# EFFECT OF IRON AND ZINC NUTRITION ON SEED YIELD, NUTRIENT UPTAKE AND QUALITY OF FENUGREEK (*Trigonella foenum-graecum* L.) IN INCEPTISOL

By

**Miss. Chougale Rutuja Bhairu**
(Reg. No. P/016/097)

A Thesis submitted to the
**MAHATMA PHULE KRISHI VIDYAPEETH**
**RAHURI – 413 722, DIST. AHMEDNAGAR**
**MAHARASHTRA, INDIA**

in partial fulfillment of the requirements for the degree

of

**MASTER OF SCIENCE (AGRICULTURE)**

in

**SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

**DIVISION OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

**COLLEGE OF AGRICULTURE, PUNE – 411 005**
**MAHATMA PHULE KRISHI VIDYAPEETH**
**RAHURI – 413 722, DIST. - AHMEDNAGAR**
**MAHARASHTRA, INDIA.**

**2019**

# EFFECT OF IRON AND ZINC NUTRITION ON SEED YIELD, NUTRIENT UPTAKE AND QUALITY OF FENUGREEK (*Trigonella foenum-graecum* L.) IN INCEPTISOL

By

**Miss. Chougale Rutuja Bhairu**
(Reg. No. P/016/097)

A Thesis submitted to the
**MAHATMA PHULE KRISHI VIDYAPEETH**
**RAHURI – 413 722, DIST. AHMEDNAGAR**
**MAHARASHTRA, INDIA.**

in partial fulfillment of the requirements for the degree

of

**MASTER OF SCIENCE (AGRICULTURE)**

in

**SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

APPROVED BY

**Dr. P. B. Jagtap**
(Chairman and Research Guide)

**Dr. B. D. Tamboli**
(Committee Member)

**Dr. A. L. Pharande**
(Committee Member)

**Dr. M. B. Kadam**
(Committee Member)

**DIVISION OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

**COLLEGE OF AGRICULTURE, PUNE-411 005**
**MAHATMA PHULE KRISHI VIDYAPEETH**
**RAHURI – 413 722, DIST. - AHMEDNAGAR**
**MAHARASHTRA, INDIA.**

**2019**

# CANDIDATE’S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institution
for a Degree or
Diploma

Place : Pune

Date : / /2019

**(R. B. Chougale)**

**Dr. P. B. Jagtap**
Chairman, SAC and Research Guide
Associate Professor (CAS)
Soil Science and Agricultural Chemistry
NARP, Ganeshkhind, Pune
Maharashtra State, INDIA

# CERTIFICATE

This is to certify that the thesis entitled, "**EFFECT OF IRON AND ZINC NUTRITION ON SEED YIELD, NUTRIENT UPTAKE AND QUALITY OF FENUGREEK (*Trigonella foenum-graecum* L.) IN INCEPTISOL"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY,** embodies the results of a piece of *bona fide* research work carried out by **MISS. CHOUGALE RUTUJA BHAIRU,** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

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

Place : A.C., Pune **(P. B. Jagtap)**
Date : / /2019 Research Guide

**Dr. R. B. Nazirkar**
Professor
Division of Soil Science and Agricultural Chemistry
College of Agriculture, Pune-411 005
Maharashtra State, INDIA

# CERTIFICATE

This is to certify that the thesis entitled, "**EFFECT OF IRON AND ZINC NUTRITION ON SEED YIELD, NUTRIENT UPTAKE AND QUALITY OF FENUGREEK (*Trigonella foenum-graecum* L.) IN INCEPTISOL"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY,** embodies the results of a piece of *bona fide* research work carried out by **MISS. CHOUGALE RUTUJA BHAIRU,** under the guidance and supervision of **Dr. P. B. JAGTAP,** Assistant Professor of Soil Science and Agricultural Chemistry, College of Agriculture, Pune, Maharashtra State (India) and that no part of this thesis has been submitted for any other degree or diploma.

Place : A.C., Pune **(R. B. Nazirkar)**

Date : / /2019

**Dr. P. N. Rasal**
Associate Dean
College of Agriculture, Pune-411 005
Maharashtra State, INDIA

# CERTIFICATE

This is to certify that the thesis entitled, "**EFFECT OF IRON AND ZINC NUTRITION ON SEED YIELD, NUTRIENT UPTAKE AND QUALITY OF FENUGREEK (*Trigonella foenum-graecum* L.) IN INCEPTISOL"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY,** embodies the results of a piece of *bona fide* research work carried out by **MISS. CHOUGALE RUTUJA BHAIRU,** under the guidance and supervision of **Dr. P. B. JAGTAP,** Assistant Professor of Soil Science and Agricultural Chemistry, College of Agriculture, Pune, Maharashtra State (India) and that no part of this thesis has been submitted for any other degree or diploma.

Place : A.C.,Pune **(P. N. Rasal)**

Date : / /2019

## ACKNOWLEDGEMENT

*The culimination of research work is a corner stone in the life of any student with research guide, being the driving force behind. At the outset, word fail to express the depth of gratitude to my Chairman and Research Guide Dr. P. B. Jagtap, Associate Professor (CAS), Soil Science and Agricultural Chemistry, NARP, Ganeshkhind, Pune for his gracious encouragement, constant inspiration, talented advice, right from suggestion of this investigation, still completion of manuscript.*

*It gives me immense pleasure to express the depth of my respect to Advisory Committee Member Dr. B. D. Tamboli, Professor (CAS) of Soil Science , College of Agriculture, Pune for his scholastic investigation guidance, appreciable and constructive criticism, everlasting patience throughout the course of this for him can not be adequately expressed my emotions in words.*

*My sincere thanks to Dr. A. L. Pharande, Dean (F/A) and Director of Instructions, M.P.K.V., Rahuri, Dr. M. B. Kadam , Associate Professor of Horticulture, Regional Fruit Research station, Vengurla, Sindudurg for their co-operation and guidance during this investigation. I wish to express co-ordinal thanks and deep sense of gratitude to Dr. R. B. Nazirkar, Professor, Division of Soil Science and Agril. Chemistry, Dr. A. B. Jadhav, Assistant Professor, Mr. A. D. Jagdhani, Asstt. Professor and Prof. V. R. Gaikwad, Asstt. Professor, Dr. A. V. Patil, Assistant Professor, division of Soil Science and Agricultural Chemistry, College of Agriculture, Pune and other teaching and non- teaching staff of department of Soil Science and Agriculture Chemistry, College of Agriculture, Pune. I express sincere thanks to Dr. G.D. Patil, Professor, Division of Soil Science and Agricultural Chemistry, College of Agriculture, Kolhapur.*

*I am extremely greatful to, Dr. Vedshri Patil, Assistant Professor, Dr. Vrushali Ghorpade (SRA), Mr. R. U. Nimbalkar (JRA) and Mrs. U. A. Gavit (JRA), for their untiring help and cheerful presence during conduct of the experiment and laboratory investigations. I would like to special thanks to Mr. Santosh Argade, Mrs. R N. Dhas, Agril. Assistant, Mr. Kondhalkar and Mr. Mayur Lokhande, Lab Boy for their valuable helping in times of need.*

*I am also thankful to Dr. P. N. Rasal, Associate Dean, College of Agriculture, Pune and Dr. Vinay Supe , Associate Director of Research, NARP, Ganeshkhind, Pune for enabling me to available all the required facilities during tenure of the study.*

