T ₅	RD + Ca @ 0.6 % (FA)	24.97	30.71	27.84
T ₆	RD + Mg @ 0.1 % (FA)	11.55	17.72	14.64
T ₇	RD + Mg @ 0.2 % (FA)	13.52	18.92	16.22
T ₈	RD + Mg @ 0.4 % (FA)	15.63	21.42	18.52
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	18.75	26.27	22.51
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	22.16	28.29	25.23
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	23.85	30.84	27.34
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	26.90	36.47	31.68
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	35.43	36.20	35.81
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	29.81	37.71	33.76
CD (5 %)		2.81	3.80	2.70

Further examination of table 4.22 revealed that the foliar spray of calcium and magnesium, when applied separately, significantly improved the P uptake of the tomato fruit. In comparison to the control treatment T₁, the spray of calcium @ 0.6 % significantly increased the P uptake in tomato fruit in treatment T₅ (24.97 % in 2017, 30.71 % in 2018, and 27.84 % in the mean data) with the percent increase of 267.21 % in 2017, 194.44 % in 2018, and 222.97 % in the mean data over the control T₁.

Likewise, the foliar spray of magnesium @ 0.4 percent also presented an increase in the P uptake of the tomato fruit in the treatment T₈ (15.63 % in 2017, 21.42 % in 2018, and 18.52 % in the mean data of both years) in comparison to the control treatment T₁ with the percent increase of 129.85 % in 2017, 105.37 % in 2018, and 114.85 % in the mean data over the control T₁.

4.4.3 Potassium content and its uptake in tomato leaves and fruits

Potassium content in the leaves of tomato

The data presented in Table 4.23 revealed that application of calcium and magnesium along with the recommended dose of FYM and NPK registered a significant effect on K content in tomato leaves. The foliar application of calcium and magnesium @ 0.6 and 0.2 % along with recommended dose of FYM and NPK fertilizers recorded the highest K content in T₁₃ (3.91 % in 2017, 4.03 % in 2018 and 3.97 % in the mean data) over the control treatment T₁ (3.16 % in 2017, 3.30 % in 2018 and 3.23 % in the mean data). The percent increase of 23.73 % in 2017, 22.12 % in 2018 and 22.91 % in the mean data was recorded in T₁₃ over the control T₁.

The foliar spray of calcium and magnesium @ 0.6 and 0.4 % along with recommended dose of FYM and NPK fertilizers in T₁₄ (3.87 % in 2017, 3.99 % in 2018 and 3.93 % in the mean data) recorded non significant decrease in K content over T₁₃ but the percent increase of 22.47 % in 2017, 20.91 % in 2018 and 21.67 % in the mean data was recorded over the control T₁.

The analysis of the data in table 4.23 recorded the significant increase of K content in T₂ (3.28 % in 2017, 3.46 % in 2018 and 3.37 % in the mean data) with the percent increase of 3.80 % in 2017, 4.85 % in 2018 and 4.33 % in the mean data in comparison to T₁ and 3.32 % in 2017, 3.54 % in 2018 and 3.43 % in the mean data with the percent increase of 5.06 % in 2017, 7.27 % in 2018 and 6.19 % in the mean data in T₃ where only NPK fertilizers were applied as compared to the control.

The application of calcium @ 0.6 % improved significantly the K content in the leaf in T₅ (3.77 % in 2017, 3.85 % in 2018 and 3.81 % in the mean data) with the percent increase of 19.30 % in 2017, 16.67 % in 2018 and 17.96 % in the mean data over the control treatment T₁ (Table 4.23).

Similarly, the foliar feeding of magnesium @ 0.4 % also indicated the increase in the K content of the leaves in the treatment T₈ (3.53 % in 2017, 3.67 % in 2018 and 3.60 % in the mean data) with the percent increase of 11.71 % in 2017, 11.21 % in 2018 and 11.46 % in the mean data over the control treatment T₁.

Table 4.23 Effect foliar application of Ca and Mg on K content of leaves of tomato

Treatments		K content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	3.16	3.30	3.23
T ₂	NPK @ 150:120:60	3.28	3.46	3.37
T ₃	FYM + NPK @ 150:120:60 (RD)	3.32	3.54	3.43
T ₄	RD + Ca @ 0.3% Foliar application (FA)	3.57	3.67	3.62
T ₅	RD + Ca @ 0.6 % (FA)	3.77	3.85	3.81
T ₆	RD + Mg @ 0.1 % (FA)	3.42	3.58	3.50
T ₇	RD + Mg @ 0.2 % (FA)	3.52	3.58	3.55
T ₈	RD + Mg @ 0.4 % (FA)	3.53	3.67	3.60
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	3.56	3.78	3.67
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	3.61	3.83	3.72
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	3.71	3.83	3.77
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	3.83	3.89	3.86
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	3.91	4.03	3.97
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	3.87	3.99	3.93
CD (5 %)		0.05	0.07	0.07

Potassium uptake by the leaves of tomato

The analysis of data in table 4.24 revealed a substantial increase in K uptake in tomato leaves with the recommended dose of FYM and NPK and foliar feeding of calcium and magnesium. Foliar application of calcium and magnesium at 0.6 and 0.2 % yielded the highest K uptake in the treatment T₁₃ (355.36 kg ha⁻¹ in 2017, 415.52 kg ha⁻¹ in 2018, and 385.44 kg ha⁻¹ in the mean data) as compared to the control in the treatment T₁ (237.96 kg ha⁻¹ in 2017, 287.58 kg ha⁻¹ in 2018 and 262.77 kg ha⁻¹ in the mean data). The percent increase of 49.34 % in 2017, 44.49 % in 2018 and 46.68 % in the mean data in T₁₃ was recorded over the control T₁.

Increase in the level of magnesium to 0.4 % with recommended dose of FYM and NPK fertilizers also recorded the non significant decrease in K uptake in T₁₄ (349.59 % in 2017, 407.03 % in 2018 and 378.31 % in the mean data) as compared to T₁₃ with the percent increase of 46.91 % in 2017, 41.54 % in 2018 and 43.97 % in the mean data over the control T₁.

Further, examination of data also reflects percent increase in K uptake in T₂ (9.15 % in 2017, 8.67 % in 2018 and 8.89 % in the mean data) where only NPK fertilisers were applied, whereas application of FYM and NPK fertilisers in treatment T₃ recorded the percent increase of 13.58 % in 2017, 13.62 % in 2018 and 13.60 % in the mean data of both years over the control T₁.

Table 4.24 Effect of foliar application of Ca and Mg on uptake of K in leaves of tomato

Treatments		K uptake		
		2017	2018	Mean
T ₁	FYM (Control)	237.96	287.58	262.77
T ₂	NPK @ 150:120:60	259.73	312.50	286.12
T ₃	FYM + NPK @ 150:120:60 (RD)	270.28	326.74	298.51
T ₄	RD + Ca @ 0.3% Foliar application (FA)	315.66	357.44	336.55
T ₅	RD + Ca @ 0.6 % (FA)	336.47	382.54	359.51
T ₆	RD + Mg @ 0.1 % (FA)	263.77	318.25	291.01
T ₇	RD + Mg @ 0.2 % (FA)	279.47	322.86	301.17
T ₈	RD + Mg @ 0.4 % (FA)	290.61	342.92	316.77
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	303.09	367.83	335.46
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	308.66	374.35	341.51
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	328.25	381.53	354.89
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	343.79	394.11	368.95
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	355.36	415.52	385.44
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	349.59	407.03	378.31
	CD (5 %)	9.03	12.88	6.83

Moreover, foliar spray of calcium and magnesium separately (Table 4.24) revealed significant improvement in K uptake of tomato leaf. In comparison to the control treatment T₁, the application of calcium @ 0.6 % significantly amplified the K uptake in tomato leaf in T₅ (336.47 kg ha⁻¹ in 2017, 382.54 kg ha⁻¹ in 2018, and 359.51 kg ha⁻¹ in the mean data) with the percent increase of 41.40 % in 2017, 33.02 % in 2018 and 36.82 % in the mean data over the control.

The magnesium applied as a foliar spray at 0.4 % also indicated an increase in the K uptake of the tomato leaf in the treatment T₈ (290.61 kg ha⁻¹ in 2017, 342.92 kg ha⁻¹ in 2018 and 316.77 in the mean data as compared to the control treatment T₁ with the percent increase of 22.13 % in 2017, 19.24 % in 2018 and 20.55 % in the mean data.

Potassium content in fruits of tomato

The perusal of data in table 4.25 revealed that with recommended dose of FYM and NPK and foliar feeding of calcium and magnesium significantly enhanced the K content in the fruits of tomato. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest K content in the treatment T₁₃ (3.17 % in 2017, 3.23 % in 2018 and 3.20 % in the mean data) over the control in the treatment T₁ (2.70 % in 2017, 2.82 % in 2018 and 2.76 % in the mean data). The percent increase of 17.41 % in 2017, 14.54 % in 2018 and 15.94 % in the mean data was recorded over the control.

Increase in the level of magnesium to 0.4 % with recommended dose of FYM and NPK fertilizers also recorded the significant decrease in K content in T₁₄ (3.15 % in 2017, 3.21 % in 2018 and 3.18 % in the mean data) over T₁₃ with the percent increase of 16.67 % in 2017, 13.83 % in 2018 and 15.22 % in the mean data over the control T₁.

The significant enhancement was also recorded K content in T₂ (2.78 % in 2017, 2.86 % in 2018 and 2.82 % in the mean data) with the percent increase of 2.96 % in 2017, 1.42 % in 2018 and 2.17 % in the mean data where only NPK fertilizers was applied whereas application of FYM and NPK fertilizers in treatment T₃ (2.79 % in 2017, 2.87 % in 2018 and 2.83 % in the mean data) with the percent increase of 3.33 % in 2017, 1.77 % in 2018 and 2.54 % in the mean data also revealed the significant growth in K content over the control T₁ in the tomato fruit (Table 4.25).

The perusal of the table 4.25 revealed that the foliar application of the calcium and magnesium when applied separately also improved the K content of the tomato fruit significantly. The application of calcium @ 0.6 % raised significantly the K content in the fruits of tomato in treatment T₅ (3.03 % in 2017, 3.09 % in 2018 and 3.06 % in the mean data) with the increase of 12.22 % in 2017, 9.57 % in 2018 and 10.87 % in the mean data in comparison to the control treatment T₁.

The magnesium applied as foliar spray @ 0.4 % also indicated the increase in the K content of tomato fruits in the treatment T₈ (2.95 % in 2017, 2.99 % in 2018 and 2.97 % in the mean data of both the years) with the increase of 9.26 % in 2017, 6.03 % in 2018 and 7.61 % in the mean data over the control treatment T₁.

Table 4.25 Effect of foliar application of Ca and Mg on K content in fruits of tomato

Treatments		K content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	2.70	2.82	2.76
T ₂	NPK @ 150:120:60	2.78	2.86	2.82
T ₃	FYM + NPK @ 150:120:60 (RD)	2.79	2.87	2.83
T ₄	RD + Ca @ 0.3% Foliar application (FA)	2.95	3.01	2.98
T ₅	RD + Ca @ 0.6 % (FA)	3.03	3.09	3.06
T ₆	RD + Mg @ 0.1 % (FA)	2.87	2.93	2.90
T ₇	RD + Mg @ 0.2 % (FA)	2.90	2.96	2.93
T ₈	RD + Mg @ 0.4 % (FA)	2.95	2.99	2.97
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	2.96	3.02	2.99
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	2.98	3.08	3.03
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	3.05	3.11	3.08
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	3.13	3.19	3.16
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	3.17	3.23	3.20
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	3.15	3.21	3.18
	CD (5 %)	0.06	0.11	0.03

Potassium uptake in fruits of tomato

The examination of the data (Table 4.26) indicated an improvement in K uptake in the tomato fruit. With the recommended doses of FYM and NPK, as well as foliar feeding of calcium and magnesium, K uptake in to K content and tomato leaves increased significantly. The foliar spray of calcium and magnesium @ 0.6 and 0.2 % recorded the highest K uptake in the treatment T₁₃ (287.78 kg ha⁻¹ in 2017, 333.11 kg ha⁻¹ in 2018 and 310.28 kg ha⁻¹ in the mean data) over the control in the treatment T₁ (203.33 kg ha⁻¹ in 2017, 245.28 kg ha⁻¹ in 2018 and 224.05 kg ha⁻¹ in the mean data). The percent increase of 41.53 % in 2017, 35.81 % in 2018 and 38.49 % in the mean data was recorded over the control T₁. With the increase in the level of magnesium to 0.4 % with recommended dose of FYM and NPK fertilizers also recorded the significant decrease in K uptake in T₁₄ (284.57 kg ha⁻¹ in 2017, 327.54 kg ha⁻¹ in 2018 and 305.90 kg ha⁻¹ in the mean data) over T₁₃ but the percent increase of 39.95 % in 2017, 33.54 % in 2018 and 36.53 % in the mean data was recorded over the control T₁.

The study of data also recorded an increase in K uptake in T₂ (220.47 kg ha⁻¹ in 2017, 258.20 kg ha⁻¹ in 2018, and 239.20 in the mean data of both years) where only NPK fertilisers were used, whereas in T₃ (226.41 kg ha⁻¹ in 2017, 264.84 kg ha⁻¹ in 2018, and 245.45 kg ha⁻¹ in the mean data of both years) where FYM and NPK fertilisers were used. The percent increase of 8.43 % in 2017, 5.27 % in 2018 and 6.76 % in the mean data in T₂ and 11.35 % in 2017, 7.97 % in 2018 and 9.55 % in the mean data in T₃ was recorded in K uptake over the control T₁.

Table 4.26 Effect of foliar application of Ca and Mg on uptake of K in fruits of tomato

Treatments		K uptake		
		2017	2018	Mean
T ₁	FYM (Control)	203.33	245.28	224.05
T ₂	NPK @ 150:120:60	220.47	258.20	239.20
T ₃	FYM + NPK @ 150:120:60 (RD)	226.41	264.84	245.45
T ₄	RD + Ca @ 0.3% Foliar application (FA)	260.82	292.94	276.83
T ₅	RD + Ca @ 0.6 % (FA)	270.43	306.56	288.58
T ₆	RD + Mg @ 0.1 % (FA)	221.36	260.45	240.76
T ₇	RD + Mg @ 0.2 % (FA)	230.14	266.85	248.41
T ₈	RD + Mg @ 0.4 % (FA)	242.76	279.17	260.97
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	251.95	293.86	272.79
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	254.72	301.08	277.66
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	269.82	309.97	289.74
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	280.97	323.42	301.99
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	287.78	333.11	310.28
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	284.57	327.54	305.90
CD (5 %)		7.62	12.45	7.45

A perusal of table 4.26 revealed that the foliar application of calcium and magnesium, when applied separately, significantly improved the K uptake of the tomato fruit. In comparison to the control treatment T₁, the application of calcium @ 0.6 % significantly increased the P uptake in tomato fruit in treatment T₅ (270.43 kg ha⁻¹ in 2017, 306.56 kg ha⁻¹ in 2018, and 288.58 kg ha⁻¹ in the mean data) with the percent increase of 33.00 % in 2017, 24.98 % in 2018 and 28.80 % in the mean data over the control.

