AUGMENTATION OF NATIVE MICRONUTRIENTS AVAILABILITY IN GUAVA (*Psidium guajava* L.) CV. SARDAR THROUGH DIFFERENT FERTILIZER SOURCES

A. R. AKARSHA

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF HORTICULTURE, BAGALKOT
UNIVERSITY OF HORTICULTURAL SCIENCES
BAGALKOT – 587 104

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By
A. R. AKARSHA
UHS17PGM925

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF HORTICULTURE, BAGALKOT
UNIVERSITY OF HORTICULTURAL SCIENCES
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UNIVERSITY OF HORTICULTURAL SCIENCES, BAGALKOT
COLLEGE OF HORTICULTURE, BAGALKOT
DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

CERTIFICATE

This is to certify that the thesis entitled **"AUGMENTATION OF NATIVE MICRONUTRIENTS AVAILABILITY IN GUAVA (*Psidium guajava* L.) CV. SARDAR THROUGH DIFFERENT FERTILIZER SOURCES"** submitted by **A. R. AKARSHA bearing ID No. UHS17PGM925** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the University of Horticultural Sciences, Bagalkot is a record of research work carried out by him during the period of his study in this University, under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

Place: BAGALKOT
Date: SEPTEMBER, 2019

(PRASANNA S. M.)
Major Advisor

Approved by

Major Advisor: ____________________
(PRASANNA S. M.)

Members:

1.____________________
(M. S. NAGARAJA)

2.____________________
(SHANKAR METI)

3.____________________
(D. P. PRAKASH)

4.____________________
(SHRIPAD VISHWESHWAR)

5.____________________
(SUMA R.)

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BAGALKOT

September, 2019 **(A. R. AKARSHA)**

Affectionately Dedicated to
My Beloved Parents and
Guide

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LIST OF ABBREVIATIONS

Sl. No.	Abbreviations	Expansion
1	%	Per cent
2	^0C	Degree Celsius
3	cm.	Centimetre
4	*et al.*	Et alia (and others)
5	ha.	Hectare
6	kg ha^{-1}	kilogram per hectare
7	mg kg^{-1}	milligram per kilogram
8	ppm	parts per million
9	cc	cubic centimeter
10	Fig.	Figure
11	dSm^{-1}	DeciSiemens per meter
12	cmol (p+)kg^{-1}	centi mol per kilogram
13	GPS	Global positioning system
14	GIS	Geographical information system
15	pH	Puissance de hydrogen
16	EC	Electrical conductivity
17	OC	Organic carbon
18	$CaCO_3$	Calcium carbonate
19	OM	Organic matter
20	N	Nitrogen
21	P	Phosphorus
22	K	Potassium
23	S	Sulphur
24	Ca	Calcium

25	Mg	Magnesium
26	Na	Sodium
27	Fe	Iron
28	Zn	Zinc
29	Cu	Copper
30	Mn	Manganese
31	B	Boron
32	DTPA	Diethylene Triamine Penta Acetic acid
33	MSL	Mean sea level
34	NH_4OAc	Ammonium acetate
35	$CaCl_2$	Calcium chloride
36	$KMnO_4$	Potassium permanganate
37	HCl	Hydrochloric acid
38	HNO_3	Nitric acid
39	$HClO_4$	Perchloric acid
40	NH_4Cl	Ammonium chloride
41	DAT	Days after treatment imposition

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1. INTRODUCTION

Guava (*Psidium guajava* L.) is one of the most popular fruit grown in tropical and sub-tropical regions of India, which belongs to the family Myrtaceae. This originated in Central America, distributed from Mexico to Peru, and gradually became a commercial crop in several countries like Brazil, China, Malaysia, Cuba and India. It is cultivated in India since early 17th century owing to its wider adaptability for diverse soils and agro-climatic regions, low cost of cultivation, prolific bearing and being highly remunerative with nutritive values (Das *et al*. 1995). The fruit occupied a key role in horticulture wealth of our nation and ranks fifth with respect to area and production. In India, guava occupies an area of 0.26 m ha with 4.045 m MT production (NHB, 2018). It is successfully grown all over the country but leading guava growing states are Uttar Pradesh, Bihar, Madhya Pradesh, Maharashtra, Gujarat and Karnataka.

Karnataka produces 5.8 per cent of the total production of guava in the country. The state produces 137 thousand MT of guava from an area of 7024 ha with productivity of 19.54 MT/ha (KSHD, 2017). Major guava producing belts in the state are Dharwad, Chikkaballapura, Bangalore rural, Kolar, and Haveri.

The crop has gained considerable vital prominence in our country in general and state of Karnataka in particular because of its high nutritive value, pleasant aroma and availability at reasonable price. Hence it is known as ‘Poor man’s Apple’ and ‘Apple of Tropics’. The fruit is rich source of vitamin C which have 220-228 mg/100 g and also good source of pectin. Guava bears twice i.e. (rainy and winter) in a year under north Indian conditions. However it also harvested as third crop in some states like Maharashtra and Tamil Nadu during the month of October. The February or spring flowering is called ‘*Ambe Bahar’*, June or Monsoon flowering is called ‘*Mrig Bahar*’, flowering in October is called ‘*Hast Bahar* ’. In spring season flowers will initiated and fruits ripen start from July to September, and in monsoon season fruits ripen from November to February, however, *Hast Bahar* fruits ripen in spring season, which is also known as summer season crop.

Of late guava cultivation is expanded in marginal lands where soil salinity, alkalinity and calcareousness are the prominent problems associated with normal production. Most of the alkaline and calcareous land lies in the arid and semiarid environment and guava is extensively cultivated in these regions with inherent salt related problems. These problems in the arid and semi-arid regions are because of low or scanty rainfall, unscrupulous use of irrigation waters besides exploration of marginal ground waters for irrigation. This problem is marginal irrigation water, secondary salinization and sodication spreading its tentacles towards hitherto normal and productive soils also. Salt stress interrupting water balance in the plants, excessive exchangeable sodium deteriorating soil physical properties besides inducing nutrient deficiencies for the growing crops are the prominent adversaries associated with calcareous and saline soils. Moreover, micronutrient deficiencies are quite common causing nutrient imbalance in the crop plants with serious repercussions on yield and quality. Paradoxically, the nutrient deficiency is created in these soils despite the presence of the metallic micronutrients in appreciable quantities owing to their transformations towards unavailable pools. A scientific intervention to bring back the unavailable micronutrients to the available forms through different fertilizers appears to be a rational venture for mitigating the nutrient deficiencies.

High levels of alkalinity and precipitated calcium carbonate in soils affect the transformations and availability of several essential plant nutrients. This particular problem is more conspicuous as far as metallic micronutrients owing to their precipitation as their respective hydroxides under alkaline soil reaction. For this reason, optimum crop production in alkaline soils calls for an intervention of special fertilizer management practices to transform large unavailable pools of nutrients to available forms. As such reclamation of entire lands using different fertilizers requires huge investments and takes more time for normalization. On the contrary, localized application of acid forming nitrogenous fertilizers to the rhizosphere soils would augment the micronutrients availability through transformation in to available forms. In this approach, the acid forming fertilizers applied in bands in the vicinity of the crop roots bring vital changes in soil reaction. By this method the soil near the active root zone will be acidified rendering solubilisation of metallic oxides, dissolution of phosphorus associated with calcium besides bridling toxic levels of certain nutrients and contaminants in the soil. With this small change brought in the crop management appreciable changes in growth, yield and quality could be anticipated in the marginal salt afflicted situations.

Leaf tissue analysis is a useful tool to assess the nutrient content of leaf at a selected time in the growth of the plant. It can be used to determine the appropriate fertilizer requirement in the general maintenance (nutrient monitoring) or to help in determining the cause of specific problems (diagnostic testing). Mineral composition of the guava leaves varies with the maturation process of leaves (Sanyal and Mitra, 1990), reflecting thereby the uptake of different nutrients at various stages of growth of the tree. An intimate relationship of leaf nutritional status is expected to exist with growth and yield of fruit trees (Chetri *et al.*, 1999).

Guava cultivation has assumed great significance in arid and semi-arid region of Karnataka. Obviously, decline in productivity has been observed owing to numerous reasons. However, the recent studies have revealed that the nutrient imbalance is one of the most pivotal causes for the irregularity. Keeping these facts in view, a comprehensive study on soil and leaf tissue analysis in guava orchard in the University of Horticultural Sciences, main campus was selected for undertaking experiment with following objectives;

1. To study the effects of different fertilizers on soil chemical properties and available nutrients
2. To study the effects of different fertilizers on secondary and micronutrient assimilation in guava
3. To study the effect of micronutrients availability on crop growth, yield and quality

2. REVIEW OF LITERATURE

Present investigation entitled "Augmentation of native micronutrients availability in Guava *(Psidium guajava* L.) cv. Sardar through different fertilizer sources" was carried out and their relevant literatures in India and abroad have been referred subsection wise as here under:

2.1 Soil chemical properties

2.1.1 Soil reaction

The pH of soil being important chemical property, which influences the availability of nutrients, microbial activity, and physical properties like structure, infiltration, permeability and other vital soil properties. Belay *et al*. (2002) conducted the field experiment to evaluate the long-term effect of direct Nitrogen, potassium and residual phosphorous fertilizers on chemical properties of soil and grain yield of maize in rotation with field pea. They revealed that nitrogen plots showed the pH of 5.7 which was significantly lower than pH in phosphorous (6.13), Potassium (6.24) and control plots (6.35). This was mainly due to the fact that most nitrogen fertilizers supply NH_4^+. Upon oxidation NH_4^+ releases H^+ ions which are potential sources of soil acidity. McCauley (2003) revealed a common amendment used to acidify alkaline soils is sulphur. Elemental sulphur is oxidized by microbes to produce sulphate (SO_4^{2-}) and H^+, causing a lower pH. Ferrous sulphate and ammonium sulphate can also be used to lower pH.

Lungu and Dynoodt (2008) conducted the field experiment to examine the development of soil acidity from long-term use of urea and its effects on selected soil properties in maize grown in Alfisol. They reported that lower pH values were measured starting from the second cropping season and at the end of the fourth season the pH had decreased 0.87 units on the plots that received 180 kg nitrogen ha^{-1} in the form of urea.

Malhi *et al*. (2008) conducted an experiment to know the effects of ammonium nitrate, urea, ammonium sulphate, and calcium nitrate on soil acidification in brome grass. They observed higher soil acidification with soil application of ammonium sulphate at the rate of 336 kg nitrogen ha^{-1}followed by ammonium nitrate and urea, The $CaCl_2$ extractable Al and Fe in the 0-15 cm layer increased with nitrogen application which closely followed the decrease in soil pH.

Fageria *et al.* (2010) studied the influence of urea and ammonium sulphate on soil acidity indices in lowland rice production. They reported that soil pH was decreased linearly with increasing N rate by ammonium sulphate (0 to 210 kg N ha$^{–1}$) and urea (0 to 200 kg N ha$^{–1}$). However, the decrease in pH with ammonium sulphate was from 5.8 to 5.2 with an increase in the fertilizer dose (0 to 210 kg N ha$^{–1}$). This means that the decrease at the greatest N rate applied with ammonium sulphate was 12 per cent compared with the lowest N rate for the same fertilizer. Similarly, the decrease in pH with urea fertilizer was 5.7 to 5.5 when more fertilizer was applied (0 to 200 kg N ha$^{–1}$). This decrease corresponds to mere 4 per cent at the greatest N rate compared with the lowest N rate.

2.1.2 Electrical conductivity

Oliveira *et al.* (2000) studied the effect of magnesium sulphate on common bean cultivated in an Ultisol of Northeast Australia. Result revealed that the pH reached the equilibrium and higher electrical conductivity (EC) was observed when sulphate of magnesium was applied to reach 8 mmol/cm^3 of Mg in the soil in the absence of the plant. When the plant was present, there was an increase of electric conductivity, proportional to the amount of magnesium sulphate applied.

Bryla *et al*. (2010) studied the effect of method and level of nitrogen fertilizer application on soil electrical conductivity in Blueberry. The results revealed that electrical conductivity was often >2 dS m^{-1} when granular fertilizer was applied and decreased by < 1.5dS m^{-1} with continuous fertigation. Plants fertilized with the highest rates of ammonium sulphate were suffered from apparent salt stress it may due to higher electric conductivity and none of the plant showed signs of salt stress when fertigated continuously with urea.

2.2 Soil micronutrients

In general, the availability of soil Fe, Zn, and Mn micronutrients decreases with increasing soil pH (Moraghan and Mascagni, 1991). Soil acidification induced by N fertilizers, therefore, should help improve their availability.

Zinc is taken up as a divalent ion and involved in the production and functioning of many enzymes as well as many growth hormones (Salisbury and Ross, 1992). Zn may become deficient in sandy soils, high pH soils, soils with high P content and were the top soil has been removed. Similarly, iron is an essential component of a number of proteins and enzymes as well as acting as a proton carrier during photosynthesis and respiration. Deficiency symptoms have been called iron chlorosis, lime chlorosis and lime-induced chlorosis. Further, plants need very small amount of Cu and because of this they are very rarely deficient. Deficiency symptoms occur as dark green and twisted leaves, the ion is used in several enzymes and proteins involved in oxidation and reduction (Salisbury and Ross, 1992). Use of copper based fungicide would be sufficient to meet the plant requirements in most of the cases. Manganese deficiencies are more likely to occur on alkaline, sandy soils high in organic matter or on limey soils. Boron is an essential element for higher plants, but its toxicity is observed when the element is present in higher concentration. Its deficiency causes inhibition of plant growth. It is generally up-taken by roots of a tree from soils containing boric acid solutions. Lowest level of boron concentration was in sandy and loamy soils and highest concentration was reported for lateritic and calcareous soils (Pendias, 2001).

Awad and Edwards (1977) studied the reversal of adverse effects of excess ammonium sulphate application on growth and nutrient status of a kikuyu pasture. They revealed that ammonium sulphate application at 336 kg N/ha/annum for 4 years followed by 672 kg N/ha/annum for 2 years decreased soil pH from 5.0 to 4.0. Soluble Al in the soil increased, while exchangeable Ca, Mg, and K decreased. Concentrations of Ca, Mo, and P in the kikuyu tops were lowered, while concentrations of Mn were raised. Hemingway (1962) revealed that application of ammonium sulphate to grass land increased the amounts of copper, manganese and iron and reduced the levels of molybdenum in all years and at each time of sampling.

Modaihsh *et al*. (1989) conducted an experiment to know effect of elemental sulphur on chemical changes and nutrient availability in calcareous soils. They reported that with application of sulphur at a rate of 0.5% significantly decreased the pH and increased the EC. Sulphur application generally increased 0.5M $NaHCO_3$ extractable P and DTPA extractable Mn, slightly increased DTPA extractable Fe and Cu but had no significant effect on DTPA extractable Zn.

Malhi *et al*. (1998) reported that increase of $CaCl_2$ extractable Al and DTPA extractable Fe in soil was closely correlated with the decrease in soil pH from nitrogen fertilization. DTPA extractable Mn was first increased with nitrogen application at 112 kg N ha^{-1} and then decreased sharply beyond that nitrogen rate. In the 5±10 cm layer, extractable Mn increased at168 and 224 kg N ha^{-1}rates, while in the 10±15 cm layer Mn maximized at the 336 kg N ha^{-1}rate.

McDaniel *et al.* (1992) examined the accumulation of secondary manganese relative to that of secondary iron as influenced by field-scale water movement. They revealed that manganese is a more mobile component of soil systems than is iron and therefore subject to more extensive redistribution within soils and landscapes.

Nilsson and Wiklund (1995) studied the nutrient balance and P, K, Ca, Mg, S and B accumulation in Norway spruce following ammonium sulphate application, fertigation, irrigation, drought and N-free-fertilisation. They reported that application with ammonium sulphate at a rate of 5-6 times higher than the current deposition of N and S did not lead to decreased accumulation above ground of any of the macro nutrients P, K, Ca or Mg. The accumulation of B, however, was significantly reduced.

Siman *et al.* (1971) conducted an experiment to study the effects of calcium carbonate and ammonium sulphate on manganese toxicity in an acid soil. They reported that application of ammonium sulphate acidified the soil, increased manganese levels in both soil and plant tissue of beans crop and frequency of manganese toxicity was also shown with increased rate of ammonium sulphate.

Sims and Patrick (1978) studied the distribution of micronutrient cations in soil under conditions of varying redox potential and pH. They reported that the distribution of all micronutrients within soil fractions was influenced by both pH and Eh although

Fe and Mn were affected to a greater extent than Zn and Cu. Chien *et al*. (2011) opine that the ammonium sulphate produces the most acidity in rhizosphere than urea as well as ammonium nitrate. The acidic rhizosphere induced by NH^{4+} N improves uptake of micronutrients such as Fe, Zn, and Mn in soil.

Islam (2012) studied the effect of different rates and forms of sulphur on seed yield and micronutrient uptake by chickpea. He reported that ammonium sulphate was a more efficient source of sulphur as compared to gypsum. Ammonium sulphate application at the rate of 30 kg/ha resulted in a significant increase in micronutrient uptake by plant, however effect of sulphur application on soil pH at the end of experiment was not significant. Availability of soil zinc and copper increased with sulphur application at the end of two year experiment.

Mir *et al.* (2013) conducted the experiment to study the effects of bio-organics and chemical fertilizers on nutrient availability and biological properties of pomegranate orchard soil. They reported that application of bio fertilizer along with NPK in the form of urea, single super phosphate and muriate of potash showing maximum iron (66.9 ppm), manganese (61.9 ppm), zinc (2.3 ppm) and copper (3.2 ppm) in soil.

Karimizarchi *et al*. (2014) reported that application of elemental sulphur at the rate of 0.5 g/kg to the maize was found to decreases the soil pH from 7.03 to 6.29 and significantly increased the Mn by 0.38 per cent and Zn by 0.91 per cent. Cui *et al* (2004) conducted a pot culture experiment to know the effect of elemental sulphur on Zn and Pb uptake in Indian mustard as well as in winter wheat. They reported that highest application rate of elemental sulphur (160 mmol kg^{-1}) acidified the soil from pH 7.1 to 6.0. Soil extractable Pb and Zn and their uptake increased as soil pH decreased.

Kaur and Kaur (2017) investigated the effect of inorganic and organic fertilizers on fruit quality and yield attributes in guava cv. Sardar. It was revealed from the study that guava trees with application of urea 600g/tree, super phosphate 2000g/tree, MOP 1000g/tree took minimum days (98.3) for fruit maturation and yielded maximum number of fruits (282.0) per tree with the fruit yield of 62.73 kg. Hence, inorganic fertilizers were found to be the most efficacious in encouraging the quality and yield of Sardar guava fruits.

2.3 Available soil nutrient status

2.3.1 Soil organic carbon

Apthorp *et al.* (1987) reported that increased P uptake by the lettuce plant correlated well with decreased soil pH. Soil fertilized with soluble phosphorous, mono calcium phosphate and the form of the nitrogen fertilizer had little effect on plant P uptake. Application of acidifying nitrogen fertilizers like ammonium sulphate and urea help in increases availability of phosphorous by 42 per cent and 27 per cent respectively.

Aula *et al.* (2016) studied the effect of nitrogen fertilizer on soil organic carbon, total nitrogen and soil pH in long term continuous winter wheat. They revealed that nitrogen fertilizer significantly increased soil organic carbon, especially when nitrogen rates exceeded 90 kg ha^{-1}. The highest SOC (13.1 g/kg) occurred when 134 kg N/ha was applied annually.

2.3.2 Nitrogen

Seddik *et al.* (2011) conducted an experiment to know the efficiency of some slow and fast release fertilizers and organic manures on soil nutrients availability and nutritional status of carrot. They reported that among all the nitrogen fertilizers, ammonium sulphate treatment was more effective on increasing the available NPK in soil as compared to others forms (urea and ammonium nitrate) at first season. This may be due to acidic effect and high solubility of ammonium sulphate that decreased pH values and increased the availability of NPK in soil. Further, 75 per cent nitrogen was found to be better as compared to low rate 50 per cent nitrogen for increasing the availability of NPK in soil. Hernandes *et al.* (2012) conducted an experiment on balancing guava nutrition with liming and fertilization. They reported that added nitrogen through ammonium sulphate at 240 g tree^{-1} showed the linear increased yield in guava.

Jamwal *et al.* (2018) studied the effect of integrated nutrient management on physical characteristics of guava cv. Allahabad Safeda. They reported that maximum number of fruits tree-^{1} (21), maximum average fruit weight (190.1gm), maximum fruit length (7.1 cm), maximum fruit diameter (7.1 cm), Maximum fruit volume (192.1 cc), maximum fruit yield tree^{-1} (3.9 Kg) and fruit yield/ha (199.5 q) has been obtained with application of 75 per cent of nitrogen through urea along with bio fertilizer.

2.3.3 Phosphorous

Phosphorous is the second most important nutrient to plants and is absorbed in both monovalent ($H_2PO_4^-$) and divalent (HPO_4^{2-}) orthophosphate ions (Salisbury and Ross 1992).

Grunes (1959) he reported that ammonium form of nitrogen frequently increases phosphorus absorption more than the nitrate form. Nitrogen additions affect plant metabolism and may change the ability of unit areas of root surface to absorb phosphorus. Nitrogen salts may influence absorption of phosphorus by plants by altering the phosphorus solubility in the soil. Shankaralingappa *et al*. (2000) reported that significant synergistic effect on uptake of K and S was observed with combined application of P and S up to 50 kg P_2O_5 and 40 kg S/ha. The antagonistic effect of phosphorous and sulphur on uptake of N,P,K and S by pigeon pea was observed only when they were applied together at higher rates of phosphorous (75 kg P_2O_5/ha) and sulphur (40 kg/ha).

2.3.4 Potassium

Potassium is often referred as the quality element for crop production (Usherwood 1985) and it has widely proven to have a crucial role in many crop quality parameters. Fruit size, appearance, colour, soluble solids, acidity, vitamin content, taste, as well as shelf-life are significantly influenced by adequate supply of potassium. Shankaralingappa *et al*. (2000) studied the interaction effect of phosphorous and sulphur on uptake of nitrogen, phosphorous, potassium and sulphur by pigeon pea. They reported that uptake of N, P, K and S by pigeon pea differed significantly due to interaction between phosphorous and sulphur. Combined application of phosphorous and sulphur up to 50 kg P_2O_5/ha and 20 kg S/ha showed significant synergistic effect on the uptake of nitrogen and phosphorous by pigeon pea.

2.3.5 Calcium

Calcium plays an important role in root development and root functioning, cell division, chromosome stability and in enzyme system like ATP respiration and amylase. Zhang *et al.* (2017) conducted a study on the impacts of long-term nitrogen fertilization on acid buffering rates and mechanisms of a slightly calcareous clay soil. They reported that soil pH and exchangeable Ca^{2+} and Mg^{2+}declined in the first 12 years with the annual application of urea at the rate of 300 kg, soil pH in the plots receiving urea and NH_4Cl were 0.9 and 2.0 units lower than the control, respectively, while the total exchangeable base cations were about 10 per cent and 16 per cent lower, respectively.

2.3.6 Magnesium

Like Ca, plants take up Mg as a divalent ion, generally deficiency symptoms can be seen as inter veinal chlorosis of older leaves. Mg is an essential component of chlorophyll as well as the functional ability of ATP in many reactions. It is also responsible for the activation of many enzymes in photosynthesis, respiration and the formation of DNA and RNA (Salisbury and Ross, 1992). Ross *et al.* (1985) evaluated the soil chemical and mineralogical changes due to acidification in apple orchards. They reported that acidification produced by fertilization reduced the soil pH values between 5.0 and 6.0. The proportional losses of exchangeable bases during acidification followed the order Ca > Mg >K.

Belton and Goh (1992) studied the effects of urea fertigation of apple trees on soil pH, exchangeable cations and extractable manganese in a sandy loam soil. Results obtained showed that largest changes in soil pH and cations in soils with application of 50 kg N ha^{-1} yr^{-1}.Where the soil pH decreased by 1.6 units at all soil depths and the estimated losses of Ca, Mg and K from the upper soil profile depth (0-10 cm) represented 23, 63 and 27 per cent of their respective total exchangeable levels.

2.3.7 Sulphur

Sulphur is present in proteins and chlorophyll and plays a role in energy metabolism. It is available to the plants through organic or inorganic sources. Sulphur is found in soil minerals and becomes available to the plants as sulphate ions through weathering. Nasreen *et al.* (2007) studied the nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization. They reported that maximum uptake of nitrogen and sulphur by bulb were recorded by the combined application of 120 kg N and 40 kg S/ha with a blanket dose of 90 kg P_2O_5, 90 kg K_2O, and 5 kg Zn/ha plus 5 tons of cow dung/ha. The antagonistic effect of nitrogen and sulphur on the uptake of nitrogen and sulphur by bulb was observed only when they were applied together at higher rates of nitrogen (160 kg/ha) and sulphur (40kg/ha). Skwierawska and Zawart (2009) studied the effect of different rates and forms of sulphur on content of available phosphorus in soil. Results demonstrating that effect of fertilization with different forms and rates of sulphur on the content and transfer of available phosphorus in soil were inconsistent. Only the dose of 120 kg $ha^{-1}$of sulphate caused a significant increase in the concentration of available sulphur in soil depth of 0-40 and 40-80 cm layers.