*I convey the depth of my heartfelt thanks to my batch mates and friends Payal, Ganesh, Shubham, Krishnapriya and Dhanashree for their enthusiastic company and co-operation.*

*I am highly greatful to the authors past and present whose literature has been cited.*

*No words could justice to express my deepest sense of gratitude and respect to my father, Shri. Bhairu Chougale, mother Ujwala Chougale, grandmother Parvati Chougale and brother Omkar Chougale as they been and in exhaustible source of inspiration to me. Their blessings, love and affection have brought cherished, expectation, dream true.*

*Finally, last but not the least, I thank one and all those who have helped and inspired me to complete this dissertation.*

*Place* : *Pune*

*Date* : / /2019

*Rutuja Chougale*

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURE

# LIST OF PLATES

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| % | : | Percentage |
| @ | : | At the rate of |
| Av. N | : | Available nitrogen |
| Av. P | : | Available phosphorus |
| Av. K | : | Available potassium |
| C. D. | : | Critical difference |
| $CaCO_3$ | : | Calcium carbonate |
| *cv.* | : | Cultivar |
| dS $m^{-1}$ | : | Decisiemon per meter |
| EC | : | Electrical conductivity |
| *et al.* | : | *et alli* (and others) |
| Fig. | : | Figure |
| FYM | : | Farm yard manure |
| g | : | Gram |
| GRDF | : | General Recommanded Dose of Fertilizers |
| ha | : | Hectare |
| *i.e.* | : | id est (that is) |
| kg $ha^{-1}$ | : | Kilogram per hectare |
| kg | : | Kilogram (s) |
| L | : | Litre (s) |
| mg $kg^{-1}$ | : | Milligram per kilogram |
| N | : | Normality |
| N.S. | : | Non-significant |
| No. | : | Number |
| ppm | : | Parts per million |
| q $ha^{-1}$ | : | Quintal per hectare |
| Sr. No. | : | Serial number |
| *viz.*, | : | Namely |
| DTPA | : | Diethylenetriamine Penta Acetic Acid |
| SEM | : | Standard error of the mean |

# ABSTRACT

**EFFECT OF IRON AND ZINC NUTRITION ON SEED YIELD, NUTRIENT UPTAKE AND QUALITY OF FENUGREEK (*Trigonella foenum-graecum* L.) IN INCEPTISOL.**

By

**MISS. CHOUGALE RUTUJA BHAIRU**

A candidate for the degree

of

**MASTER OF SCIENCE (AGRICULTURE)**

in

**SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

Research Guide : **Dr. P. B. Jagtap**

Department : Soil Science and Agricultural Chemistry

The investigation was undertaken on fenugreek *cv*. Phule Kasturi planted at 30 × 20 $cm^2$ row length distance at National Agriculture Research Project, Ganeshkhind, Pune- 7, during the year 2017-18, with view to study the effect of iron and zinc nutrition on seed yield, nutrient uptake and quality of fenugreek (*Trigonella foenum-graecum* L.) in Inceptisol.

The soil of the experimetal site was clay loam in texture had pH 8.15, electrical conductivity (EC) 0.14 dS $m^{-1}$, organic carbon 0.66 %, available N 313.6 kg $ha^{-1}$, available P 30.19 kg $ha^{-1}$, available K 752.64 kg $ha^{-1}$, DTPA- extractable Fe 4.1 mg $kg^{-1}$, Zn 0.4 mg $kg^{-1}$, Mn 12.7 mg $kg^{-1}$ and Cu 5 mg $kg^{-1}$. The soil was deficient in iron and zinc content. The experiment was laid out in Randomized Block Design with three replications consisted eleven treatments.

Among the various treatments, GRDF (40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$ + FYM 10 t $ha^{-1}$) + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ ($T_{11}$) recorded significantly higher plant height (29.83 cm), number of branches (3.53 $plant^{-1}$), number of trifoliate leaves (66.70), plant weight at harvest (18.35 g), 1000 grain weight (12.85 g), seed yield (9.12 ql $ha^{-1}$), number of pods per plant (32.27), total chlorophyll content (31.11 mg $g^{-1}$ fresh weight), protein content (25.92%), seed

germination (89%), viability of seeds (93.62%), seed vigour index (1618), iron content in seed (34.9 mg $kg^{-1}$) and zinc content in seed (71.2 mg $kg^{-1}$).

The uptake of nitrogen, phosphorous, potassium, iron, zinc, manganese and copper by fenugreek was significantly higher due to treatment $T_{11}$ i.e. GRDF (40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$) + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$.

At harvest, treatment $T_{11}$ (40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$ + FYM 10 t $ha^{-1}$) + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) recorded significantly higher content of soil available nitrogen, iron and zinc. The foliar application of iron and zinc could helped to increase growth, yield and quality parameters of fenugreek grown in iron and zinc deficient soil. However, the application of $FeSO_4$ @ 15 kg $ha^{-1}$ and $ZnSO_4$ @ 10 kg $ha^{-1}$ to fenugreek not only helped to improve growth, yield and quality parameters of fenugreek but it helped to built up iron and zinc content respectively in iron and zinc deficient soil. The soil application of $FeSO_4$ and $ZnSO_4$ to fenugreek could bring DTPA iron and DTPA zinc respectively to the sufficient level in soil after harvest of fenugreek crop. Soil available phosphorous, manganese and copper content remained significantly unchanged due to iron and zinc application to fenugreek. Application of iron and zinc either through foliar or soil did not influenced significantly the soil pH, electrical conductivity and organic carbon content of soil after harvest of fenugreek.

**Page 1 to 59**

# 1. INTRODUCTION

The importance of micronutrients in Indian agriculture is truly well recognized and their use had significantly contribution to the increased productivity of several crops. Micronutrients are essentially as important as macronutrients to have better growth, yield and quality in plants. In the past, there was no need of addition of micronutrients in soil because these trace elements were naturally supplied by soil. There was an adequate use of organic manures which could supply some quantities of micronutrients to the crops.

Micronutrients are present in soil but may not be available to plants. Micronutrients are to be necessarily taken up by the plants from soil or supplemented through foliar application for good growth and yield of crops. In the absence of these micronutrients, the plants are known to suffer from physiological disorders which eventually lead to imbalanced growth and low yield. The role of micronutrients in various metabolic processes and the enzymes involved in these processes has been reported by Zende (1996). Micronutrients are involved in all metabolic and cellular functions. Plants differ in their need for micronutrients.

Iron is involved in the production of chlorophyll and iron chlorosis is easily recognized on iron-sensitive crops growing on calcareous soil. Critical limit of iron in the plant is 100 ppm. It is available in $Fe^{3+}$and $Fe^{2+}$ forms. Iron is a component of many enzymes associated with energy transfer, nitrogen reduction and fixation, and lignin formation. Iron is associated with sulphur in plants to form compounds that catalyze other reactions. Iron deficiencies are mainly manifested by yellow leaves due to low levels of chlorophyll. Leaf yellowing first appears on the younger upper leaves in interveinal tissues. Severe iron deficiencies cause leaves to turn completely yellow or almost white and then brown as leaves die. Iron deficiencies are found mainly on high pH soil, although some acid, sandy soil low in organic matter also may be iron-deficient. Poorly aerated or compacted soil also reduces iron uptake by plants, uptake of iron decreases with increase in soil pH and is adversely affected by high level of available phosphorus, manganese and zinc in soil.