The magnesium applied as a foliar spray at 0.4 % also presented an increase in the K uptake in the tomato fruit in the treatment T₈ (242.76 kg ha⁻¹ in 2017, 279.17 kg ha⁻¹ in 2018, and 260.67 kg ha⁻¹ in the mean data) with the percent increase of 19.39 % in 2017, 13.82 % in 2018 and 16.34 % in the mean data in comparison to the control treatment T₁.

4.4.4 Calcium content and its uptake in leaves and fruits of tomato

Calcium content in leaves of tomato

The data presented in table 4.27 revealed that application of calcium and magnesium along with the recommended dose of FYM and NPK registered a significant effect on Ca content in tomato leaves. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest P content in T₁₃ (1.35 % in 2017, 1.28 % in 2018 and 1.32 % in the mean data) over the control in the treatment T₁ (0.79 % in 2017, 0.85 % in 2018 and 0.82 % in the mean data) with the percent increase of 70.89 % in 2017, 50.59 % in 2018 and 60.98 % in the mean data over the control. The Ca content with the foliar spray of calcium and magnesium @ 0.6 % and 0.4 % in T₁₄ (1.29 % in 2017, 1.23 % in 2018 and 1.26 % in the mean data) was recorded over the control with the increase of 63.29 % in 2017, 44.71 % in 2018 and 53.66 % in the mean data over the control.

The incorporation of NPK fertilizer in T₂ recorded improvement in the Ca content viz. 0.84 % in 2017, 0.89 % in 2018 and 0.87 % in the mean data with the per cent increase of 6.33 % in 2017, 4.71 % in 2018 and 6.10 % in the mean data. The FYM along with the NPK fertilizers applied in the treatment T₃ recorded the Ca content to the tune of 0.89 % in 2017, 0.96 % in 2018 and 0.93 % in the mean data with the percent increase of 12.66 % in 2017, 12.94 % in 2018 and 13.41% in the mean data.

Further, looking in the table 4.27, the foliar application of the calcium and magnesium when applied individually the positive results were observed. The application of calcium @ 0.6 % improved significantly the Ca content in the leaves in the treatment T₅ (1.13 % in 2017, 1.18 % in 2018 and 1.16 % in the mean data) over the control treatment with the percent increase of 43.04 % in 2017, 38.82 % in 2018 and 41.46 % in the mean data over the control.

Table 4.27 Effect of foliar application of Ca and Mg on uptake of Ca content in leaves of tomato

Treatments		Ca content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	0.79	0.85	0.82
T ₂	NPK @ 150:120:60	0.84	0.89	0.87
T ₃	FYM + NPK @ 150:120:60 (RD)	0.89	0.96	0.93
T ₄	RD + Ca @ 0.3% Foliar application (FA)	1.00	1.04	1.02
T ₅	RD + Ca @ 0.6 % (FA)	1.13	1.18	1.16
T ₆	RD + Mg @ 0.1 % (FA)	0.91	0.97	0.94
T ₇	RD + Mg @ 0.2 % (FA)	0.93	0.99	0.96
T ₈	RD + Mg @ 0.4 % (FA)	0.97	1.01	0.99
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	1.03	1.05	1.04
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	1.05	1.11	1.08
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	1.09	1.15	1.12
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	1.20	1.24	1.22
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	1.35	1.28	1.32
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	1.29	1.23	1.26
CD (5 %)		0.04	0.04	0.03

Similarly, the foliar feeding of magnesium @ 0.4 % along with FYM and NPK fertilizers also indicated the increase in the Ca content of the leaves in T₈ (0.97 % in 2017, 1.01 % in 2018 and 0.99 % in the mean data) over the control treatment T₁. The percent increase recorded was 22.78 % in 2017, 18.82 % in 2018 and 20.73 % in the mean data over the control.

Calcium uptake in leaves of tomato

The perusal of the data in table 4.28 revealed an increase in Ca uptake in the tomato leaves. With the recommended doses of FYM and NPK, as well as foliar feeding of calcium and magnesium applied @ 0.6 and 0.2 % recorded the highest Ca uptake in the treatment T₁₃ (119.55 kg ha⁻¹ in 2017, 138.85 kg ha⁻¹ in 2018 and 129.20 kg ha⁻¹ in the mean data) over the control in the treatment T₁ (61.69 kg ha⁻¹ in 2017, 68.85 kg ha⁻¹ in 2018 and 65.27 kg ha⁻¹ in the mean data). The percent increase recorded was 93.79 % in 2017, 101.67 % in 2018 and 97.95 % in the mean data over the control. With the increase of magnesium level to 0.4 % in T₁₄ (113.81 kg ha⁻¹ in 2017, 131.30 kg ha⁻¹ in 2018 and 122.55 kg ha⁻¹ in the mean data) the significant decrease in the Ca uptake was recorded over T₁₃ but, the percent increase of 84.49 % in 2017, 90.70 % in 2018 and 87.76 % in the mean data was observed as compared to the control.

The perusal of data (Table 4.28) indicated an increase in Ca uptake in T₂ (68.50 kg ha⁻¹ in 2017, 75.52 kg ha⁻¹ in 2018, and 72.01 kg ha⁻¹ in the mean data) where only NPK fertilisers were applied indicated the percent increase of 11.04 % in 2017, 9.69 % in 2018 and 10.33 % in the mean

data over control. Likewise, in T₃ (75.13 kg ha⁻¹ in 2017, 82.18 kg ha⁻¹ in 2018, and 78.66 kg ha⁻¹ in the mean data) where FYM and NPK fertilisers were incorporated the percent increase of 21.79 % in 2017, 19.36 % in 2018 and 20.51 % in the mean data was recorded in comparison to the control.

Further examination of table 4.28 revealed that the foliar application of calcium and magnesium separately, also improved Ca uptake in tomato leaves. In comparison to the control treatment T₁, the application of calcium @ 0.6 % significantly increased the Ca uptake in tomato leaves in treatment T₅ (103.10 kg ha⁻¹ in 2017, 111.82 kg ha⁻¹ in 2018 and 107.46 kg ha⁻¹ in the mean data) with the increase of 67.13 % in 2017, 62.41 % in 2018 and 64.64 % in the mean data (Table 4.28).

Table 4.28 Effect of foliar application of Ca and Mg on Ca uptake in leaves of tomato

Treatments		Ca uptake		
		2017	2018	Mean
T ₁	FYM (Control)	61.69	68.85	65.27
T ₂	NPK @ 150:120:60	68.50	75.52	72.01
T ₃	FYM + NPK @ 150:120:60 (RD)	75.13	82.18	78.66
T ₄	RD + Ca @ 0.3% Foliar application (FA)	90.20	97.41	93.80
T ₅	RD + Ca @ 0.6 % (FA)	103.10	111.82	107.46
T ₆	RD + Mg @ 0.1 % (FA)	72.50	81.19	76.85
T ₇	RD + Mg @ 0.2 % (FA)	76.19	83.52	79.86
T ₈	RD + Mg @ 0.4 % (FA)	81.50	90.27	85.88
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	88.55	99.91	94.23
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	92.34	102.37	97.35
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	99.08	108.71	103.90
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	109.52	121.18	115.35
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	119.55	138.85	129.20
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	113.81	131.30	122.55
	CD (5 %)	3.43	5.06	4.77

The magnesium applied as a foliar spray at 0.4 % with the recommended dose of FYM and NPK fertilizers also indicated an increase in the Ca uptake of the leaves in the treatment T₈ (81.50 kg ha⁻¹ in 2017, 90.27 kg ha⁻¹ in 2018, and 85.88 kg ha⁻¹ in the mean data of both years) compared to the control treatment T₁. The percent increase recorded was 32.11 % in 2017, 31.11 % in 2018 and 31.58 % in the mean data over T₁.

Calcium content in fruits of tomato

The perusal of data in table 4.28 revealed that with the foliar feeding of calcium and magnesium along with recommended dose of FYM and NPK enhanced the Ca content in the tomato

fruits. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest Ca content in the treatment T₁₃ (0.74 % in 2017, 0.81 % in 2018 and 0.79 % in the mean data) over the control in the treatment T₁ (0.43 % in 2017, 0.49 % in 2018 and 0.46 % in the mean data). The percent increase of 72.09 % in 2017, 65.31 % in 2018 and 71.74 % in the mean data was recorded over the control. The significant decrease in Ca content was recorded in T₁₄ (0.75 % in 2017, 0.78 % in 2018 and 0.77 % in the mean data) where the calcium and magnesium applied @ 0.6 and 0.4 % with recommended dose of FYM and NPK fertilizers. The percent increase recorded in T₁₄ was to the tune of 74.72 % in 2017, 59.18 % in 2018 and 67.39 % in the mean data over the control.

Table 4.29 Effect of foliar application of Ca and Mg on Ca content in fruits of tomato

Treatments		Ca content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	0.43	0.49	0.46
T ₂	NPK @ 150:120:60	0.47	0.51	0.49
T ₃	FYM + NPK @ 150:120:60 (RD)	0.5	0.54	0.52
T ₄	RD + Ca @ 0.3% Foliar application (FA)	0.57	0.63	0.60
T ₅	RD + Ca @ 0.6 % (FA)	0.68	0.76	0.72
T ₆	RD + Mg @ 0.1 % (FA)	0.52	0.56	0.54
T ₇	RD + Mg @ 0.2 % (FA)	0.51	0.59	0.55
T ₈	RD + Mg @ 0.4 % (FA)	0.52	0.62	0.57
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	0.59	0.65	0.62
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	0.61	0.69	0.65
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	0.61	0.71	0.66
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	0.71	0.77	0.74
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	0.74	0.81	0.79
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	0.75	0.78	0.77
	CD (5 %)	0.04	0.04	0.03

The significant enhancement in Ca content was also recorded in T₂ (0.47 % in 2017, 0.51 % in 2018 and 0.49 % in the mean data) with the percent increase of 9.30 % in 2017, 4.08 % in 2018 and 6.52 % in the mean data where only NPK fertilizers were applied whereas application of FYM and NPK fertilizers in treatment T₃ (0.50 % in 2017, 0.54 % in 2018 and 0.52 % in the mean data) recorded the significant increase in Ca content with the percent increase of 16.28 % in 2017, 10.20 % in 2018 and 13.04 % in the mean data over the control treatment in the tomato fruit.

Further, perusal of data in table 4.29 revealed that the foliar application of the calcium and magnesium when applied singly significantly improved the Ca content of the tomato fruit. The application of calcium @ 0.6 % raised significantly the Ca content in the tomato fruit in the treatment T₅ (0.68 % in 2017, 0.76 % in 2018 and 0.72 % in the mean data) in comparison to the control

treatment T₁ with the percent increase of 58.14 % in 2017, 55.10 % in 2018 and 56.62 % in the mean data over the control.

The magnesium applied as foliar spray @ 0.4 % also exhibited the development in the Ca content in the tomato fruit in treatment T₈ (0.52 % in 2017, 0.62 % in 2018 and 0.57 % in the mean data) over the control treatment T₁. The percent increase of 20.93 % in 2017, 26.53 % in 2018 and 23.91 % in the mean data was recorded over the control.

Calcium uptake in fruits of tomato

The data presented in the table 4.30 indicated an increase in Ca uptake in the tomato fruits. With the recommended doses of FYM and NPK, as well as foliar feeding of calcium and magnesium, Ca uptake in tomato fruits increased significantly. The foliar spray of calcium and magnesium @ 0.6 and 0.2 % recorded the highest Ca uptake in the treatment T₁₃ (67.22 kg ha⁻¹ in 2017, 83.60 kg ha⁻¹ in 2018 and 75.41 kg ha⁻¹ in the mean data) over the control in the treatment T₁ (32.40 kg ha⁻¹ in 2017, 42.77 kg ha⁻¹ in 2018 and 37.58 kg ha⁻¹ in the mean data). The percent increase of 107.47 % in 2017, 95.46 % in 2018 and 100.67 % in the mean data over the control. Unlikely, with increase in magnesium level to 0.4 % the Ca uptake in T₁₄ recorded to the tune of 67.76 kg ha⁻¹ in 2017, 79.63 kg ha⁻¹ in 2018 and 73.70 kg ha⁻¹ in the mean data and documented the percent increase of 109.14 % in 2017, 86.18 % in 2018 and 96.11 % in the mean data over the control.

Likewise, the study of data also recorded an significant increase in Ca uptake in T₂ (37.16 kg ha⁻¹ in 2017, 46.14 kg ha⁻¹ in 2018 and 41.65 kg ha⁻¹ in the mean data) where only NPK fertilisers were used and indicated the percent increase of 14.69 % in 2017, 7.88 % in 2018 and 10.83 % in the mean data over the control. Similarly, the incorporation of FYM and NPK fertilisers also improved significantly the Ca uptake in treatment T₃ (40.57 kg ha⁻¹ in 2017, 49.93 kg ha⁻¹ in 2018, and 45.25 kg ha⁻¹ in the mean data) with the percent increase of 25.22 % in 2017, 16.74 % in 2018 and 20.41 % in the mean data over the control.

Further, study of data (Table 4.30) revealed, that the foliar application of calcium and magnesium, alone significantly improved the Ca uptake of the tomato fruits. In comparison to the control treatment T₁, the application of calcium @ 0.6 % significantly increased the Ca uptake in tomato fruit in treatment T₅ (60.64 kg ha⁻¹ in 2017, 75.59 kg ha⁻¹ in 2018, and 68.11 kg ha⁻¹ in the mean data). The percent increase observed was 87.16 % in 2017, 76.74 % in 2018 and 81.24 % in the mean data over the control.