2.4 Leaf nutrient content in guava

2.4.1 Nitrogen

Dwivedi *et al.* (1990) evaluated the effect of various concentration of urea on crop regulation in guava (*Pisidium guajava* L.) cv. *Sardar*. They reported that foliar application of urea with 15 per cent resulted in increased terminal and lateral extension growth. Percentage flower/fruit drop (96-99%) increased with 20 per cent of urea foliar application. Fruit set decreased with urea treatment. High urea concentration reduced yield (kg/tree) in the rainy season but increased yield in winter. Individual fruit weight increased with urea concentration. Fruit TSS, total sugar and vitamin C contents increased with increasing urea concentration up to 15 per cent and decreased with 20 per cent urea.

Kumar *et al.* (2008) studied the effect of N, P and K on fruiting, and yield and fruit quality in guava cv. Pant Prabhat. They reported that treatments with higher nitrogen level attained maximum yield and fruiting compared to treatments with lower nitrogen levels, in combination with phosphorus and potassium. Maximum yield of 69.64, 60.72 kg/plant and 22.66, 26.35 kg/plant, and, fruit set of 73.23%, 75.07%, 34.73% and 35.65% were recorded with 150g N, 50g P_2O_5 and 75g K_2O/plant/year in the rainy and winter seasons in both years, respectively, while treatment combinations with high potassium level recorded higher ascorbic acid and sugar content in the fruit.

Sharma *et al*. (2013) studied the influence of drip irrigation and nitrogen fertigation on yield and water productivity of guava. The result showed that the maximum fruit yield of 16.9 t/ha was registered at 100% of recommended dose of N. The interaction between irrigation schedules and N fertigation levels revealed that maximum fruit yield of 21.6 t/ha.

Sharma *et al*. (2014) conducted an experiment to know the effect of N, P and their interaction on Physico- Chemical Parameters of Guava (*Psidium guajava*) cv. L-49. The results were obtained from the investigation shows that the individual application of nitrogen and phosphorus and their interaction significantly influence the physico- chemical properties of guava cv. L-49. Treatments with higher doses of nitrogen were found very effective in improve the physicochemical parameters of guava fruit. The maximum fruit diameter (7.40 cm), fruit length (7.31 cm) and pulp weight (200.01g) was recorded by combined application of 600 g N and 400 g P_2O_5 per tree.

Khan *et al.* (2018) reported that application of higher fertilizers resulted in enhanced uptake of nitrogen, phosphorus and potassium from soil which ultimately led to better plant growth, yield and leaf nutrient status. Nitrogen, phosphorus and potassium, being the essential major elements and required by plants in relatively large quantities especially responsible for maximising physiological activities of the plant and for plant, water and soil relationships, which ultimately affect fruiting and quality but excess amount of application can result deteriorate fruit quality.

2.4.2 Phosphorous

Hemmaty *et al.* (2012) studied the effect of sulphur application on soil pH and uptake of phosphorus, iron and zinc in apple trees. Results showed that sulphur treatments had significant effects on soil pH, chlorophyll content of leaves and phosphorus, iron and zinc concentrations of leaves and fruits. On the average, applying sulphur decreased pH of soil and increased the chlorophyll content of leaves, and iron, zinc and phosphorus concentration of fruits in apple by (17.09%, 4.8%, 30.24%, 11.61% and 18.76%, respectively) as compared to the control. Regarding the soil pH and other criteria about the nutrients availability and concentration, it seems that the application of 2 kg/tree sulphur fertilizer would be beneficial for apple orchards located in the highly alkaline soils.

Sharma *et al.* (2013) conducted an experiment to know the effect of integrated nutrient management strategies on nutrient status, yield and quality of guava. They reported that highest leaf nitrogen and phosphorous (1.76 & 0.26%, respectively) and leaf Calcium and Magnesium (2.01 & 0.86%, respectively) contents, was obtained with the treatment comprising Azotobacter + 25% of N tree^{-1} through FYM + 75% of N tree^{-1} through inorganic fertilizer. Khan *et al.* (2017) reported that nitrogen leaf content of pear increased with increasing doses of nitrogen whereas phosphorus and potassium leaf content decreased. The pear leaves nitrogen content was 2.43 per cent with application of 800 g nitrogen/plant. The maximum leaves nitrogen 2.41 per cent, phosphorus 0.20 per cent and potassium 1.37 per cent nutrient content with application of 90 kg of manure/plant. The interaction between nitrogen and FYM is positive impact on leaves nutrient content. The nitrogen 2.51 per cent, phosphorus 0.19 per cent and potassium 1.35 per cent was recorded with application of 600 g nitrogen and FYM 90 kg/plant.

2.4.3 Potassium

Intrigliolo and Intelisano (1997) conducted an experiment to know the effect of differential nitrogen application on nutrition growth, yield and fruit quality in young lemon trees. They reported that tree receiving intermediate level of nitrogen fertilizer gave the best nutritional response. In addition to that leaf with nitrogen level (2.1-2.4%) negatively affected the phosphorous and potassium concentration. Sharma *et al*. (2013) conducted an experiment to know the effect of integrated nutrient management strategies on nutrient status, yield and quality of guava. They reported that highest soil potassium (148.23 kg ha^{-1}) and leaf potassium (1.25%) contents was obtained with the application of *Azotobacter* + 50% of N tree^{-1} through FYM + 50% of N tree^{-1} through inorganic fertilizer.

2.4.4 Calcium

Hao *et al.* (2004) studied the effect of calcium and magnesium on plant growth, biomass partitioning and fruit yield in tomato. They revealed that total fruit yield and fruit dry matter increased linearly with application of 300 mg L^{-1} calcium along with magnesium. Khaosumain *et al.* (2013) reported that application of 640 g N tree^{-1} treatment led to lowest leaf Calcium concentration. Similar results were obtained in lychee, with increasing nitrogen supply decreasing leaf phosphorous concentrations. On the other hand, the different N treatments had no effect on the leaf potassium and magnesium.

2.4.5 Magnesium

Thokchom *et al.* (2018) conducted an effect of rejuvenation pruning and nitrogen levels on leaf nutrient status of old and senile apricot (*Prunus armeniaca* L.) cv. *new castle* trees. They reported that leaf nitrogen, iron, manganese and zinc content increased with increasing pruning severity coupled with high dose of nitrogen, while leaf phosphorous, calcium, magnesium and copper content showed declining trends with the increasing pruning severity and nitrogen levels.

2.4.6 Sulphur

Maier *et al*. (2002) conducted an experiment to know the effect of nitrogen source and calcite lime on soil pH and potato yield, leaf chemical composition. They reported that use of urea (0.72%) and ammonium sulphate (1.15%) resulted in higher sulphur concentration in leaf when compared with ammonium nitrate (0.54%) and calcium nitrate (0.52%). Similarly Jeong and Lee (1992) reported that sulphur concentration in tissues of ageratum, marigold, petunia, and salvia were higher in the ammonium-N fertilized plants.

2.4.7 Leaf micronutrients content

Labanauskas *et al.* (1959) studied the Influence of soil applications of nitrogen, phosphate, potash, dolomite, and manure on the micronutrient content of avocado leaves. They reported that leaves receiving the high nitrogen rate (2.0 pound/tree) resulted in significantly less zinc, copper, and boron, copper and significantly more manganese and iron than leaves from trees that received the low nitrogen rate (0.5 pound/tree).

Intrigliolio and Intelisano (1997) reported that tree receiving highest nitrogen fertilizer shown increased leaf nitrogen content (2.4%) in lemon. That increased nitrogen concentration had a positive effect on manganese (0.311%), zinc (0.411%) concentration and nitrogen did not influence on iron concentration of leaves.

Nalewajko *et al.* (1997). Studied the effects of pH on growth, photosynthesis, respiration, and copper tolerance of three Scenedesmus strains. They reveal that pH has a strong influence on speciation of trace metals such as copper, the pro- portion of free copper (as Cu^{2+}) increases from 37% at pH 7 to 100% at pH 5. Malvi (2011) studied the interaction of micronutrients with major nutrients with special reference to potassium. He revealed that there was a synergetic effect shown between the Cu, Zn along with the available potassium.

Petrie and Jackson (1984) reported that soil solution pH in fertilizer bands 7 days after fertilization of barley was decreased from 8.1 to 7.5 by ammonium sulphate. In contrast, urea fertilizer increased the soil solution pH from 7.7 to 8.0. Band application of ammonium sulphate in the seed row at rates of 22 and 45 kg N/ha increased both barley yield and leaf Mn concentration, whereas urea application decreased yields.

Wear and Patterson (1962) studied the effect of soil pH in relation of water-soluble B of the soil to B content of the plant. They revealed that, at the lowest pH level the change in plant concentration of B is greater for each unit change in water soluble B than at the higher pH level. This was mainly due to increased pH increased the amount of water-soluble B. Lal *et al.* (2000) reported that application of nitrogen at 600 g per plant per year significantly enhanced the fruit yield of guava, and nitrogen and manganese content of leaves, while it reduced the phosphorous, potassium and zinc content of leaves.

De Varennes *et al*. (2001) studied the characterization of manganese toxicity in two species of annual medics. They revealed that high level of Mn in the solution resulted in increased concentration of Mn, and decreased concentration of Zn in the whole plant. The partition of Fe, K, and Ca between roots and shoots was affected by Mn.

Erdal *et al*. (2003) conducted an experiment to study the effect of elemental sulphur and sulphur containing waste on the iron nutrition of strawberry plants grown in a calcareous soil. They reported that applications of elemental sulphur and sulphur containing waste resulted in a decrease of soil pH., applied sulphur corresponding to 500 and 1000 kg ha^{-1} from both sources, decreased pH to 7.9 and 7.7 for elemental S and 7.9 and 7.8 for waste application, respectively. The leaf iron concentration increased by 64.0 and 78.3 mg kg^{-1} with elemental sulphur and increased to 67.0 and 73.3 mg kg^{-1} with waste application.

Wang *et al.* (2006) studied the effect of soil pH on uptake of Zn by *Thlaspi caerulescens.* They revealed that soluble metal form of Zn was greatly increased with decreasing pH. Lowering pH significantly influenced plant metal uptake.

Domagala and Sadya (2010) studied the effect of nitrogen fertilization on copper, manganese, zinc, iron, boron and molybdenum availability in commercially grown white head cabbage. They reported that application of ammonium sulphate in placement method significantly increases the manganese and iron concentration in the cabbage heads and decreases the boron and molybdenum concentration.

2.5 SCMR (SPAD Chlorophyll Meter Readings) Values.

Swiader and Moore (2000) conducted an experiment to study the SPAD-chlorophyll response to nitrogen fertilization and evaluation of nitrogen status in dry land and irrigated pumpkins. They revealed that maximum or near-maximum yields of both dry land and irrigated pumpkins could be expected when leaf SPAD readings were 56.7–59.0 units at anthesis, 55.1–57.6 units at early-fruiting, and 52.2–54.3 units at mid-fruiting. The results also showed that while normalized leaf SPAD readings derived from high-N reference plots can readily identify the critical threshold (i.e. 10% yield reduction) for N deficiency in pumpkins, they would be less precise while predicting optimum N status (i.e. maximum yield).

Liu *et al*. (2006) studied the leaf chlorophyll readings as an indicator for spinach yield and nutritional quality with different nitrogen fertilizer applications. The results suggested that the treatment with 120 mg N/kg media was found to improve significantly both leaf yield and leaf quality (i.e., leaf nitrate-N concentration and ascorbic acid). Too little and too much N fertilizer was not good for yield or spinach quality.

Brunetto *et al*. (2012) conducted an experiment to know the use of the SPAD-502 in estimating nitrogen content in leaves and grape yield in grapevines in soils with different texture. They reported that SPAD-502 readings estimated the total N content in flowering and at change in colour of the berries in the Cabernet Sauvignon grapevines grown on soils with clayey texture and sandy texture, particularly in the first year of evaluation. However, the precision of the SPAD-502 readings was found to be low, with there being no relationship between the SPAD-502 readings and grape yield.

Erdal *et al*. (2016) studied the variations in chlorophyll, SPAD values and some nutrient concentrations depending on chlorosis in peach leaves. They reported that leaf chlorophyll content, SPAD readings and Fe, Mg, and Mn concentrations increased with the leaf green colour increase. SPAD readings were significantly correlated with leaf chlorophyll content, Fe, Mn and Mg. Also, close correlation was seen between chlorophyll content and leaf Fe concentration.

3. MATERIAL AND METHODS

The present investigation on ″Augmentation of native micronutrients availability in Guava *(Psidium guajava* L.) cv. Sardar through different fertilizer sources‶ was carried out to estimate soil and leaf nutrient concentration in relation to guava yield. An attempt was made to transform large unavailable pools of nutrients to available forms by using special fertilizer management practices. The material used and the methodology adopted for the present study is made available in this chapter.

3.1 General description of the study area

3.1.1 Experimental site

The experiment was conducted at Main Horticultural Research and Extension Centre (MHREC), University of Horticultural Sciences, Bagalkot main campus. The location situated at 16^{o} $49^{'}$ N latitude and 75^{o} $43^{'}$ E longitude at an altitude of 678.00 m above Mean Sea Level (MSL).

3.1.2 Climate

Bagalkot taluk lies in northern dry zone of Karnataka (Zone III). Most of the area is under warm and dry climate throughout the year and mean annual rainfall is of 562 mm. The average maximum temperature is 34^{o} C and minimum temperature is 22.7^{0} C. The average winter temperature will drop to 14^{o} C during the months of December and January. The annual relative humidity is 46 per cent.

3.1.3 Experimental design

Design used : Randomized Block Design
Treatments : 08
Replication : 03
Variety : Sardar (L-49)
Spacing : 2 x 2 m^2 UHD Planting
Net plot size : 11 m x 7 m
No. plants per treatment : 08

3.1.4 Experimental material

The experimental material for this study comprised 8 treatments is presented in Table 1. Different sources of fertilizers were applied to soil.

Table 1. Treatment details

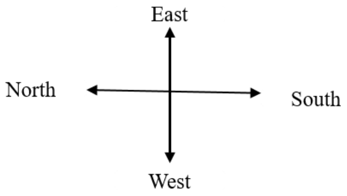
Treatment details	
T_1	RDF (100:40:75 g/plant) - Nitrogen in the form of Urea
T_2	RDF (100:40:75 g/plant) - Nitrogen in the form Ammonium sulphate
T_3	RDF (100:40:75 g/plant) - Nitrogen in the form of Urea + Magnesium sulphate (500 g/plant)
T_4	RDF (100:40:75 g/plant) - Nitrogen in the form Ammonium sulphate + Magnesium sulphate (500 g/plant)
T_5	RDF (100:40:75 g/plant) –Nitrogen in the form of Urea + Elemental sulphur (100 g/plant)
T_6	RDF (100:40:75 g/plant) - Nitrogen in the form Ammonium sulphate + Sulphur (100 g/plant)
T_7	RDF (100:40:75 g/plant) - Nitrogen in the form of Urea + Elemental sulphur (100 g/plant) + Chelated micronutrients (50g/plant)
T_8	RDF (100:40:75 g/plant) - Nitrogen in the form of Ammonium sulphate + Sulphur (100 g/plant) + Chelated micronutrients (50g/plant)

All the treatments were imposed in august and timely intercultural operations as well as pest and disease control measures were taken up based on the necessity.

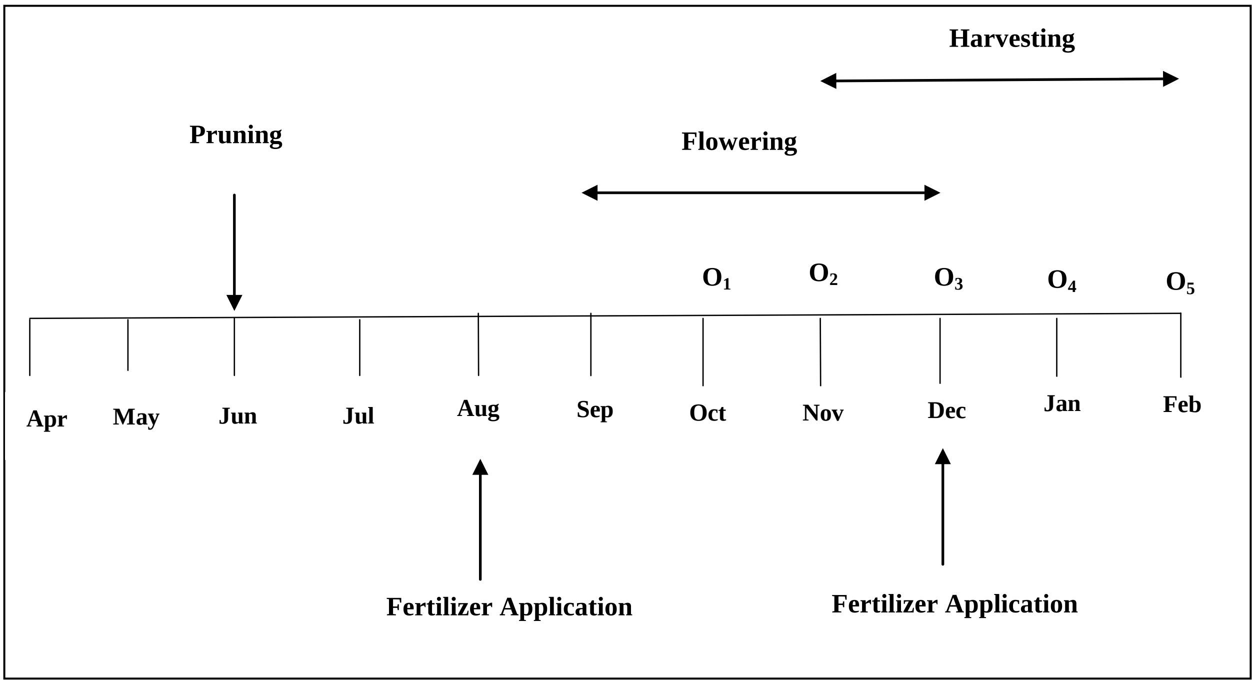
Plate 1. General view of experimental field

3 .1.5 Layout of experimental plot

R-I	R-II	R-III
T_6	T_7	T_5
T_1	T_8	T_6
T_5	T_3	T_1
T_8	T_6	T_2
T_3	T_4	T_8
T_2	T_1	T_3
T_7	T_5	T_4
T_4	T_2	T_7



3.1.6 Calendar of operation



3.1.7 Fertilizer application

The fertilizer recommendation for guava as per package of practices (pop) of University of Horticultural Sciences, Bagalkot *i.e* 100:40:75 N:P_2O_5:K_2O g/plant was applied to all treatments. Half dose of nitrogen, phosphorous as well as full dose of potassium fertilizers were applied in the month of August and balanced half dose of nitrogen and phosphorous fertilizers were applied in the month of December.

3.2 Collection and analysis of soil samples

The present experimental was laid out in a 7 year old guava orchard planted at a distance of 2 x 2 m^2 (ultra high density planting). The drippers were placed along the crop rows. The fertilizers were added directly to soil through fertilizers (in ring method) at a distance of 30 to 45 cm from the main stem. The soil samples were collected from points such that they are approximately 35 - 50 cm away from the main stem.

In each treatment, four soil samples were collected near four different guava plants at 15-20 cm depth at monthly interval. The collected soil samples were mixed thoroughly, made into one composite sample and air dried. Then, the samples were sieved (2 mm) and stored in air tight containers for further analysis

Table 2. Method employed for the analysis of soil samples

Parameters	**Methods**	**References**
pH	Potentiometric method	Jackson,(1973)
EC (dSm^{-1})	Conductivity method	Jackson,(1973)
Soil organic carbon (%)	Walkley and Black’s wet oxidation method	Walkley and Black, (1934)
Available N (kg ha^{-1})	Alkaline $KMnO_4$ distillation method	Subbiah and Asija, (1956)
Available P_2O_5(kg ha^{-1})	Olsen’s method, Colorimetry	Jackson, (1973)
Available K_2O (kg ha^{-1})	Neutral normal NH_4OAC method, Flame photometry	Jackson, (1973)
Exchangeable Ca [c mol (p+) kg^{-1}]	Versanate titration method	Jackson, (1973)

Exchangeable Mg [c mol (p+) kg^{-1}]		
Available S (ppm)	$CaCl_2$ method, Turbidometry	Black, (1965)
Exchangeable Na [c mol (p+) kg^{-1}]	Neutral normal NH_4OAC method, Flame photometry	Jackson, (1973)
DTPA extractable Fe, Cu, Mn, Zn, (ppm)	Microwave plasma atomic emission spectrophotometer	Arora, (2002)
Available B (ppm)	Azomethine-H method	Burger and Trough, (1939)

3.3. Collection and analysis of leaf samples

3.3.1 Collection of leaf

Index leaf (3rd pair of leaves from the apex) from each treatment was collected after 60 days of treatment imposition. About 50 leaves per treatment were collected randomly at chest height from all sides of the tree to form a composite and representative sample (Bhargava and Chadha, 1993). The leaf samples was decontaminated by washing in a sequentially with tap water, 0.2 per cent detergent solution, N/10 HCl and, finally, with double distilled water. Leaf samples was dried at 65-70^{o} C for 48 h. Then the samples were powdered and analyzed for different nutrients.

3.3.2 Leaf nutrient analysis

The leaf tissue nitrogen content was determined by Kjeldahl digestion and distillation method (Piper, 1966). For determination of nutrients other than total nitrogen, a known weight of leaf sample was digested in di-acid mixture HNO_3: $HClO_4$ (10:4) till a colourless solution was obtained. This digested sample was diluted to 100 ml and used for further analysis. The methodology adopted for estimating petiole nutrients content is presented in detail below.

Table: 3 Methods employed for the analysis of plant samples

Sl. No	Parameters	Methods	References
1	Nitrogen (%)	Micro Kjeldahl method	Subbiah and Asija, (1956)
2	Phosphorus (%)	Microwave Plasma Atomic Emission Spectrophotometer	Arora, (2002)
3	Potassium (%)	Flame photometer method	Jackson, (1973)
4	Calcium and Magnesium (%)	Versanate titration method	Jackson, (1973)
5	Sulphur (%)	Cacl$_2$ method, Turbidometry	Black, (1965)
6	Zinc, Iron, Copper, Manganese (ppm)	Microwave Plasma Atomic Emission Spectrophotometer	Arora, (2002)

3.4 Chlorophyll Content

The chlorophyll content of the representative samples in all the treatments of the study area were recorded at monthly interval using SPAD chlorophyll meter (Konica Minolta SPAD 502 plus).

3.5 Growth and yield parameters

3. 5.1 Shoot length (cm)

Shoot length of four selected plants in each treatments was measured at 30, 60 and 90 DAT with the help of measuring scale and expressed in cm.

3.5.2 Number of leaves per branch

The number of leaves present on four branches of four labelled plants in each treatment was recorded at 30, 60 and 90 DAT and mean was expressed in numbers.

3.5.3 Fruit drop percentage

Fruit drop were recorded at 60, 90 and 120 DAT. The percentage of fruit drop under each treatment was calculated by taking the average of the data obtained from each replication within a treatment.

$$\text{Fruit drop percentage} = \frac{\text{Total number of dropped fruits}}{\text{Total number of fruits}} \times 100$$

3.5.4 Fruit volume (cc)

The volume of fruit was measured at 60, 90 and 120 DAT by the conventional water displacement method and it was expressed in cubic centimetres.

3.5.5 Number of fruit per plant

The total number of fruits was counted from all the four labelled plants in each treatment and average was computed to indicate the number of fruit per plant.

3.5.6 Fruit weight (g)

The total number and total weight of fruit harvested from four selected plants of each treatment were measured. Then, the fruit weight was calculated and expressed in gram per fruit.

3.5.7 Yield per plant (kg/plant)

Weights of fruit from all four labelled plants were recorded in each picking. The cumulative weight from each picking (3-4) were added and average was computed to express fruit yield per plant in kilo gram.

3.6 Statistical analysis

The field experiments were laid out in Randomized Complete Block Design (RCBD). The data collected from the experimental study was analyzed statistically by two factorial randomized block design procedure. The level of significance used in F test was P=0.05. Critical difference was calculated wherever F test was significant. Correlation study was made to understand the interaction effect between plant and soil nutrients as well as yield.

4. EXPERIMENTAL RESULTS

In most of the soils of arid and semi-arid regions the soil reactions is the most conspicuous factor deciding the nutrient availability and in turn the plant growth and yield. In general alkaline pH restricts the availability of micronutrients besides fixation of vital nutrients like phosphorus. Moreover the nitrogen efficiency is drastically reduced owing to the chances of volatilization of ammonia in the alkaline soil. In order to restore an optimum soil reaction, it requires huge investment besides gestation period for restoration of ideal soil reaction. In this context, the approach of application of acid forming fertilizers tends to bring about a miniscule change in the soil reaction especially in the rhizosphere which is enough to maintain optimum conditions for the nutrient availability. With this backdrop a study was conducted during 2018-19 to know the effect of different acid forming fertilizers on augmentation of nutrients in general and micronutrients in particular in guava orchard in the University of Horticultural Sciences main campus, Bagalkot. The results pertaining to various soil fertility attributes as influenced by the application of different acid forming fertilizers is presented in this chapter.

4.1 Soil fertility attributes

4.1.1 Soil reaction

The data on temporal variation in soil reaction (pH) in all the treatments is presented in Table 4. In each of the treatments, instead of presenting the soil reaction of the rhizosphere as well as away from the rhizosphere separately, it was tabulated to account the difference (pH) between the former and the latter to arrive at valid inferences. In general the rhizosphere soils recorded lower soil pH as compared to the soils collected away from the rhizosphere; hence the delta pH remained negative in all the cases.