Zinc is one of the essential micronutrients required for the growth of plants and is also very important for the primary and secondary metabolism of plants. Critical limit of zinc is 20 ppm. It is available in the $Zn^{2+}$ form. Zinc regulates several vital physiological functions in plants. There are 59 kinds of zinc containing enzymes, representing almost all enzyme groups in plants. Zinc is a constituent of metalloenzymes and an activator of metalloenzyme complexes as well as being involved in the allosteric regulation of enzymes by virtue of its ability to modify enzyme conformation. Accordingly, the metabolic functions of zinc are various than those of most other micronutrients. Zinc participates in the glycolytic pathway, the tricarbolisms. Zinc also governs the synthesis of chlorophyll, tryptophan and ascorbic acid in plants. Deficiency of zinc starts first on younger leaves and becomes chloratic, followed by reduced in growth. The protein synthesis suffers due to the reduced activity of nitrate reductive and other enzymes.

Fenugreek *(Trigonella foenum- graecum* L.) is an annual crop, dicotyledonous plant belonging to the family *Fabaceae*. The genus name *Trigonella* means tri angled may be because of triangular shape of its flowers and the word *foenum- graecum* means ‘Greek hay’ indicating its use as a forage crop in the past. Fenugreek also is known as one of the oldest medicinal plants recognized in recorded history. As per the literature available, around 260 species of fenugreek are available worldwide. But currently, only 18 species of *Trigonella* are well known (Petropoulos, 2002).

Fenugreek plant has natural draught resistant ability and it can also grow well in the areas with moderate to low rain falls, its temperature requirement is as low as 10-15ºC, but it can neither grow well in extreme high temperature nor in extreme low temperature and especially show resistant to grow in the areas covered with snow. Researchers have reported that fenugreek yields maximum in the areas where low temperature dry season follows rainy season which is the typical subtropical and Mediterranean atmosphere.

The fenugreek seeds germinate in soil within three days. Seedling grows up to 30 to 60 cm which can be erect, semi-erect or branched based on its variety. It has compound pinnate, trifoliate leaves, axillary white to yellow flowers, and 3-15 cm long thin pointed hoop-like beaked pods with 10-20 oblong greenish-brown seeds with unique hoop like groves. The plant has trifoliate, pinnate leaves, 3-15 cm long thin pointed hoop-like beaked yellow-brown pods with 10-20 seeds and white to yellow flowers, flowering starts after 30-40 days of sowing. Fenugreek is a self- pollinating annual legume bean of *Fabaceae* family.

Fenugreek has been referred to as a medicinal herb both in Indian Ayurvedic and traditional Chinese medicines. It was used medicinally from wound-healing to bust enhancement and for promoting lactation in weaning mothers. Its leaves and seed have been used extensively to prepare extracts and powders for medicinal use. Generally, three chemical constituents of fenugreek are very important; *i.e.* i) steroidal sapogenins, ii) galactomannans and iii) isoleucine. These constituents have placed fenugreek among the most commonly recognized "nutraceutical" or health food products. Three main constituents of fenugreek are saponins, flavonoids and alkaloids. The bitter taste and specific smell of fenugreek is due to alkaloids and some other volatile compounds. Fenugreek contains 4.8 per cent saponin, 35 per cent alkaloids, 10 per cent falvanoids

(100mg flavanoid per gram of fenugreek seed). Fenugreek is a rich source of vitamin B1, iron, silicon, sodium, saponins, dietary fibres, protein, amino acids and fatty acid contents.

Fenugreek is spread across the world because of its ability to survive in vast range of temperatures and soil types. Fenugreek is cultivated as crop in countries like Portugal, Spain, United Kingdom, Germany, Austria, Switzerland, Greece, Turkey, Egypt, Sudan, Ethiopia, Kenya, Tanzania, Israel, Lebanon, Morocco, Tunisia, India, Pakistan, China, Japan, Russia, Argentine. India ranks first in the production.

In India fenugreek is grown in winters as *rabi* crop. The major states growing fenugreek are Rajasthan, Madhya Pradesh, Gujarat, Uttar Pradesh, Maharashtra and Punjab. As per APEDA Agriculture Exchange Report, in the year 2015-2016, total production (000 Tonnes) was 247.14 in India. Rajasthan had 77.03 per cent, Madhya Pradesh with 10.12 per cent and Gujarat with 5.73 per cent share.

The micronutrients increase productivity. Macro and micronutrient play a vital role in the physiology of plants. The application of micronutrient either foliar or through soil is very essential for higher production and quality improvement of fenugreek. Amongst the micronutrients iron and zinc have recently assumed greater importance in vegetable production. The application of micronutrients to fenugreek crops has shown promises, however the research work on this aspect is scanty and staggered. Therefore, the present investigation was undertaken to study the effect of micronutrients on nutrient uptake, seed yield and quality of fenugreek with following objectives :

1.To study the influence of iron and zinc on growth parameters of fenugreek

2. To study the influence of iron and zinc on yield and nutrients uptake by fenugreek

3.To study the influence of iron and zinc on soil chemical properties after harvest of fenugreek

# 2. REVIEW OF LITERATURE

Fenugreek is (*Trigonella foenum-graecum* L.*)* native of South Eastern Europe and West Asia, is cultivated as a leafy vegetable, condiment and as medicinal plant. The fresh tender leaves and stem are consumed as curried vegetable and the seeds are mainly used as spice for flavouring almost all dishes. It has a high medicinal value as it prevents constipation, removes indigestion, stimulates spleen and liver and is appetizing and diuretic. India is the largest producer in the world. It is exported to Saudi Arabia, Japan, Sri Lanka, Korea and UK.

In plants a micronutrient deficiency is a physiological plant disorder which occurs when a micronutrient is deficient in the soil in which a plant grows. Micronutrients are distinguished from macronutrients (nitrogen, phosphorus, sulphur, potassium, calcium and magnesium) by the relatively low quantities needed by the plant. A number of elements are known to be needed in these small amounts for proper plant growth and development. Nutrient deficiencies in these areas can adversely affect plant growth and development. Some of the best known trace mineral deficiencies include: zinc deficiency, boron deficiency, iron deficiency, and manganese deficiency. For proper maintenance of balanced nutrition, better health and proper growth, it is most essential that plants be properly fed with essential mineral elements.

The available literature on the effect of iron and zinc nutrition on seed yield, nutrient uptake and quality of fenugreek and various other crops has been reviewed and presented in this chapter.

1. Influence of iron and zinc on growth parameters of fenugreek and other vegetables.
2. Influence of iron and zinc on yield and nutrients uptake by fenugreek and other vegetables.
3. Influenceof iron and zinc on soil chemical properties after harvest of fenugreek and other vegetables.

## 2.1 Influence of Iron and Zinc on Growth Parameters of Vegetable Crops

### 2.1.1 Influence of Iron and Zinc on Plant Height

Shivappa (2005) carried experiment to study effect of micronutrients on growth, yield and quality of tomato. He observed that at 30 DAT, combined foliar spray of manganese and iron each at 0.1% recorded maximum plant height (19.90 cm). The increase in plant height by foliar application of manganese and iron was to an extent of about 13.7 per cent over control. At 60 DAT a combined foliar spray of zinc, boron, iron and manganese each at 0.1 per cent concentration was most effective followed by the treatments, foliar spray of Zinc + Boron + Iron (57.22 cm), Zinc + Boron + Iron (59.50 cm) in that they increase the plant height significantly over the other treatments. The combined spray (foliar spray of zinc, boron, iron and manganese each at 0.2%.) augmented the plant growth resulting in 45% increase in plant height over control.