The magnesium applied as a foliar spray @ 0.4 % along with recommended dose also indicated an increase in the Ca uptake of the tomato fruits in the treatment T₈ (42.77 kg ha⁻¹ in 2017, 58.0 kg ha⁻¹ in 2018 and 50.39 kg ha⁻¹ in the mean data of both years) as compared to the control treatment T₁ with the increase of 32.01 % in 2017, 35.61 % in 2018 and 34.09 % in the mean data recorded over the control.

Table 4.30 Effect of foliar application of Ca and Mg on uptake of Ca in fruits of tomato

Treatments		Ca uptake		
		2017	2018	Mean
T ₁	FYM (Control)	32.40	42.77	37.58
T ₂	NPK @ 150:120:60	37.16	46.14	41.65
T ₃	FYM + NPK @ 150:120:60 (RD)	40.57	49.93	45.25
T ₄	RD + Ca @ 0.3% Foliar application (FA)	50.33	61.43	55.88
T ₅	RD + Ca @ 0.6 % (FA)	60.64	75.59	68.11
T ₆	RD + Mg @ 0.1 % (FA)	40.07	49.88	44.98
T ₇	RD + Mg @ 0.2 % (FA)	40.43	53.27	46.85
T ₈	RD + Mg @ 0.4 % (FA)	42.77	58.00	50.39
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	50.19	63.31	56.75
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	52.11	67.52	59.81
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	53.93	70.83	62.38
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	63.70	78.09	70.90
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	67.22	83.60	75.41
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	67.76	79.63	73.70
CD (5 %)		2.06	5.54	5.57

4.4.5 Magnesium content and its uptake in leaves and fruits of tomato***Magnesium content in leaves of tomato***

A perusal of data in table 4.31 revealed that application of calcium and magnesium along with the recommended dose of FYM and NPK registered a significant effect on Mg content in tomato leaves. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest Mg content in T₁₃ (0.75 % in 2017, 0.81 % in 2018 and 0.78 % in the mean data) over the control in the treatment T₁ (0.43 % in 2017, 0.51 % in 2018 and 0.47 % in the mean data) with the percent increase of 74.42 % in 2017, 58.82 % in 2018 and 65.96 % in the mean data in comparison to the control. The decrease in the Mg content was recorded in tomato leaves with increase in the level of magnesium to 0.4 % in treatment T₁₄ (0.71 % in 2017, 0.81 % in 2018 and 0.76 % in the mean data) with the percent increase of 65.12 % in 2017, 58.82 % in 2018 and 61.70 % in the mean data over the control.

Likewise, the increase in the Mg content was recorded in the treatment T₂ (0.45 % in 2017, 0.53 % in 2018 and 0.49 % in the mean data) where only NPK fertilizers were applied over the control and the percent increase to the tune of 4.65 % in 2017, 3.92 % in 2018 and 4.26 % in the mean data was observed over the control. Likewise, the treatment where the FYM along with the NPK fertilizers were incorporated in the treatment T₃ (0.49 % in 2017, 0.55 % in 2018 and 0.52 % in the

mean data) the increase in the Mg content recorded with the percent increase of 13.95 % in 2017, 7.84 % in 2018 and 10.64 % in the mean data in comparison to the control.

Further, looking in the table 4.31, the foliar application of the calcium and magnesium when applied individually the positive results were observed. The application of calcium @ 0.6 % improved significantly the Mg content in the tomato leaves in T₅ (0.68 % in 2017, 0.76 % in 2018 and 0.72 % in the mean data) with the percent increase recorded to be 58.14 % in 2017, 49.02 % in 2018 and 53.19 % in the mean data over the control.

Table 4.31 Effect of foliar application of Ca and Mg on Mg content in leaves of tomato

Treatments		Mg content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	0.43	0.51	0.47
T ₂	NPK @ 150:120:60	0.45	0.53	0.49
T ₃	FYM + NPK @ 150:120:60 (RD)	0.49	0.55	0.52
T ₄	RD + Ca @ 0.3% Foliar application (FA)	0.58	0.62	0.6
T ₅	RD + Ca @ 0.6 % (FA)	0.68	0.76	0.72
T ₆	RD + Mg @ 0.1 % (FA)	0.51	0.57	0.54
T ₇	RD + Mg @ 0.2 % (FA)	0.51	0.59	0.55
T ₈	RD + Mg @ 0.4 % (FA)	0.55	0.59	0.57
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	0.59	0.65	0.62
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	0.63	0.67	0.65
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	0.63	0.69	0.66
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	0.71	0.77	0.74
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	0.75	0.81	0.78
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	0.71	0.81	0.76
	CD (5 %)	0.03	0.04	0.03

Similarly, the foliar feeding of magnesium @ 0.4 % also indicated the increase in the Mg content in the tomato leaves in the treatment T₈ (0.55 % in 2017, 0.59 % in 2018 and 0.57 % in the mean data) with the percent increase of 27.91 % in 2017, 15.69 % in 2018 and 21.28 % in the mean data over the control treatment T₁.

Magnesium uptake in leaves of tomato

The data presented in table 4.32 indicated an increase in Mg uptake in the tomato leaves. With the recommended doses of FYM and NPK, as well as foliar feeding of calcium and magnesium, Mg uptake in tomato leaves increased significantly. The foliar spray of calcium and magnesium @ 0.6 and 0.2 % recorded the highest Mg uptake in the treatment T₁₃ (68.14 kg ha⁻¹ in 2017, 83.63 kg ha⁻¹ in 2018 and 75.88 kg ha⁻¹ in the mean data) over the control in the treatment T₁ (32.4 kg ha⁻¹ in 2017,

44.5 kg ha⁻¹ in 2018 and 38.45 kg ha⁻¹ in the mean data). The percent increase recorded was 110.31 % in 2017, 87.93 % in 2018 and 97.35 % in the mean data over the control.

With the foliar spray of calcium and magnesium @ 0.6 and 0.4 %, non significant decrease in the Mg uptake was recorded in T₁₄ (67.76 kg ha⁻¹ in 2017, 82.59 kg ha⁻¹ in 2018 and 75.18 kg ha⁻¹ in the mean data) with the percent increase of 109.14 % in 2017, 85.60 % in 2018 and 95.53 % in the mean data over the control.

The study of data (Table 4.32) also recorded an increase in Mg uptake in the treatment T₂ (35.58 kg ha⁻¹ in 2017, 47.93 kg ha⁻¹ in 2018, and 41.75 kg ha⁻¹ in the mean data of both years) with the percent increase of 9.81 % in 2017, 7.71 % in 2018 and 8.58 % in the mean data) over the control where only NPK fertilisers were applied. In treatment T₃ (39.76 kg ha⁻¹ in 2017, 50.83 kg ha⁻¹ in 2018, and 45.3 kg ha⁻¹ in the mean data) the increase of 22.72 % in 2017, 14.22 % in 2018 and 17.82 % in the mean data over the control T₁ was recorded where recommended dose of FYM and 100 % NPK fertilisers was incorporated.

Table 4.32 Effect of foliar application on Ca and Mg on Mg uptake in leaves of tomato

Treatments		Mg uptake		
		2017	2018	Mean
T ₁	FYM (Control)	32.40	44.50	38.45
T ₂	NPK @ 150:120:60	35.58	47.93	41.75
T ₃	FYM + NPK @ 150:120:60 (RD)	39.76	50.83	45.30
T ₄	RD + Ca @ 0.3% Foliar application (FA)	51.22	60.43	55.82
T ₅	RD + Ca @ 0.6 % (FA)	60.64	75.57	68.10
T ₆	RD + Mg @ 0.1 % (FA)	39.30	50.75	45.02
T ₇	RD + Mg @ 0.2 % (FA)	42.02	51.49	46.76
T ₈	RD + Mg @ 0.4 % (FA)	45.24	55.21	50.22
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	51.04	62.37	56.70
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	52.97	66.55	59.76
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	55.70	68.82	62.26
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	63.70	78.09	70.90
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	68.14	83.63	75.88
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	67.76	82.59	75.18
	CD (5 %)	2.41	4.85	5.21

Foliar application of calcium and magnesium, separately, significantly improved the Mg uptake of the tomato fruit. In comparison to the control treatment T₁, the application of calcium @ 0.6 % significantly increased the Mg uptake in tomato fruit in treatment T₅ (60.64 kg ha⁻¹ in 2017, 75.57

kg ha⁻¹ in 2018, and 68.1 kg ha⁻¹ in the mean data) with the increase of 87.16 % in 2017, 69.82 % in 2018 and 77.11 % in the mean data .

Likewise, the magnesium applied as a foliar spray @ 0.4 % also indicated an significant enhancement in the Mg uptake of the tomato leaves in the treatment T₈ (45.24 kg ha⁻¹ in 2017, 55.21 kg ha⁻¹ in 2018, and 50.22 kg ha⁻¹ in the mean data of both years) with the increase of 39.63 % in 2017, 24.07 % in 2018 and 30.61 % in the mean data in comparison to the control treatment T₁ (Table 4.32).

Magnesium content in fruits of tomato

The examination of data presented in table 4.33 revealed that with the recommended dose of FYM and NPK and foliar feeding of calcium and magnesium recorded a significant improvement in Mg content in the tomato fruits. The foliar application of calcium and magnesium @ 0.6 and 0.2 % along with 100 % NPK fertilizers recorded the highest Mg content in the treatment T₁₃ (0.44 % in 2017, 0.48 % in 2018 and 0.46 % in the mean data) over the control treatment T₁ (0.10 % in 2017, 0.14 % in 2018 and 0.12 % in the mean data) with the percent increase of 74.42 % in 2017, 58.82 % in 2018 and 65.96 % in the mean data. The foliar feeding of calcium and magnesium @ 0.6 and 0.4 % in treatment T₁₄ the Mg content recorded was 0.41 % in 2017, 0.47 % in 2018 and 0.44 % in the mean data with the percent increase of 65.12 % in 2017, 58.82 % in 2018 and 61.70 % in the mean data over the control.

Table 4.33 Effect of foliar application of Ca and Mg on Mg content in fruits of tomato

Treatments		Mg content (%)		
		2017	2018	Mean
T ₁	FYM (Control)	0.10	0.14	0.12
T ₂	NPK @ 150:120:60	0.19	0.25	0.22
T ₃	FYM + NPK @ 150:120:60 (RD)	0.21	0.27	0.24
T ₄	RD + Ca @ 0.3% Foliar application (FA)	0.31	0.33	0.32
T ₅	RD + Ca @ 0.6 % (FA)	0.35	0.43	0.39
T ₆	RD + Mg @ 0.1 % (FA)	0.23	0.31	0.27
T ₇	RD + Mg @ 0. 2 % (FA)	0.27	0.31	0.29
T ₈	RD + Mg @ 0.4 % (FA)	0.28	0.34	0.31
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	0.31	0.37	0.34
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	0.35	0.37	0.36
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	0.36	0.44	0.40
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	0.38	0.46	0.42
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	0.44	0.48	0.46
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	0.41	0.47	0.44
CD (5 %)		0.03	0.04	0.03

The significant enhancement was also recorded in Mg content in T₂ (0.19 % in 2017, 0.25 % in 2018 and 0.22 % in the mean data of both the years) where only NPK fertilizers was applied with the percent increase of 4.65 % in 2017, 3.92 % in 2018 and 4.26 % in the mean data over the control. Similarly, the application of FYM and 100 % NPK fertilizers in treatment T₃ (0.21 % in 2017, 0.27 % in 2018 and 0.24 % in the mean data of both the years) also reported the significant growth in Mg content over the control with the percent increase of 13.95 % in 2017, 7.84 % in 2018 and 10.64 % in the mean data over the control T₁ in the tomato fruits (Table 4.33).

A perusal of data presented in the table 4.33 further, revealed that the foliar application of the calcium and magnesium when applied separately also significantly improved the Mg content in the fruits of tomato. The foliar spray of calcium @ 0.6 % significantly raised the Mg content in the tomato fruits in treatment T₅ (0.35 % in 2017, 0.43 % in 2018 and 0.39 % in the mean data) in comparison to the control treatment T₁. The percent increase of 58.14 % in 2017, 49.02 % in 2018 and 53.19 % in the mean data were recorded over the control.

The magnesium applied as foliar spray @ 0.4 % also exhibited the development in the Mg content of the tomato fruits in the treatment T₈ (0.28 % in 2017, 0.34 % in 2018 and 0.31 % in the mean data) with the percent increase of 27.91 % in 2017, 15.69 % in 2018 and 21.28 % in the mean data over the control treatment T₁.

Magnesium uptake in fruits of tomato

The study of the data (Table 4.34) reported an increase in Mg uptake in the tomato fruits. With the recommended doses of FYM and NPK, as well as foliar feeding of calcium and magnesium, Ca uptake in tomato fruits increased significantly.

The foliar spray of calcium and magnesium @ 0.6 and 0.2 % recorded the maximum Mg uptake in the treatment T₁₃ (39.97 kg ha⁻¹ in 2017, 49.46 kg ha⁻¹ in 2018 and 44.71 kg ha⁻¹ in the mean data) over the control in the treatment T₁ (7.55 kg ha⁻¹ in 2017, 12.18 kg ha⁻¹ in 2018 and 9.87 kg ha⁻¹ in the mean data). The percent increase recorded was 429.40 % in 2017, 306.07 % in 2018 and 352.99 % in the mean data over the control.

Further examination of data it was found that foliar spray of calcium and magnesium @ 0.6 and 0.4 %, non significant decrease in the Mg uptake was recorded in T₁₄ (37.03 kg ha⁻¹ in 2017, 47.94 kg ha⁻¹ in 2018 and 42.49 kg ha⁻¹ in the mean data) with the percent increase of 390.46 % in 2017, 298.59 % in 2018 and 330.49 % in the mean data over the control.

The study of data also indicated an increase in Mg uptake in T₂ (15.03 kg ha⁻¹ in 2017, 22.63 kg ha⁻¹ in 2018, and 18.83 kg ha⁻¹ in the mean data) with the percent increase of 4.65 % in 2017, 3.92 % in 2018 and 4.26 % in the mean data where only NPK fertilisers were used. The incorporation of recommended dose of FYM and 100 % NPK fertilisers in T₃ (17.01 kg ha⁻¹ in 2017, 24.99 kg ha⁻¹ in

2018, and 21.0 kg ha⁻¹ in the mean data) the percent increase of 13.95 % in 2017, 7.84 % in 2018 and 10.64 % in the mean data were recorded over the control.