The delta pH varied significantly amongst treatments on the temporal scale within the stipulated time of the observation. The effect of reduction in pH was more conspicuous after the fertilizer application (45-60 days). This period corresponds to the observations made during October and February months during the schedule of the study. The treatment which received ammonium sulphate + elemental sulphur (T_6)

showed significant reduction in pH as indicated by higher (0.54) delta pH compared to all other treatments when observed at 45 days after treatment imposition (October). Further, the treatments receiving ammonium sulphate + magnesium sulphate (T_4) as well as urea + elemental sulphur + chelated micronutrients (T_7) remained next best with significantly lower (0.46) delta pH. Later the treatments receiving urea + magnesium sulphate (T_3) as well as urea (T_1) showed moderately lower delta pH of 0.43 and 0.35 respectively which remained significantly lower compared to the former treatments. However, the treatments receiving urea + elemental sulphur (T_5), ammonium sulphate + elemental sulphur + chelated micronutrients (T_8) besides ammonium sulphate (T_2) projected similar soil reaction in rhizosphere as well as away from the rhizosphere as indicated by the least delta pH.

In general, the reduction in pH was of higher magnitude in February due to top dressing application of nitrogen and phosphorous fertilizer in the month of December. Upon detailed observations the treatment receiving ammonium sulphate + elemental sulphur (T_6) as well as ammonium sulphate (T_2) was found to cede significant reduction in pH as indicated by higher delta pH (0.71 and 0.65, respectively) as compared to all other treatments when observed at 45 days after treatment imposition (February).Further treatments receiving ammonium sulphate + elemental sulphur + chelated micronutrients (T_8) showed lower (0.45) difference in delta pH. However rest of the treatments projected similar soil reaction in rhizosphere as well as away from the rhizosphere as indicated by least delta pH.

On the contrary, it was very interesting to observe in the treatment receiving ammonium sulphate + elemental sulphur (T_6) showed significantly higher (0.46) difference in delta pH. Further, treatment receiving ammonium sulphate (T_2), urea + elemental sulphur (T_5) and urea (T_1) showed slight (0.27, 0.24 and 0.22, respectively) difference in delta pH. Further, rest of the treatments projected similar soil reaction in rhizosphere as well as away from the rhizosphere as indicated by least delta pH. Extent of pH reduction was in the order of $T_6>T_2\overline{\ }T_5>T_8>T_3>T_4>T_7>T_1$ amongst the treatments.

On the temporal scale, the reduction in rhizosphere soil pH was more conspicuous in the months of October (0.37) and February (0.35) owing to the fertilizer application. However, the difference in pH between rhizosphere and away from the

Table 4: Temporal reduction of soil pH in rhizosphere as influenced by different fertilizers

Treatment details		**October**	**November**	**December**	**January**	**February**	**Treatment mean**
T_1	**Urea (N)**	0.35 (7.31)*	0.08 (7.30)	0.10 (7.62)	0.10 (7.57)	0.22 (7.22)	0.17
T_2	**Ammonium sulphate (N)**	0.24 (7.31)	0.23 (7.27)	0.07 (7.52)	0.15 (7.57)	0.65 (7.08)	0.27
T_3	**Urea (N) + Magnesium sulphate (500 g/plant)**	0.43 (7.06)	0.24 (7.33)	0.24 (7.38)	0.11 (7.33)	0.11 (7.24)	0.22
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	0.46 (7.18)	0.18 (7.34)	0.24 (7.48)	0.13 (7.45)	0.11 (7.44)	0.22
T_5	**Urea (N) + Elemental sulphur @ (100 g/plant)**	0.28 (7.19)	0.16 (7.38)	0.23 (7.51)	0.22 (7.45)	0.32 (7.33)	0.24
T_6	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant)**	0.54 (6.90)	0.52 (6.95)	0.35 (7.22)	0.22 (7.28)	0.71 (6.81)	0.46
T_7	**Urea (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	0.46 (7.20)	0.07 (7.45)	0.09 (7.45)	0.20 (7.40)	0.22 (7.36)	0.21
T_8	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	0.26 (7.32)	0.08 (7.44)	0.19 (7.38)	0.19 (7.37)	0.45 (7.11)	0.23
Month mean		0.37	0.19	0.19	0.16	0.35	0.25
		Treatments		**Months**		**Treatment x Months**	
S.Em±		0.01		0.009		0.024	
CD at 5%		0.03		0.02		0.06	
CV (%)		16.84					

*Values in parenthesis depict rhizosphere pH

Table 5: Temporal variation in electrical conductivity (dS m^{-1}) as influenced by different fertilizers

Treatment details		**October**	**November**	**December**	**January**	**February**	**Treatment mean**
T_1	**Urea (N)**	0.89 (1.25)*	0.21 (0.26)	0.48 (0.64)	0.37 (0.64)	0.27 (0.52)	0.42
T_2	**Ammonium sulphate (N)**	0.45 (0.67)	0.12 (0.39)	0.33 (0.50)	0.29 (0.49)	0.11 (0.32)	0.26
T_3	**Urea (N) + Magnesium sulphate (500 g/plant)**	0.88 (1.07)	0.16 (0.37)	0.22 (0.41)	0.18 (0.40)	0.22 (0.45)	0.53
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	0.76 (1.00)	0.57 (0.78)	0.18 (0.35)	0.12 (0.35)	0.18 (0.41)	0.36
T_5	**Urea (N) + Elemental sulphur @ (100 g/plant)**	0.49 (0.62)	0.35 (0.43)	0.27 (0.41)	0.17 (0.42)	0.24 (0.50)	0.28
T_6	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant)**	0.58 (0.76)	0.25 (0.35)	0.36 (0.50)	0.34 (0.50)	0.19 (0.36)	0.32
T_7	**Urea (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	0.53 (0.72)	0.38 (0.52)	0.28 (0.43)	0.13 (0.40)	0.43 (0.68)	0.33
T_8	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	0.98 (1.14)	0.23 (0.38)	0.19 (0.34)	0.13 (0.35)	0.41 (0.63)	0.38
Month mean		0.76	0.33	0.29	0.29	0.25	0.32
		Treatments		**Months**		**Treatment x Months**	
S.Em±		0.07		0.05		0.16	
CD at 5%		NS		NS		NS	
CV (%)		25.33					

*Values in parenthesis depict rhizosphere EC rhizosphere was significantly and consistently narrowed in the months of November (0.19), December (0.19) and January (0.16).

4.1.2 Soil electrical conductivity

The data on temporal variation in electrical conductivity towards rhizosphere as influenced by application of acid forming fertilizer is made available in Table 5. In general, the salinity level recorded in rhizosphere as well as soil away from the rhizosphere remained far below than the threshold limit as such the treatments did not have any significant effect on soil salinity. However salt accumulation was relatively higher in rhizosphere compared to soil away from the rhizosphere.

Amongst the treatments, the different source of nitrogen fertilizer did not reveal the significant changes in the salt flux in rhizosphere. However the temporal variation remained significantly higher in the month of October compared to rest of the period. Further, gradual reduction in electric conductivity was the common phenomenon in the treatments**.**

4.1.3 Available zinc

The micronutrient availability is augmented by the combined action of rhizosphere as well as applied acid forming fertilizers. As far as metallic micronutrients are concerned, both the above factors work cohesively to augment the nutrient availability. Application of acid forming fertilizers showed significant effect on available Zn in the rhizosphere compared to the soils outside the regime of rhizosphere. The incremental Zn manifested in the rhizosphere owing to the localized application of acid forming fertilizers is depicted as delta Zn in Table 6. The delta Zn differed significantly amongst the treatments as well as on the temporal scale within the study period. The effect of augmentation of was more conspicuous immediately (45-60 days) after the fertilizer application which corresponds to the observations made during October and February months. Among the treatments, application of urea + elemental sulphur (T_5) recorded significantly higher (1.21 mg/kg) delta Zn in the month of October followed by ammonium sulphate + elemental sulphur (T_6) 1.05 mg/kg and urea (T_1) 0.87 mg/kg which was on par with treatment receiving urea + magnesium sulphate (T_3) 0.83 mg/kg. However treatment receiving ammonium sulphate + elemental sulphur

+ chelated micronutrients (T_8) as well as ammonium sulphate (T_2) showed similar augment capacity with slender range of delta zinc (0.61 and 0.58 mg/kg respectively). Further application of ammonium sulphate + magnesium sulphate (T_4) as well as urea + elemental sulphur + chelated micronutrients (T_7) showed reduction in Zn availability (0.37 and 0.24 respectively) as indicated by less delta difference of Zn between the rhizosphere soil and soil away from the rhizosphere.

In general, the incremental Zn manifested in the rhizosphere was higher in the month of February due to top dressing application of nitrogen and phosphorous fertilizes in December. Upon detailed probe, the treatment receiving urea + elemental sulphur recorded significantly higher (0.81 mg/kg) delta Zn followed by urea (T_1) 0.61 mg/kg which was on par with treatments ammonium sulphate + elemental sulphur + Chelated micronutrients (T_8) as well as urea + elemental sulphur + Chelated micronutrients (T_7) which had similar delta Zn (0.59 mg/kg). However rest of the treatments recorded lesser zinc manifestation in the rhizosphere as indicated lower delta Zn content.

The average delta zinc over the month revealed very interesting features where the treatments receiving application of ammonium sulphate + elemental sulphur (T_6) showed higher (0.61 mg/kg) delta Zn throughout the experiment followed by treatments receiving urea + elemental sulphur (T_5) 0.50 mg/kg and urea (T_1) 0.49 mg/kg. However rest of the treatments (T_3, T_2, T_8, T_7 and T_4) showed similar Zn in rhizosphere as well as in non rhizosphere soil as indicated by lower (0.35, 0.33, 0.32, 0.28 and 0.27 mg/kg, respectively) delta Zn contents. Overall Zn augmentation efficiency was in the order of $T_6>T_5=T_1>T_3>T_2>T_8>T_7>T_4$ amongst the treatments.

On the temporal scale available zinc content in soil was more conspicuous in the month of October (0.72 mg/kg) and February (0.49 mg/kg) owing to the fertilizer application. However the difference in zinc between the rhizosphere and away from the rhizosphere was significantly narrowed in the months of November (0.24 mg/kg), December (0.20 mg/kg) and January (0.28 mg/kg).

4.1.4 Available iron

Application of acid forming fertilizers showed significant effect on available Fe in the rhizosphere compared to the soils outside the regime of rhizosphere. The incremental Fe manifested in the rhizosphere owing to the localized application of acid forming fertilizers is depicted as delta Fe in Table 7. The delta Fe differed significantly amongst the treatments as well as on the temporal scale within the study period. The effect of augmentation of Fe was more prominent after the fertilizer application (45-60 days) which corresponds to the observations made during October and February months. Among the treatments application of ammonium sulphate + elemental sulphur (T_6) recorded significantly higher (9.71 mg/kg) delta Fe in the month of October which was followed urea+ elemental sulphur (T_5), urea (T_1), ammonium sulphate (T_2) and urea + elemental sulphur + chelated micronutrients (T_7) 7.96, 5.47, 3.47 and 3.08 mg/kg respectively. However treatment receiving ammonium sulphate + magnesium sulphate (T_4) as well as ammonium sulphate + elemental sulphur + chelated micronutrients (T_8) showed close range of delta Fe (2.50 and 2.29 mg/kg respectively). Further the treatment which received urea + magnesium sulphate (T_3) showed similar Fe in rhizosphere as well as in non rhizosphere soils as indicated by the least value of (0.73 mg/kg) delta Fe.

In general, available Fe in the rhizosphere was higher in the month of February due to top dressing application of nitrogen and phosphorous fertilizes in the month of December. Upon detailed observation the treatment receiving ammonium sulphate + elemental sulphur (T_6) showed significantly higher (5.14 mg/kg) delta Fe followed by application of Urea + magnesium sulphate (T_3) 4.68 mg/kg as well as ammonium sulphate (T_2) 3.56 mg/kg which was on par with treatment receiving urea (T_1) 3.55 mg/kg. However rest of all the treatments showed similar Fe in rhizosphere as well as in non rhizosphere soil.

The average delta iron over the month revealed very interesting features where the treatments receiving application of ammonium sulphate + elemental sulphur (T_6) showed higher (5.56 mg/kg) delta Fe throughout the experiment followed by treatments receiving ammonium sulphate (T_2) 3.06 mg/kg, urea + elemental sulphur (T_5) 3.03 mg/kg, urea (T_1) 2.34 mg/kg. However rest of the treatments (T_4, T_8, T_7 and T_3) showed

Table 6: Augmentation of zinc availability (ppm) with different fertilizers over temporal scale

Treatment details		**October**	**November**	**December**	**January**	**February**	**Treatment mean**
T_1	**Urea (N)**	0.87 (1.47)*	0.44 (1.07)	0.11 (0.59)	0.43 (0.57)	0.61 (0.78)	0.49
T_2	**Ammonium sulphate (N)**	0.58 (1.33)	0.09 (0.59)	0.22 (0.57)	0.40 (0.55)	0.10 (0.59)	0.33
T_3	**Urea (N) + Magnesium sulphate (500 g/plant)**	0.83 (1.56)	0.19 (0.49)	0.21 (0.52)	0.09 (0.25)	0.42 (0.62)	0.35
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	0.37 (1.15)	0.30 (0.65)	0.16 (0.49)	0.23 (0.54)	0.25 (0.47)	0.27
T_5	**Urea (N) + Elemental sulphur @ (100 g/plant)**	1.21 (1.95)	0.10 (0.97)	0.18 (0.53)	0.19 (0.34)	0.81 (0.99)	0.50
T_6	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant)**	1.05 (1.66)	0.47 (0.87)	0.48 (0.85)	0.47 (0.67)	0.55 (0.77)	0.61
T_7	**Urea (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	0.24 (1.13)	0.20 (0.63)	0.14 (0.55)	0.21 (0.38)	0.59 (0.79)	0.28
T_8	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	0.61 (1.31)	0.12 (0.51)	0.09 (0.43)	0.18 (0.32)	0.59 (0.77)	0.32
Month mean		0.72	0.24	0.20	0.28	0.49	0.39
		Treatments		**Months**		**Treatment x Months**	
S.Em±		0.01		0.01		0.04	
CD at 5%		0.05		0.04		0.12	
CV (%)		19.22					

***** Values in parenthesis depict rhizosphere zinc

Table 7: Augmentation of iron availability (ppm) with different fertilizers over temporal scale

Treatment details		**October**	**November**	**December**	**January**	**February**	**Treatment mean**
T_1	**Urea (N)**	5.47 (9.9)*	0.67 (5.35)	0.85 (4.63)	1.13 (3.30)	3.55 (5.88)	2.34
T_2	**Ammonium sulphate (N)**	3.47 (9.0)	2.10 (5.45)	2.33 (5.65)	3.82 (5.25)	3.56 (5.13)	3.06
T_3	**Urea (N) + Magnesium sulphate (500 g/plant)**	0.73 (6.8)	0.62 (5.19)	1.29 (4.92)	2.63 (4.63)	4.68 (6.88)	1.99
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	2.50 (6.8)	3.03 (5.61)	1.95 (4.36)	0.91 (3.05)	3.05 (5.33)	2.29
T_5	**Urea (N) + Elemental sulphur @ (100 g/plant)**	7.96 (11.2)	2.29 (5.79)	1.46 (4.42)	1.99 (4.33)	1.47 (4.12)	3.03
T_6	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant)**	9.71 (13.5)	6.25 (8.61)	2.99 (5.09)	2.19 (4.12)	5.14 (7.27)	5.56
T_7	**Urea (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	3.08 (6.8)	1.12 (5.09)	1.21 (4.95)	2.10 (3.77)	2.87 (4.73)	2.08
T_8	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	2.29 (5.8)	1.33 (3.93)	1.91 (5.03)	1.93 (3.56)	2.97 (4.87)	2.09
Month mean		4.40	2.18	1.75	2.09	3.41	2.76
		Treatments		**Months**		**Treatment x Months**	
S.Em±		0.12		0.09		0.27	
CD at 5%		0.34		0.27		0.76	
CV (%)		17.02					

* Values in parenthesis depict rhizosphere iron

similar Fe in rhizosphere as well as in non rhizosphere soil as indicated by lower (2.29, 2.09, 2.08 and 1.99 mg/kg, respectively) delta Fe contents. By and large Fe augmentation efficiency was in the order of $T_6>T_2\geq T_5>T_1>T_4>T_8>T_7>T_3$ amongst the treatments.

On the temporal scale higher available iron content in rhizosphere was more evident in the month of October (4.40 mg/kg) and February (3.41 mg/kg) owing to the fertilizer application in the preceding period. However the difference in iron between the rhizosphere and away from the rhizosphere was significantly narrowed in the months of November (2.18 mg/kg), December (1.75 mg/kg) and January (2.09 mg/kg).

4.1.5 Available copper

Application of acid forming fertilizers showed significant effect on available Cu in the rhizosphere compared to the soils outside the regime of rhizosphere. The incremental Cu manifested in the rhizosphere owing to the localized application of acid forming fertilizers is depicted as delta Cu in Table 8.The delta Cu differed significantly amongst the treatments as well as on the temporal scale within the study period. The effect of augmentation of Cu was more conspicuous immediately (45-60 days) after the fertilizer application which corresponds to the observations made during October and February months. Among the treatments, application of ammonium sulphate (T_2) as well as urea + elemental sulphur (T_5) recorded significantly higher (1.65 and 1.60 mg/kg respectively) delta Cu followed by urea + elemental sulphur + chelated micronutrients (T_7) 1.50 mg/kg, ammonium sulphate + elemental sulphur (T_6), ammonium sulphate elemental sulphur + chelated micronutrients (T_8) and urea (T_1) (1.46, 1.01 and 0.88 mg/kg, respectively) in the month of October. However rest of the treatments showed similar Cu in rhizosphere as well as in non rhizosphere soil as indicated by lower delta Cu contents.

In general, the incremental Cu manifested in the rhizosphere was higher in the month of February due to top dressing application of nitrogen and phosphorous fertilizes in the month of December. Upon detailed observation the treatments receiving urea + elemental sulphur + chelated micronutrients (T_7) recorded higher (0.95 mg/kg) delta Cu which was on par with treatment receiving urea + elemental sulphur (T_5) 0.93

Table 8: Augmentation of copper availability (ppm) with different fertilizer over temporal scale

Treatment details		**October**	**November**	**December**	**January**	**February**	**Treatment mean**
T_1	**Urea (N)**	0.88 (2.10)*	0.15 (1.53)	0.16 (1.29)	0.25 (1.20)	0.89 (1.93)	0.47
T_2	**Ammonium sulphate (N)**	1.65 (2.95)	0.17 (1.28)	0.27 (1.22)	0.37 (1.47)	0.73 (1.97)	0.64
T_3	**Urea (N) + Magnesium sulphate (500 g/plant)**	0.34 (1.85)	0.17 (1.27)	0.20 (1.10)	0.39 (1.24)	0.69 (1.69)	0.36
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	0.36 (1.69)	0.28 (1.51)	0.22 (1.21)	0.14 (1.19)	0.47 (1.63)	0.29
T_5	**Urea (N) + Elemental sulphur @ (100 g/plant)**	1.60 (2.78)	0.50 (1.55)	0.42 (1.35)	0.24 (1.15)	0.93 (1.89)	0.74
T_6	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant)**	1.46 (2.79)	1.95 (3.49)	0.80 (1.37)	0.45 (1.11)	0.81 (1.56)	1.09
T_7	**Urea (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	1.50 (2.08)	0.55 (1.41)	0.43 (1.19)	0.25 (1.17)	0.95 (2.03)	0.73
T_8	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	1.1 (2.21)	0.59 (1.97)	0.78 (2.02)	0.45 (1.63)	0.87 (1.91)	0.74
Month mean		1.10	0.54	0.41	0.31	0.79	0.63
		Treatments		**Months**		**Treatment x Months**	
S.Em±		0.03		0.02		0.06	
CD at 5%		0.08		0.06		0.18	
CV (%)		20.38					

***** Values in parenthesis depict rhizosphere copper mg/kg. Further, urea (T_1) 0.89 mg/kg, ammonium sulphate + elemental sulphur + Chelated micronutrients (T_8) 0.87 mg/kg and ammonium sulphate + elemental sulphur (T_6) 0.81 mg/kg revealed significantly lower delta Cu contents. However, rest of the treatments showed similar Cu in rhizosphere as well as in non rhizosphere soil as indicated by lower delta Cu contents.

The average delta copper over the month revealed very interesting features where the treatments receiving application of ammonium sulphate + elemental sulphur (T_6) showed higher (1.09 mg/kg) delta Cu throughout the experiment followed by treatments receiving urea + elemental sulphur (T_5) 0.74 mg/kg, ammonium sulphate + elemental sulphur + Chelated micronutrients (T_8) 0.74 mg/kg and urea + elemental sulphur + chelated micronutrients (T_7) 0.73 mg/kg. However rest of the treatments (T_2, T_1, T_3 and T_4) showed similar Cu in rhizosphere as well as in non rhizosphere soil as indicated by lower (0.47. 0.36, 0.29 and 0.29 mg/kg, respectively) delta Cu contents. On the whole Cu augmentation efficiency was in the order of $T_6>T_5=T_8>T_7>T_2>T_1>T_3\geq T_4$ amongst the treatments.

On the temporal scale available Cu content in soil was more conspicuously higher in the month of October (1.10 mg/kg) and February (0.79 mg/kg) owing to the fertilizer application. However the difference in copper between the rhizosphere and away from the rhizosphere was significantly and consistently narrowed in the months of November (0.54 mg/kg), December (0.41 mg/kg) and January (0.31 mg/kg) until February.

4.1.6 Available manganese

Application of acid forming fertilizers showed significant effect on available Mn in the rhizosphere compared to the soils outside the regime of rhizosphere. The incremental Mn manifested in the rhizosphere owing to the localized application of acid forming fertilizers is depicted as delta Mn in Table 9.The delta Mn differed significantly amongst the treatments as well as on the temporal scale within the study period. The effect of augmentation of Mn was more conspicuous immediately (45-60 days) after the fertilizer application which corresponds to the observations made during October and February months. Among the treatments application of ammonium sulphate + elemental sulphur (T_6) recorded significantly higher (40.36 mg/kg) delta Mn in the month of

October followed by treatments receiving urea + elemental sulphur (T_5) 34.42 mg/kg as well as urea (T_1) 20.51 mg/kg which was on par with treatments receiving urea + elemental sulphur + chelated micronutrients (T_7) 19.63 mg/kg. However rest of the treatments showed similar Mn in rhizosphere as well as in non rhizosphere soil as indicated by lower delta Mn contents.

In general, the incremental Mn manifested in the rhizosphere is higher in the month of February due to top dressing application of nitrogen and phosphorous fertilizes in the month of December. Upon detailed observation the treatments receiving ammonium sulphate + elemental sulphur (T_6), ammonium sulphate + elemental sulphur + chelated micronutrients (T_8) and urea + elemental sulphur + chelated micronutrients (T_7) recorded significantly higher (33.52, 32.43 and 32.10 mg/kg, respectively) delta Mn contents. Further application of ammonium sulphate + magnesium sulphate (T_4) 24.62 mg/kg, as well as ammonium sulphate (T_2) 18.55 mg/kg showed medium delta Mn value between rhizosphere soils as well as in non rhizosphere soil. However, rest of the treatments projected lower Mn availability in rhizosphere as indicated by lower delta Mn contents.

The average delta manganese over the month revealed very interesting features where the treatments receiving application of ammonium sulphate + elemental sulphur (T_6) showed higher (26.79 mg/kg) delta Mn throughout the experiment followed by treatments receiving ammonium sulphate + elemental sulphur + Chelated micronutrients (T_8) 18.84 mg/kg and urea + elemental sulphur + Chelated micronutrients (T_7) 17.55 mg/kg and urea + elemental sulphur (T_5) 16.12 mg/kg. However rest of the treatments (T_2, T_4, T_1 and T_3) showed similar Mn in rhizosphere as well as in non rhizosphere soil as indicated by lower (15.39, 14.33, 12.29 and 11.83 mg/kg, respectively) delta Mn contents. Largely, the Mn augmentation efficiency was in the order of $T_6>T_8>T_7>T_5>T_2>T_4>T_1>T_3$ amongst the treatments.

On the temporal scale available manganese content in soil was more conspicuous in the month of October (22.67 mg/kg) and February (23.48 mg/kg) owing to the fertilizer application. However the differences in manganese between the rhizosphere and away from the rhizosphere were significantly narrowed in the months of November (5.75 mg/kg), December (16.45 mg/kg) and January (14.86 mg/kg).