Kotecha *et. al.* (2011) conducted experiment on effect of foliar application of micronutrients and growth regulators on growth and yield of cabbage. Among all the interactions of micronutrients and growth regulators treatments, interaction of zinc sulphate 0.5 per cent + GA3 100 ppm recorded significantly highest plant height (15.85 cm).

Maximum plant height (67.500 cm) was observed in P @ 50 kg $ha^{-1}$ and Zinc @ 4 ppm $ha^{-1}$ in garlic (Arif *et. al*. 2016).

Significantly maximum increase in plant height was recorded with combined application of foliar spray of 0.5 per cent zinc sulphate + 0.5 per cent ferrous sulphate over control in fennel. The results indicated that soil application of 30 kg $ha^{-1}$zinc sulphate being at par with 100 kg $ha^{-1}$ ferrous sulphate recorded significantly higher plant height of fennel over control (Choudhary *et. al.* 2015). Saleha Tawab *et. al.* (2015) reported maximum plant height (131.89 cm) for plants treated with 0.2 per cent zinc in brinjal.

Saravaiya *et. al*. (2014) recorded that the yield obtained with treatment N: $P_2O_5$: $K_2O$ kg $ha^{-1}$ (75: 37.5: 62.5) + mixture of 100 ppm boric acid + 100 ppm zinc sulphate + 100 ppm copper sulphate + 100 ppm ferrous sulphate + 100 ppm manganese sulphate) had significantly maximum plant height (131.73 cm) in tomato.

The highest plant height (2.93 cm) observed due to Boron 1.25 g $L^{-1}$ + Zinc 1.25 g $L^{-1}$ treatment in tomato. (Shnain *et. al*. 2014)

Palankar (2014) studied 'effect of major and micronutrients, plant spacing and stages of picking on seed yield and quality of cluster bean'. At harvest, spraying of boron @ 0.1 per cent + zinc sulphate @ 0.5 per cent recorded significantly the higher plant height (83.14 cm) compare to other treatments which was on par with foliar spray of zinc sulphate @ 0.5 per cent (82.00 cm).

Saravaiya *et. al.* (2014) reported significantly maximum plant height (131.73 cm) was recorded due to the RD NPK through chemical fertilizers N: $P_2O_5$ :$K_2O$ (75 :37.5:62.5) kg $ha^{-1}$ + mixture of all micronutrients (100 ppm Copper + 100 ppm Boron + 100 ppm Zinc + 100 ppm Mangenese + 100 ppm Iron) in tomato.

Ali *et. al*. (2015) conducted experiment on effects of foliar application of zinc and boron on growth and yield of summer tomato. Maximum plant height (106.9 cm) was found from foliar application of 12.5 ppm $ZnSO_4$ + 12.5 ppm $H_3BO_3$.Combined foliar application of zinc and boron was more effective than the individual application of zinc or boron on growth and yield.

Seed inoculation with *Azospirillum* + PSB + foliar spray of zinc sulphate @ 0.5 per cent recorded maximum plant height in coriander (Mounika *et. al.* 2017). The plant height (cm) at 60, 90 and at maturity increased significantly with increasing concentration of micronutrients (up to 0.4%) in eggplant cv HLB 12. The study suggested that for getting maximum plant growth of eggplant cv HLB 12, the crop should be sprayed with zinc sulphate @ 0.4 per cent (Pandav *et. al.* 2016).

Soil application of 7.5 zinc kg $ha^{-1}$ significantly enhanced the plant height (118.23 cm) in okra which was reported by Sharma *et. al.* (2018**)**. Plant height in brinjal was influenced by 10 mg Zn + 10 mg B and was significantly superior at 5 per cent over rest of the treatments reported by Solanki *et. al.* (2017). Uikey (2018) observed significantly maximum plant height in RDF + Borax (0.2%) + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) in brinjal.

Khatemenla *et. al*. (2018) conducted experiment on effect of zinc and boron on growth, yield and quality of onion. The highest plant height (57.47 cm) was in treatment combination of Zn 25 kg + B 5 kg $ha^{-1}$.The results clearly indicated that soil application of Zn 25 kg $ha^{-1}$ + B 5 kg $ha^{-1}$ significantly improved the growth of onion compared to other treatment combinations and control.

Kuldeep *et. al.* (2018) studied effect of iron and zinc nutrition on growth attributes and yield of chickpea. The results of experiment indicated that plant height increased significantly with the increase in iron levels up to 4.0 kg $ha^{-1}$ Fe. Zinc application had also positive effect on all growth attributes are significantly increased with the levels of zinc up to 2.5 kg $ha^{-1}$.

Kumawat (2018) studied on the effect of plant growth regulators and micronutrients on growth, yield and quality of okra and reported that growth regulators and micronutrients significantly improved the plant height of okra. The Maximum plant height (28.67 cm) was recorded when sprayed NAA @ 20 ppm followed by $FeSO_4$ 0.25 per cent at 20, 40 and 60 days after sowing.

### 2.1.2 Influence of Iron and Zinc on Number of Branches per Plant

Patel *et. al.* (2011) studied effect of zinc and iron on yield and yield attributes of rainfed cowpea**.** The results revealed that the application of $ZnSO_4$ at 25 kg $ha^{-1}$ through soil proved to be most effective and increased the seed yield by 43.0 per cent when compared with control followed by the spraying of 0.5 per cent $ZnSO_4$ at 25 and 45 DAS. The increase in yield was due to increase in number of branches per plant.

Saravaiya *et. al.* (2014) conducted experiment on the effect of foliar application of micronutrients in tomato. Showed that the yield obtained with treatment N: $P_2O_5$ : $K_2O$ (75 : 37.5 : 62.5) kg $ha^{-1}$ + mixture of 100 ppm boric acid + 100ppm zinc sulphate + 100ppm copper sulphate + 100 ppm ferrous sulphate + 100ppm manganese sulphate) had significantly maximum number of branches $plant^{-1}$ (5.81).

Maximum number of branches (11.9 $plant^{-1}$) was found by foliar application of 12.5 ppm $ZnSO_4$ + 12.5 ppm $H_3BO_3$ in summer tomato. (Ali *et. al.*, 2015). The highest number of branches were recorded due to B-0.2 per cent foliar + Zn-0.2 per cent foliar + Si-20 ppm in soil in bitter gourd (Mohammed, 2015).

Seed inoculation with *Azospirillum* + PSB + foliar spray of zinc sulphate @ 0.5 per cent recorded maximum number of primary branches in coriander (Mounika *et. al.* 2017).

Sharma *et. al.* (2018**)** conducted experiment to study the effect of zinc on growth, yield and quality of okra. Results indicated that the soil application of 7.5 kg $ha^{-1}$ zinc significantly enhanced the number of branches per plant (2.58).

Maximum number of branches per plant were obtained in brinjal by combination of treatment 10 mg Zn + 10 mg B and was significantly superior at 5 per cent over rest of the treatments (Solanki *et. al.* 2017). Significantly maximum number of branches $plant^{-1}$ was registered in RDF + Borax (0.2%) + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) treatment in brinjal (Uikey 2018).