The review of the data in the table 4.34 revealed that the foliar application of calcium and magnesium, when applied separately, significantly improved the Mg uptake in the tomato fruits. As compared to the treatment T₁ the control, the application of calcium @ 0.6 % significantly increased the Mg uptake in tomato fruits in treatment T₅ (31.18 kg ha⁻¹ in 2017, 42.83 kg ha⁻¹ in 2018, and 37.01 kg ha⁻¹ in the mean data) with the percent increase of 58.14 % in 2017, 49.02 % in 2018 and 53.19 % in the mean data over the control.

Examination of the data further in the table 4.34, the magnesium applied as a foliar spray @ 0.4 % also exhibited an increase in the Mg uptake of the fruits of tomato in the treatment T₈ (23.03 kg ha⁻¹ in 2017, 31.86 kg ha⁻¹ in 2018 and 27.44 kg ha⁻¹ in the mean data) in comparison to the control T₁ with the percent increase of 27.91 % in 2017, 15.69 % in 2018 and 21.28 % in the mean data over the control.

The increasing level of calcium and magnesium improved the N, P, K, Mg and Ca content of the leaves and fruits (Gunes *et al* 1998).

Table 4.34: Effect of foliar application Ca and Mg on uptake of Mg in fruits of tomato

Treatments		Mg uptake		
		2017	2018	Mean
T ₁	FYM (Control)	7.55	12.18	9.87
T ₂	NPK @ 150:120:60	15.03	22.63	18.83
T ₃	FYM + NPK @ 150:120:60 (RD)	17.01	24.99	21.00
T ₄	RD + Ca @ 0.3% Foliar application (FA)	27.35	32.10	29.72
T ₅	RD + Ca @ 0.6 % (FA)	31.18	42.83	37.01
T ₆	RD + Mg @ 0.1 % (FA)	17.71	27.54	22.63
T ₇	RD + Mg @ 0.2 % (FA)	21.41	27.99	24.70
T ₈	RD + Mg @ 0.4 % (FA)	23.03	31.86	27.44
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	26.38	35.94	31.16
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	29.88	36.09	32.99
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	31.83	43.82	37.83
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	34.09	46.56	40.33
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	39.97	49.46	44.71
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	37.03	47.94	42.49
	CD (5 %)	2.04	4.01	3.91

It is clear from the results that application of calcium levels as a foliar spray significantly increased the concentrations of nutrients in the leaves and fruits of the tomato crop. The increasing

rates of calcium and magnesium had a positive results on most of the nutrient contents in leaves and which might increase phosphorous, potassium, calcium and magnesium concentrations (Tejashvini and Thippeshappa, 2017).

The increase in nutrient concentration can be seen in all the treatments where the calcium was applied except the treatments where only the recommended dose of NPK fertilizers and FYM were incorporated. Calcium is very essential for meristematic activity. It had an important role in mitosis and assimilation of organic constituents is also supported by it. The results were in conformity with the findings of Mohammad (2014), Orlovius and Mchoul (2015) and Tejashvini and Thippeshappa (2017) in tomato.

4.5 Effect of different treatments on soil properties

4.5.1 Soil pH and organic carbon after harvest of the crop

The data relating to the impact of various levels of calcium and magnesium on soil properties in different treatments recorded after harvest of the crop during 2017 and 2018 have been presented in table 4.35.

Table 4.35 Effect of foliar application of Ca and Mg on soil properties after crop harvest

Treatments		pH			Organic Carbon (%)		
		2017	2018	Mean	2017	2018	Mean
T ₁	FYM (Control)	6.82	6.86	6.84	0.81	0.83	0.82
T ₂	NPK @ 150:120:60	6.85	6.89	6.87	0.82	0.84	0.83
T ₃	FYM + NPK @ 150:120:60 (RD)	6.87	6.93	6.9	0.81	0.83	0.82
T ₄	RD + Ca @ 0.3% Foliar application (FA)	6.85	6.89	6.87	0.82	0.82	0.82
T ₅	RD + Ca @ 0.6 % (FA)	6.82	6.88	6.85	0.83	0.85	0.84
T ₆	RD + Mg @ 0.1 % (FA)	6.85	6.89	6.87	0.82	0.86	0.84
T ₇	RD + Mg @ 0.2 % (FA)	6.84	6.92	6.88	0.83	0.85	0.84
T ₈	RD + Mg @ 0.4 % (FA)	6.83	6.87	6.85	0.81	0.83	0.82
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	6.87	6.91	6.89	0.81	0.85	0.83
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	6.86	6.96	6.91	0.82	0.84	0.83
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	6.88	6.92	6.90	0.81	0.85	0.83
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	6.85	6.89	6.87	0.82	0.86	0.84
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	6.87	6.91	6.89	0.81	0.83	0.82
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	6.84	6.92	6.88	0.84	0.82	0.83
CD (5 %)		NS	NS	NS	NS	NS	NS

The soil pH after crop harvest of the tomato crop in individual year and for the data averaged over two years, did not change due to the foliar feeding of nutrients and incorporation of FYM and NPK fertilizers (Table 4.35). The values after the harvest of crop and for soil initial pH were statistically similar and were non-significant. However, foliar spray of calcium and magnesium along

with the recommended dose of FYM and 100 % NPK fertilizers ranged from 6.85 to 6.88 during 2017, 6.84 to 6.88 during 2018 and 6.82 to 6.96 to in the mean value of both the years. The highest numerical value of pH recorded was 6.88 in 2017, 6.96 in 2018 and 6.91 for mean data of both years in comparison to control where the numerical value was 6.82 in 2017, 6.86 in 2018 and 6.84 for mean data as the initial value of pH recorded at the start of the experiment was pH (6.88). Further, the foliar feeding of the treatments did not exert any significant effect on the initial value and remained at par. Although, the glimpse of the data relating to organic carbon in soil in the present study, was not influenced due to foliar application of calcium and magnesium. However, its contents were maintained at 0.81 to 0.86 % at different calcium and magnesium levels as compared to initial organic carbon status (0.82 per cent). This improvement in soil organic carbon under the present study cannot be seen due to addition of FYM in soil and though there might be partial effect of foliar application on organic carbon. The similar findings have been reported by Aydin and Toltas (2004), Singh *et al* (2016), and Shete *et al* (2018).

4.5.2 Soil available N, P and K after harvest of crop

The data pertaining to the availability of major nutrients in soil have been presented in table 4.36. The foliar spray of calcium and magnesium had no effect on the soil available nitrogen but the significant outcome of soil available nitrogen was displayed in the all the treatments with the recommended dose of 100 % NPK fertilizers and FYM had been incorporated as compared to the T₁. The soil available nitrogen was recorded in the range of 162.71 kg ha⁻¹ to 225.14 kg ha⁻¹ in 2017, 143.48 kg ha⁻¹ to 125.90 kg ha⁻¹ in 2018 and 153.09 kg ha⁻¹ to 224.52 kg ha⁻¹ during the mean data of both the years. All the treatments were found significantly superior to the treatment T₁ the control where only FYM was applied (Table 4.36).

Further, study of the data indicated that the available soil phosphorus was also recorded to be significantly superior in the treatments where 100 % NPK fertilizers were incorporated in comparison to the T₁ (Table 4.36). The phosphorous was recorded in the range of 218.73 kg ha⁻¹ to 224.06 kg ha⁻¹ in the year 2017, 220.72 kg ha⁻¹ to 227.57 kg ha⁻¹ in 2018 and 220.61 kg ha⁻¹ to 224.84 kg ha⁻¹ for mean data. The foliar feeding of calcium and magnesium in the tomato crop had no effect on the on the soil available phosphorous.

Likewise, with the foliar feeding of calcium and magnesium along with the recommended dose of FYM and 100 % NPK fertilizers, calcium and magnesium had no effect on the availability of soil potassium. The available potassium content in soil varied from 195.74 kg ha⁻¹ to 239.14 kg ha⁻¹ in 2017, 178.49 kg ha⁻¹ to 236.88 kg ha⁻¹ in 2018 and 187.12 kg ha⁻¹ to 31.6 kg ha⁻¹ for mean data of both the years. In all the treatments available potassium content enhanced significantly in comparison to the control but revealed recorded to at par with each other statistically (Table 4.36).

The reason might be that the soil available nutrients did not change due to the foliar application of the calcium and magnesium but the recommended dose of FYM and 100 % NPK

fertilizers incorporated significantly affected the nutrients available in the soil (Available N, P and K) in all the treatments except the control treatment. The above findings are in agreement with the findings of other researchers viz. Aydin and Yoltas (2004), Singh *et al* (2016), Tiritan *et al* (2016) El Dissoky *et al* (2017) and Phuong *et al* (2019).

4.5.3 Soil Exchangeable Ca and Mg after harvest

The data with regards to the availability of secondary nutrients (Ca and Mg) in soil has been presented in Table 4.37. The foliar feeding of calcium and magnesium along with FYM and 100% NPK the recommended dose in the all treatments resulted in the non-significant effect on the calcium content in the soil and remained at par with one another. The range of the exchangeable calcium varied from 1.66 to 1.70 c mol (p+) kg⁻¹ in 2017, 1.67 to 1.71 c mol (p+) kg⁻¹ in 2018 and 1.67 to 1.71 c mol (p+) kg⁻¹ in the mean data of both the years.

Similarly, foliar application of calcium and magnesium indicated non-significant effect on the build-up of exchangeable soil Mg in all the treatments during 2017, 2018 and in the mean data. The range of exchangeable magnesium recorded varied from 3.45 to 3.61 c mol (p+) kg⁻¹ in 2017, 3.49 to 3.59 c mol (p+) kg⁻¹ in 2018 and 3.47 to 3.60 c mol (p+) kg⁻¹ in the mean data of both the years (Table 4.37).

The calcium and magnesium foliar application did not change the soil exchangeable Ca and Mg status. The data recorded was non-significant and the results are in association with the work reported by Martin and Liebhardt (1994), Colla *et al* (2002), Jiang *et al* (2009), Mehmet *et al* (2015), Saqib *et al* (2017) and Shete *et al* (2018)

Table 4.36 Effect of foliar application of Ca and Mg on soil available N, P and K after harvest of tomato crop

Treatments		Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
		2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
T ₁	FYM (Control)	162.71	143.48	153.09	13.61	12.91	13.26	195.74	178.49	187.12
T ₂	NPK @ 150:120:60	223.15	225.90	224.52	23.29	23.26	23.27	229.94	236.88	233.41
T ₃	FYM + NPK @ 150:120:60 (RD)	222.26	223.21	222.74	23.21	23.21	23.21	230.48	228.16	229.32
T ₄	RD + Ca @ 0.3% Foliar application (FA)	225.14	221.48	223.31	23.38	23.38	23.38	224.36	225.71	225.04
T ₅	RD + Ca @ 0.6 % (FA)	222.35	223.68	223.02	23.71	23.66	23.69	228.54	229.44	228.99
T ₆	RD + Mg @ 0.1 % (FA)	221.50	221.67	221.58	23.37	23.37	23.37	230.24	229.74	229.99
T ₇	RD + Mg @ 0.2 % (FA)	223.68	226.01	224.84	23.43	23.42	23.43	227.18	230.15	228.66
T ₈	RD + Mg @ 0.4 % (FA)	224.06	223.06	223.56	23.39	23.38	23.38	224.39	236.64	230.51
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	221.73	222.73	222.25	23.45	23.40	23.43	228.42	228.10	228.26
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	223.67	224.01	223.84	23.54	23.48	23.51	224.36	230.66	227.51
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	222.88	225.54	224.21	23.46	23.44	23.45	228.54	230.09	229.32
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	223.30	220.44	221.87	23.48	23.45	23.46	239.14	229.57	234.35
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	220.91	221.91	221.41	23.42	23.41	23.41	227.57	224.83	226.20
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	222.15	222.99	222.57	23.52	23.49	23.50	227.03	231.75	229.39
	CD (5 %)	4.21	3.23	3.16	0.45	0.57	0.49	6.37	6.32	3.65

Table 4.37 Effect of foliar application of Ca and Mg on exchangeable Ca and Mg after harvest of crop

Treatments		Exchangeable Ca (c mol (p+) kg ⁻¹)			Exchangeable Mg (c mol (p+) kg ⁻¹)		
		2017	2018	Mean	2017	2018	Mean
T ₁	FYM (Control)	1.67	1.67	1.67	3.48	3.54	3.51
T ₂	NPK @ 150:120:60	1.68	1.68	1.68	3.47	3.49	3.48
T ₃	FYM + NPK @ 150:120:60 (RD)	1.70	1.71	1.71	3.57	3.51	3.54
T ₄	RD + Ca @ 0.3% Foliar application (FA)	1.69	1.70	1.69	3.56	3.57	3.57
T ₅	RD + Ca @ 0.6 % (FA)	1.69	1.70	1.69	3.52	3.56	3.54
T ₆	RD + Mg @ 0.1 % (FA)	1.68	1.67	1.67	3.58	3.53	3.56
T ₇	RD + Mg @ 0.2 % (FA)	1.68	1.69	1.68	3.56	3.59	3.58
T ₈	RD + Mg @ 0.4 % (FA)	1.70	1.72	1.70	3.58	3.55	3.57
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	1.70	1.68	1.69	3.47	3.51	3.49
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	1.71	1.69	1.70	3.49	3.53	3.51
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	1.69	1.68	1.69	3.61	3.59	3.60
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	1.70	1.69	1.70	3.59	3.57	3.58
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	1.68	1.69	1.69	3.45	3.49	3.47
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	1.69	1.68	1.69	3.48	3.51	3.50
CD (5 %)		NS	NS	NS	NS	NS	NS

4.6 Economic evaluation of treatments

The data relating to the impact of treatments on net monetary returns (net returns) and benefit cost ratio in tomato crop are given in the table 4.38 to table 4.40.

4.6.1 Net returns and B: C ratio in tomato crop during 2017

The data in table 4.38 reported that foliar spray of calcium and magnesium in different doses along with the FYM and 100 % NPK fertilizers significantly increased net returns and B:C ratio of the tomato crop during the years of study. The net returns and B:C ratio were recorded highest in the treatment T₁₃ (Rs. 3,89,310/- ha⁻¹ and 3.36) where the foliar spray of calcium and magnesium was applied @ 0.6 % and 0.2 % along with FYM and 100 % NPK fertilizers as compared to the control T₁ (Rs. 20715/- ha⁻¹ and 1.14) where only FYM was applied during the first year of the experimental trial 2017. The percent increase of 1779 % and 194.74 % in net returns and B:C ratio in T₁₃ as compared to the control.