Table 9: Augmentation of manganese availability (ppm) with different fertilizer over temporal scale

Treatment details		October	November	December	January	February	Treatment mean
T_1	**Urea (N)**	20.51 (43.72)*	1.81 (20.07)	12.73 (29.41)	11.62 (29.41)	14.79 (33.63)	12.29
T_2	**Ammonium sulphate (N)**	19.03 (44.13)	11.81 (25.85)	16.31 (28.58)	11.25 (28.58)	18.55 (34.97)	15.39
T_3	**Urea (N) + Magnesium sulphate (500 g/plant)**	18.95 (41.83)	1.49 (18.75)	10.45 (26.27)	10.47 (26.27)	17.81 (33.00)	11.83
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	19.23 (40.63)	2.32 (20.16)	11.69 (28.07)	13.80 (28.07)	24.62 (38.52)	14.33
T_5	**Urea (N) + Elemental sulphur @ (100 g/plant)**	34.42 (52.95)	2.52 (19.10)	16.66 (31.70)	12.97 (31.70)	14.04 (31.37)	16.12
T_6	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant)**	40.36 (58.00)	20.12 (31.80)	21.99 (35.27)	17.97 (35.27)	33.52 (48.97)	26.79
T_7	**Urea (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	19.63 (37.38)	0.96 (22.50)	16.51 (35.23)	18.55 (35.23)	32.10 (46.02)	17.55
T_8	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	9.23 (29.45)	4.99 (19.07)	25.27 (37.67)	22.29 (37.67)	32.43 (47.77)	18.84
Month mean		22.67	5.75	16.45	14.86	23.48	16.69
		Treatments		**Months**		**Treatment x Months**	
S.Em±		0.64		0.51		1.45	
CD at 5%		1.82		1.44		4.08	
CV (%)		15.06					

***** Values in parenthesis depict rhizosphere manganese

4.1.7 Available boron

Application of acid forming fertilizers showed significant effect on available B in the rhizosphere compared to the soils outside the regime of rhizosphere. The incremental B manifested in the rhizosphere owing to the localized application of acid forming fertilizers is depicted as delta B in Table 10. In general, the metallic micronutrient availability is augmented by the combined action of rhizosphere as well as applied acid forming fertilizers. On the contrary, the rhizosphere works positively towards augmentation while the acid forming fertilizers work antagonistically with respect to B availability. However, there was net negative effect on augmentation of B immediately (45-60 days) after the fertilizer application which corresponds to the observations made during October and February months. Among the treatments application of urea (T_1), ammonium sulphate + elemental sulphur (T_6) as well as ammonium sulphate + elemental sulphur + chelated micronutrients (T_8) recorded significantly higher (0.016 mg/kg) delta B in the month of October which was on par with treatment receiving urea + elemental sulphur (T_5) 0.015 mg/kg. However application of urea + magnesium sulphate (T_3), ammonium sulphate + magnesium sulphate (T_4) as well as urea + elemental sulphur + chelated micronutrients (T_7) showed the least (0.013 mg/kg) delta B. The treatment which received ammonium sulphate (T_2) showed similar B in rhizosphere soil as well soil away from the rhizosphere as indicated by low (0.011mg/kg) delta B content.

The Boron availability showed entirely a different trend contrary to the metallic micronutrients. In general, there was decremented B manifestation in the rhizosphere in the month of February due to top dressing application of nitrogen and phosphorous fertilizes in the month of December. Upon detailed observation the treatments receiving urea (T_1) and urea + elemental sulphur + chelated micronutrients (T_7) recorded significantly higher (0.016 mg/kg, each) delta B contents. Further application of urea + magnesium sulphate (T_3) showed the least (0.003 mg/kg) delta B value between rhizosphere soils as well as in non rhizosphere soil.

The average delta boron over the month revealed very interesting features where the treatments receiving application of urea + magnesium sulphate (T_3) showed higher (0.038 mg/kg) delta B throughout the experiment followed by treatments

Table 10: Augmentation of boron availability (ppm) with different fertilizer over temporal scale

Treatment details		**October**	**November**	**December**	**January**	**February**	**Treatment mean**
T_1	**Urea (N)**	0.016 (0.038)*	0.015 (0.036)	0.038 (0.080)	0.023 (0.042)	0.016 (0.032)	0.027
T_2	**Ammonium sulphate (N)**	0.011 (0.036)	0.01 (0.035)	0.036 (0.074)	0.013 (0.041)	0.006 (0.030)	0.014
T_3	**Urea (N) + Magnesium sulphate (500 g/plant)**	0.013 (0.035)	0.014 (0.035)	0.136 (0.172)	0.016 (0.041)	0.003 (0.027)	0.038
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	0.013 (0.036)	0.013 (0.039)	0.013 (0.053)	0.013 (0.039)	0.007 (0.027)	0.016
T_5	**Urea (N) + Elemental sulphur @ (100 g/plant)**	0.015 (0.035)	0.016 (0.037)	0.043 (0.088)	0.013 (0.039)	0.006 (0.029)	0.024
T_6	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant)**	0.016 (0.031)	0.016 (0.030)	0.013 (0.058)	0.018 (0.039)	0.006 (0.029)	0.013
T_7	**Urea (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	0.013 (0.035)	0.016 (0.037)	0.033 (0.067)	0.013 (0.040)	0.016 (0.036)	0.024
T_8	**Ammonium sulphate (N) + Elemental sulphur @ (100 g/plant) + Chelated micronutrients @ (50 g/plant)**	0.016 (0.037)	0.013 (0.037)	0.053 (0.092)	0.013 (0.040)	0.006 (0.028)	0.022
Month mean		0.011	0.017	0.048	0.018	0.009	0.021
		Treatments		**Months**		**Treatment x Months**	
S.Em±		0.001		0.001		0.002	
CD at 5%		0.003		0.002		0.007	
CV (%)		20.10					

***** Values in parenthesis depict rhizosphere boron receiving urea (T_1) 0.027 mg/kg, urea + elemental sulphur (T_5) 0.024 mg/kg as well as urea + elemental sulphur + chelated micronutrients (T_7) 0.024 mg/kg. However rest of the treatments (T_8, T_4, T_2 and T_6) showed similar B in rhizosphere as well as in non rhizosphere soil as indicated by lower (0.022, 0.016, 0.014 and 0.013 mg/kg, respectively) delta B contents. Largely, the B availability was in the order of $T_3>T_1\geq T_5\geq T_7\geq T_8>T_4>T_2>T_6$ amongst the treatments.

On the temporal scale available boron content in soil was more conspicuously negative in the months of October (0.011mg/kg) and February (0.009 mg/kg) owing to the fertilizer application. However the differences in boron between the rhizosphere and away from the rhizosphere were significantly broadened in the months of November (0.017 mg/kg), December (0.048 mg/kg) and January (0.018 mg/kg).

4.2 Leaf nutrient content at 60 DAT

4.2.1 Leaf nitrogen content

The observations recorded on leaf nitrogen content at 60DAT are presented in Table 11. The data revealed that, the leaf nitrogen content varied from 0.98 to 1.57 per cent. The treatments differed significantly with respect to leaf N content. Amongst the treatments T_3 (urea + magnesium sulphate) recorded the highest (1.57%) leaf nitrogen content which was statistically on par with T_1 (urea) 1.29%, followed by T_2 (1.26%), T_4 (1.22%) and T_5 (1.22%). While, the treatment T_8 (ammonium sulphate + elemental sulphate + chelated micronutrients) showed the least (0.98%) nitrogen content.

4.2.2 Leaf phosphorous content

The observations recorded on leaf phosphorous content at 60 DAT showed that there was no significant difference among the treatments (Table 11). The results differed numerically among the treatments with minimum (0.17%) leaf phosphorous content in T_1 (urea) while the maximum (0.22%) was in T_6 (ammonium sulphate + elemental sulphur).

4.2.3 Leaf potassium content

Observations on leaf potassium content at 60 DAT (Table 11) revealed that, the treatments differed significantly and leaf potassium content varied from 1.46 to 1.91 per cent. Amongst the treatments T_3 (urea + magnesium sulphate) recorded the highest

Table 11: Nitrogen, phosphorous, potassium content in guava leaf

Treatment details		Nitrogen (%)	Phosphorous (%)	Potassium (%)
T_1	Urea (N)	1.29	0.17	1.64
T_2	Ammonium sulphate (N)	1.26	0.19	1.71
T_3	Urea (N) + Magnesium sulphate @ (500 g/plant)	1.57	0.18	1.91
T_4	Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)	1.22	0.20	1.61
T_5	Urea (N) + Elemental sulphur (100 g/plant)	1.22	0.21	1.90
T_6	Ammonium sulphate (N) + Elemental sulphur (100 g/plant)	1.05	0.22	1.72
T_7	Urea (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)	1.14	0.20	1.64
T_8	Ammonium sulphate (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)	0.98	0.19	1.46
Mean		1.22	0.19	1.70
S.Em±		0.10	0.01	0.06
CD at 5%		0.30	NS	0.19
CV (%)		14.47	11.64	6.64

Table 12: Calcium, Magnesium, Sulphur content in guava leaf

Treatment details		Calcium (%)	Magnesium (%)	Sulphur (%)
T_1	Urea (N)	1.59	0.87	0.09
T_2	Ammonium sulphate (N)	1.45	0.85	0.08
T_3	Urea (N) + Magnesium sulphate @ (500 g/plant)	1.22	0.96	0.11
T_4	Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)	1.40	0.78	0.08
T_5	Urea (N) + Elemental sulphur (100 g/plant)	1.52	0.85	0.12
T_6	Ammonium sulphate (N) + Elemental sulphur (100 g/plant)	1.38	1.00	0.14
T_7	Urea (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)	1.09	0.72	0.14
T_8	Ammonium sulphate (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)	1.25	1.03	0.13
Mean		1.36	0.88	0.11
S.Em±		0.10	0.08	0.01
CD at 5%		NS	NS	NS
CV (%)		13.30	15.77	25.31

(1.91%) leaf potassium content which was statistically on par with T_5 (1.90%), followed by T_6 (1.72%), T_2 (1.71%). While, the treatment T_4 (ammonium sulphate + magnesium sulphate) showed the least (1.61%) potassium content.

4.2.4 Leaf calcium content

The observations on leaf calcium content at 60 DAT showed that there was no significant difference among the treatments (Table 12). The results differed numerically among the treatments with minimum (1.09%) leaf calcium content observed in T_7 (urea + elemental sulphur + chelated micronutrients) and the maximum (1.59%) was in T_1 (urea).

4.2.5 Leaf magnesium content

The observations recorded on leaf magnesium content at 60 DAT showed that there was no significant difference among the treatments (Table 12). The results differed numerically among the treatments as minimum (0.72%) leaf magnesium content was observed in T_7 (urea + elemental sulphur + chelated micronutrients) while the maximum (1.03%) was in T_8 (ammonium sulphate + elemental sulphur + chelated micronutrients).

4.2.6 Leaf sulphur content

The observations recorded on leaf sulphur content at 60 DAT showed that there was no significant difference among the treatments (Table 12). The results differed numerically among the treatments as minimum (0.08%) leaf sulphur content was observed in T_4 (ammonium sulphate + magnesium sulphate) as well as T_6 (ammonium sulphate + elemental sulphur) and maximum (0.14%) was in addition to T_7 (urea + elemental sulphur + chelated micronutrients).

4.2.7 Leaf zinc content

The observations on leaf zinc content at 60 DAT showed that there was no significant difference among the treatments (Table 13). The results differed numerically among the treatments as minimum (20.00 ppm) zinc content in leaf was observed in T_7 (urea + elemental sulphur + chelated micronutrients) and maximum (30.67 ppm) was in T_1 (urea).

4.2.8 Leaf iron content

The data presented in Table 13 on leaf iron content at 60 DAT revealed significant variations amongst the treatments. The leaf iron content varied from 134.7 to 251.3 ppm. Amongst the treatments T_5 (urea + elemental sulphur) recorded significantly higher (251.3 ppm) leaf iron content which was superior over all other treatments. Later the trend followed was T_8 (180.0 ppm) which was on par which T_2 (172.0 ppm). While, the treatment T_1 (urea) showed the least (134.7 ppm) leaf iron content.

4.2.9 Leaf copper content

The leaf copper content at 60 DAT presented in Table 13 revealed that, the treatments differed significantly. The leaf copper contents varied from 10.67 to 22.67 ppm. Amongst the treatments T_5 (urea + elemental sulphur) recorded significantly higher (22.37 ppm) leaf copper content which was on par with T_3 (18.00 ppm), followed by T_6 (17.33 ppm), T_1 (16.00 ppm), T_2 (13.33). While treatments T_4 (ammonium sulphate + magnesium sulphate) 12.67 ppm as well as T_7 (urea + elemental sulphur + chelated micronutrients) 12.00 ppm depicted lower leaf copper contents.

4.2.10 Leaf manganese content

The data presented in Table 13 on leaf manganese content at 60 DAT revealed that, the treatments differed significantly. The leaf manganese content varied from 80.00 to 142.00 ppm. Amongst the treatments T_8 (ammonium sulphate + elemental sulphur + chelated micronutrients) recorded higher (142.00 ppm) leaf manganese which was significantly superior over all other treatments. Later a decreasing trend followed with T_5 (107.3 ppm) which was on par with T_6 (104.00 ppm), T_4 (100.00 ppm), T_1 (95.30 ppm) and T_3 (92.00 ppm). While, the treatment T_2 (ammonium sulphate) showed the least (80.00 ppm) leaf manganese content.

Table 13: Zinc, Iron, Copper, Manganese content in guava leaf

Treatment details		Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)
T_1	Urea (N)	30.67	134.67	16.00	95.3
T_2	Ammonium sulphate (N)	26.00	172.00	13.33	80.0
T_3	Urea (N) + Magnesium sulphate @ (500 g/plant)	27.33	149.33	18.00	92.0
T_4	Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)	26.00	146.00	12.67	100.0
T_5	Urea (N) + Elemental sulphur (100 g/plant)	30.00	251.33	22.67	107.3
T_6	Ammonium sulphate (N) + Elemental sulphur (100 g/plant)	26.00	140.67	17.33	104.0
T_7	Urea (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)	20.00	146.00	12.00	87.3
T_8	Ammonium sulphate (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)	24.00	180.00	10.67	142.0
Mean		26.25	165.00	15.33	101.0
S.Em±		3.11	13.87	1.55	9.49
CD at 5%		NS	42.07	4.70	28.81
CV (%)		20.57	14.56	17.51	16.28

4.3 Growth parameters

4.3.1 Shoot length (cm) at 30 Days after treatment imposition (DAT)

The observations recorded for shoot length at 30 DAT revealed that there was no significant difference among the treatments (Table 14). The results differed numerically among the treatments as minimum (32.5 cm) shoot length was observed in T_8 (ammonium sulphate + elemental sulphur + chelated micronutrients) and the maximum (48.9 cm) was in T_6 (ammonium sulphate + elemental sulphur).

4.3.2 Shoot length (cm) at 60 DAT

The observations recorded for shoot length at 60 DAT revealed that there was no significant difference among the treatments (Table 14). However, the T_7 (urea + elemental sulphur + chelated micronutrients) remained numerically superior (53.5 cm) among the treatments while the minimum (37.2 cm) shoot length was observed in T_4 (ammonium sulphate + magnesium sulphate).

4.3.3 Shoot length (cm) at 90 DAT

The observations recorded for shoot length at 90 DAT revealed that there was no significant difference amongst the treatments (Table 14). The results differ numerically among the treatments as minimum (46.3 cm) shoot length was observed in T_8 (ammonium sulphate + elemental sulphur + chelated micronutrients) and maximum (59.7 cm) was in T_7 (urea + elemental sulphur + chelated micronutrients).

4.3.4 Number of leaves at 30 DAT

The results on number of leaves per branches at 30 DAT revealed that there was no significant difference among the treatments (Table 14). The results differed numerically among the treatments as minimum (294.7) number of leaves per branches was observed in T_7 (urea + elemental sulphur + chelated micronutrients) and the maximum (501.3) was in T_1 (urea).

Table 14: Effect of different fertilizers on growth attributes of guava

Treatment details		**Shoot length (cm)**			**No. of leaves/branches**		
		30DAT	60DAT	90DAT	30DAT	60DAT	90DAT
T_1	**Urea (N)**	40.6	44.8	52.1	501.3	511.7	503.3
T_2	**Ammonium sulphate (N)**	43.9	41.3	51.3	365.3	369.7	353.3
T_3	**Urea (N) + Magnesium sulphate @ (500 g/plant)**	43.0	46.3	53.9	405.3	431.3	400.0
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	35.7	37.2	50.1	340.0	390.0	393.3
T_5	**Urea (N) + Elemental sulphur (100 g/plant)**	35.8	40.1	52.4	305.3	343.3	366.7
T_6	**Ammonium sulphate (N) + Elemental sulphur (100 g/plant)**	48.9	50.5	54.4	482.7	516.7	553.3
T_7	**Urea (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	45.3	53.5	59.7	294.7	300.0	294.3
T_8	**Ammonium sulphate (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	32.5	38.2	46.3	417.3	456.7	490.0
Mean		40.7	44.0	52.5	389.0	414.9	419.3
S. E.m ±		4.25	3.85	3.76	47.38	53.84	42.00
CD (p=0.05)		NS	NS	NS	NS	NS	NS
CV (%)		18.11	15.18	12.41	21.10	22.47	27.02

DAT – Days after treatment imposition

Table 15: Effect of different fertilizers on fruit drop and fruit volume of guava

Treatment details		Fruit drop (%)			Fruit volume (cc)		
		60DAT	90DAT	120DAT	60DAT	90DAT	120DAT
T_1	**Urea (N)**	11.11	10.22	4.60	118.7	122.2	132.2
T_2	**Ammonium sulphate (N)**	10.83	10.48	2.92	106.2	111.6	125.6
T_3	**Urea (N) + Magnesium sulphate @ (500 g/plant)**	14.88	14.12	7.80	102.4	113.5	122.3
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	18.15	14.63	9.22	97.4	115.7	123.9
T_5	**Urea (N) + Elemental sulphur (100 g/plant)**	18.75	14.07	12.67	83.9	99.3	104.8
T_6	**Ammonium sulphate (N) + Elemental sulphur (100 g/plant)**	19.57	18.49	12.39	80.3	95.5	106.5
T_7	**Urea (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	19.23	16.35	10.24	99.9	111.8	113.6
T_8	**Ammonium sulphate (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	14.92	16.87	12.11	92.8	102.4	122.7
Mean		15.93	14.40	8.99	97.70	108.98	118.95
S. E.m ±		2.19	1.76	1.12	11.39	12.69	17.58
CD (p=0.05)		NS	NS	3.42	NS	NS	NS
CV (%)		23.87	21.26	21.72	20.28	19.77	23.97

DAT – Days after treatment imposition

4.3.5 Number of leaves at 60 DAT

The results on number of leaves per branches at 60 DAT revealed that there was no significant difference among the treatments (Table 14). The results differ numerically among the treatments as minimum (300) number of leaves per branches was observed in T_7 (urea + elemental sulphur + chelated micronutrients) while the maximum (516.7) was in T_6 (ammonium sulphate + elemental sulphur).

4.3.6 Number of leaves at 90 DAT

The results on number of leaves per branches at 90 DAT didn't reveal any specific trend as there was no significant difference among the treatments (Table 14). The results differed numerically among the treatments with minimum (294.3) number of leaves per branches observed in T_7 (urea + elemental sulphur + chelated micronutrients) while the maximum (553.3) was in T_6 (ammonium sulphate + elemental sulphur).

4.3.7 Fruit drop per cent at 60 DAT

The results of fruit drop per cent at 60 DAT revealed that there was no significant difference among the treatments (Table 15). The results differ numerically among the treatments with minimum fruit drop (10.8 %) observed in T_2 (ammonium sulphate) while the maximum (19.5 %) was in T_6 (ammonium sulphate + elemental sulphur).

4.3.8 Fruit drop per cent at 90 DAT

The results of fruit drop per cent at 90 DAT indicated that there was no significant difference among the treatments (Table 15). The results differed numerically among the treatments with minimum (10.2 %) fruit drop observed in T_1 (urea) while the maximum was in T_6 (ammonium sulphate).

4.3.9 Fruit drop per cent at 120 DAT

The results of fruit drop per cent at 120 DAT revealed that there was significant difference among the treatments (Table 15). Among the treatments T_5 (urea + elemental sulphur) recorded significantly higher (12.67 %) fruit drop which was on par with T_6 (12.39 %), T_8 (12.11 %), T_7 (10.24 %), followed by T_4 (9.22 %), T_3 (7.80 %). While, treatment T_2 (ammonium sulphate) showed lowest (2.92 %) fruit drop.

4.3.10 Fruit volume (cc) at 60 DAT

The results of fruit volume at 60 DAT revealed that there was no significant difference among the treatments (Table 15). The results differed mere numerically among the treatments with minimum (80.3 cc) fruit volume observed in T_6 while the maximum was in T_1 (118.7 cc).

4.3.11 Fruit volume (cc) at 90 DAT

The results of fruit volume at 90 DAT revealed that there was no significant difference among the treatments (Table 15). The results differed numerically among the treatments with minimum (95.5 cc) fruit volume observed in T_6 (ammonium sulphate) and the maximum (122.2 cc) was in T_1 (urea).

4.3.12 Fruit volume (cc) at 120 DAT

The results of fruit volume at 120 DAT revealed that there was no significant difference among the treatments (Table 15). The results differed numerically among the treatments as minimum (104.8 cc) fruit volume was observed in T_5 (urea + elemental sulphur) and the maximum (132.2 cc) was in T_1 (urea).

4.4 SCMR (SPAD Chlorophyll Meter Readings) Values.

The SPAD observations collected during the month of October 2018 across different treatments are presented in Table 16. It was evident from the table that there was no significant difference among the treatments. The results differed numerically among the treatments with minimum (37.30) SPAD reading recorded in T6 (ammonium sulphate + elemental sulphur) while the maximum (42.08) was in T_8 (ammonium sulphate + elemental sulphur + chelated micronutrients). In the month of November too it was evident from the table that there was no significant difference among the treatments. The results differed numerically among the treatments as minimum (34.73) SPAD reading was recorded in T1 (urea) and maximum (37.44) was in T_4 (ammonium sulphate + magnesium sulphate). In the month of December too it was evident from the table that there was no significant difference among the treatments. The results differed numerically among the treatments as minimum (33.90) SPAD reading was recorded in T2 (ammonium sulphate) and maximum (37.81) was in T_3 (urea + magnesium sulphate).The SPAD meter reading for the month of January 2018 also showed that there was no significant difference among the treatments. The results differed numerically among the treatments as minimum (33.00) SPAD reading was recorded in T_6 (ammonium sulphate + elemental sulphur) and maximum (36.96) was in T_3 (urea + magnesium sulphate).Similarly, the data on SPAD meter reading which was recorded during the month of February also shown that there was no significant difference among the treatments. The results differed numerically among the treatments as minimum (33.19) SPAD reading was recorded in T1 (urea) and maximum (36.02) was in T_8 (ammonium sulphate + elemental sulphur + chelated micronutrients). In principal, the SPAD readings were in the order of $T_3>T_8>T_5>T_7>T_2>T_4>T_6>T_1$ amongst the treatments.

4.5 Guava yield parameters

4.5.1 Number of fruits per plant

The observations recorded on number of fruits per plant showed that there was significant difference among the treatments (Table 17). Number of fruits per plant varied from 100.83 to 162.50. Among the treatments T_2 (ammonium sulphate) recorded significantly higher (162.50) fruit per plant which was on par with T_1 (135.83), followed by T_3 (117.50), T_7 (108.33). While, treatment T_6 (ammonium sulphate + elemental sulphur) showed lowest (100.83) fruit per plant. Number of the fruits per plant were in the order of $T_2\overline{\ }T_1>T_3>T_7>T_4>T_5>T_8>T_6$ amongst the treatments.

4.5.2 Average fruit weight (g)

The data presented in Table 17 on average fruit weight revealed that, there were significant differences among the treatments. Average fruit weight varied from 74.72 to 95.51 g. Among the treatments T_2 (ammonium sulphate) recorded significantly higher (95.51 g) fruit weight which was on par with T_1 (92.59 g), T_3 (86.94 g), T_4 (85.50 g), followed by T_5 (84.76 g), T_7 (79.57 g). While, treatment T_6 (ammonium sulphate + elemental sulphur) recorded lowest (74.72 g) fruit weight. Average fruit weight were in the order of $T_2\overline{\ }T_1\overline{\ }T_3\overline{\ }T_4>T_5>T_7>T_8>T_6$ amongst the treatments.

Table 16: SPAD observation of guava orchard at monthly intervals

Treatment details		October	November	December	January	February	Treatment mean
T_1	**Urea (N)**	38.23	34.73	34.22	33.27	33.19	34.73
T_2	**Ammonium sulphate (N)**	38.63	37.27	35.84	33.65	34.65	36.01
T_3	**Urea (N) + Magnesium sulphate @ (500 g/plant)**	40.60	37.05	37.81	36.96	35.34	37.55
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	39.32	37.44	33.90	34.65	34.17	35.90
T_5	**Urea (N) + Elemental sulphur (100 g/plant)**	37.82	36.39	36.56	36.00	35.47	36.45
T_6	**Ammonium sulphate (N) + Sulphur (100 g/plant)**	37.30	35.82	34.29	33.00	35.98	35.28
T_7	**Urea (N) + Sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	40.03	36.78	34.06	34.02	35.82	36.14
T_8	**Ammonium sulphate (N) + Sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	42.08	35.62	35.63	34.66	36.02	36.80
Mean		39.25	36.39	35.29	34.53	35.08	36.11
S.Em±		1.55	0.81	1.29	0.85	1.37	-
CD at 5%		NS	NS	NS	NS	NS	-
CV (%)		6.86	3.85	6.33	4.27	6.78	-

Table 17: Effect of acid forming fertilizers on yield attributes of guava

Treatment details		**No. fruit per plant**	**Avg. fruit weight (g/plant)**	**Fruit yield (kg/plant)**
T_1	**Urea (N)**	135.83	92.59	11.43
T_2	**Ammonium sulphate (N)**	162.50	95.51	13.47
T_3	**Urea (N) + Magnesium sulphate @ (500 g/plant)**	117.50	86.94	9.89
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	105.83	85.50	9.39
T_5	**Urea (N) + Elemental sulphur (100 g/plant)**	105.83	84.76	9.05
T_6	**Ammonium sulphate (N) + Sulphur (100 g/plant)**	100.83	74.72	7.91
T_7	**Urea (N) + Sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	108.33	79.57	8.92
T_8	**Ammonium sulphate (N) + Sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	104.17	79.40	7.93
Mean		117.60	84.87	9.75
S.Em±		11.71	3.53	1.01
CD at 5%		33.88	10.72	3.06
CV (%)		16.45	7.21	17.97

4.5.3 Average fruit yield (kg/plant)

The observations recorded on fruit yield per plant showed that there was significant difference among the treatments (Table 17). Average fruit yield per plant varied from 13.47 to 7.91 kg/plant. Among the treatments T_2 (ammonium sulphate) recorded significantly higher (13.47 kg/plant) fruit yield which was on par with T_1 (11.43 kg/plant), followed by T_3 (9.89 kg/plant), T_4 (9.39 kg/plant), T_5 (9.05 kg/plant). While, treatment T_6 (ammonium sulphate + elemental sulphur) recorded lowest (7.91 kg/plant) fruit yield. Average fruit yield per plant were in the order of $T_2\overline{T}_1>T_3>T_4>T_5>T_7>T_8>T_6$ amongst the treatments.