Kuldeep *et. al.* (2018) studied 'effect of iron and zinc nutrition on growth attributes and yield of chickpea**.** The results of experiment indicated that number of branches per plant increased significantly with the increase in iron levels up to 4.0 Fe kg $ha^{-1}$.

### 2.1.3 Influence of Iron and Zinc on Number of Trifoliate Leaves

The maximum number of leaves $plant^{-1}$ (6.85) in P @ 50 kg $ha^{-1}$ and Zn @ 4 ppm in garlic (Arif *et. al.* 2016). Maximum number of leaves per plant (437.78) was recorded for plants treated with 0.2% zinc in brinjal (Saleha Tawab *et. al.* 2015).

Hallur (2013) reported that number of inner leaves in cabbage increase significantly due to soil application of zinc, iron and boron. Application of $ZnSO_4$ @ 25 kg $ha^{-1}$ + Borax @ 2 kg $ha^{-1}$ along with RDF recorded significantly higher performance of growth parameters.

Arabhavi (2014) recorded that number of inner leaves of knol-khol increased significantly due to soil application of $ZnSO_4$ @ 20 kg $ha^{-1}$ + Borax @ 2.5 kg $ha^{-1}$ along with RDF.

Ali *et. al*. (2015) conducted experiment on effects of foliar application of zinc and boron on growth and yield of summer tomato. Maximum number of leaves (68.9 plant$^{-1}$) was found due to foliar application of 12.5 ppm $ZnSO_4$ + 12.5 ppm $H_3BO_3$. Combined foliar application of zinc and boron was more effective than the individual application of zinc or boron on growth and yield.

Ghritlahare *et. al.* (2015) conducted experiment effect of zinc and iron on yield and yield attributes of okra. The results of experiment indicated that, application of $ZnSO_4$ at 50 kg ha$^{-1}$ significantly increased number of leaves per plant. Among different levels of iron, application of 50 kg ha$^{-1}$ $FeSO_4$ significantly increased number of leaves per plant.

Maximum number of leaves (10.00) was produced when the soil was applied with 125% of recommended dose of NPK + Zn @ 7.5 kg ha$^{-1}$ ($T_{10}$) in garlic (Kaushal, 2016). In brinjal maximum number of leaves per plant was obtained by combination of treatments 10 mg Zn + 10 mg B and was significantly superior over rest of the treatments (Solanki *et. al.* 2017).

Significantly maximum number of leaves plant$^{-1}$ was registered by treatment RDF + Borax (0.2%) + $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) in brinjal (Uikey 2018). Maximum leaves per plant due to the treatment RDF + Zinc sulphate 25 kg ha$^{-1}$ in onion (Veer *et. al*. 2018) .

Khatemenla *et. al*. (2018) conducted experiment on effect of zinc and boron on growth, yield and quality of onion. The highest number of leaves (12.37) was in treatment combination of Zn 25 kg ha$^{-1}$ + B 5 kg ha$^{-1}$.

## 2.2 Influence of Iron and Zinc on Yield Parameters of Vegetable Crops

### 2.2.1 Influence of Iron and Zinc on Plant Weight at Harvest

Saimbhi *et. al.* (1979) conducted a field experiment to study the influence of phorate at 1.25 kg ha$^{-1}$, alone and in combination with Fe-EDTA (4 ppm Fe) on okra. Phorate alone and in combination with Fe-EDTA increased both fresh and dry weights per plant in comparison to control, $FeSO_4$, EDTA and Fe-EDTA.

The treatment (RDF N: $P_2O_5$: $K_2O$ kg ha$^{-1}$ (75:37.5:62.5) + 100 ppm Copper + 100 ppm Boron + 100 ppm Zinc + 100 ppm Mangenese + 100 ppm Iron) had significantly maximum fresh weight of plants (25.65 t ha$^{-1}$), dry matter yield of plants (7670.03 kg ha$^{-1}$) in tomato cv. Gujarat Tomato-2 (Saravaiya *et. al.* 2014).

### 2.2.2 Influence of Iron and Zinc on 1000 Seeds Weight

Abid Ali *et. al.* (2017) studied effect of phosphorus and zinc on yield of lentil. Statistically found that plots received 9 and 12 Zn kg $ha^{-1}$ produced more 1000 grain weights (30.6 g and 29.4 g).

### 2.2.3 Influence of Iron and Zinc on Number of Pods per Plant

Patel *et. al.* (2011) studied effect of zinc and iron on yield and yield attributes of rainfed cowpea. The results revealed that the application of $ZnSO_4$ at 25 kg $ha^{-1}$ through soil proved to be most effective and increased the seed yield by 43.0% when compared with control followed by the spraying of 0.5% $ZnSO_4$ at 25 and 45 DAS. The increase in yield was due to increase in number of pods per plant.

Palankar (2014) noticed significantly higher number of pods per plant (30.77) in cluster bean by spraying of boron @ 0.1 per cent + zinc sulphate @ 0.5 per cent as compared to other treatments. But it was on par with spraying of zinc sulphate @ 0.5 per cent alone.

Maximum number of pods per plant (27.40 pod $plant^{-1}$) were noted under the treatment RDF + zinc sulphate 20 kg $ha^{-1}$ (soil application) in fenugreek (Mahobiya, 2016). Application of zinc at 9 kg $ha^{-1}$ produced more pods $plant^{-1}$ (117) in lentil (Abid Ali *et. al.* 2017).

### 2.2.4 Influence of Iron and Zinc on Seed Yield

Saimbhi *et. al.* (1979) conducted a field experiment to study the influence of phorate at 1.25 kg $ha^{-1}$, alone and in combination with Fe-EDTA (4 ppm Fe) on okra. Phorate alone and in combination with Fe-EDTA increased seed yield (12 ql $ha^{-1}$) in comparison to control, $FeSO_4$, EDTA and Fe-EDTA alone.

Patel *et. al.* (2011) studied effect of zinc and iron on yield and yield attributes of rainfed cowpea. The results revealed that the application of $ZnSO_4$ at 25 kg $ha^{-1}$ through soil proved to be most effective and increased the seed yield by 43.0% when compared with control followed by the spraying of 0.5% $ZnSO_4$ at 25 and 45 DAS. The increase in yield was due to increase in number of pods per plant, 100-seed weight and number of branches per plant.

Choudhary *et. al*. (2015) conducted experiment on effect of soil and foliar application of zinc and iron on yield, quality and economics of fennel. The results indicated that soil application of 30 kg $ha^{-1}$ zinc sulphate being at par with 100 kg $ha^{-1}$ ferrous sulphate recorded significantly higher seed yield of fennel over control. The significantly maximum seed yield was recorded with combined foliar spray of 0.5 % zinc sulphate + 0.5 % ferrous sulphate over control.

Diana *et. al.* (2015) conducted experiment on coriander cv CO4 to study impact of micronutrients. The study revealed that highest seed yield per hectare (623.3 kg in *rabi* and 599.9 kg in *kharif*) were observed for the foliar application of 0.5% $FeSO_4$ if compared to other treatments. Foliar application of iron and zinc exhibited significant effect on resultant seed quality parameters. The study revealed the need for application of micronutrients in maximum realization of yield and quality of the coriander seed crop in calcareous soils.