With, increase in the magnesium level to 0.4 % in the Net returns and BC ratio in the treatment T₁₄ recorded were Rs. 379610/- ha⁻¹ and 3.30 but remained as par to the treatment T₁₃ but

recorded the percent increase of 1732.54 % and 189.47 % in the net returns and B:C ratio as compared to the control treatment T₁.

Table 4.38 Effect of foliar application of Ca and Mg on net returns and B: C ratio during 2017

Treatments		Yield (q/ha)	Gross Return (Rs.)	Cost of cultivation (Rs.)	Net Return (Rs.)	B: C Ratio
T1	FYM (Control)	110.94	166415	145700	20715	1.14
T2	NPK @ 150:120:60	210.41	315610	153690	161920	2.05
T3	FYM + NPK @ 150:120:60 (RD)	252.47	378705	161700	217005	2.34
T4	RD + Ca @ 0.3% Foliar application (FA)	304.36	456535	162585	293950	2.81
T5	RD + Ca @ 0.6 % (FA)	344.18	516270	163165	353105	3.16
T6	RD + Mg @ 0.1 % (FA)	261.30	391950	163175	228775	2.40
T7	RD + Mg @ 0.2 % (FA)	268.54	402805	163580	239225	2.46
T8	RD + Mg @ 0.4 % (FA)	273.55	410320	163845	246475	2.50
T9	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	306.69	460035	164055	295980	2.80
T10	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	316.15	474220	164225	309995	2.89
T11	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	318.71	478063	164590	313473	2.90
T12	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	360.85	541270	164990	376280	3.28
T13	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	369.64	554460	165150	389310	3.36
T14	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	363.31	544960	165350	379610	3.30
CD (5 %)		-	-	-	17155	0.11

Likewise, treatment T₂ and T₃ also recorded the significant improvement in the net returns and BC ratio over the control. The incorporation of the NPK fertilizers was recorded the Net returns of Rs. 1,61,920/- and B:C ratio of 2.05 in the treatment T₂ and Rs. 2,17,005/- in the net returns and B:C ratio of 2.34 in the treatment T₃ where the FYM and 100 % NPK fertilizers were applied over the treatment T₁. The increase of 681.66 and 947.57 % in net returns and 79.82 and 105.26 % in B:C ratio were observed in the treatment T₂ and T₃ as compared to control

Foliar spray of calcium alone @ 0.6 % in the treatment T₅ the significant increase in the Net returns and B:C ratio of Rs. 3,53,105/- and 3.16. as compared to the control T₁. The percent increase of 1604.59 % and 177.19 % were recorded in the net returns and B:C ratio as compared to the control.

Further analysis of the data in table 4.38 also revealed that, the foliar feeding of the magnesium individually @ 0.4 % with recommended FYM and 100 % NPK fertilizers in treatment T₈ also remained beneficial and gave the significant improvement of the net returns and B:C ratio to the tune of Rs. 2,46,475 and 2.50 over the control T₁ with the percent increase of 1089.84 % and 119.30 % over T₁ the control.

The cost of cultivation was documented in the range of Rs. 1,45,700/- in the control T_1 and Rs. 1,65,350/- in the treatment T_{14} with the difference of Rs. 19,650/- during 2017, due to the incorporation of the NPK fertilizers in the soil and Ca and Mg in form of the foliar spray, respectively.

4.6.2 Net returns and B: C ratio in tomato crop during 2018

The examination of the data in table 4.39 reported that the foliar application of calcium and magnesium in different doses along with the recommended dose of FYM and 100 % NPK fertilizers significantly improved net returns and B:C ratio of the tomato crop during 2018. The significant improvement in the net returns and B:C ratio was recorded in the treatment with foliar feeding of calcium and magnesium @ 0.6 % and 0.2 % with application of FYM and 100 % NPK fertilizers in T_{13} (Rs. 4,22,820 ha⁻¹ and 3.56) as compared to the control T_1 (Rs. 54785/- and 1.37) where only FYM was incorporated in the soil. The percent increase of 671.78 % and 159.85 % were recorded in net returns and B:C ratio in treatment T_{13} as compared to the control T_1 . The increase in the level of magnesium to 0.4 % in T_{14} the non-significant decrease in the net returns (Rs. 4,13,455/-) and the B:C ratio (3.50) were recorded which is statistically at par with treatment T_{13} but significantly superior to the control with the percent increase of 654.69% and 155.47 % in the net returns and the B:C ratio.

Likewise, the treatments T_2 and T_3 also recorded the significant improvement in the net returns and B:C ratio as compared to the control. The incorporation of the NPK fertilizers in the treatment T_2 recorded the significant increase in net returns and B:C ratio of Rs. 1,93,680/- and 2.26 with percent increase of 253.53 % and 64.96 % over the control. The incorporation of FYM and NPK fertilizers in the treatment T_3 indicated improvement in net return and B:C ratio of Rs. 2,44,580/- and 2.50 over the control treatment T_1 with the percent increase of 346.44 % and 82.48 % (Table 4.39).

Foliar spray of calcium separately @ 0.6 % along with FYM and 100 % NPK in the treatment T_5 significantly enhanced net returns and B:C ratio viz. Rs. 3,84,165/- and 3.33. The percent increase of 601.22 % and 143.07 % were recorded in the net returns and the B:C ratio in T_5 as compared to the control T_1 .

Similarly, further study of the data also revealed that due to the application of magnesium individually @ 0.4 % along with FYM and 100 % NPK fertilizers the net returns (Rs. 2,79,285/-) and B:C ratio (2.70) improved significantly over the control T_1 with the percent increase of 409.78 % and 97.08 % in the net returns and the B:C ratio in T_8 in comparison to the control T_1 .

The cultivation cost was recorded in the range of Rs. 1,46,850/- in the control T_1 and Rs. 1,65,215/- in the treatment T_{14} with the difference of Rs. 18,375/- during 2018, due to the incorporation of the NPK fertilizers in the soil and Ca and Mg in form of the foliar spray, respectively.

Table 4.39 Effect of foliar application of Ca and Mg on Net returns and B: C ratio during 2018

Treatments		Yield (q/ha)	Gross Return (Rs.)	Cost of cultivation (Rs.)	Net Return (Rs.)	B: C Ratio
T1	FYM (Control)	134.42	201625	146840	54785	1.37
T2	NPK @ 150:120:60	231.98	347970	154290	193680	2.26
T3	FYM + NPK @ 150:120:60 (RD)	271.52	407280	162700	244580	2.50
T4	RD + Ca @ 0.3% Foliar application (FA)	326.33	489495	162985	326510	3.00
T5	RD + Ca @ 0.6 % (FA)	365.82	548730	164565	384165	3.33
T6	RD + Mg @ 0.1 % (FA)	283.49	425235	164975	260260	2.58
T7	RD + Mg @ 0.2 % (FA)	287.22	430825	164580	266245	2.62
T8	RD + Mg @ 0.4 % (FA)	295.95	443930	164645	279285	2.70
T9	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	329.41	494120	164885	329235	3.00
T10	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	339.16	508735	164850	343885	3.09
T11	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	341.50	512255	164890	347365	3.11
T12	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	381.51	572260	164910	407350	3.47
T13	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	391.82	587730	164910	422820	3.56
T14	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	385.78	578670	165215	413455	3.50
	CD (5 %)	-	-	-	16651	0.10

4.6.3 Mean net returns and B: C ratio in tomato crop

The mean of net returns and B:C ratio in tomato crop for 2017 and 2018 are presented in table 4.40. The data indicated that foliar application of calcium and magnesium in different doses along with the recommended dose of FYM and 100 % NPK fertilizers improved net returns and B:C ratio of the tomato crop during the years of study significantly. The maximum net returns and B:C ratio (Rs. 4,06,065 ha⁻¹ and 3.46) were obtained in the treatment T₁₃ with foliar feeding of calcium and magnesium @ 0.6 and 0.2 % with recommended dose of FYM and 100 % NPK fertilizers as compared to the control T₁ (Rs. 37750 ha⁻¹ and 1.26). The percent increase of 975.67 % and 174.60 % were recorded in the net returns and B:C ratio in T₁₃ over the control T₁. Magnesium level increased to 0.4 % decreased non-significantly the net returns (Rs. 3,96,533) and B:C ratio (3.40) in the treatment T₁₄ as compared to the treatment T₁₃ and recorded at par to it. But, likely, the significant enhancement in the treatment T₁₄ was recorded in net returns and in the B:C ratio with the percent increase of 950.42 % and 169.84 % as compared to the control.

Further, perusal of data (Table 4.40) in treatments T₂ and T₃ recorded the significant enhancement in net returns (Rs. 1,77,800 ha⁻¹ and Rs. 2,30,793 ha⁻¹) and BC ratio (2.15 and 2.42) over the control T₁. The incorporation of the NPK fertilizers in the treatment T₂ was recorded with the percent increase of 370.99 % in net returns and 70.63 % in B:C ratio over the treatment T₁ and 511.37

% in net returns and 92.06 % in the B:C ratio in the treatment T₃ where the FYM and 100 % NPK fertilizers were applied over the control T₁.

Table 4.40 Effect of foliar application of Ca and Mg on mean net returns and B:C ratio

Treatments		Yield (q/ha)	Gross Return (Rs.)	Cost of cultivation (Rs.)	Net Return (Rs.)	B: C Ratio
T1	FYM (Control)	122.68	184020	146270	37750	1.26
T2	NPK @ 150:120:60	221.19	331790	153990	177800	2.15
T3	FYM + NPK @ 150:120:60 (RD)	262.00	392993	162200	230793	2.42
T4	RD + Ca @ 0.3% Foliar application (FA)	315.34	473015	162785	310230	2.91
T5	RD + Ca @ 0.6 % (FA)	355.00	532500	163865	368635	3.25
T6	RD + Mg @ 0.1 % (FA)	272.40	408593	164075	244518	2.49
T7	RD + Mg @ 0.2 % (FA)	277.88	416815	164080	252735	2.54
T8	RD + Mg @ 0.4 % (FA)	284.75	427125	164245	262880	2.60
T9	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	318.05	477078	164470	312608	2.90
T10	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	327.65	491478	164538	326940	2.99
T11	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	330.11	495159	164740	330419	3.01
T12	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	371.18	556765	164950	391815	3.38
T13	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	380.73	571095	165030	406065	3.46
T14	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	374.54	561815	165283	396533	3.40
CD (5 %)		-	-	-	14809	0.09

Similarly, foliar application of calcium alone @ 0.6 % with recommended dose of FYM and 100 % NPK fertilizers in the treatment T₅ the significant increase in the net returns and B:C ratio (Rs. 368635 ha⁻¹ and 3.25) with the percent increase of 876.52 % in net returns and 157.94 % in B:C ratio over the control treatment T₁.

Further study of the data also revealed that, the foliar feeding of the magnesium individually @ 0.4 % with recommended FYM and 100 % NPK fertilizers in T₈ also remained beneficial and gave the net returns and B:C ratio to the tune of Rs. 2,62,880 ha⁻¹ and 2.60 with the percent increase of 596.37 and 106.35 % over the control T₁.

The mean cost of cultivation of both the years 2017 and 2018 recorded in the range of Rs. 146270/- and Rs. 1655030/- and the difference of Rs. 19013/- was recorded both in the treatments T₁ and T₁₄, respectively.

In the present study, the highest net returns and B:C ratio with foliar application of calcium and magnesium improved growth characters and yield attributes which might resulted in higher yield and maximum net returns and B:C ratio. The net returns and B:C ratio were recorded highest and with the foliar spray of calcium and magnesium. The similar results have also been reported earlier by

Reddy *et al* (1998), Biradar *et al* (2014), Kumar *et al* (2017), Khurshid *et al* (2019), Lakshmi *et al* (2018), Tripathy *et al* (2018) and Chaity and Sarkar (2009)

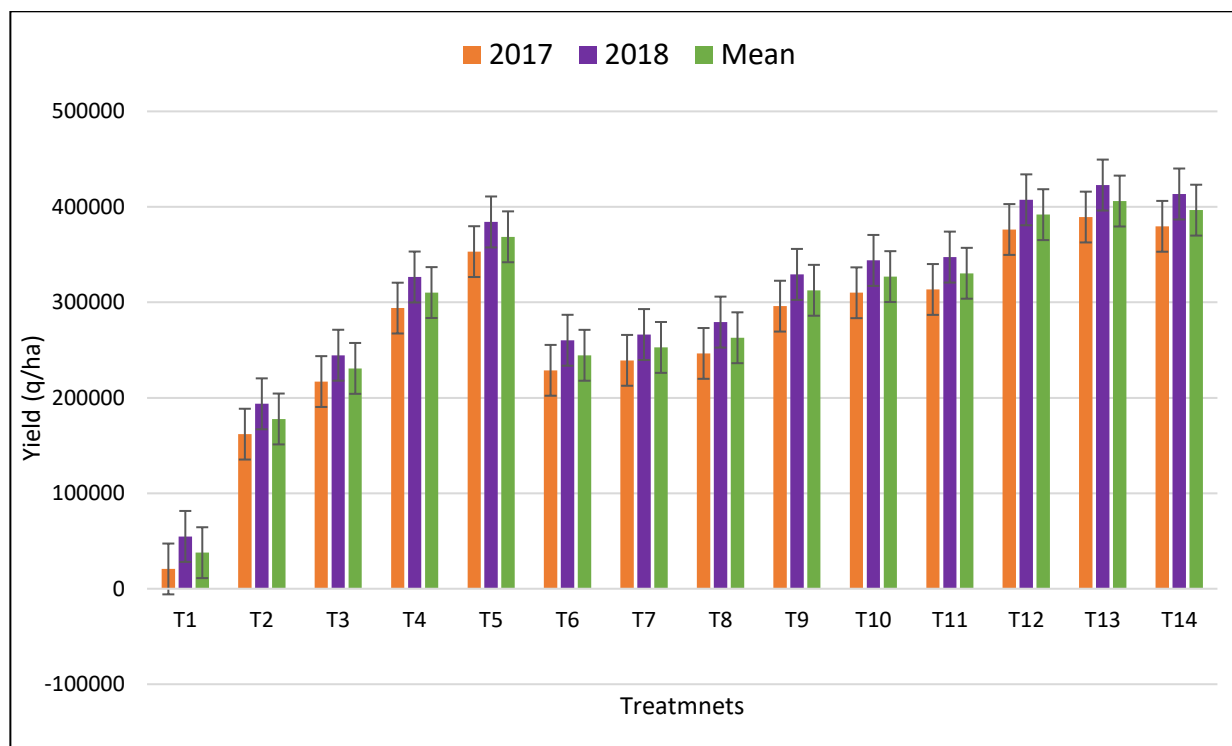


Fig. 4.2 Effect of foliar application of Ca and Mg on net returns of 2017, 2018 and Mean of both years