4.6 Soil nutrient status after harvest

4.6.1 Soil organic carbon (SOC)

The SOC status of different treatments is presented in Table 18. The SOC values ranged from 1.11 to 1.70 per cent. Amongst the treatments T_5 (urea + elemental sulphur) recorded significantly higher (1.70%) soil organic carbon content which was statistically on par with T_3 (1.63%), followed by T_1 (1.42%), T_2 (1.40%). While the treatment T_7 (urea + elemental sulphur + chelated micronutrients) showed the lowest (1.11%) soil organic carbon content.

4.6.2 Available nitrogen in soil

Available nitrogen status of soil samples at harvest taken from different treatments are presented in Table 18. The available nitrogen values ranged from 357.50 to 434.86 kg/ha. Amongst the treatments T_1 (urea) recorded significantly higher (434.86 kg/ha) available nitrogen content which was statistically on par with T_5 (422.31 kg/ha), T_6 (409.79 kg/ha), T_4 (409.76), followed by T_8 (393.05 kg/ha), T_2 (390.95 kg/ha). However, the treatment T_3 (urea + magnesium sulphate) showed the lowest (357.50 kg/ha) available nitrogen contents in the soil.

4.6.3 Available phosphorous in soil

Available phosphorous status of soil samples at harvest taken from different treatments are presented in Table 18. The phosphorous values ranged from 31.93 to

50.02 kg/ha. Amongst the treatments T_7 (urea + elemental sulphur + chelated micronutrients) recorded significantly higher (50.02 kg/ha) available phosphorous which was superior over all other treatments followed by T_5 (38.23 kg/ha) which was statistically on par with T_8 (37.83 kg/ha), T_6 (34.53 kg/ha), T_2 (34.37 kg/ha). Conversely, the treatment T_3 (urea + magnesium sulphate) showed the least (31.93 kg/ha) available phosphorous content.

4.6.4 Available potassium in soil

Available potassium status of soils taken from different treatments is presented in Table 18. The available potassium ranged from 397.74 to 293.07 kg/ha. Amongst the treatments T1 (urea) recorded significantly higher (397.74 kg/ha) soil potassium content which was statistically on par with T_2 (389.4 kg/ha), T_6 (370.3 kg/ha) followed by T_5 (348.4 kg/ha), T_3 (340.3 kg/ha). However, the treatment T_8 (ammonium sulphate + elemental sulphur + chelated micronutrients) showed the least (236.41 kg/ha) available potassium content in the soils.

4.6.5 Available Calcium in soil

Available calcium status of soil at harvest taken from different treatments is presented in Table 19. The available calcium ranged from 11.04 to 15.15 cmol (p+) kg-1 soil. Amongst the treatments T_1 (urea) recorded significantly higher (15.15 cmol (p^+) kg^{-1} soil) available calcium content which was on par with T_7 (13.80 cmol (p^+) kg^{-1} soil), T_3 (13.45 cmol (p^+) kg^{-1} soil), T_4 (13.43 cmol (p^+) kg^{-1} soil) followed by T_5 (12.41 cmol (p^+) kg^{-1} soil), T_2 (12.14 cmol (p^+) kg^{-1} soil). On the contrary, the treatment T_6 (ammonium sulphate + elemental sulphur) showed the least (11.04 cmol (p^+) kg^{-1} soil) soil calcium content.

4.6.6 Available Magnesium in soil

Available magnesium status in soils at harvest from different treatments is presented in Table 19. The magnesium values ranged from5.81 to 10.16 cmol (p^+) kg^{-1} soil. Amongst the treatments T_3 (urea + magnesium sulphate) recorded significantly higher (10.16 cmol (p^+) kg^{-1} soil) soil magnesium content which was on par with T_8 (9.80 cmol (p^+) kg^{-1} soil), T_2 (9.00 cmol (p^+) kg^{-1} soil), T_1 (7.89 cmol (p^+) kg^{-1} soil)

Table 18: SOC, Nitrogen, phosphorous, potassium content in final soil samples

Treatment details		SOC (%)	Nitrogen (kg/ha)	Phosphorous (kg/ha)	Potassium (kg/ha)
T_1	**Urea (N)**	1.42	434.86	34.06	397.74
T_2	**Ammonium sulphate (N)**	1.40	390.95	34.37	389.49
T_3	**Urea (N) + Magnesium sulphate @ (500 g/plant)**	1.63	357.50	31.93	340.39
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	1.19	409.76	33.74	303.47
T_5	**Urea (N) + Elemental sulphur (100 g/plant)**	1.70	422.31	38.23	348.49
T_6	**Ammonium sulphate (N) + Elemental sulphur (100 g/plant)**	1.30	409.79	34.53	370.33
T_7	**Urea (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	1.11	401.40	50.02	294.22
T_8	**Ammonium sulphate (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	1.20	393.05	37.83	293.07
Mean		1.37	402.45	36.84	342.15
S.Em±		0.03	12.22	3.15	9.27
CD at 5%		0.10	37.06	9.56	28.13
CV (%)		4.23	5.25	14.82	4.69

Table 19: Calcium, Magnesium, sulphur and Sodium content in final soil samples

Treatment details		Calcium (cmol (p^+) kg^{-1} soil)	Magnesium (cmol (p^+) kg^{-1} soil)	Sulphur (ppm)	Sodium (cmol (p^+) kg^{-1} soil)
T_1	**Urea (N)**	15.15	7.89	0.11	0.64
T_2	**Ammonium sulphate (N)**	12.14	9.00	0.10	0.66
T_3	**Urea (N) + Magnesium sulphate @ (500 g/plant)**	13.45	10.16	0.10	0.69
T_4	**Ammonium sulphate (N) + Magnesium sulphate @ (500 g/plant)**	13.43	7.06	0.13	0.67
T_5	**Urea (N) + Elemental sulphur (100 g/plant)**	12.41	6.03	0.13	0.58
T_6	**Ammonium sulphate (N) + Elemental sulphur (100 g/plant)**	11.04	5.81	0.11	0.60
T_7	**Urea (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	13.80	6.61	0.15	0.56
T_8	**Ammonium sulphate (N) + Elemental sulphur (100 g/plant) + Chelated micronutrients (50 g/plant)**	11.72	9.80	0.13	0.67
Mean		12.89	7.80	0.12	0.64
S.Em±		0.65	0.79	0.02	0.05
CD at 5%		1.97	2.39	NS	NS
CV (%)		8.73	17.57	23.08	14.89

followed by T_4 (7.06 cmol (p^+) kg^{-1} soil), T_7 (6.61 cmol (p^+) kg^{-1} soil). While the treatment T_6 (ammonium sulphate + elemental sulphur) showed the least (5.81 cmol (p^+) kg^{-1} soil) soil magnesium content.

4.6.7 Available sulphur in soil

Available sulphur status of soil samples taken from different treatments is presented in Table 19. Treatments showed no significant difference but results differed numerically among the treatments. The minimum (0.10 ppm) sulphur content was observed in T_2 (ammonium sulphate) as well as T_3 (urea + magnesium sulphate) and the maximum (0.15 ppm) was in T_7 (urea + elemental sulphur + chelated micronutrients).

4.6.8 Available sodium in soil

Available sodium status of soil samples taken from different treatments are presented in Table 19. Treatments showed no significant difference but results differed numerically among the treatments as minimum (0.56 cmol (p^+) kg^{-1} soil) sodium content was observed in T_7 (urea + elemental sulphur + chelated micronutrients) and maximum (0.69 cmol (p^+) kg^{-1} soil) was in T_3 (urea + magnesium sulphate).

4.7 Correlation between soil and plant micronutrients

Simple correlations were worked out to deliberate the ternary relation between soil micronutrients and their uptake as influenced by soil reaction. In addition, the partial correlation between soil nutrients and plant uptake were also computed by masking the effect of soil reaction (Table 20). In the former case, the correlations revealed more rational outcomes and projected deeper understanding about the chemistry of metallic micronutrients. In general Fe (-0.84) and Mn (-0.79) were more influenced by the soil reaction, while Cu (-0.71) was intermediate in response to the change in soil reaction. However, Zn (-0.59) was least responsive to the changes in soil reaction as indicated by lower coefficients. Further, the correlations between soil-Zn versus plant Zn (0.57) as well as plant Cu (0.68) revealed higher values compared to those of Plant Fe (0.14) and plant Mn (0.07). On the contrary, soil boron availability was positively correlated (0.48) with soil reaction

In the later case when the effect of pH was masked to study the relation between plant nutrients concentration and its uptake interesting features emerged. In case of Zn a stronger correlation (0.76) was obtained when pH effect was masked compared to that of with soil pH (0.57). On the contrary, in case of Fe a negative (-0.02) correlation was observed when the relations were probed by considering the pH while a positive (0.35) correlations were recorded by masking the soil reaction effect. Copper was more sceptical as its uptake was largely dependent on soil reaction as indicated by higher (0.31) correlation coefficients with pH compared to that of muting the effect of soil reaction (0.24). Manganese uptake was little influenced by soil pH as indicated by narrow difference (0.32 to 0.39) in correlation coefficients in the two separate cases.

4.8 Correlations between assimilated nutrients, growth and yield attributes

An attempt was made to compute simple correlations involving soil pH, leaf nutrients, growth and yield attributes. Similarly these variables were partially correlated without considering the soil reaction. Most of the nutrients didn’t show any specific correlations on the growth and yield attributes. Only the significant correlation coefficients and their possible trends with yield is made available in Table 21. Plant Zn was having positive significant correlation with plant calcium (0.86) and average fruit weight (0.82). It was well supported by the correlations without considering the soil pH where identical values recorded for plant Ca and average fruit weight. It was quite evident that Cu was significantly correlated to plant potassium content (0.85). Finally calcium was positively correlated with average fruit weight (0.79).

Table 20: correlation between soil and plant micronutrients

	Soil Zn	**Soil Zn without pH**	**Soil Fe**	**Soil Fe without pH**	**Soil Cu**	**Soil Cu without pH**	**Soil Mn**	**Soil Mn without pH**	**Soil B**	**Soil B without pH**
Soil Zn	1.00	1.00	0.77	0.63	0.74	0.57	0.49	0.05	0.09	0.52
Soil Fe	0.77	0.63	1.00	1.00	0.83	0.63	0.82	0.47	-0.53	-0.27
Soil Cu	0.74	0.57	0.83	0.63	1.00	1.00	0.79	0.53	-0.40	-0.11
Soil Mn	0.49	0.05	0.82	0.47	0.79	0.53	1.00	1.00	-0.59	-0.39
Soil B	0.09	0.52	-0.53	-0.27	-0.40	-0.11	-0.59	-0.39	1.00	1.00
Plant Zn	0.57	0.76	0.12	0.35	0.19	0.35	-0.35	-0.47	0.40	0.41
Plant Fe	0.14	0.37	-0.02	0.35	0.30	0.68	-0.03	0.29	-0.07	-0.22
Plant Cu	0.68	0.71	0.34	0.32	0.31	0.24	-0.03	-0.32	0.20	0.35
Plant Mn	0.07	0.01	-0.003	-0.23	0.40	0.46	0.32	0.39	0.00	0.06
Plant B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
pH	-0.59		-0.84		-0.71		-0.79		0.48	

Significant at the 0.75 level

Table 21: Correlations between assimilated nutrients, growth and yield attributes

	Plant zinc	**Zinc without pH**	**Plant Copper**	**Copper without pH**	**Plant Calcium**	**Calcium without pH**	**Number of fruits**	**Number of fruits without pH**
Plant Calcium	0.86**	0.86*	0.46	0.50	1	1	0.44	0.42
Average fruit weight	0.82**	0.82*	0.34	0.35	0.79**	0.79*	0.57	0.59
Plant potassium	0.42	0.44	0.85**	0.85*	0.16	0.19	0.08	0.14
Fruit yield	0.31	0.31	0.04	-0.65	0.44	0.42	0.97**	0.97*
pH	0.08		-0.20		0.14		0.32	

** Significant at the 0.01 level, * significant at the 0.05 level

5. DISCUSSION

Solubilisation and consecutively rendering metallic micronutrients available to the plants appears to be a tough task in the alkaline soils. For this crop plants have innate mechanism to acidify the rhizosphere through exudation of hydronium ions in exchange with cationic nutrients. This mechanism enables relative acidification of the rhizosphere which enhances the metal ion solubility and renders it available for the plants. In this context, application of acid forming fertilizers seems to be of vital importance to augment the metallic micronutrients availability to the plants. The results pertaining to various soil fertility attributes as influenced by the application of different acid forming fertilizers which is presented in the previous chapter are discussed in this section.

5.1 Soil fertility attributes

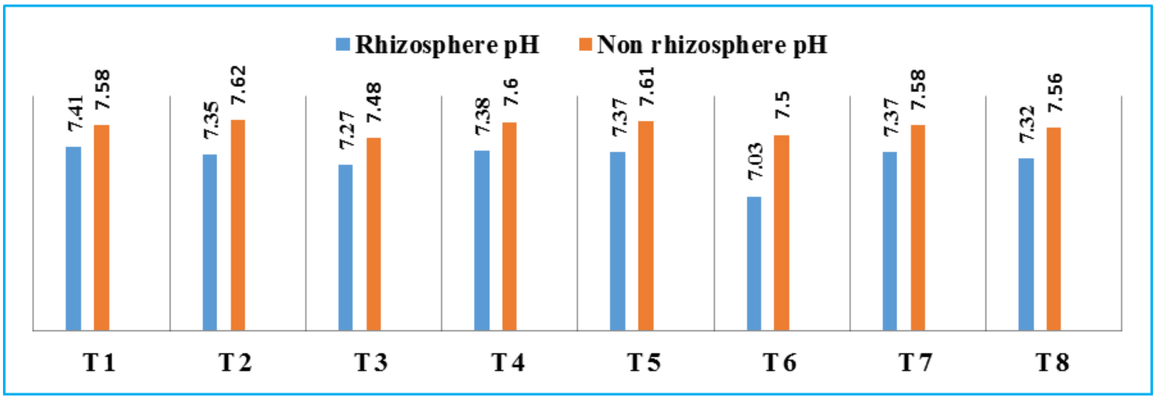
5.1.1 Soil reaction

The delta pH varied significantly amongst treatments both micro-spatially as well as on the temporal scale within the stipulated time of the observation. The effect of reduction in pH was more conspicuous after the fertilizer application (45-60 days). This period corresponded to the observations made during October and February months during the schedule of the study. The variations in the soil pH may be attributed to the localized application of acid forming fertilizers besides the inherent capacity of the crop plants to maintain acidic environment in the rhizosphere (Fig.1). Earlier works of Belay *et al*. (2002) where reduction in pH associated with application of nitrogenous fertilizers corroborated the present results. The effect of manifestation of soil acidity could not be observed immediately after the fertilizer application. It requires adequate time for hydrolysis, dissolution and nitrification to occur which was around 45-60 days in the present study. Further, a long lasting effect on manifestation soil reaction could not be expected as the entire gamut depends on the quantum of fertilizers applied. This very fertilizer would be exhausted by crop uptake and the soil reaction tends to revert to the previous situation. However, this miniscule transformation for a short period would enhance the micronutrient solubility and in turn availability to the crop plants.

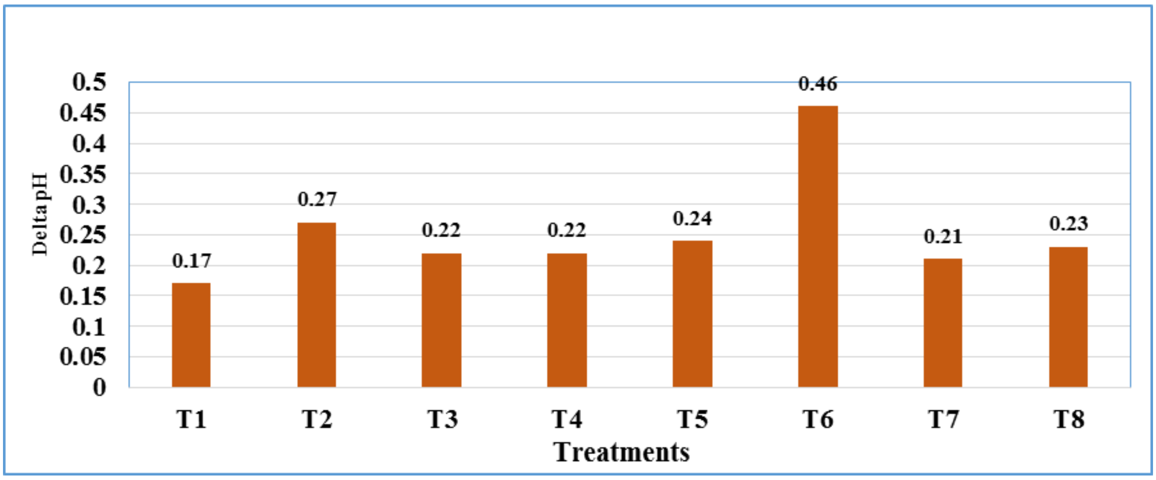
No doubt the urea (T_1) was effective in reducing the rhizosphere pH, however when it was combined with magnesium sulphate (T_3) and elemental sulphur (T_5) the effect was more prominent. Urea containing nitrogen in the amide form would be consequently converted in to ammonium and nitrate forms. Ammonium-based fertilizers will acidify soil as they generate two H^+ ions for each ammonium molecule nitrified to nitrate. The extent of acidification depends on whether the nitrate produced from ammonium is leached or is taken up by plants. If nitrate is taken up by plants the net acidification per molecule of ammonium is halved compared to the scenario when nitrate is leached. This is due to the consumption of one H^+ ion (or excretion of OH^-) for each molecule of nitrate taken up this is often observed as pH increases in the rhizosphere (Smiley and Cook, 1973). Elemental sulphur oxidized by soil bacteria to create sulphuric acid, which certainly lowers soil pH (McCauley *et al.,* 2009).Thus elemental sulphur applied along with urea reduced the rhizosphere pH more prominently in the present study. As such magnesium sulphate being a neutral salt doesn’t affect the soil reaction. However, the effect of higher magnesium in knocking down the sodium ion responsible for alkalinity cannot be undermined. As a result, the treatment which received magnesium sulphate along with urea resulted in lower rhizosphere pH compared to the treatment which received only urea.

As such ammonium sulphate was more efficient compared to urea in acidulating the rhizosphere soils in the current study.Earlier works of Malhi *et al.* (2008) where reported that higher soil acidification was shown with application of ammonium sulphate followed by urea stood testimony for the present results. As far as urea and ammonium sulphate are concerned the calcium carbonate equivalent (CCE) acidity created in the soil would be to the tune of 82 and 93 kg, respectively per 100 kg of fertilizers applied to the soil (Fageria *et al*., 1989). Further, the treatments which received magnesium sulphate and elemental sulphur along with ammonium sulphate resulted in marked reduction of pH in the rhizosphere (Fig. 1). This phenomenon is attributed to oxidation of elemental sulphur to sulphuric acid besides magnesium eliminating the sodium responsible for alkaline soil reaction.

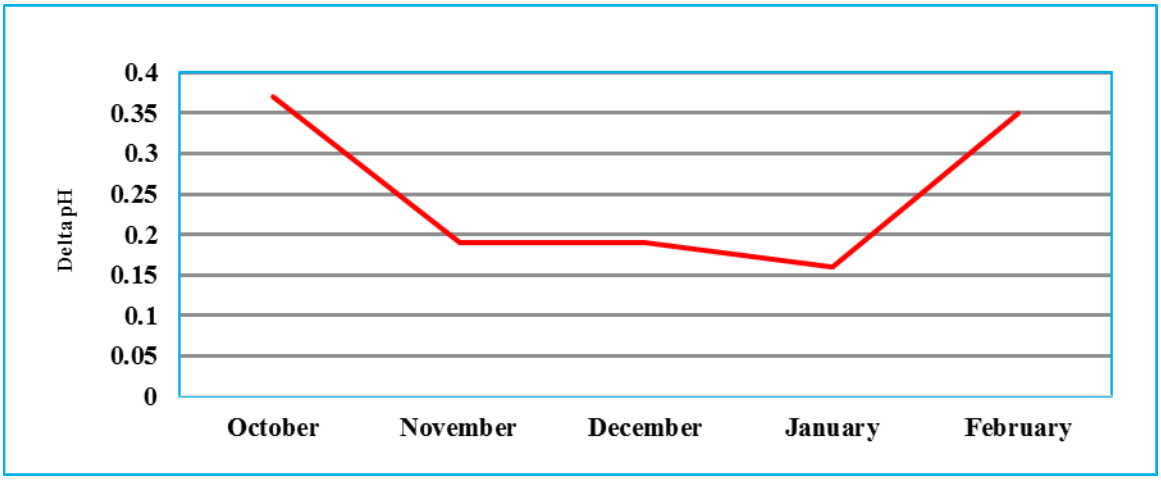
Further, in the treatments where ammonium sulphate was applied along with elemental sulphur and chelated micronutrients (T_8) revealed lower pH in the rhizosphere compared to that which received these supplements along with urea (T_7). This is owing



A. Comparison of rhizosphere and non rhizosphere soil reaction

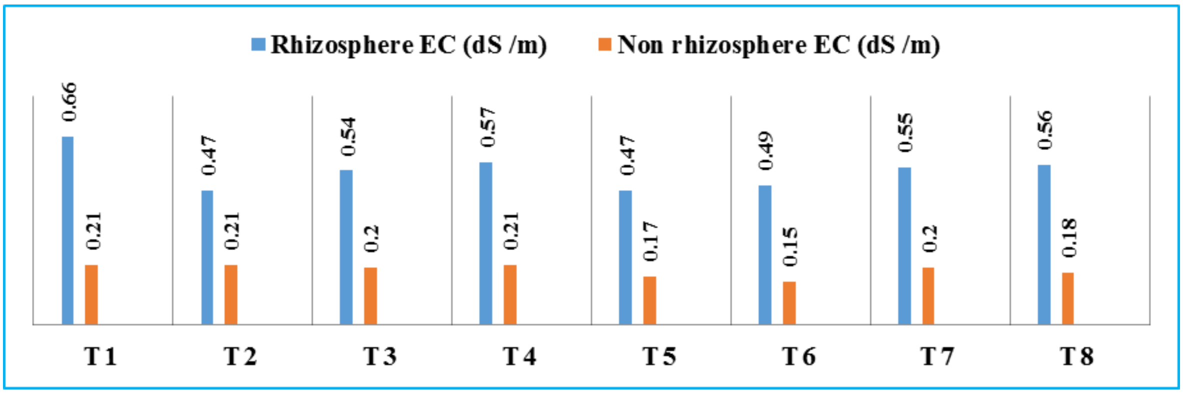


B. Reduction of soil pH in rhizosphere as influenced by different fertilizers

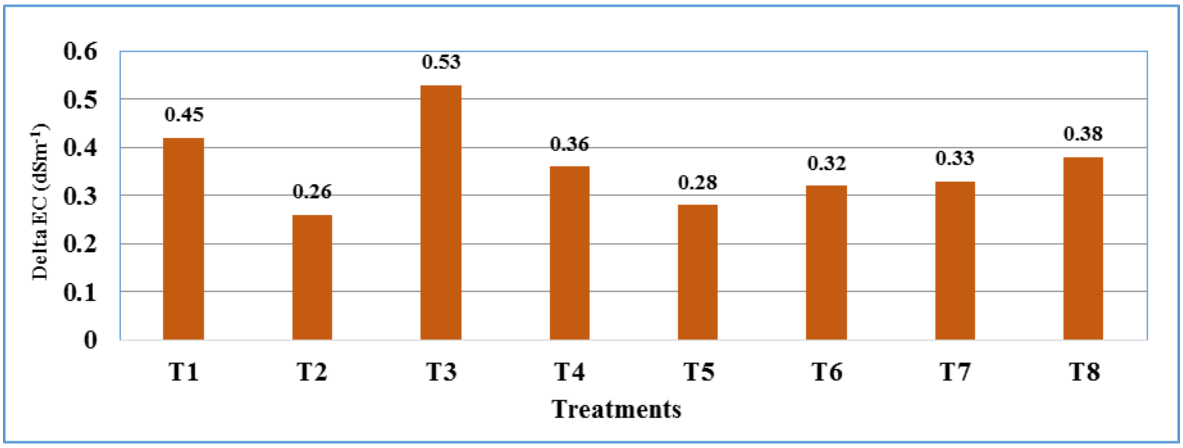


C. Temporal variation of soil pH as influenced by different fertilizers

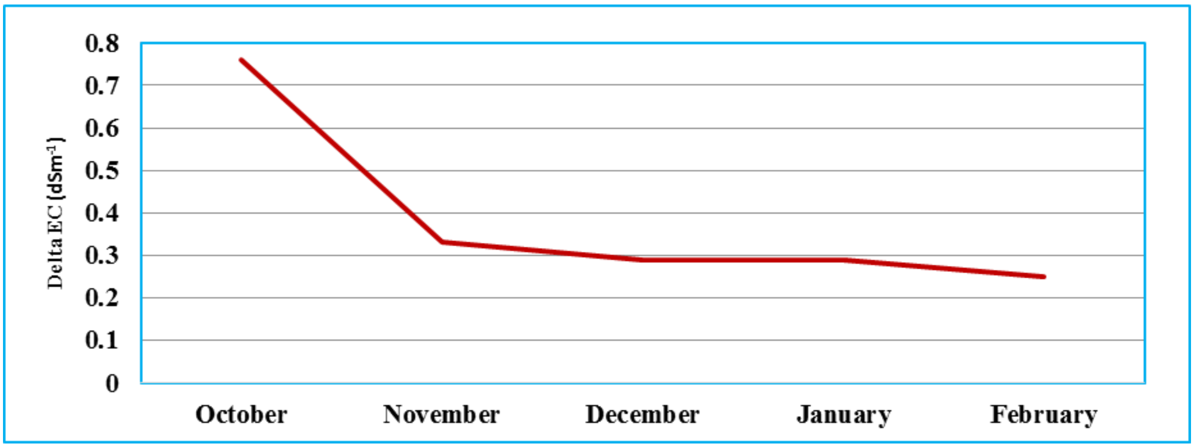
Fig 1.Variation in Soil pH as influenced by different fertilizers



A. Comparison of rhizosphere and non rhizosphere electrical conductivity



B. Variation in electrical conductivity as influenced by different fertilizers



C. Temporal variation in electrical conductivity as influenced by different fertilizers

Fig 2.Variation in electrical conductivity as influenced by different fertilizers to higher CCE possessed by ammonium sulphate compared to urea besides oxidation of elemental sulphur in the soil.