Esmaeil Rezaei-Chiyaneh *et. al.* (2018) conducted experiment on response of seed yield and essential oil of black cumin affected as foliar spraying of nano-fertilizers. Concluded that combined usage of micronutrients Nano-Fe + Nano-Zn + Nano-Mn showed the greatest increase in studied traits than their individual usage. The highest seed yield (706.67 kg $ha^{-1}$) was obtained from Fe + Zn + Mn treatment.

Abid Ali *et. al.* (2017) recorded that application of zinc at 9 kg $ha^{-1}$ produced more grain yield (1846 kg $ha^{-1}$) in lentil. The experimental result concluded that phosphorus and zinc should be used at the rates of 100 kg $ha^{-1}$and 9 kg $ha^{-1}$ for the yield of lentil.

Kuldeep *et. al.* (2018) conducted experiment 'effect of iron and zinc nutrition on growth attributes and yield of chickpea'. The results of experiment indicated significant improvement in seed yield observed with the increasing levels of iron up to 4.0 kg $ha^{-1}$ Fe over control and 2.0 kg $ha^{-1}$ Fe. Similarly zinc is also an essential plant nutrient for yield. Zinc application had also positive effect on yield parameters as significantly increased with the levels of zinc up to 2.5 kg $ha^{-1}$.

**2.3 Influence of Iron and Zinc on Qualitative Parameters of Vegetable Crops**

**2.3.1 Influence of Iron and Zinc on Total Chlorophyll Content**

Jacobson and Orteli, (1956) reported that iron was essential for chlorophyll synthesis. A general chlorosis of young leaves was the most prominent symptoms of iron deficiency. (Bogard, 1966).

Mansur *et. al.* (1995) reported that zinc application through zinc sulphate to onion at 2.5 or 5 kg $ha^{-1}$ zinc increased in chlorophyll content.

Salam *et. al*. (2011) conducted experiment on quality of tomato as influenced by boron and zinc in presence of different doses of cowdung. The results revealed that the highest chlorophyll-a (42.0 μg l00$g^{-1}$) and chlorophyll-b (61.0 μg 100 $g^{-1}$) were recorded with the combination of 2.5 B kg $ha^{-1}$ + 6 Zn kg $ha^{-1}$, and 20 t $ha^{-1}$ cowdung.

Arif *et. al*. (2016) conducted experiment on interactive effect of phosphorus and zinc on the growth, yield and nutrient uptake of garlic. Maximum chlorophyll content of leaves (12.527 mg 100 $g^{-1}$) obtained with treatment P @ 50 kg $ha^{-1}$ and Zn @ 4 ppm $ha^{-1}$.

Zn at 50 mg $L^{-1}$ and Fe at 100 mg $L^{-1}$ increased chlorophyll content and yield in cucumber. The effect of Zn and Fe was promoting too, as 50 mg $L^{-1}$ and at 100 mg $L^{-1}$ of Zn and Fe led to significant increments of vegetative factors, chlorophyll. However, the best results were found when Zn was applied accompanied by Fe **(**Mohsen, 2013).

Jat *et. al.* (2017) studied, the effect of zinc and iron on quality of amaranth. The quality parameters are concerned chlorophyll a, chlorophyll b and total chlorophyll content were significantly increased by individual application of zinc at 0.45 % and iron at 0.30 % concentration.

Soil application of 7.5 zinc kg $ha^{-1}$ significantly enhanced the chlorophyll content (1.60 mg 100 $g^{-1}$) in okra. (Sharma *et. al.* 2018**).** The application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ significantly increased total chlorophyll content in french bean (Bhamare *et. al.* 2018).

### 2.3.2 Influence of Iron and Zinc on Protein Content

Hallur (2013), recorded crude protein improved with application of zinc, iron and boron in cabbage. This quality parameters of head registered significant increase due to application of $ZnSO_4$ @ 25 kg $ha^{-1}$ + Borax @ 2 kg $ha^{-1}$ over control.

Arabhavi (2014) conducted experiment on knol-khol. The crude protein improved with application of $ZnSO_4$ @ 20 kg $ha^{-1}$ + Borax @ 2.5 kg $ha^{-1}$ over control.

Application of $ZnSO_4$ at 50 kg $ha^{-1}$ significantly increased protein content of okra at harvest. Among different levels of iron application of 50 kg $ha^{-1}$ $FeSO_4$ significantly higher protein content at harvest of okra (Ghritlahare *et al.*, 2015). Seed inoculation with *Azospirillum* + PSB + foliar spray of zinc sulphate @ 0.5% recorded maximum protein content in coriander (Mounika *et. al.* 2017)

Jat *et. al.* (2017) reported in amaranth, protein content was significantly increased by individual application of zinc at 0.45 % and iron at 0.30 % concentration.

Sharma *et. al.* (2018) conducted experiment to study the effect of zinc on growth, yield and quality of okra. Results indicated that soil application of 7.5 zinc kg $ha^{-1}$ significantly enhanced the protein content (1.40 %).

Bhamare *et. al.* (2018*)* studied the effect of iron and zinc on quality and nutrient uptake of french bean on iron and zinc deficient inceptisol. Among the various treatments the application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ significantly increased protein content of french bean.

### 2.3.3 Influence of Iron and Zinc on Iron and Zinc Content of Seeds

Hossain *et. al.* (2008) reported that the Zn and N concentrations of maize grains were significantly increased with Zn application.

Said-Al Ahl *et. al.* (2009) conducted experiment to study effect of spraying with zinc and / or iron on growth and chemical composition of coriander (*Coriandrum sativum* L.) harvested at three stages of development. The results reported that the highest contents of zinc and iron in seeds produced from plants sprayed with 400 ppm zinc (118.30 ppm) and 400 ppm iron (395.00 ppm), respectively.

Pahlvan-Rad and Pessarakli (2009) reported that foliar application of Zn increased Zn concentration and Fe concentration in wheat grains 99 % and 8 % respectively. Foliar application of Fe resulted in a 21 % increased in Fe concentration and 13 % increased in Zn concentration respectively in grains.

**2.3.4 Influence of Iron and Zinc on Seed Germination**

Palankar (2014) studied effect of major and micronutrients, plant spacing and stages of picking on seed yield and quality of cluster bean. The significantly higher germination percentage (93.08 %) and seedling vigour index (2889) were recorded by application of boron @ 0.1 per cent + zinc sulphate @ 0.5 per cent compare to other treatment but which was on par with zinc sulphate @ 0.5 per cent.

Rukeiya Begum (2014) studied effect of some micronutrients application on seed yield and quality in green gram. Maximum seed germination percentage has been observed with application of micronutrients mixture (94.0%) followed by zinc sulphate @ 25 kg $ha^{-1}$ (91.6%) and borax @ 10kg $ha^{-1}$ (91.0%). All the treatments had enhancing effects on seed vigour but the maximum effect was observed with application of micronutrients mixture ($ZnSO_4$ @ 25kg $ha^{-1}$ + Borax @10 kg $ha^{-1}$ + Ammonium molybdate @ 5g $kg^{-1}$ seed + Cobalt nitrate @ 1g $kg^{-1}$ seed + Manganese dioxide @ 0.5%). Other treatments showing significantly higher enhancement of seed vigour were application of zinc sulphate @ 25 kg $ha^{-1}$, borax @10 kg $ha^{-1}$and foliar spray of $MnO_2$.