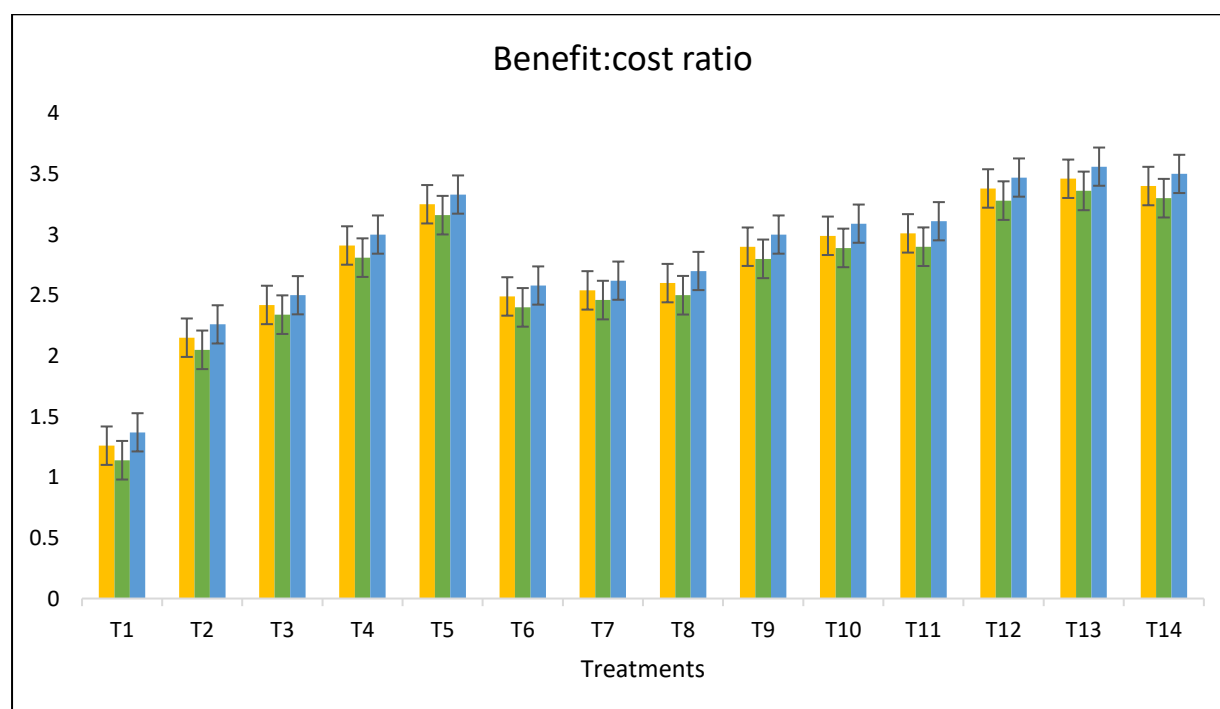


Fig. 4.3 Effect of foliar application of Ca and Mg on B:C ratio of 2017, 2018 and Mean of both years

4.7 Correlation studies

4.7.1 Correlation studies among studied parameters of tomato crop

The data pertaining to inter-relations among various parameters of tomato crop have been presented in Table 41 to 43. The different growth parameters (plant height and number of branches) observed a significant and positive correlation with the marketable yield during 2017, 2018 and in the mean data. Similarly, the yield parameters (number of flowers per cluster, number of fruits per plant, fruit weight and fruit diameter) also observed a significant and positive correlation with the marketable yield of the tomato. The quality of the tomato crop in terms of total soluble solids (TSS), pericarp thickness, vitamin C and titratable acidity also presented strong and positive correlations with the yield during both the years (2017 and 2018) and for the mean data (Table 41 and 43).

Further, perusal of the data revealed that the increase in yield have the strong and positive correlation between uptake of different nutrients. The increase in the marketable yield due to the foliar application of calcium and magnesium along with recommended dose of FYM and 100 % NPK fertilizers significantly improved the uptake of the nutrients viz. nitrogen, phosphorous, potassium, calcium and magnesium in tomato plants which shows the strong and positive correlation during 2017, 2018 and in the mean data.

Unlikely, the further examination of data (Table 41 to 43) indicated the negative correlation among the growth parameters (plant height and number of branches) and non-marketable yield of tomato crop during 2017, 2018 and in the mean data. The negative correlation was also recorded between the non-marketable yield and the yield parameters (number of flowers per cluster, number of fruits per plant, fruit weight and fruit diameter) in the tomato crop. Similarly, the quality parameters (TSS, titratable acidity and vitamin C) of the produce obtained also observed a negative correlation with the non marketable yield of the tomato fruit.

The interpretation of the data pertaining to the uptake of the different nutrients also observed the negative correlation between the uptake of the nutrients (nitrogen, phosphorus, potassium, calcium and magnesium) with the produce in the non-marketable fruit yield during 2017, 2018 and in the mean data of both the years.

Above significant relations among different parameters can be explained on the basis that yield is a function of various growth attributes (plant height and number of branches) and yield attributes (number of flowers per cluster, number of fruits per plant, fruit weight and fruit diameter) availability of nutrients, which might have contributed to effect fruit yield to a significant level. The present findings are in consonance with that of Ramzam *et al* (2014), Esposito *et al* (2009), Achakzai and Bangulzai (2006), Afzal *et al* (2015) and Kumar (2013).

Table 41 Correlation between different parameters of tomato during 2017

	Plant height (cm)	Branches (No.)	Flowers Per cluster (No.)	Fruits per cluster (No.)	Fruit diameter (cm)	Fruit weight (g)	Fruits per plant (No.)	Marketable yield (q ha ⁻¹)	Non Marketable (q ha ⁻¹)	Pericarp Thickness (mm)	Titrateable acidity (mm)	Vitamin C (mg 100g ⁻¹)	TSS (° brix)	Fruit N uptake (kg ha ⁻¹)	Fruit P uptake (kg ha ⁻¹)	Fruit K uptake (kg ha ⁻¹)	Fruit Ca uptake (kg ha ⁻¹)
Branches (No.)	0.962*																
Flowers per cluster (No.)	0.924*	0.955*															
Fruits per cluster (No.)	0.934*	0.948*	0.977*														
Fruit diameter (cm)	0.952*	0.979*	0.960*	0.965*													
Fruit weight (g)	0.960*	0.964*	0.915*	0.943*	0.979*												
Fruits per plant (No.)	0.961*	0.970*	0.949*	0.953*	0.989*	0.982*											
Marketable yield (q ha ⁻¹)	0.923*	0.956*	0.911*	0.905*	0.968*	0.976*	0.978*										
Non- Marketable (q ha ⁻¹)	-0.860	-0.905	-0.946	-0.925	-0.929	-0.903	-0.916	-0.926									
Pericarp Thickness	0.925*	0.957*	0.924*	0.922*	0.964*	0.966*	0.980*	0.980*	-0.912								
Titrateable acidity (%)	0.942	0.958*	0.905*	0.924*	0.977*	0.975*	0.979*	0.957*	-0.865	0.974*							
Vitamin C (mg 100g ⁻¹)	0.885	0.857*	0.777*	0.823*	0.896*	0.911*	0.906*	0.861*	-0.697	0.869*	0.946*						
TSS (o brix)	0.925	0.927*	0.860*	0.897*	0.950*	0.962*	0.962*	0.932*	-0.792	0.943*	0.983*	0.976*					
Fruit N uptake (kg ha ⁻¹)	0.972	0.958*	0.887*	0.919*	0.962*	0.985*	0.970*	0.952*	-0.849	0.938*	0.960*	0.927*	0.963*				
Fruit P uptake (kg ha ⁻¹)	0.934	0.923*	0.855*	0.900*	0.947*	0.956*	0.950*	0.906*	-0.783	0.913*	0.974*	0.984*	0.987*	0.965*			
Fruit K uptake (kg ha ⁻¹)	0.963	0.941*	0.858*	0.892*	0.948*	0.966*	0.959*	0.932*	-0.809	0.924*	0.959*	0.944*	0.967*	0.992*	0.968*		
Fruit Ca uptake (kg ha ⁻¹)	0.926	0.902*	0.817*	0.867*	0.922*	0.956*	0.937*	0.911*	-0.753	0.913*	0.960*	0.973*	0.987*	0.968*	0.977*	0.976*	
Mg Uptake (kg ha ⁻¹)	0.966	0.962	0.910*	0.931*	0.978*	0.983*	0.985*	0.958*	-0.871	0.952*	0.979*	0.945*	0.973*	0.988*	0.978*	0.984*	0.964*

Significant at 5% level of significance

Table 42 Correlation between different parameters of tomato during 2018

	Plant height (cm)	Branches (No.)	Flowers Per cluster (No.)	Fruits per cluster (No.)	Fruit diameter (cm)	Fruit weight (g)	Fruits per plant (No.)	Marketable yield (q ha ⁻¹)	Non Marketable (q ha ⁻¹)	Pericarp Thickness (mm)	Titrateable acidity (mm)	Vitamin C (mg 100g ⁻¹)	TSS (° brix)	Fruit N uptake (kg ha ⁻¹)	Fruit P uptake (kg ha ⁻¹)	Fruit K uptake (kg ha ⁻¹)	Fruit Ca uptake (kg ha ⁻¹)
Branches (No.)	0.986*																
Flowers per cluster (No.)	0.923*	0.938*															
Fruits per cluster (No.)	0.943*	0.950*	0.971*														
Fruit diameter (cm)	0.972*	0.970*	0.948*	0.936*													
Fruit weight (g)	0.952*	0.932*	0.893*	0.891*	0.963*												
Fruits per plant (No.)	0.986*	0.980*	0.931*	0.928*	0.985*	0.974											
Marketable yield (q ha ⁻¹)	0.955*	0.965*	0.928*	0.911*	0.975*	0.943	0.978*										
Non- Marketable (q ha ⁻¹)	-0.894	-0.921	-0.770	-0.808	-0.857	-0.808	-0.888	-0.890									
Pericarp Thickness	0.960*	0.966*	0.943*	0.924*	0.985*	0.959	0.971*	0.961*	-0.846								
Titrateable acidity (%)	0.940*	0.915*	0.930*	0.919*	0.960*	0.977	0.963*	0.941*	-0.765	0.945*							
Vitamin C (mg 100g-1)	0.819*	0.788*	0.759*	0.752*	0.854*	0.912	0.863*	0.786*	-0.667	0.863*	0.883*						
TSS (o brix)	0.967*	0.959*	0.897	0.918*	0.964*	0.969	0.975*	0.920*	-0.855	0.956*	0.942*	0.916*					
Fruit N uptake (kg ha ⁻¹)	0.986*	0.978*	0.924*	0.922*	0.974*	0.969	0.990*	0.965*	-0.896	0.974*	0.949*	0.857*	0.967*				
Fruit P uptake (kg ha ⁻¹)	0.978*	0.964*	0.904*	0.933*	0.955*	0.972	0.969*	0.922*	-0.834	0.957*	0.940*	0.866*	0.981*	0.970*			
Fruit K uptake (kg ha-1)	0.976*	0.955*	0.896*	0.912*	0.949*	0.976	0.976*	0.921*	-0.839	0.949*	0.945*	0.893*	0.980*	0.981*	0.989*		
Fruit Ca uptake (kg ha ⁻¹)	0.968*	0.955*	0.900*	0.922*	0.947*	0.978	0.967*	0.917*	-0.846	0.958*	0.948*	0.893*	0.981*	0.979*	0.988*	0.990*	
Mg Uptake (kg ha ⁻¹)	0.978*	0.961*	0.937*	0.940*	0.979*	0.981	0.984*	0.962*	-0.840	0.970*	0.979*	0.862*	0.965*	0.985*	0.974*	0.973*	0.974*

*Significant at 5% level of significance

Table 43 Correlation between different parameters of tomato (based on mean data)

	Plant height (cm)	Branches (No.)	Flowers Per cluster (No.)	Fruits per cluster (No.)	Fruit diameter (cm)	Fruit weight (g)	Fruits per plant (No.)	Marketable yield (q ha ⁻¹)	Non Marketable (q ha ⁻¹)	Pericarp Thickness (mm)	Titrateable acidity (mm)	Vitamin C (mg 100g ⁻¹)	TSS (° brix)	Fruit N uptake (kg ha ⁻¹)	Fruit P uptake (kg ha ⁻¹)	Fruit K uptake (kg ha ⁻¹)	Fruit Ca uptake (kg ha ⁻¹)
Branches (No.)	0.985*																
Flowers per cluster (No.)	0.938*	0.962*															
Fruits per cluster (No.)	0.944*	0.954*	0.989*														
Fruit diameter (cm)	0.966*	0.980*	0.966*	0.954*													
Fruit weight (g)	0.959*	0.959*	0.919*	0.924*	0.978*												
Fruits per plant (No.)	0.979*	0.982*	0.951*	0.944*	0.990*	0.983*											
Marketable yield (q ha ⁻¹)	0.942*	0.965*	0.933*	0.910*	0.974*	0.965*	0.980*										
Non- Marketable (q ha ⁻¹)	-0.944	-0.962	-0.938	-0.916	-0.948	-0.907	-0.958	-0.968									
Pericarp Thickness	0.951*	0.975*	0.949*	0.929*	0.986*	0.968*	0.982*	0.976*	-0.936								
Titrateable acidity (%)	0.951*	0.959*	0.939*	0.934*	0.989*	0.991*	0.983*	0.961*	-0.904	0.978*							
Vitamin C (mg 100g ⁻¹)	0.859*	0.832*	0.779*	0.796*	0.879*	0.921*	0.891*	0.828*	-0.748	0.874*	0.923*						
TSS (o brix)	0.958*	0.952*	0.905*	0.915*	0.966*	0.980*	0.976*	0.930*	-0.885	0.963*	0.979*	0.954*					
Fruit N uptake (kg ha ⁻¹)	0.979*	0.974*	0.911*	0.917*	0.968*	0.985*	0.982*	0.959*	-0.926	0.960*	0.970*	0.903*	0.974*				
Fruit P uptake (kg ha ⁻¹)	0.968	0.956*	0.908*	0.925*	0.964*	0.983*	0.970*	0.921*	-0.875	0.955*	0.978*	0.945*	0.994*	0.980*			
Fruit K uptake (kg ha ⁻¹)	0.978*	0.958*	0.891*	0.906*	0.954*	0.980*	0.973*	0.928*	-0.891	0.942*	0.966*	0.922*	0.980*	0.991*	0.989*		
Fruit Ca uptake (kg ha ⁻¹)	0.955*	0.944*	0.879*	0.900*	0.945*	0.981*	0.960*	0.917*	-0.861	0.943*	0.967*	0.943*	0.990*	0.980*	0.994*	0.988*	
Mg Uptake (kg ha ⁻¹)	0.975*	0.975*	0.937*	0.941*	0.988*	0.993*	0.991*	0.964*	-0.929	0.971*	0.990*	0.913*	0.982*	0.991*	0.985*	0.985*	0.977*

*Significant at 5% level of significance

SUMMARY AND CONCLUSIONS

Tomato crop is grown in fields as well as greenhouse conditions. In Himachal Pradesh, it is popular as one of the most remunerative crops among farmers. It is grown in every part of the state from low hill zone to high hill zone, however, the mid hill zone is considered as a major commercial tomato growing area of the state. However, the average productivity of tomato in Himachal Pradesh in general is low as compared to the national average.