On the temporal scale, the reduction in rhizosphere soil pH was more conspicuous in the months of October and February owing to the fertilizer application. This was quite obvious the reduction in pH was associated with hydrolysis, dissolution and nitrification of applied fertilizers (Fageria *et al.*, 2010). However, the difference in pH between rhizosphere and away from the rhizosphere was significantly and consistently narrowed in the months of November, December and January (Fig. 1C). This owes to the fact that upon nitrification nitrates are assimilated into the plant system by exuding hydroxyl ions which tends to narrow down the pH difference between rhizosphere and the control.

5.1.2 Electric conductivity

In the present study the salinity level recorded in rhizosphere as well as in the soils away from the rhizosphere remained far below than the threshold limit as such the treatments did not have any significant effect on soil salinity. However salt accumulation was relatively higher in rhizosphere compared to soil away from the rhizosphere. This is rather apparent that the nutrients moved towards the rhizosphere owing to transpiration pull, mass flow and diffusion. Amongst the treatments, the different source of nitrogen fertilizer did not reveal the significant changes in the salt flux in rhizosphere (Fig. 2). It is apparently dependent on the quantum of fertilizers applied to the plant which was invariably of lower magnitude. The significantly higher temporal variation in the month of October compared to rest of the period might be due to fertilizer application as well as nutrient flux **(**Bryla *et al*., 2010). Further, gradual reduction in electric conductivity in the subsequent months could be related to the nutrient uptake which was common phenomenon in all the treatments (Fig. 2C)**.**

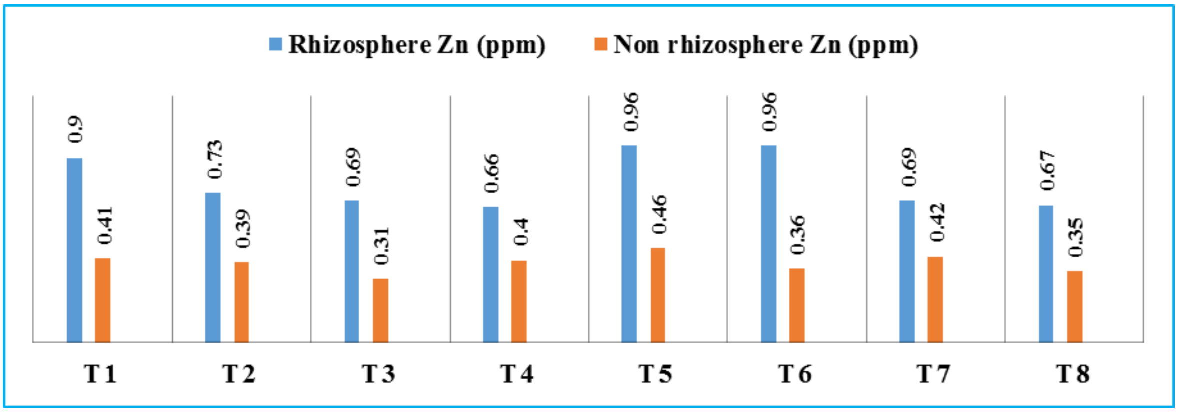
5.1.3. Available zinc

One of the prerequisites for Zn solubilisation would be acidic soil reaction which was accomplished with the application of acid forming fertilizers in general and ammonium sulphate in particular. Ammonium sulphate was more efficient compared to urea in augmenting the plant available Zn in the rhizosphere soils. It resulted in relatively more acidic environment owing to the trait of higher CCE possessed by ammonium sulphate than Urea (Fageria *et al.,* 1989). Relatively acidic environment enhances the metallic ion solubility and in turn its availability to the crop plants. Further, the treatments which received magnesium sulphate and elemental sulphur along with ammonium sulphate resulted in marked increment of available Zn in the rhizosphere (Fig. 3). Oxidation of sulphur to sulphuric acid besides magnesium eliminating the sodium resulted in higher acidic reaction which consequently enhanced the Zn availability (Karimizarchi *et al*., 2014).

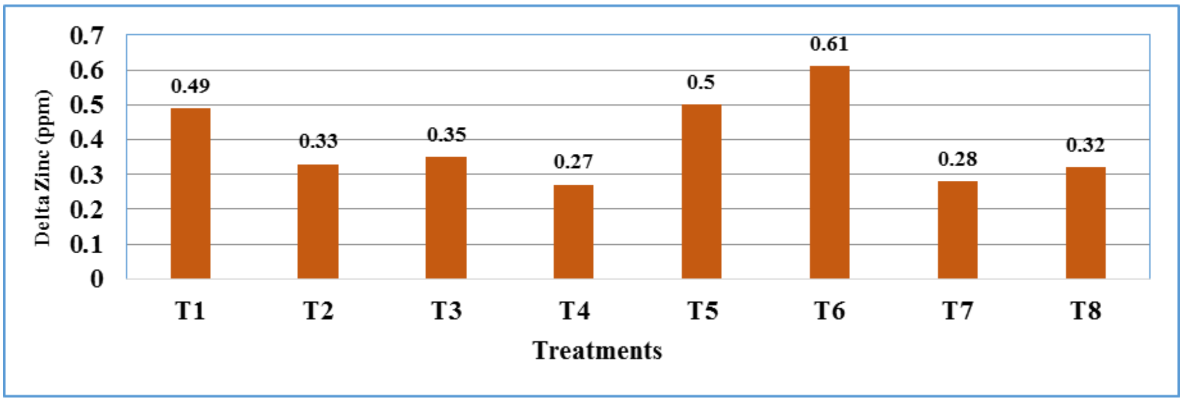
Urea (T_1) was obviously next effective to ammonium sulphate in augmenting the available Zn in the rhizosphere soils. Mir *et al.* (2013) reported that application of urea, single super phosphate and muriate of potash showed maximum zinc. However when it was combined with elemental sulphur (T_5) the effect was more prominent as far as augmentation of Zn is concerned. Earlier works of Karimizarchi *et al.* (2014) reported that application of elemental sulphur significantly increases the Zn by 0.91 per cent. This can be attributed oxidation of sulphur which paves way for further acidification and resultant augmentation of Zn availability. Previous works of Cui *et al.* (2004) indicating hiked available Zn through sulphur application in Indian mustard was a testimonial for the current study. On the contrary, urea blended with magnesium sulphate (T_3) resulted in lower Zn augmentation. This is owing to the fact that Magnesium sulphate (Epsom) would be neutral in reaction and its contribution towards augmentation of Zn would be negligible.

Further, in the treatments where ammonium sulphate was applied along with elemental sulphur and chelated micronutrients (T_8) revealed higher Zn in the rhizosphere compared to that which received these supplements along with urea (T_7). This is owing to higher CCE possessed by ammonium sulphate compared to urea besides oxidation of elemental sulphur in the soil which contributes for the incremental soil acidity. Similar work of Chien *et al.* (2011) stating that ammonium sulphate induced higher acidity than urea and ammonium nitrate in rhizosphere through nitrification thus improves the uptake of zinc in soil confirmed the present results.

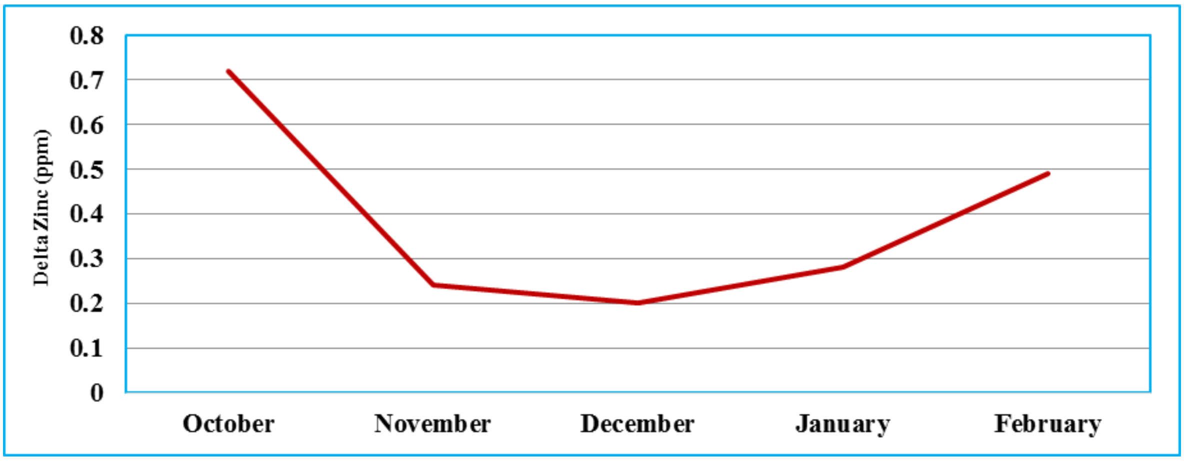
On the temporal scale, availability of soil zinc was more conspicuous in the months of October and February owing to the fertilizer application. Similar works of



A. Comparison of available zinc in rhizosphere and non rhizosphere regimes



B. Augmentation of available zinc as influenced by different fertilizers



C. Temporal variation in augmentation of zinc as influenced by different fertilizers

Fig 3.Variation in available zinc as influenced by different fertilizers

Rengel (2000) stating that application of acid forming fertilizer owing to exudation of H^+ ions can lower the pH of alkaline soils and increases micronutrient availability. However, the difference in available zinc between rhizosphere and away from the rhizosphere was significantly and consistently narrowed in the months of November, December and January (Fig. 3C).

5.1.4. Available iron

Iron solubilisation was more favoured in acidic soil reaction which was accomplished with the application of acid forming fertilizers in general and ammonium sulphate in particular. Ammonium sulphate was more efficient compared to urea in augmenting the plant available Fe in the rhizosphere soils. It resulted in relatively more acidic environment owing to the trait of higher CCE possessed by ammonium sulphate than Urea (Fageria *et al.*, 1989). Relatively acidic environment enhances the metallic ion solubility and in turn its availability to the crop plants. Further, the treatments which received magnesium sulphate and elemental sulphur along with ammonium sulphate resulted in marked increment of available Fe in the rhizosphere (Fig. 4). Oxidation of sulphur to sulphuric acid (Nor and Tabatabai, 1977) besides magnesium eliminating the sodium resulted in higher acidic reaction which subsequently enhanced the Fe availability.

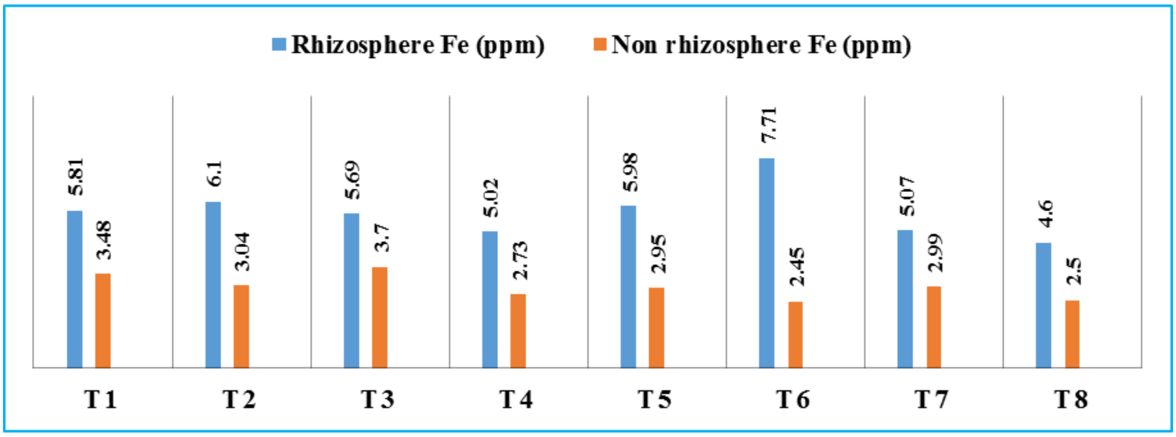
Urea (T_1) was obviously next best choice after ammonium sulphate in augmenting the available Fe in the rhizosphere soils. Previous works of Fageria *et al.* (2010) reported that application of ammonium, sulphate could reduce the pH by 12 percent where urea by 4 percent in rice cultivated land there by increased the micronutrients availability. However when it was combined with elemental sulphur (T_5) the effect was more prominent as far as augmentation of Fe is concerned. Similar works of Modaish *et al.* (1989) stating that application of elemental sulphur reduced the soil pH thereby significantly increased DTPA extractable iron. This can be attributed oxidation of sulphur which support for further acidification and resultant augmentation of Fe availability. On the contrary, Urea blended with magnesium sulphate (T_3) resulted in lower Fe augmentation. This is owing to the fact that Magnesium sulphate (Epsom) would be neutral in reaction and its contribution towards augmentation of Fe would be negligible. Similar works of Oliveria *et al.* (2000) stated that application of magnesium sulphate to Ultisol made pH to approach neutral condition.

Further, in the treatments where ammonium sulphate was applied along with elemental sulphur and chelated micronutrients (T_8) revealed higher Fe in the rhizosphere compared to that which received these supplements along with urea (T_7).This was owing to higher CCE possessed by ammonium sulphate compared to urea besides oxidation of elemental sulphur in the soil which contributes for the incremental soil acidity. Similar works of Chien *et al.* (2011) stating that urea as well as ammonium sulphate induced higher acidity by producing H^+ions in rhizosphere through nitrification by producing the H^+ions thus improved the uptake of metallic micronutrients in general and Zn in particular and confirmed the present results.

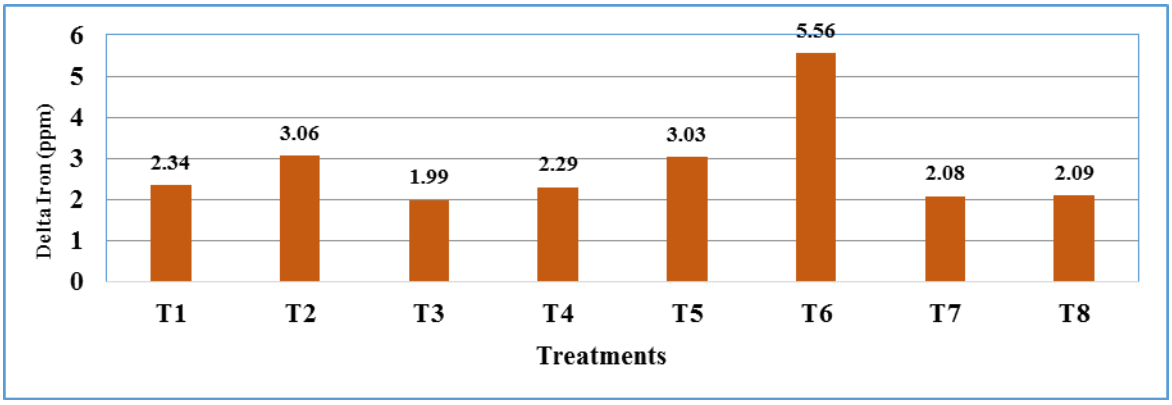
On the temporal scale, availability of soil iron was more conspicuous in the months of October and February owing to the fertilizer application. Similar works of Rengel (2000) stating that application of acid forming fertilizer owing to exudation of H^+ ions can lower the pH of alkaline soils and increases micronutrient availability. However, the difference in available iron between rhizosphere and away from the rhizosphere was significantly and consistently narrowed in the months of November, December and January (Fig. 4C).

5.1.5. Available copper

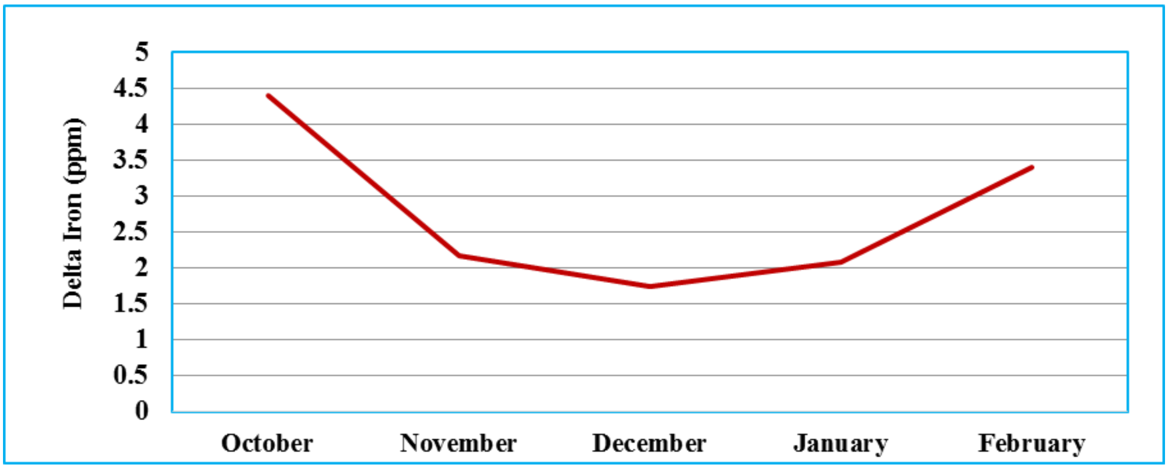
In general enhanced Cu solubilisation would be achieved with acidic soil reaction which was accomplished with the application of acid forming fertilizers in general and ammonium sulphate in particular. Ammonium sulphate was more efficient compared to urea in augmenting the plant available Cu in the rhizosphere soils. It resulted in relatively more acidic environment owing to the trait of higher CCE possessed by ammonium sulphate than Urea (Fageria *et al.*, 1989). Relatively acidic environment enhances the metallic ion solubility and in turn its availability to the crop plants. Further, the treatments which received magnesium sulphate and elemental sulphur along with ammonium sulphate resulted in marked increment of available Cu in the rhizosphere (Fig. 5). Oxidation of sulphur to sulphuric acid (Nor and Tabatabai, 1977) besides magnesium eliminating the sodium resulted in higher acidic reaction which consequently enhanced the Cu availability.



A. Comparison of available iron in rhizosphere and non rhizosphere regimes

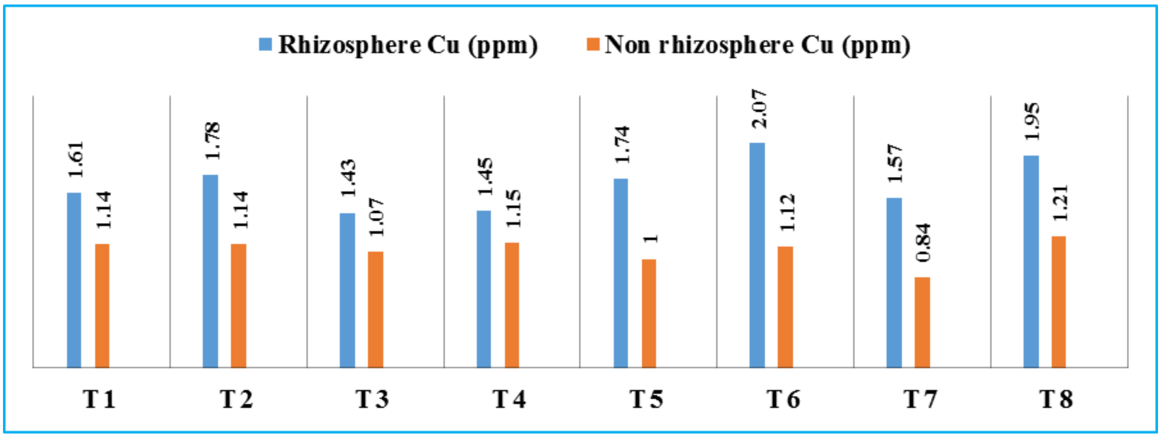


B. Augmentation of available iron as influenced by different fertilizers

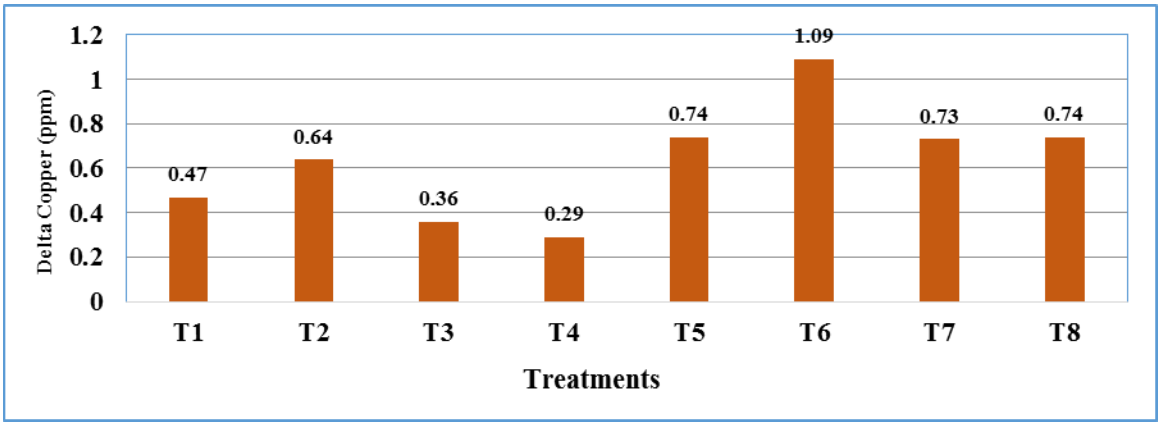


C. Temporal variation in augmentation of iron as influenced by acid forming fertilizers

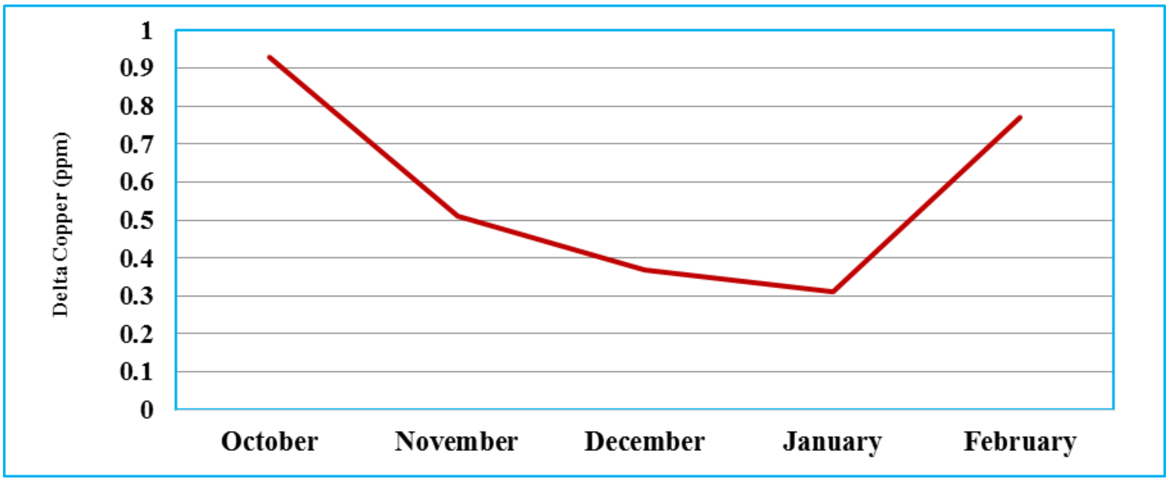
Fig 4.Variation in available iron as influenced by different fertilizers



A. Comparison of available copper in rhizosphere and non rhizosphere regimes



B. Augmentation of available copper as influenced by different fertilizers



C. Temporal variation in augmentation of copper as influenced by acid forming fertilizers

Fig 5.Variation in available copper as influenced by different fertilizers

Urea (T_1) was obviously next effective to ammonium sulphate in augmenting the available Cu in the rhizosphere soils. Works of the predecessor (Fageria *et al*., 2010) revealed that application of ammonium sulphate could reduce the pH by 12 percent where urea by 4 percent in rice cultivated land there by increased the micronutrients availability. However when it was combined with elemental sulphur (T_5) the effect was more prominent as far as augmentation of Cu is concerned. Similar works of Modaish *et al.* (1989) stating that application of elemental sulphur reduce the soil pH there by significantly increases DTPA extractable copper. This can be attributed oxidation of sulphur which paves way for further acidification and resultant augmentation of Cu availability. On the contrary, Urea blended with magnesium sulphate (T_3) resulted in lower Cu augmentation. This is owing to the fact that Magnesium sulphate (Epsom) would be neutral in reaction and its contribution towards augmentation of Mn would be negligible. Similar works of Oliveria *et al.* (2000) stated that application of magnesium sulphate to Ultisol made pH to approach neutral condition.