Diana *et. al.* (2015) conducted experiment on coriander cv CO4 to study impact of micronutrients. The study revealed that germination was enhanced by foliar spray of zinc, iron and copper (90%, 93% and 95%, respectively during *rabi*) and maximum germination was for the seeds of plants sprayed with zinc (94%) during *kharif*.

**2.3.5 Influence of Iron and Zinc on Seed Vigour Index**

Palankar (2014) studied effect of major and micronutrients, plant spacing and stages of picking on seed yield and quality of cluster bean. The significantly higher seedling vigour index (2889) was recorded by application of boron @ 0.1 per cent + zinc sulphate @ 0.5 per cent compare to other treatment but which was on par with zinc sulphate @ 0.5 per cent.

Rukeiya Begum (2014) studied effect of some micronutrients application on seed yield and quality in green gram. All the treatments had enhancing effects on seed vigour but the maximum effect was observed with application of micronutrients mixture ($ZnSO_4$ @ 25 kg $ha^{-1}$+ Borax @10 kg $ha^{-1}$ + Ammonium molybdate @ 5g $kg^{-1}$ seed + Cobalt nitrate @ 1g $kg^{-1}$ seed + Manganese dioxide @ 0.5%). Other treatments showing significantly higher enhancement of seed vigour were application of zinc sulphate @ 25 kg $ha^{-1}$, borax @ 10 kg $ha^{-1}$ and foliar spray of $MnO_2$.

Diana *et. al.* (2015) conducted experiment on coriander cv CO4 to study impact of micronutrients. The study revealed that foliar spray of $FeSO_4$ recorded highest vigour index (2780 in *rabi* and 1908 in *kharif*).

## 2.4 Influence of Iron and Zinc on Nutrient Uptake

Navrot and Banin (1975) evaluated that tomato plant response to iron supply in various carrier forms. The effectiveness of a new carrier for iron supply $Fe^{2+}$ and $Fe^{3+}$ absorbed to montmorillonite clay was compared to the more conventional $FeSO_4$, $FeCl_2$, NaFe-EDTA, and HFe-EDDHA. In the greenhouse experiment, iron absorbed to clay and added to the soil is superior or similar in its effects on yield and iron uptake to chelated iron added in equivalent rates and to iron salts added at much higher rates.

Samui *et. al.* (1981) observed that due to Zn and Fe application nitrogen content in seed of mustard increased. Total nitrogen and nitrogen uptake increased due to Fe and Zn application. Potassium uptake was also increased due to Fe application.

EI-Naggar and Awad (1986) reported that the amounts of NPK content in leaf material were slightly increased by spraying plants (*Visica faba*) with iron.

Abou-Hadid *et. al.* (1994) studied effect of different zinc concentrations in the nutrient solution on uptake and translocation of macro and micro nutrients in cucumber grown in nutrient film technique. Reducing zinc concentration in the nutrient solution reduced zinc concentration in the leaves and roots, and increased the percent of P and Mn concentration in the leaves and reduced it in the roots. In contrast, increasing zinc in the nutrient solution increased per cent of P and Mn concentration in the roots to toxic levels and reduced these elements in the leaves.

Balasubramanium *et. al.* (1998) revealed that in tomato application of 100 per cent soil test based NPK combined with zinc sulphate (50 kg $ha^{-1}$) borax (10 kg $ha^{-1}$) and compost coir pith (5 t $ha^{-1}$) recorded the highest dry matter production and uptake of nutrients as also the residual soil fertility over the control and other treatment combinations.

Raj *et. al.* (2001) conducted an investigation on the effect of soil application and foliar spray of Zn and Fe on yield and quality of brinjal. Significant increase in yield and

Zn and Fe content in fruit was recorded through respective application either through soil or foliage. The higher Fe content was recorded in combination treatment of 0.5 kg $ha^{-1}$ boron with 2.5 kg $ha^{-1}$ zinc (Varghese and Duraisami 2005).

Bhatt and Srivastava (2006) conducted a field experiment to study the effect of foliar application of micronutrients viz., boron, zinc, molybdenum, copper, iron and manganese mixture of all and multiplex on the nutrient content of tomato shoot and fruits. Foliar spray of most of the micronutrients significantly increased the concentration of nitrogen, phosphorus, potassium, the accumulation of manganese and boron in fruits, in shoot also except nitrogen and potassium. The accumulation of other minerals was influenced significantly by micronutrients treatment. The application of mixture of micronutrients was found to be most effective for improving the nutritional content.

Ghasemi-Fasaei and Ronaghi (2008) noticed that Fe application increased Fe uptake but decreased that of Mn, Zn and Cu uptake in wheat crop.

Radder *et. al.* (2008) studied the response of okra to moisture regimes and micronutrients in Vertisols of Malaprabha Command, Karnataka**.** Response of okra was significant due to both irrigation levels as well as micronutrient application. Application of micronutrients increased the yield of okra. The N, P, K, Zn and Fe uptake by the crop was significant due to moisture levels and micronutrient application.

Ravi (2008) noticed that application of sulphur, zinc and iron in safflower increased the uptake of nitrogen, phosphorus, potassium, sulphur, zinc and iron significantly.

Sahu *et. al.* (2008) conducted experiment to study effect of micronutrient and biofertilizers on growth yield and nutrients uptake by chickpea (*Cicer aeritinum* L.) in Vertisol. In pursuance of total uptake of Zn, Fe and B, it was revealed that micronutrient treatments as well as biofertilizers inoculate significantly increased their uptake over control. The total zinc uptake significantly affected by micronutrients and biofertilizers application. Application of RDF + $ZnSO_4$ recorded significantly highest Zn uptake (0.048 Zn kg $ha^{-1}$) followed by treatment combinations of B, Mo, Zn and Fe (0.045 Zn kg $ha^{-1}$). Similarly, the superiority of application of RDF with Mo in maintaining highest uptake of Fe (0.82 kg $ha^{-1}$ Fe) and B (0.6 $kgha^{-1}$ B) indicates synergetic effect of no inoculation.

Savitha H. R. (2008) conducted experiment to study the effect of Fe-EDTA on yield and quality of red chilli in a calcareous soil. Highest potassium, sulphur and iron uptake were recorded in treatment receiving soil application of Fe-EDTA equivalent to $FeSO_4$ at 20 kg $ha^{-1}$ + 0.5% foliar spray of Fe-EDTA at 50 and 90 DAT.

Chandra Deo and Khandelwal (2009) noticed that application of Zn and P significantly increased the P and Zn uptake with increasing level of P and Zn, but P uptake decreased at higher level of Zn.

Hallur (2013) conducted experiment on zinc, iron and boron nutrition on yield, quality and nutrient uptake by cabbage. The uptake of nutrient was significantly influenced by application of zinc, iron and boron at all the stages of crop individually and in combination. Significantly the highest uptake of N, P, K and S was recorded with application of $ZnSO_4$ @ 25kg $ha^{-1}$ + Borax @ 2 kg $ha^{-1}$ over RDF. Iron also interacted positively with a uptake of N, P, K and S. Uptake of micronutrients also increased significantly with application of the respective micronutrients alone or in combination over RDF. Application of $ZnSO_4$ @ 25kg $ha^{-1}$ + Borax @ 2 kg $ha^{-1}$ recorded the significantly highest uptake of zinc and boron and this treatment was found to be better than their individual application which in turn might have improved the yield and quality of cabbage by increasing the availability of zinc and boron in soils of the experiment site which is deficient in these micronutrients. Though soil was adequate in iron, their was significant increase in uptake of iron. $ZnSO_4$ @ 25 kg $ha^{-1}$ + $FeSO_4$ @ 25 kg $ha^{-1}$ + Borax @ 2 kg $ha^{-1}$ showing good response crop to iron application however it was on par with $ZnSO_4$ @ 25kg $ha^{-1}$ + Borax @ 2 kg $ha^{-1}$.