Nutrition of plants is one of the significant factors responsible for the proper development of the plants. Mining of mineral elements and imbalanced use of plant nutrients is responsible for low productivity of the tomato crop. Enhancing the usage of primary nutrients and ignoring secondary nutrients makes soil deficient in them. Low supply of calcium leads to deterioration of the quality by enhancing fruit cracking in tomato crop, BER, cell walls and membranes breakdown, making crop susceptible to various diseases and post-harvest problems in fresh produce of tomato. However, the magnesium deficiency affects earliness, uniform maturity and the fruit quality.

Fixation and immobilization of nutrients in soil loses their efficiency. Method used for the application of the nutrients play a significant role in giving nutrients to the plants. Under the situations where soil nutrient availability is limited or deficient, method of foliar spray is commonly used to provide nutrients to the crops. Application of calcium and magnesium as a foliar spray is very efficient technique as compared to incorporation in soil and which also enhances the efficacy of fertilizers. To study the impact of Ca and Mg individually and their collective impact on plant growth, yield and its attributes, quality and soil properties for enhancing the mineral nutrition of tomato was undertaken. Though, on the requirement major nutrients (N, P and K) in tomato lot of studies have been done but data available on secondary nutrients (Ca and Mg) and effects of their interactions on tomato under field conditions is scarce. Thus, the present investigation 'Effect of Ca and Mg in the yield and quality of tomato (*Lycopersicon esculentum* L.) in the soils of Balh valley of Mandi district, Himachal Pradesh' was undertaken to find out the consequences of foliar feeding of Ca and Mg on tomato hybrid (US-920) with following objectives:

1. To study the different physical and chemical properties of the tomato growing soils of Balh valley
2. To study the effect and uptake of different levels of calcium and magnesium on quality and yield of tomato
3. To work out the best treatment combination for quality, yield and C:B ratio

The experiments were carried out from the month of May to September for two consecutive seasons during 2017 and 2018 at Krishi Vigyan Kendra, Sundernagar, Distt. Mandi (HP). The experimental site had the initial soil status of the pH 6.86, organic carbon 8.2 g kg⁻¹ and available status of N, P and K was 211.7 kg ha⁻¹, 15.4 kg ha⁻¹ and 174.2 kg ha⁻¹, respectively. The experiments

consisted of fourteen different treatments in which the recommended dose of FYM and 100 % NPK fertilizers (150:100:50) incorporated in the soil along with calcium applied @ 0.3 and 0.6 % and magnesium @ 0.1, 0.2 and 0.4 % as a foliar spray. The control treatment with incorporation of FYM alone and NPK fertilizers application in soil was also carried out and compared with other treatments. The treatments were replicated thrice in a randomized block design. The data recorded for various soil and plant parameters were statistically analyzed. The results presented and discussed in Chapter IV are summarized:

5.1 Effect of different treatments on growth and yield attributes

5.1.1 Height of the tomato plants

The results indicated that foliar spray of Ca and Mg fertilizers significantly influenced height of tomato plants. Foliar application of calcium and magnesium @ 0.6 and 0.2 % along with the of FYM and 100 % NPK recorded the maximum improvement with an increase of 22.32 % in 2017, 19.06 % in 2018 and 20.65 % in the mean data during both the years and produced the taller plants comparison to all other treatments applied in combination or separately in comparison to the control.

5.1.2 Number of branches in tomato plants

Foliar application of calcium and magnesium @ 0.6 and 0.2 % with the incorporation of FYM and 100 % NPK fertilizers recorded the improvement in the branches to the tune of 24.11 % in 2017, 24.36 % in 2018 and 24.21 % in the mean data. The foliar spray of Ca and Mg in combination or separately along with FYM and 100 % NPK fertilizers showed improvement in number of branches in comparison to the control.

5.1.3 Number of flower clusters per plant in tomato

The recorded data revealed that application of FYM and 100 % NPK fertilizers along with the calcium and magnesium @ 0.6 and 0.2 % recorded the percent increase of 70.86 % in 2017, 62.05 % in 2018 and 68.84 % in the mean data over the control. The control treatment exhibited the minimum number of flowers in comparison to all other treatments.

5.1.4 Number of fruits per cluster in tomato

More the quantity of flowers clusters produced more will be the number of fruits. The maximum flowers were produced with the application of FYM and 100 % NPK fertilizers along with foliar application of calcium and magnesium @ 0.6 and 0.2 % likewise more fruits were produced when calcium and magnesium applied @ 0.6 % and 0.2 % with the percent increase of 70.86 % in 2017, 62.05 % in 2018 and 68.84 % in the mean data of both the years.

5.1.5 Diameter of the tomato fruit

The application of FYM and 100 % NPK fertilizers along with foliar application of calcium and magnesium @ 0.6 and 0.2 % marked substantial effect on diameter of tomato fruit. The percent increase recorded was 16.88 % in 2017, 21.16 % in 2018 and 19.04 % in the mean data over the

control. The diameter of tomato fruit recorded significantly higher in all treatment combinations during the years of study but the minimum was recorded in control.

5.1.6 Weight of tomato fruits

It was observed that FYM and 100 % NPK fertilizers along with foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the increase of 26.81 % in 2017, 26.99 % in 2018 and 26.90 % in the weight of the tomato fruits over the control. The foliar spray in different treatment in combinations or separately also recorded more weight during the period of study when compared to the control.

5.1.7 Number of fruits per plant in tomato

The calcium and magnesium had a marked and significant impact on number of fruits per plant and maximum increase was recorded in fruit count with incorporation of FYM and 100 % NPK fertilizers along with foliar application of calcium and magnesium @ 0.6 and 0.2 % during both years recorded the increase of 78.73 % in 2017, 74.67 % in 2018 and 76.55 % in the mean data in comparison to the control. The minimum number of fruits were observed in the control where only FYM was incorporated and all other treatments were significantly superior to the control.

5.2 Effect of different treatments on yield

5.2.1 Marketable yield of the tomato crop

The outcomes of the experiment indicated that incorporation of FYM and 100% NPK fertilizers along with foliar application of calcium and magnesium @ 0.6 % and 0.2 % recorded significant increase in marketable yield in over the control with the percent increase to the tune of 233.19 % in 2017, 191.49 % in 2018 and 210.34 % for mean marketable yield data in comparison to control. The Ca @ 0.3 and 0.6 % and Mg @ 0.1, 0.2 and 0.4 % in combinations and alone as foliar feeding also improved the marketable yield of tomato.

5.2.2 Non marketable yield of the tomato crop

The data recorded indicated that the calcium and magnesium foliar spray @ 0.6 % and 0.2 % and incorporation of recommended dose of FYM and 100 % NPK fertilizers, significantly decreased the non-marketable yield of tomato in treatment in T₁₃ (42.59 q ha⁻¹ in 2017, 61.27 q ha⁻¹ in 2018 and 51.92 q ha⁻¹ the mean data) over the control treatment T₁ (79.97 q ha⁻¹ in 2017, 92.60 q ha⁻¹ in 2018 and 86.28 q ha⁻¹ in the mean data) where only FYM was applied. Likewise, Ca @ 0.3 and 0.6 % and Mg @ 0.1, 0.2 and 0.4 % applied in combinations as a foliar spray also reduced the non-marketable tomato in contrary to the control.

5.2.3 Dry matter yield of the tomato crop

The results indicated that foliar feeding of calcium and magnesium @ 0.6 % and 0.2 % recorded maximum increase in dry matter yield with percent increase of 20.74 % in 2017, 18.35 % in 2018 and 19.46 % for mean data over the control. Similarly, other treatment combinations of Ca (0.3 % and 0.6 %) and Mg (0.1 %, 0.2 % and 0.4) also improved the dry matter yield including the

treatments with NPK fertilizers and FYM applied along with NPK fertilizer. Minimum dry matter yield was observed in the control treatment.

5.3 Effect of different treatments on quality

5.3.1 Pericarp thickness of tomato fruit

The maximum improvement in pericarp thickness was recorded when the calcium and magnesium were applied @ 0.6 and 0.2 % along with FYM and 100 % NPK fertilizers. The percent increase of 9.66 % in 2017, 10.28 % in 2018 and 9.98 % in the mean data was recorded over the control. The significant increase was also recorded when Ca and Mg applied separately in comparison to the control. Incorporation of NPK fertilizers and FYM along with NPK fertilizers also improved the pericarp thickness of the tomato fruits.

5.3.2 Total soluble solids (TSS) of fresh tomato fruit

Calcium and magnesium @ 0.6 and 0.2 % foliar feeding with FYM and 100 % NPK fertilizers enhanced the TSS in the tomato fruits to the tune of 10.49 % in 2017, 10.31 % in 2018 and 10.40 % in the mean data in comparison to the control. Increasing the level of magnesium to 0.4 % in the foliar spray the non-significant decrease was recorded. All the treatment combinations of Ca (0.3 % and 0.6 %) and Mg (0.1 %, 0.2 % and 0.4) including that of NPK fertilizers and FYM along with NPK fertilizers improved the TSS of tomato fruit.

5.3.3 Vitamin C in tomato fruits

The application of calcium and magnesium @ 0.6 and 0.2 % as a foliar spray with FYM and NPK fertilizers enhanced the vitamin C in the tomato fruits over the control. The percent increase of 16.11 % in 2017, 18.65 % in 2018 and 17.38 % in the mean data in vitamin C was recorded over the control during the years of study. The other treatment combinations also improved the vitamin C content in the tomato fruits.

5.3.4 Titratable acidity in tomato fruits

It was recorded that calcium and magnesium @ 0.6 and 0.2 % applied as a foliar spray with FYM and 100 % NPK fertilizers enhanced the titratable acidity in the tomato fruit with percent increase of 56.25 % in 2017, 39.66 % in 2018 and 47.17 % in the mean data over the control. The non-significant decrease in the titratable acidity was recorded with increase in magnesium level to 0.4 %. The different Ca (0.3 and 0.6 %) and Mg (0.1, 0.2 and 0.4 %) level combinations also improved the titratable acidity of tomato fruits over the control where only FYM was applied.

5.4 Effect of different treatments on nutrient content and uptake in tomato

5.4.1 Nitrogen content and uptake in the leaves of tomato

Foliar application of calcium and magnesium along with the FYM and 100 % NPK significantly improved N content and uptake in tomato leaves. The foliar application of calcium and magnesium @ 0.6 and 0.2 % recorded the highest N content with percent increase of 28.70 % in 2017, 29.96 % in 2018 and 29.33 % in the mean data and percent improvement in N uptake to the tune of 55.31 % in 2017, 53.83 % in 2018 and 54.48 % in the mean data over the control. Similarly, the other treatment combinations of Ca (0.3 % and 0.6 %) and Mg (0.1 %, 0.2 % and 0.4) also improved the N content and uptake in the tomato leaves.

5.4.2 Nitrogen content and uptake in fruits of tomato

In tomato fruit FYM and 100 % NPK along with foliar feeding of calcium and magnesium enhanced the N content and its uptake. The foliar spray of Ca and Mg @ 0.6 and 0.2 % recorded the significant effect on N content and recorded the increase of 35.51 % in 2017, 37.17 % in 2018 and 36.36 % in the mean data over the control. Similarly, the maximum nitrogen uptake was recorded in the treatment T₁₃ increased to the tune of 63.55 % in 2017, 62.36 % in 2018 and 62.88 % in the mean data over the control. The calcium and magnesium at different levels (0.3 % and 0.6 %) and (0.1 %, 0.2 % and 0.4) applied as a foliar spray including treatments T₂ (NPK fertilizers) and T₃ (FYM and NPK fertilizers) also improved the N content and uptake in the tomato fruits.

5.4.3 Phosphorous content and uptake in leaves of tomato

Foliar feeding of calcium and magnesium @ 0.6 and 0.2 % recorded the highest P content with an increase of 200.0 % in 2017, 175.0 % in 2018 and 186.36 % in the mean data over the control among all the treatments. Likewise, the P uptake also increased to the tune of 261.47 % in 2017, 226.61 % in 2018 and 241.24 % in the mean data in with the application of calcium and magnesium @ 0.6 and 0.2 % over the control. The other treatment combinations with Ca (0.3 % and 0.6 %) and Mg (0.1 %, 0.2 % and 0.4) also improved the N content and uptake in the leaves of tomato. The treatments with NPK fertilizers and FYM and NPK fertilizers also recorded the significant improvement in the P content and its uptake in the leaves of tomato.

5.4.4 Phosphorous content and uptake in fruits of tomato

The study of the data related to the foliar feeding of Ca and Mg application @ 0.6 and 0.2 % observed the highest increase of P content in the fruits of tomato. The percent increase to the tune of 277.78 % in 2017, 233.33 % in 2018 and 236.36 % in the mean data was recorded over the control treatment. Similarly, the P uptake also recorded the significant enhancement and percent increase of 421.03 % in 2017, 247.08 % in 2018, and 315.43 % in the mean data over the control. Other treatment combinations with Ca (0.3 % and 0.6 %) and Mg (0.1 %, 0.2 % and 0.4) also improved the P content and uptake in the tomato fruits as over the control. The treatments with recommended doses of NPK fertilizers and FYM and NPK fertilizers also found to be superior in the P content and its uptake.