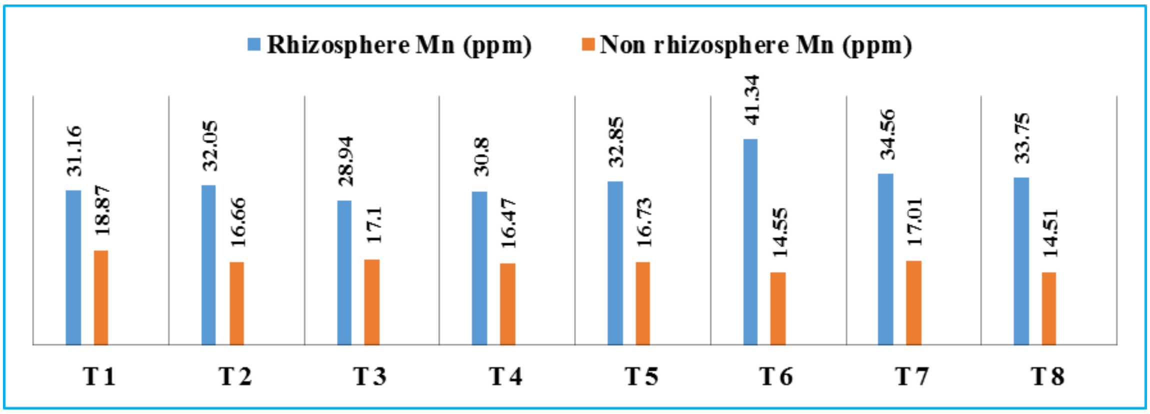
Further, in the treatments where ammonium sulphate was applied along with elemental sulphur and chelated micronutrients (T_8) revealed higher Cu in the rhizosphere compared to that which received these supplements along with urea (T_7).This is owing to higher CCE possessed by ammonium sulphate compared to urea besides oxidation of elemental sulphur in the soil which contributes for the incremental soil acidity. Similar works of Hemingway (1962) stating that application of ammonium sulphate increased the amounts of copper by 50 per cent, manganese and iron and reduced the levels of molybdenum in all years and at each time of sampling in grasses land.

On the temporal scale, availability of soil copper was more conspicuous in the months of October and February owing to the fertilizer application. Similar works of Rengel (2000) stating that application of acid forming fertilizer owing to exudation of H^+ ions can lower the pH of alkaline soils and increases micronutrient availability. However, the difference in available copper between rhizosphere and away from the rhizosphere was significantly and consistently narrowed in the months of November, December and January (Fig. 5C).

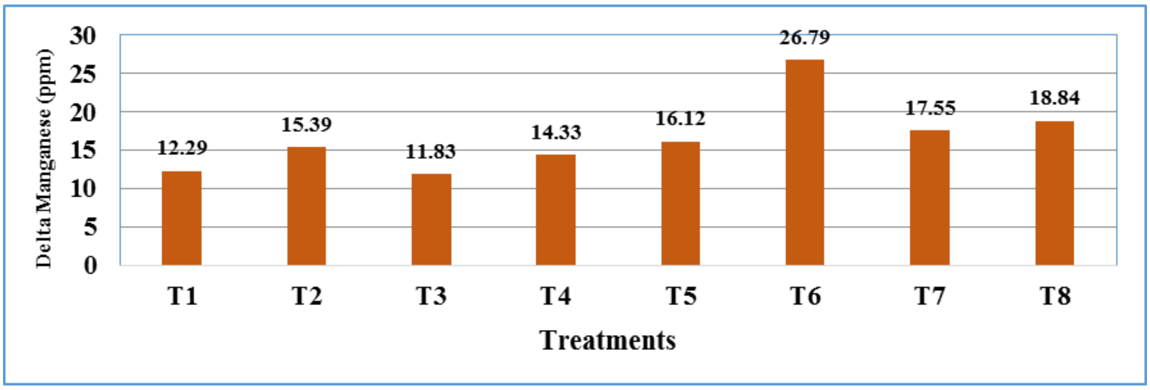
5.1.6. Available manganese

One of the vital conditions for Mn solubilisation would be acidic soil reaction which was accomplished with the application of acid forming fertilizers in general and ammonium sulphate in particular(Malhi *et al.*, 1998). Ammonium sulphate was more efficient compared to urea in augmenting the plant available Mn in the rhizosphere soils. It resulted in relatively more acidic environment owing to the trait of higher CCE possessed by ammonium sulphate than Urea (Fageria *et al.*, 1989). Relatively acidic environment enhances the metallic ion solubility and in turn its availability to the crop plants. Previous works Siman *et al.* (1970) stating that of pH values showed a decreasing trend with increasing rates of ammonium sulphate, while levels of the manganese fractions increased. Further, the treatments which received magnesium sulphate and elemental sulphur along with ammonium sulphate resulted in marked increment of available Mn in the rhizosphere (Fig. 6). Oxidation of sulphur to sulphuric acid (Nor and Tabatabai, 1977) besides magnesium eliminating the sodium resulted in higher acidic reaction which consequently enhanced the Mn availability.

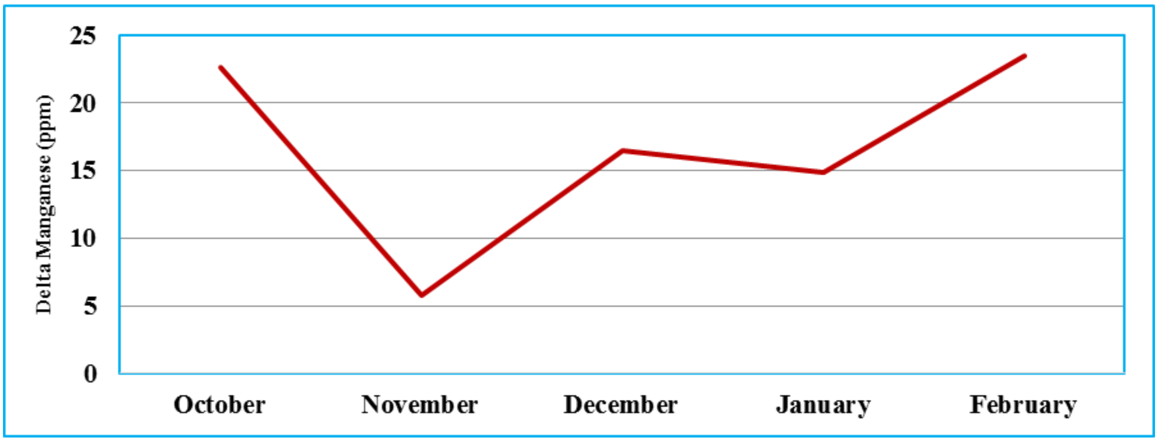
Urea (T_1) was obviously next effective to ammonium sulphate in augmenting the available Mn in the rhizosphere soils. Fageria *et al*., 2010 reported that application of ammonium, sulphate can reduce the pH by 12 percent where urea by 4 percent in rice cultivated land there by increases the micronutrients availability. However when it was combined with elemental sulphur (T_5) the effect was more prominent as far as augmentation of Mn is concerned. Similar works of Modaish *et al.* (1989) stating that application of elemental sulphur reduce the soil pH there by significantly increases DTPA extractable manganese. This can be attributed oxidation of sulphur which paves way for further acidification and resultant augmentation of Mn availability. Similar works of Karimizarchi *et al.* (2014) stating that application of elemental sulphur reduce the soil pH from 7.03 to 6.29 there by hikes the manganese availability. On the contrary, Urea blended with magnesium sulphate (T_3) resulted in lower Mn augmentation. This is owing to the fact that Magnesium sulphate (Epsom) would be neutral in reaction and its contribution towards augmentation of Mn would be negligible. Similar works of Oliveria *et al.* (2000) stated that application of magnesium sulphate to Ultisol made the pH approach neutral condition.



A. Comparison of available manganese in rhizosphere and non rhizosphere regimes



B. Augmentation of available manganese as influenced by different fertilizers



C. Temporal variation in augmentation of manganese as influenced by different fertilizers

Fig 6.Variation in available manganese as influenced by different fertilizers

Further, in the treatments where ammonium sulphate was applied along with elemental sulphur and chelated micronutrients (T_8) revealed higher Mn in the rhizosphere compared to that which received these supplements along with urea (T_7). Similar works of Gulser (2005) stating that Urea applications at the high doses in spinach generally increased the nitrate and nitrite content than ammonium sulphate which is negatively correlated with zinc and manganese concentration. In addition to that higher CCE possessed by ammonium sulphate compared to urea besides oxidation of elemental sulphur in the soil which contributes for the incremental soil acidity. Similar works of Awad and Edwards (1977) stating that ammonium sulphate application 336 kg N/ha/annum for four years decreased soil pH while concentrations of manganese were raised.

On the temporal scale, availability of soil manganese was more conspicuous in the months of October and February owing to the fertilizer application. Similar works of Rengel (2000) stating that application of acid forming fertilizer owing to exudation of H^+ ions can lower the pH of alkaline soils and increases micronutrient availability. However, the difference in available manganese between rhizosphere and away from the rhizosphere was significantly and consistently narrowed in the months of November, December and January (Fig. 6C).

5.1.7. Available boron

Generally, the application of acidifying fertilizers decreased the availability of boron. Application ammonium sulphate alone (T_2) as well as in combination with sulphur and magnesium sulphate resulted in relatively more acidic environment owing to the trait of higher CCE possessed by ammonium sulphate than Urea (Fageria *et al.*, 1989). Relatively acidic environment make retention of anion it is because of reduction in soil pH make boron unavailable for crop plants (Peterson and Newman, 1976).

In general application of urea (T_1) in combination with magnesium sulphate (T_3) and sulphur (T_5) showed the slight increase in boron compared to the compatriot treatments with ammonium sulphate (Fig. 7). It may be primarily due to lower CCE of urea compared to ammonium sulphate besides magnesium effect. This is owing to the fact that Magnesium sulphate (Epsom) would be neutral in reaction and its contribution towards augmentation of boron would be countable. Similar works of Oliveria *et al.*

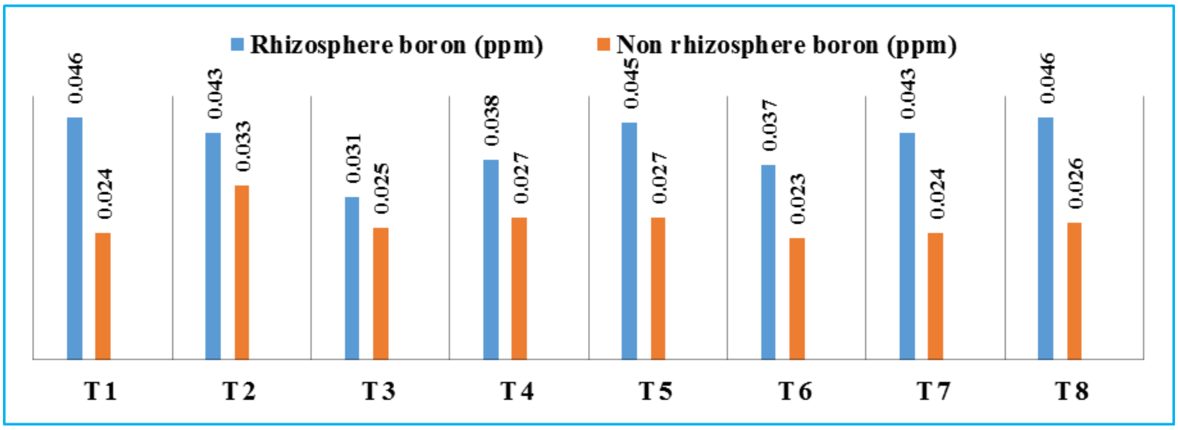
(2000) stated that application of magnesium sulphate to Ultisol soil make pH reached to neutral condition over a time.

Further, in the treatments where urea was applied along with elemental sulphur and chelated micronutrients (T_7) revealed higher B in the rhizosphere compared to that which received these supplements along with ammonium sulphate (T_8). Similar works of Nilsson and Wiklund (1995) with the application ammonium sulphate did not affect P, K, Ca or Mg while accumulation of B was significantly reduced.

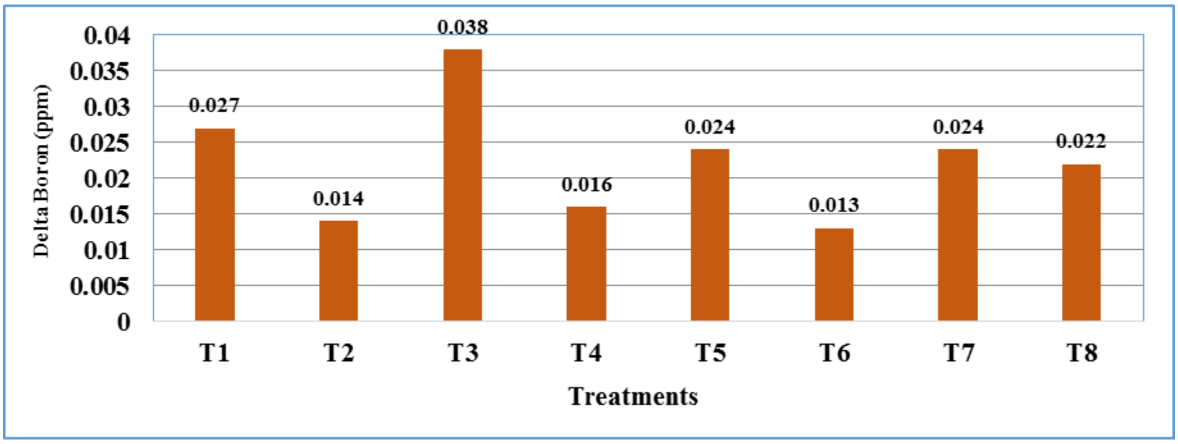
On the temporal scale available boron content in soil was more conspicuously negative in the months of October and February owing to the fertilizer application Rengel (2002). However the differences in boron between the rhizosphere and away from the rhizosphere were significantly broadened in the months of November, December and January (Fig. 7C).

5.2 Correlation between soil and plant micronutrients

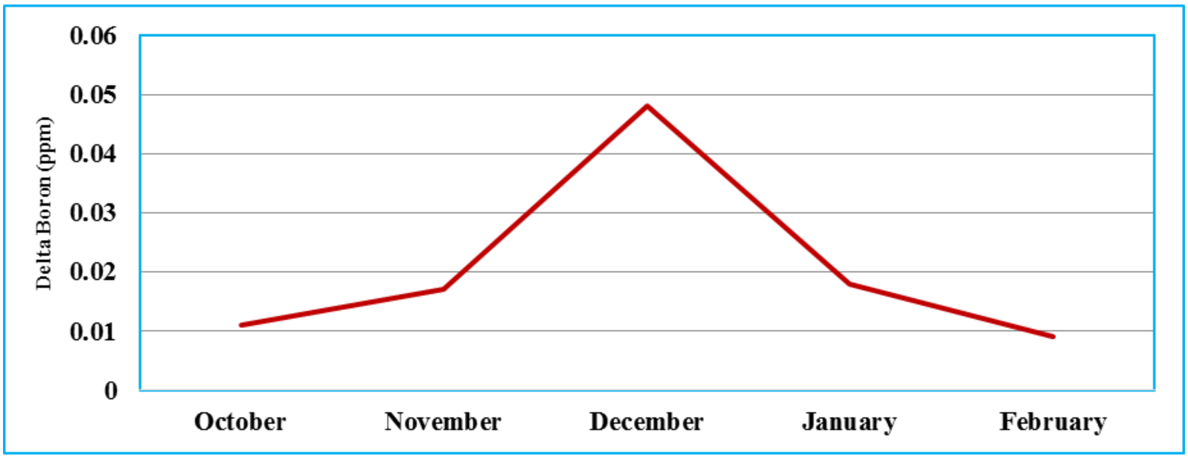
Simple correlations were worked out to deliberate the ternary relation between soil micronutrients and their uptake as influenced by soil reaction. In addition, the partial correlation between soil nutrients and plant uptake were also computed by masking the effect of soil reaction. In the former case, the correlations revealed more rational outcomes and projected deeper understanding about the chemistry of metallic micronutrients. In general Fe (-0.84) and Mn (-0.79) were more influenced by the soil reaction, while Cu (-0.71) was intermediate in response to the change in soil reaction. However, Zn (-0.59) was least responsive to the changes in soil reaction as indicated by lower coefficients. Previous works of Sims and Patrick (1978) reported that the distribution of all micronutrients with in the soil fraction was influenced by pH and Eh although Fe and Mn were affected to a greater extent than Zn and Cu In other words, Fe and Mn were mobilized in a greater magnitude compared to Cu and Zn. This may be attributed to the mineral composition (rich in Fe and Mn) and dissolution pattern favouring higher concentration of Fe and Mn in soil as well as tissue contrary to those of Cu and Zn (White and Zasoski, 1998). Further, the correlations between soil-Zn versus plant Zn (0.57) as well as plant Cu (0.68) revealed higher values compared to those of Plant Fe (0.14) and plant Mn (0.07). It inferred that the Zn and Cu behaved in



A. Comparison of available boron in rhizosphere and non rhizosphere regimes



B. Augmentation of available boron as influenced by different fertilizers



C. Temporal variation in augmentation of as boron influenced by different fertilizers

Fig 7.Variation in available boron as influenced by different fertilizers

similar pattern while Fe and Mn remained competitive which might be due to Mn is more mobile in soil system than Fe (Mc Daniel *et al.*, 1992). Higher Fe and Mn decreased the accumulation of Zn and Cu further higher Mn suppressed the Fe in the plant tissue. Similar results of De Varennes *et al*., 2001 found that increasing solution Mn reduced Zn concentration in all plant parts. On the contrary, soil boron availability was positively correlated (0.48) with soil reaction (Okazaki and Chao, 1968; Evans, 1987; Shafiq et *al*., 2008).

In the later case when the effect of pH was masked to study the relation between plant nutrients concentration and its uptake interesting features emerged. In case of Zn a stronger correlation (0.76) was obtained when pH effect was masked compared to that of with soil pH (0.57). This may be attributed to the preferential assimilation of Zn by the plants despite the fact that least amount of Zn was transformed in soil owing to the changes in soil reaction. Similar works of Wang *et al.* (2006) stating that soluble metal form Zn was greatly increased with decreasing pH. Lowering pH significantly influenced plant metal uptake in alpine penny grass. On the contrary, in case of Fe a negative (-0.02) correlation was observed when the relations were probed by considering the pH while a positive (0.35) correlations were recorded by masking the soil reaction effect. This may be attributed to higher dissolution of Fe minerals and transformation in to the available forms. Copper was more sceptical as its uptake was largely dependent on soil reaction as indicated by higher (0.31) correlation coefficients with pH compared to that of muting the effect of soil reaction (0.24) previous works of Nalewajko (1997) stating that the pH of the medium has a strong influence on speciation of trace metals such as copper, the proportion of free copper (as Cu^{2+}) increases from 37 per cent at pH 7 to cent percent at pH 5. Manganese uptake was little influenced by soil pH as indicated by narrow difference (0.32 to 0.39) in correlation coefficients in the two separate cases.

5.3 Correlation between assimilated nutrients, growth and yield attributes

An attempt was made to compute simple correlations involving soil pH, leaf nutrients, growth and yield attributes. Similarly these variables were partially correlated without considering the soil reaction. Most of the nutrients didn’t show any specific correlations on the growth and yield attributes. Only the significant correlation coefficients and their possible trends with yield is made available in Table. There was no definite trend in correlations with soil reaction and leaf nutrients as it was observed in the case of soil nutrients. Plant Zn was having positive significant correlation with plant calcium (0.86) and average fruit weight (0.82). The positive correlations between Zn and Ca may be attributed to the plant traits where near neutralization of cell sap would be achieved by providing sufficient Ca in to the cell sap. Optimum Zn might have activated the growth regulators and resulted in higher protein synthesis which plays crucial role in fruit development (Na, S. 2007). It was well supported by the correlations without considering the soil pH where identical values recorded for plant Ca and average fruit weight. By this it was evident that Ca and Zn were taken up by the plant irrespective of soil pH effects. It was quite evident that Cu was significantly correlated to plant potassium content (0.85). Presence of potassium increases the utilization of micronutrients in plants like Cu, Mn, Zn (Better Crops, 1998; Malvi, 2011). Finally calcium was positively correlated with average fruit weight (0.79) as it was understood that Ca would help in maintain the cell membrane, membrane proteins, prevented the early maturation of fruit, maintain the fruit firmness (Brady, 1987) and also increases the fruit dry matter and total fruit yield in tomato (Hao and Papadopoulos, 2004). Ferguson (1984) reported that Ca concentration has been reduced the leakage of solutes from the ripening fruit tissues there by regulate the ripening process.

5.4 Effect of different fertilizers on growth attributes

Although there was numerical difference shown on the growth parameters but there was no significant difference shown between the treatments. This is owing to the application of same quantity of major nutrients (N, P and K) in different forms of acid forming fertilizers in all the treatments (Haral, 2015). The prime objective was to augment the metallic micronutrients availability to the growing crop plants with the consequent acidification of the rhizosphere. The very objective was accomplished in all the treatments irrespective of the type of acid forming fertilizer. The treatments receiving urea and its combinations of fertilizers created mild acidity in soil whereas those of ammonium sulphates and its blends created more acidity in the rhizosphere soil. In the present study, the shoot length, number of leaves as well as chlorophyll content in leaves remained insignificant over the treatments. This was owing to the fact that by and large the growth attributes are dependent on macro nutrients (Liu *et al.*,

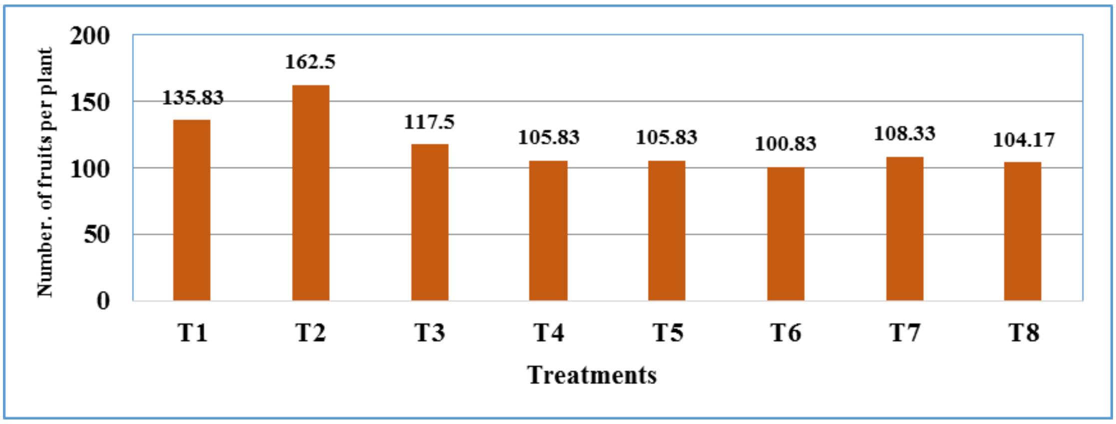


Fig A. Effect of different fertilizers on number of fruits of guava

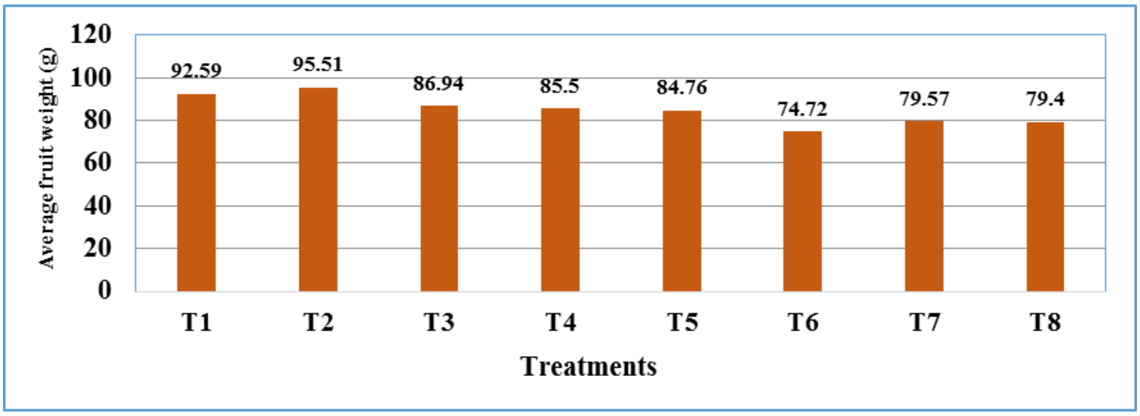


Fig B. Effect of different fertilizers on average fruit weight of guava

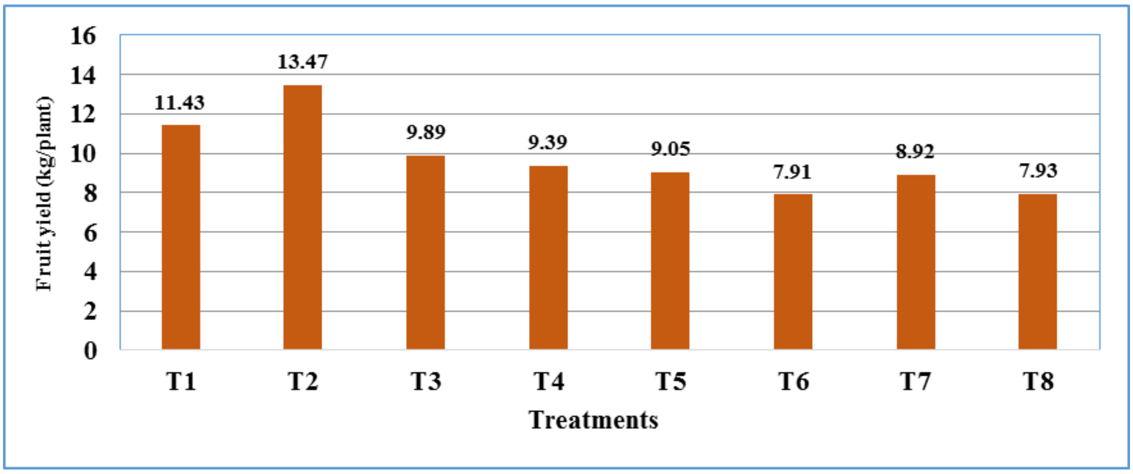


Fig C. Effect of different fertilizers on yield of guava

Fig 8. Yield and yield attributes as influenced by different fertilizers

2006; Swiader and Moore, 2000). In the present study the treatments received equal quantity of macronutrients and the critical micronutrients level was ensured in all the treatments. Thus appreciable changes in the growth attributes were not perceived.