5.4.5 Potassium content and uptake in leaves of tomato

The examination of the data pertaining to foliar feeding of calcium and magnesium @ 0.6 and 0.2 % documented the highest K content with percent increase of 23.73 % in 2017, 22.12 % in 2018 and 22.91 % in the mean data of both years over the control where FYM is applied. The foliar application of calcium and magnesium @ 0.6 and 0.2 % improved K uptake which recorded the percent increase of 49.34 % in 2017, 44.49 % in 2018 and 46.68 % in the mean data as compared to the control. The treatment combinations of Ca applied @ 0.3 % and 0.6 % and Mg @ 0.1 %, 0.2 % and 0.4 % also improved the K content and its uptake in the tomato leaves over the control. The incorporation of FYM and NPK fertilizers also improved uptake of K content in the leaves of tomato.

5.4.6 Potassium content and uptake in fruits of tomato

The foliar application of Ca and Mg @ 0.6 and 0.2 % recorded the highest K content in tomato fruits with percent increase of 17.41 % in 2017, 14.54 % in 2018 and 15.94 % in the mean data in comparison to the control. Similarly, the improvement in the K uptake was recorded to the tune of 41.53 % in 2017, 35.81 % in 2018 and 38.49 % in the mean data over the control. Other treatment combinations with Ca (0.3 % and 0.6 %) and Mg (0.1 %, 0.2 % and 0.4) along with FYM and NPK fertilizers also improved the K content and uptake in the tomato fruits. The control treatment showed the lowest K content and uptake.

5.4.7 Calcium content and uptake in leaves of tomato

The foliar application of calcium and magnesium @ 0.6 and 0.2 % along with the FYM and 100 % NPK recorded the highest Ca content with percent increase of 70.89 % in 2017, 50.59 % in 2018 and 60.98 % in the mean data over the control. Likewise, the in comparison to the control, the Ca uptake increased to the tune of 93.79 % in 2017, 101.67 % in 2018 and 97.95 % in the mean data in the leaves of tomato. Different combination levels of Ca and Mg @ 0.3 % and 0.6 % and 0.1 %, 0.2 % and 0.4 % and FYM and NPK fertilizers also improved the Ca content and its uptake in the tomato leaves.

5.4.8 Calcium content and uptake in fruits of tomato

The outcomes of the study indicated that incorporation of FYM and 100 % NPK with the foliar feeding of Ca and Mg @ 0.6 and 0.2 % significantly enhanced the Ca content in the fruits of tomato. The percent increase of 72.09 % in 2017, 65.31 % in 2018 and 71.74 % in the mean data was recorded in comparison to the control. The Ca uptake also recorded the significant enhancement to the tune of 107.47 % in 2017, 95.46 % in 2018 and 100.67 % in the mean data over the control. The foliar spray of different combinations of calcium @ 0.3 % and 0.6 % and magnesium @ 0.1 %, 0.2 % and 0.4 along with FYM and NPK fertilizers also improved the Ca content and its uptake in the fruits of tomato.

5.4.9 Magnesium content and uptake in leaves of tomato

Foliar application of Ca and Mg @ 0.6 % and 0.2 % along with the incorporation of FYM and 100 % NPK had significant effect on Mg content and its uptake in tomato leaves. As compared to the control, the Mg content recorded the increase of 74.42 % in 2017, 58.82 % in 2018 and 65.96 % in the mean data. Similarly, the Mg uptake improved to the tune of 110.31 % in 2017, 87.93 % in 2018 and 97.35 % in the mean data in the leaves of tomato over the control. The other treatment combinations of Ca and Mg @ 0.3 % and 0.6 % and 0.1 %, 0.2 % and 0.4 % and FYM and NPK fertilizers also improved the Mg content and its uptake in the tomato leaves.

5.4.10 Magnesium content and uptake in fruits of tomato

In tomato fruits incorporation FYM and 100 % NPK in soil along with foliar feeding of calcium and magnesium enhanced the Mg content and its uptake. The foliar spray of Ca and Mg @ 0.6 and 0.2 % recorded the maximum improvement in Mg content and its uptake over the control. The application of calcium (0.3 % and 0.6 %) and magnesium (0.1 %, 0.2 % and 0.4) in different combinations along with FYM and NPK fertilizers also improved the Mg content and its uptake in the tomato fruits.

5.5 Effect of different treatments on soil properties

5.5.1 Soil pH and organic carbon after harvest of the crop

The soil pH after crop harvest of the tomato crop in individual year and for the data averaged over two years, did not change due to the foliar feeding of nutrients and incorporation of FYM and NPK fertilizers. The values after the harvest of crop and for soil initial pH were statistically similar and were non-significant. The foliar spray of calcium and magnesium along with the recommended dose of FYM and 100 % NPK fertilizers ranged from 6.85 to 6.88 during 2017, 6.84 to 6.88 during 2018 and 6.82 to 6.96 to in the mean value of both the years.

The data pertaining to organic carbon, was not influenced due to foliar spray of calcium and magnesium and its contents were maintained at 0.81 to 0.86 % at different calcium and magnesium levels.

5.5.2 Soil available N, P and K after harvest of crop

The data pertaining to the availability of major nutrients in soil revealed that calcium and magnesium application as a foliar spray had no effect on the soil available nitrogen, phosphorus and potash. Calcium and magnesium applied as a foliar feeding in the treatment combinations did not affect the soil available nutrients but the treatment with addition of recommended FYM and 100 % NPK fertilizers incorporated in the soil significantly affected the N, P and K in all the treatments excluding the control where only FYM was incorporated.

5.5.3 Soil Exchangeable Ca and Mg after harvest

The foliar feeding of calcium and magnesium along with FYM and 100% NPK in the all treatments effect Ca content non-significantly in the soil and remained at par with one another.

Similarly, calcium and magnesium applied as a foliar spray did not show significant effect on buildup of exchangeable soil Mg in all the treatments during 2017, 2018 and in the mean data.

5.6 Effect of different treatments on economics

5.6.1 Net returns and B:C ratio in 2017, 2018 and in the mean data

Net returns and B:C ratio, were affected significantly due to foliar application of Ca and Mg along with FYM and NPK fertilizers. The net returns and B:C were highest when Ca and Mg applied @ 0.6 and 0.2 % with FYM and NPK fertilizers. The different levels of foliar application of Ca and Mg also had positive impact on net returns and B:C ratio in different years (2017 and 2018) of study and in the mean data. The minimum net returns were obtained in the control where only FYM was applied.

5.7 Correlation studies

5.7.1 Correlation studies among different parameters of crop in 2017, 2018 and the mean data

Growth parameters viz. plant height and number of branches, yield parameters viz. number of flowers per cluster, number of fruits per plant, fruit weight and fruit diameter and quality parameters viz. total soluble solids (TSS), pericarp thickness, vitamin C and titratable acidity presented strong and positive correlations with the yield during both the years (2017 and 2018) and for the mean data.

The growth in the marketable yield when calcium and magnesium applied as a foliar spray along with soil incorporation of FYM and 100 % NPK fertilizers significantly improved the uptake of the nutrients viz. nitrogen, phosphorous, potassium, calcium and magnesium in tomato plants which shows the strong and positive correlation during 2017, 2018 and in the mean data.

CONCLUSIONS

On the basis of the results of experiments, following conclusions can be drawn:

1. Soil and plant parameters of the tomato crop were significantly improved with the application of recommended dose of FYM and 100% NPK fertilizers along with the foliar spray of calcium and magnesium.
2. Foliar spray of calcium and magnesium had significant effect on growth, yield and yield parameters, nutrient content and uptake and economics of the tomato crop.
3. The net returns and B: C ratio was affected due to foliar spray of calcium and magnesium provided at different levels.
4. The soil properties remained unaffected due to foliar spray of calcium and magnesium applied at different concentrations.
5. Thus, on the basis of net returns and benefit: cost ratio (B:C ratio), application of recommended dose of FYM and 100% NPK fertilizers and foliar spray of calcium @ 0.6 % and magnesium @ 0.2 % is best for the tomato cultivation and can be promoted under mid-hill conditions of the Himachal Pradesh.

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APPENDICES

1. Month wise meteorological data of 2017

Month	Humidity (%)		Temperature (°C)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
April, 2017	80.80	23.06	28.16	13.04	81.5
May, 2017	88.20	23.09	34.12	15.98	20.25
June, 2017	93.87	33.90	33.08	18.91	60.50
July, 2017	98.67	60.64	31.18	22.12	377.50
August, 2017	99.58	61.06	31.31	21.94	124.25
September, 2017	98.67	60.64	31.10	18.20	34.50
October, 2017	100.00	27.00	29.70	12.70	11.75
November, 2017	100.00	23.00	27.80	6.30	7.25
December, 2017	98.00	41.00	19.40	3.10	48.20
January, 2017	96.00	35.00	19.30	2.60	13.80
February, 2017	94.00	37.00	22.30	5.10	40.20
March, 2017	92.00	36.00	26.00	9.80	81.20

2. Month wise meteorological data of 2018

Month	Humidity (%)		Temperature (°C)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
April, 2018	13.9	32.7	2.5	8.6	17.60
May, 2018	17.5	34.3	63.00	89.00	209.40
June, 2018	20.90	33.70	48.00	94.00	270.20
July, 2018	22.30	31.60	51.00	95.00	274.70
August, 2018	21.60	30.70	66.00	97.00	388.00
September, 2018	19.70	31.30	58.00	96.00	168.20
October, 2018	12.40	30.20	74.00	95.00	8.30
November, 2018	5.30	25.90	28.00	95.00	0.00
December, 2018	2.30	21.30	38.00	96.00	0.40
January, 2018	3.80	16.70	4.70	95.00	169.1
February, 2018	7.00	22.20	33.00	89.00	45.50
March, 2018	8.10	25.20	29.00	87.00	37.80

Annexure II

3. Fixed cost of tomato cultivation (ha⁻¹) 2017 and 2018

Particulars	Operational input per hectare	Rate (₹)	Units	Total cost (₹ ha ⁻¹)
1. Seed	150 g	600	25	15000
2. Ploughing and land preparation	12 hr	800	12	9600
3. Labourers				
I. Plot preparation	8 man days	250	8	2000
II. Transplanting	25 man days	250	25	6250
III. Earthing up	25 man days	250	25	6250
IV. Irrigation	20 man days	250	20	5000
V. Harvesting	25 man days	250	25	6250
VI. Staking	4 Tempo	12	5000	25000
4. Spray				
Stomp	1.2 l	340	1.2 l	408
Dithane	1.8 l	436	1.8	784.8
Ridomill	1.8 l	900	5.4	4860
Copper oxychloride	750 ml	400	1.50 l	800
5. Spray Labourers	24 man days	250	24	6000
Cost of cultivation (₹ ha⁻¹)				81952.80

4. Treatment wise cost of cultivation (Rs ha⁻¹) of 2017:

Treatments		Fixed Cost	Variable Cost	Total cost of cultivation
T ₁	FYM (Control)	81953	63747	145700
T ₂	NPK @ 150:120:60	81953	71737	153690
T ₃	FYM + NPK @ 150:120:60 (RD)	81953	79747	161700
T ₄	RD + Ca @ 0.3% Foliar application (FA)	81953	80632	162585
T ₅	RD + Ca @ 0.6 % (FA)	81953	81212	163165
T ₆	RD + Mg @ 0.1 % (FA)	81953	81222	163175
T ₇	RD + Mg @ 0.2 % (FA)	81953	81627	163580
T ₈	RD + Mg @ 0.4 % (FA)	81953	81892	163845
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	81953	82102	164055
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	81953	82272	164225
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	81953	82637	164590
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	81953	83037	164990
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	81953	83197	165150
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	81953	83397	165350

5. Treatment wise cost of cultivation (Rs ha⁻¹) of 2018:

Treatments		Fixed Cost (Rs.)	Variable Cost (Rs.)	Total cost of cultivation (Rs.)
T ₁	FYM (Control)	81953	64887	146840
T ₂	NPK @ 150:120:60	81953	72337	154290
T ₃	FYM + NPK @ 150:120:60 (RD)	81953	80747	162700
T ₄	RD + Ca @ 0.3% Foliar application (FA)	81953	81032	162985
T ₅	RD + Ca @ 0.6 % (FA)	81953	82612	164565
T ₆	RD + Mg @ 0.1 % (FA)	81953	83022	164975
T ₇	RD + Mg @ 0.2 % (FA)	81953	82627	164580
T ₈	RD + Mg @ 0.4 % (FA)	81953	82692	164645
T ₉	RD + Ca & Mg @ 0.3 & 0.1 % (FA)	81953	82932	164885
T ₁₀	RD + Ca & Mg @ 0.3 & 0.2 % (FA)	81953	82897	164850
T ₁₁	RD + Ca & Mg @ 0.3 & 0.4 % (FA)	81953	82937	164890
T ₁₂	RD + Ca & Mg @ 0.6 & 0.1 % (FA)	81953	82957	164910
T ₁₃	RD + Ca & Mg @ 0.6 & 0.2 % (FA)	81953	82957	164910
T ₁₄	RD + Ca & Mg @ 0.6 & 0.4 % (FA)	81953	83262	165215

List of Publications

S. No.	Title of paper with author names	Name of journal / conference	Published date	Issn no/ vol no, issue no	Indexing in Scopus/ Web of Science/UGC-CARE list (please mention)
1.	Impact of foliar spray of calcium and magnesium on quality and nutrient uptake of tomato (<i>Lycopersicon esculantum</i> L.) in north west Himalayas -Subhash Kumar, Raj Kumar and Prabhjot Singh	Annals of Biology	June 20, 2021	0970-0153 Vol.-37 Issue - 2	Scopus Impact Factor 0.32
2.	Effect of foliar spray of calcium and magnesium on growth, yield and economics of tomato (<i>Lycopersicon esculantum</i> L.) in north western Himalayas -Subhash Kumar, Raj Kumar and Prabhjot Singh	Annals of Agricultural Research	September 2020	Vol.- 41 Issue-3	-
3.	Effect of organic and inorganic sources on yield, quality and growth parameters of tomato	National Seminar on “Organic Farming: A way to sustainable Development”	Feb. 27, 2020	-	-
4.	Effect of foliar application on growth, quality, yield and its parameter in Mandi district.	Sustainable rural livelihood opportunities and challenges	March 7, 2020	-	-