5.5 Yield and yield attributes as influenced by different fertilizers

In the present study, the fruit volume and fruit drop remained insignificant over treatments which may be due to similar effect of all the major nutrients. As far as major nutrients are concerned, all the treatments received same amount of major nutrients however the forms of nutrient were different. Moreover, minimum fruit drop per plant was observed during 120 DAT with the application of ammonium sulphate (2.92%) and urea (4.60%) Similar effect was reported by Osman *et al.* (2010) in Olive trees. On the contrary, application of other combination fertilizer showed maximum fruit drop which may due to excess availability of micronutrients which might have created toxic environment in plant system especially with Fe and Mn (El-jaoul and Cox, 2008). This was owing to the fact that available micronutrients reached above critical range in T_6, and T_5 as a consequence of elemental sulphur application which transformed in to more acidic soil reaction.

Number of fruit per plant showed significant variation due to treatment effect. Among the treatments application of Ammonium sulphate as well as urea resulted more number of fruit per plant (162.5 and 135.8, respectively) it may due to presence of optimum level of macronutrients and micronutrients in particular. Similar results were also reported by Jamwal *et al.*, 2018; Kumar *et al.*, 2008; Hernandes *et al*., 2012; Villasurda and Baluyut (1990) which supported the outcomes of the present investigation.

Fruit yield per plant significantly increased with sole application of ammonium sulphate as well as urea (13.47 and 11.43 kg/plant respectively) Fig. 8. Similar works of Petrie and Jackson (1984) stating that application of ammonium sulphate at the rate of 22 and 45 kg N/ha increases the yield in barley than urea. On the contrary application of combined form of acid forming fertilizer resulted in excess availability of micronutrients above the critical level which might have caused toxicity in plants (Asati *et al.,* 2016). This was especially more conspicuous with combined application of ammonium sulphate and sulphur. However the higher fruit yield in T_2 and T_1 is due to more number of fruit per plant (162.50 and 135.83 respectively) and average fruit weight (95.51 and 92.51 g respectively) Fig. . Similar works of Dwivedi *et al.,* 1990 stating that application of urea at minimum concentration 15 per cent increases the individual fruit weight and fruit yield in guava. This was mainly due to optimum level of micronutrients. Even though micronutrients are required in smaller quantity their deficiency as well as excess amount causes reduction in yield. These metallic micronutrients like Zinc (Zn) is likely the most common micronutrient that is in short supply which helps in protein synthesis, maintain structural integrity plays crucial role in growth and regulation. Similarly, Iron (Fe) is required for the formation of chlorophyll in plant cells. It serves as an activator for biochemical processes such as respiration, photosynthesis and symbiotic nitrogen fixation. Copper (Cu) is an activator of several enzyme systems in plants and functions in electron transport and energy capture by oxidative proteins and enzymes. It may play a role in vitamin production. Manganese (Mn) serves as an activator for enzymes in growth processes. It assists iron in chlorophyll formation (Na, S. 2007). Boron (B) is much required for cell division and development in the growth regions of the plant near the tips of shoots and roots. It also affects sugar transport, pollination and the development of viable seeds which in turn affect the normal development of fruit. A shortage of boron also causes cracking and distorted growth in fruit. However, Micronutrients are essentially as important as macronutrients to have better growth, yield and quality in plants. The requirement of micronutrients (boron, iron, copper, zinc, manganese,) is only in traces, which is partly met from the soil or through chemical fertilizer or through other sources (Jeyakumar and Balamohan, 1997).

5.6 Soil nutrient status after harvest

Unlike other fruits, guava yields in three different seasons in a year. However crop management is made not to encourage the crop during rainy season. By and large crop during summer and winter need to be sustained with optimum nutrient status. The soil organic carbon was moderately higher in all the treatments owing to the compost applied besides litter fall in the field. The availability of major nutrients (N, P and K) was above the optimum level due to application of acid forming fertilizers (Seddik *et al*., 2011; Apthorp *et al*., 1987). On the contrary secondary nutrients (Ca, Mg and S) were effected by acidity both would encourage fresh shoots in the season to come.

6. SUMMARY AND CONCLUSION

A field experiment was conducted during *Kharif* season of 2018-19 at College of Horticulture in the University of Horticultural Sciences Bagalkot on ‛Augmentation of native micronutrients availability in Guava *(Psidium guajava* L.) cv. Sardar through different fertilizer sources’. The experiment consisted of different combination of acidifying fertilizers applied through ring method. The salient features of present investigation are summarized below.

Effect of acid forming fertilizers on soil reaction was unambiguous, where the initial soil pH was alkaline (7.80 to 7.95). Among the different treatments, ammonium sulphate and its combinations showed the greater reduction in rhizosphere pH than urea and its combinations. However, sole application of ammonium sulphate and urea showed the optimum reduction in rhizosphere pH. On the temporal scale higher reduction in soil pH was observed 45-60 days after application of acidifying fertilizer.

The salinity in terms of electrical conductivity remained far below than the threshold limit in the rhizosphere as well as in soil away from rhizosphere irrespective of treatments. On the temporal scale during the month of October more variations were observed with respect to salinity level when compared to rest of the period. It might be due to gradual uptake of nutrients from soil by the crop.

Availability of micronutrients increased significantly throughout the period of experiment due to treatments effect. However among the metallic micronutrients iron and manganese showed the greater availability when compared with zinc and copper. On the contrary, boron availability in soil was reduced with the acidification. However, the application of ammonium sulphate as well as urea along with elemental sulphur showed magnified effect which resulted in extreme reduction of soil pH compared to rest of the treatments. Thus greater variation in soil pH rendered enhanced availability of metallic micronutrients (Zn, Cu, Fe, and Mn) to the extent of more than that of critical limit. Further, solitary application ammonium sulphate as well as urea showed that increased in micronutrient availability in the rhizosphere synchronising with that of optimum concentration.

On the temporal scale the metallic micronutrients (Zn, Cu, Fe and Mn) concentration was magnified during the month October owing to the fertilizer application during 45 days prior to soil sampling. Consequently the treatments effect was reduced in the months of November, December and January owing reduction of acidity as a result of nutrient exhaustion because of uptake. However in the month of February again enhanced micronutrient availability was observed due to top dressing of nitrogen fertilizer.

In contrast, availability of boron was more in the treatments receiving urea and its combinations than that of ammonium sulphate and related combinations. It might be due to the fact that urea might have created mild acidity which is favourable for boron while ammonium sulphate created stronger acidity which decreased the boron availability. On the temporal scale, in the month of October as well as in the month of February availability of boron was reduced due the immediate effect of acidifying fertilizers which were applied before 45 days of observation.

Simple correlation was worked out to know the effect of acid forming fertilizer on leaf micronutrient concentration in relation with soil micronutrient as well as with soil pH. In general iron and manganese were more influenced by soil pH where copper showed the intermediate response and zinc showed least response for pH variation. However availability of soil boron showed positive correlation with soil pH. Further plant zinc and plant copper showed the higher correlation with soil zinc when compared plant iron and plant manganese. Later relation revealed higher accumulation of iron and manganese resulted in consequential reduction of plant zinc and copper.

Latter partial correlation by masking soil pH revealed plant Zn showed stronger correlation indicating preferential assimilation. However plant Fe showed negative correlation with soil pH and plant Cu showed higher correlation with soil pH. Further Mn showed narrow correlation in both the cases.

Further, the correlation with assimilated nutrients, growth and yield attributes in relation to soil pH revealed no definite trend. However, most of the nutrients didn’t show any specific correlation on plant, soil nutrients as well as growth and yield attributes. Plant zinc recorded positive significant correlation with plant secondary nutrients as well as yield attributes. Plant copper also recorded significant correlation with plant potassium. However the plant calcium is positively correlated with the yield attributes in both the cases.

Growth parameters and chlorophyll content remained insignificant among the treatments. These parameters are majorly depend on the macronutrients owing to the application of same quantity of major nutrients like (N, P, K)

Among the yield attributes, fruit volume and fruit drop recorded no difference among the treatments which may due to similar effect of all major nutrients but at 120 DAT minimum fruit drop was recorded with alone application of ammonium sulphate followed by urea. On the contrary application of combined form of acidifying fertilizers recorded maximum fruit drop which may be due to excess availability of micronutrients which might have caused toxicity in plant system. However, number of fruit per plant, average fruit weight and fruit yield per plant recorded higher with alone application of ammonium sulphate (T_2) as well as urea (T_1). It might be due to slight reduction in the soil pH which helps in availability of optimum level of micronutrients to the plant system. On the contrary soil pH was more likely to be reduced due to combine application of acidifying fertilizers like ammonium sulphate + elemental sulphur (T_6) recorded lower yield it might be due excess availability of metallic micronutrients especially Fe and Mn which created toxic environment in soil as well as in plant system by reducing the yield of the crop.

Soil nutrient concentration at the end of the experiment showed higher availability of major nutrients like (N, P, K) due to application of acidifying fertilizer which would have beneficiary effects on next season crop. On the contrary secondary nutrients availability (Ca, Mg, S) become reduced due to acidity effect.

Conclusion

Nevertheless all the fertilizers created acidulation of the rhizosphere and intern augmented the metallic micronutrients availability. In general Fe and Mn were relatively more mobilized compared to Zn and Cu. Generally, urea created the mild acidity whereas ammonium sulphate created stronger acidity. In alkaline soil application of ammonium sulphate (T_2) was more preferable in enhancing the optimum micronutrient availability. Ammonium sulphate performed dual role of reducing the soil reaction besides it complemented sulphur for the crops. By this it can be inferred that urea in general and ammonium sulphate in particular would be suitable to the mild alkaline (pH 7.8-8.0) soils. However, for strong alkaline soils it is better to opt for the combinations of urea and ammonium sulphate with elemental sulphur. Further, in higher alkaline soils inclusion of chelated micronutrients over and above elemental sulphur would be appropriate.

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Appendix-I

Monthly meteorological data at MHREC, UHS, Bagalkot during 2018

Month-2018	Rainy days	Rainfall (mm)	Temperature (^{0}C)		RH (%)	
			Max.	Min.	Morning	After Noon
Jan	0	0	31.0	19.6	83.00	24.70
Feb	0	0	32.9	17.1	58.80	17.80
Mar	0	0	37.9	25.6	50.00	16.50
Apr	3	24.8	39.2	28.2	54.70	18.20
May	3	45.5	37.9	27.8	66.64	29.79
Jun	5	116.3	32.7	23.6	75.64	50.53
Jul	0	9.3	29.8	22.7	77.47	63.66
Aug	5	40.8	29.6	22.0	80.61	56.29
Sept	2	24.2	32.9	21.3	75.11	44.45
Oct	1	4.8	33.6	21.1	59.61	33.94
Nov	0	0	32.3	19.3	55.48	32.93
Dec	0	0	30.3	17.5	64.73	34.20
Total	19	265.70	31.0	19.6	83.00	24.70

Monthly meteorological data at MHREC, UHS, Bagalkot during 2019

Month-2019	Rainy days	Rainfall (mm)	Temperature (^{0}C)		RH (%)	
			Max.	Min.	Morning	After Noon
Jan	0	0.00	31.25	14.58	56.01	25.18
Feb	0	0.00	34.55	17.83	49.25	19.97
Mar	0	0.00	38.50	21.03	43.23	14.14
Apr	0	0.00	40.48	24.36	48.27	17.23
May	2	18	40.01	24.77	56.40	20.74
Jun	19	199.2	34.79	23.8	73.69	43.9
Total	21	217.2	36.60	21.06	54.48	23.53

Appendix-II

Initial soil chemical properties of experimental field

Soil properties	Values
pH	7.8
EC (dS m^{-1})	0.20
Organic carbon (%)	0.78
Available N (kg ha^{-1})	275.18
Available P_2O_5(kg ha^{-1})	35.10
Available K_2O (kg ha^{-1})	142.14
Exchangeable Ca [c mol (p+) kg^{-1}]	19.46
Exchangeable Mg [c mol (p+) kg^{-1}]	10.17
Available S (ppm)	0.16
Exchangeable Na [c mol (p+)kg^{-1}]	0.31
DTPA extractable Zn (ppm)	0.36
DTPA extractable Cu (ppm)	0.95
DTPA extractable Fe (ppm)	2.45
DTPA extractable Mn (ppm)	12.01
Available B (ppm)	0.023

Appendix-III

Critical limit of micronutrients

Interpretation	DTPA Fe (ppm)	DTPA Mn (ppm)	DTPA Zn (ppm)	DTPA Cu (ppm)
Low	< 2.50	< 2.00	< 0.60	< 0.80
Medium	2.50 - 4.50	2.00 - 4.00	0.60 - 1.50	0.80 - 1.60
High	> 4.50	> 4.00	>1.50	> 1.60

AUGMENTATION OF NATIVE MICRONUTRIENTS AVAILABILITY IN GUAVA (*Psidium guajava* L.) CV. SARDAR THROUGH DIFFERENT FERTILIZER SOURCES

A. R. AKARSHA **2019** **Dr. PRASANNA S. M.**
Major Advisor

ABSTRACT

Guava (*Psidium guajava* L.) is one of the most popular fruit grown in tropical and sub-tropical regions of India. Of late guava cultivation is expanded in marginal lands where soil salinity and calcareousness are the prominent problems associated with normal production. High levels of salinity and precipitated calcium carbonate in soils affect the transformations and availability of several essential plant nutrients. This particular problem is more conspicuous as far as metallic micronutrients owing to their precipitation as their respective hydroxides under alkaline soil reaction. For this reason, optimum crop production in alkaline soils calls for an intervention of special fertilizer management practices to transform large unavailable pools of nutrients to available forms. In general localized application of acid forming fertilizers to near the root zone bring vital changes in soil reaction rendering to augment the micronutrients availability. With this small change brought in the crop management appreciable changes in growth, yield and quality could be anticipated in the slightly alkaline situations.

All the fertilizers accelerated acidulation of the rhizosphere and intern augmented the metallic micronutrients availability. Urea created the mild acidity whereas ammonium sulphate created stronger acidity. Application of ammonium sulphate was more preferable in enhancing the optimum micronutrient availability in alkaline soil. Ammonium sulphate performed dual role of reducing the soil reaction and supplied sulphur for the crops. By this it can be inferred that urea in general and ammonium sulphate in particular would be suitable to the mild alkaline (pH 7.8-8.0) soils. However, for strong alkaline soils it is better to opt for the combinations of urea and ammonium sulphate with elemental sulphur. Further, in higher alkaline soils inclusion of chelated micronutrients over and above elemental sulphur would be appropriate.

ಪೇರಲ (*ಸಿಡಿಯಮ್ ಗುಜಾವಾ* ಎಲ್.) ಸರ್ದಾರ್ ತಳಿಯಲ್ಲಿ ವಿವಿಧ ಗೊಬ್ಬರಗಳ ಮೂಲಕ ಸ್ಥಾನಿಕ ಲಘುಪೋಷಕಾಂಶಗಳ ಲಭ್ಯತೆಯ ವರ್ಧನೆ

ಎ. ಆರ್. ಆಕರ್ಷ 2019 ಡಾ. ಪ್ರಸನ್ನ ಎಸ್. ಎಮ್.
ಪ್ರಧಾನ ಮಾರ್ಗದರ್ಶಕರು

ಸಾರಾಂಶ

ಪೇರಲ ಭಾರತದ ಉಷ್ಣವಲಯದ ಮತ್ತು ಉಪ–ಉಷ್ಣವಲಯದ ಪ್ರದೇಶಗಳಲ್ಲಿ ಬೆಳೆಯುವ ಅತ್ಯಂತ ಜನಪ್ರಿಯ ಹಣ್ಣುಗಳಲ್ಲಿ ಒಂದಾಗಿದೆ. ಇತ್ತೀಚಿನ ದಿನಮಾನದಲ್ಲಿ ಪೇರಲ ಕೃಷಿಯನ್ನು ಸಣ್ಣ ಹಿಡುವಳಿಗೆ ವಿಸ್ತರಿಸಲಾಗುತ್ತಿದ್ದು ಮಣ್ಣಿನ ಲವಣಾಂಶ ಮತ್ತು ಸುಣ್ಣವು ಸಾಮಾನ್ಯ ಉತ್ಪಾದನೆಗೆ ಸಂಬಂಧಿಸಿದ ಬಹುದೊಡ್ಡ ಸಮಸ್ಯೆಯಾಗಿದೆ. ಈ ಕಾರಣ ಮಣ್ಣಿನಲ್ಲಿ ಹೆಚ್ಚಿನ ಮಟ್ಟದ ಲವಣಾಂಶ ಮತ್ತು ಅವಕ್ಷೇಪ ಸುಣ್ಣದ ಅಂಶವು ಹಲವಾರು ಅಗತ್ಯ ಸಸ್ಯ ಪೋಷಕಾಂಶಗಳ ರೂಪಾಂತರ ಮತ್ತು ಲಭ್ಯತೆಯ ಮೇಲೆ ದುಷ್ಪರಿಣಾಮವನ್ನುಂಟು ಮಾಡುತ್ತದೆ. ಕ್ಷಾರೀಯ ಮಣ್ಣಿನಲ್ಲಿ ಲೋಹೀಯ ಲಘುಪೋಷಕಾಂಶಗಳು ಆಯಾ ಹೈಡ್ರಾಕ್ಸೈಡ್‌ಗಳಾಗಿ ಪರಿವರ್ತಿತವಾಗುವುದರಿಂದ ಈ ಸಮಸ್ಯೆ ಇನ್ನಷ್ಟು ಜಟಿಲವಾಗುವುದು. ಈ ಕಾರಣಕ್ಕಾಗಿ, ಕ್ಷಾರೀಯ ಮಣ್ಣಿನಲ್ಲಿ ವಿಶೇಷ ರಸಗೊಬ್ಬರ ನಿರ್ವಹಣಾ ಪದ್ಧತಿಗಳ ಮೂಲಕ ಹೆಚ್ಚಿನ ಪ್ರಮಾಣದಲ್ಲಿ ಅಲಭ್ಯವಿರುವ ಪೋಷಕಾಂಶಗಳನ್ನು ಲಭ್ಯವಾಗುವ ರೂಪಗಳಿಗೆ ಪರಿವರ್ತಿಸುದರಿಂದ ಗರಿಷ್ಠ ಬೆಳೆ ಉತ್ಪಾದನೆಯನ್ನು ಪಡೆಯಬಹುದು. ಆಮ್ಲತೆ ರೂಪಿಸುವ ರಸಗೊಬ್ಬರಗಳನ್ನು ಸಾಮಾನ್ಯವಾಗಿ ಬೇರಿನ ವಲಯಕ್ಕೆ ಹಾಕುವುದರಿಂದ ಮಣ್ಣಿನ ರಾಸಾಯನಿಕ ಕ್ರಿಯೆಯಲ್ಲಿ ಬದಲಾವಣೆಯಾಗಿ ಲಘುಪೋಷಕಾಂಶಗಳ ಲಭ್ಯತೆಯನ್ನು ಹೆಚ್ಚಿಸುತ್ತದೆ. ಈ ಚಿಕ್ಕ ಬದಲಾವಣೆಯಿಂದ ಲವಣ ಪೀಡಿತ ಪ್ರದೇಶದಲ್ಲೂ ಸಹ ಸಸ್ಯದ ಬೆಳವಣಿಗೆಯು ಗಮನಾರ್ಹವಾಗಿದ್ದು, ಇಳುವರಿ ಮತ್ತು ಗುಣಮಟ್ಟವನ್ನು ಹೆಚ್ಚಿಸುವ ಸಂಭವವಿರುತ್ತದೆ.

ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಲ್ಲಿ ಎಲ್ಲಾ ರಸಗೊಬ್ಬರಗಳು ಬೇರು ವಲಯವನ್ನು ಆಮ್ಲೀಕರಣವಾಗಿಸಿ ಲೋಹೀಯ ಲಘುಪೋಷಕಾಂಶಗಳ ಲಭ್ಯತೆಯನ್ನು ಹೆಚ್ಚಿಸಿದವು. ಸಾಮಾನ್ಯವಾಗಿ ಯೂರಿಯಾ ಸೌಮ್ಯ ಆಮ್ಲೀಯತೆಯನ್ನು ಸೃಷ್ಟಿಸಿದರೆ, ಅಮೋನಿಯಂ ಸಲ್ಫೇಟ್ ಬಲವಾದ ಆಮ್ಲೀಯತೆಯನ್ನು ಸೃಷ್ಟಿಸಿದೆ. ಕ್ಷಾರೀಯ ಮಣ್ಣಿನಲ್ಲಿ ಅಮೋನಿಯಂ ಸಲ್ಫೇಟ್ ಬಳಕೆಯು ಲಘುಪೋಷಕಾಂಶಗಳ ಲಭ್ಯತೆಯನ್ನು ಹೆಚ್ಚಿಸುವಲ್ಲಿ ಹೆಚ್ಚು ಯೋಗ್ಯವಾಗಿದೆ. ಅಮೋನಿಯಂ ಸಲ್ಫೇಟ್ ಮಣ್ಣಿನ ರಾಸಾಯನಿಕ ಕ್ರಿಯೆಯನ್ನು ಕಡಿಮೆ ಮಾಡುವುದರ ಜೊತೆಗೆ ಗಂಧಕ ಪೂರಕವಾಗಿ ಉಭಯ ಪಾತ್ರವನ್ನು ನಿರ್ವಹಿಸಿದೆ. ಯೂರಿಯಾ ಮತ್ತು ಅಮೋನಿಯಂ ಸಲ್ಫೇಟ್ ಸೌಮ್ಯ ಕ್ಷಾರೀಯ (ಪಿಎಚ್–7.8–8.0) ಮಣ್ಣಿಗೆ ಸೂಕ್ತವಾಗಿವೆ ಎಂದು ಈ ಅಧ್ಯಯನದ ಮೂಲಕ ತಿಳಿದುಬಂದಿದೆ. ಆದಾಗ್ಯೂ, ಬಲವಾದ ಕ್ಷಾರೀಯ ಮಣ್ಣಿನಲ್ಲಿ ಯೂರಿಯಾ ಮತ್ತು ಅಮೋನಿಯಂ ಸಲ್ಪೇಟ್‌ಗಳನ್ನು ಗಂಧಕ ಪುಡಿಯೊಂದಿಗೆ ಸಂಯೋಜಿಸಿ ಬಳಸುವುದು ಉತ್ತಮ. ಇದಲ್ಲದೆ, ಹೆಚ್ಚಿನ ಕ್ಷಾರೀಯ ಮಣ್ಣಿನಲ್ಲಿ ಧಾತುರೂಪದ ಗಂಧಕದೊಂದಿಗೆ ಚಿಲೇಟೆಡ್ ಲಘುಪೋಷಕಾಂಶಗಳನ್ನು ಸೇರಿಸುವುದು ಸೂಕ್ತವಾಗಿದೆ.