Shivannanavar (2013) conducted experiment on studies of zinc and boron nutrition on yield, quality and nutrient uptake in cauliflower. The uptake of nutrients were positively influenced by the soil or foliar application of zinc and boron and their combinations. The significantly highest uptake of zinc and boron was recorded in the treatment receiving soil application of $ZnSO_4$ @ 25 kg $ha^{-1}$ along with borax @ 2 kg $ha^{-1}$ and this treatment was found to be better than their individual soil or foliar application, which in turns might have increased the yield and quality of cauliflower by improving the availability of these micronutrient in the soil.

Nagare (2014) studied effect of Fe and Zn on yield, nutrient uptake and quality of onion in inceptisol. Found that recommended dose of fertilizer (N 201.1: P 48.79 and K 212.20 kg $ha^{-1}$ Fe 2367.3 g $ha^{-1}$ and Zn 1157.6 g $ha^{-1}$) and recommended dose of fertilizer along with soil application of $FeSO_4$ + $ZnSO_4$ @ 20 kg $ha^{-1}$ improved uptake of nutrients by onion (N 190.4: P 44.74 and K 206.10 kg $ha^{-1}$, Fe 2304.3and Zn 1102.3 g $ha^{-1}$). The soil application of either iron or zinc along with recommended dose of fertilizer helped to increase the uptake of respective micronutrients. The foliar application of chelated iron or zinc could improve the uptake of these nutrients compared with the treatment recommended dose of fertilizers where no iron or zinc was applied.

Arabhavi (2014) conducted experiment on knol-khol. The uptake of nutrients were significantly influenced by soil application of zinc and boron individually and in combination at all the stages of crop. Significantly the highest uptake of N, P, K and S was recorded with application of $ZnSO_4$ @ 20 kg $ha^{-1}$ + Borax @ 2.5 kg $ha^{-1}$ along with RDF. Uptake of micronutrients also increased significantly with soil application of the respective micronutrients alone or in combination over RDF. Application of $ZnSO_4$ @ 20 kg $ha^{-1}$ + Borax @ 2.5 kg $ha^{-1}$ recorded significantly highest uptake of zinc and boron.

Jadhav *et. al.* (2017) conducted effect of foliar spray and soil application of micronutrients on major nutrient content and uptake of coriander in lateritic soils of konkan region. The highest N uptake (27.57 kg $ha^{-1}$) of coriander was obtained with the application of $ZnSO_4$ @ 0.5 per cent foliar spray along with 100 per cent RDF and P, K and S uptake (4.43, 28.01 and 4.24 kg $ha^{-1}$ respectively) of coriander was obtained with the application of $ZnSO_4$ @ 20 kg $ha^{-1}$ along with 100 per cent RDF.

Bhamare *et. al.* (2018) studied the effect of iron and zinc on quality and nutrient uptake of french bean on iron and zinc deficient inceptisol. Among the various treatments the application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ significantly increased nutrient uptake by french bean.

Khatemenla *et. al*. (2018) conducted experiment on onion. The highest Zn content in leaves (41.27 ppm) , N (1.49%), P (0.58%) and K (1.77%) content in leaves and N (1.60%), P (0.47%) and K (1.85%) content in bulbs were maximum in treatment combination of Zn 25 kg $ha^{-1}$ + B 5 kg $ha^{-1}$.

**2.5 Influence of Iron and Zinc on Soil Chemical Properties after Harvest**

Anand Swarup (1981) reported that the available Zn and Cu remained unaffected due to Fe and Mn application. After crop harvest recovery of added Fe and Mn by DTPA soil test was found to be 15.8%and 32.1% respectively.

Anand Swarup (1991) noticed that zinc application did not have any effect on soil pH, but there was significant improvement in available Zn.

Subrahmanyam *et. al.* (1991) reported that availability of Zn in soil after harvest increased with increasing Zn levels. They also found that zinc addition had no influence on availability of Fe but tended to increase availability of Mn. Zn application caused considerable increased in availability of P.

Akbari *et. al.* (2003) noticed that under various levels of zinc, iron, manganese and copper non-significant effect on pH was recorded. Organic carbon content of soil and available potash after harvest of crop were remained unchanged due to various treatments and their levels.

Vyas *et. al*. (2003) reported that there was positive balance of available N, $P_2O_5$ and $K_2O$ in soil when soyabean fertilized either with FYM alone or along with micronutrients. Meena *et. al.* (2006) reported that the Zn and Fe enriched FYM enhanced DTPA – extractable Zn and Fe content of soil.

Jatav and Kumar (2008) reported significant decreased in available phosphorus with Zn and Fe application. While there was no significant increase in available nitrogen and potassium. Available Zn increased with Zn application but not by Fe. Like wise Fe content increased significantly with Fe application, but decreased by application of Zn. Levels of Zn and Fe had little effect on $CaCO_3$.

Elayaraja *et. al.* (2016) conducted experiment on effect of zinc fertilization on the growth, yield and nutrients uptake by bhendi in coastal sandy soil. The results of the study clearly showed that the yield benefit of the treatment Zn humate @ 30 kg $ha^{-1}$ through soil application + foliar spray @ 0.5 per cent twice at 20 and 45 DAS along with recommended dose of NPK and composted coir pith @ 12.5 t $ha^{-1}$ superior in increasing the growth, yield and nutrient uptake by bhendi.

Mohammed (2015) conducted experiment on bitter gourd**.** The effect of silicon, boron and zinc application on soil nutrient status of N, P, K, Ca, Mg, S, Si, B, Zn, pH and EC was found to be significant.. Treatment application significantly influenced soil $P_2O_5$ and $K_2O$ content. Highest available $P_2O_5$ and $K_2O$ found in B-0.4% foliar + Zn-0.6% foliar + Si-40 ppm in soil and B-0.4% foliar + Zn-0.6% foliar + Si-20 ppm in soil.

Jagtap *et. al.* (2016) conducted experiment on cabbage. Reported that the application of general recommended dose of fertilizer with soil application of $FeSO_4$ and $ZnSO_4$ @ 20 kg $ha^{-1}$ each at the time of transplantation was found beneficial for maintaining iron and zinc status in iron and zinc deficient soil in medium deep black soils of western Maharashtra.

Thingujam *et. al.* (2016) carried out experiment on brinjal. The results revealed that treatment consisting of 75% RDF + *Azospirillum* + PSB + $FeSO_4$ @ 50 kg $ha^{-1}$ recorded the highest available iron (26.14 kg $ha^{-1}$) and the treatment consisting of 75% RDF + *Azospirillum* + PSB + $ZnSO_4$ @ 25 kg $ha^{-1}$ recorded the highest soil available zinc (7.62 kg $ha^{-1}$).

# 3. MATERIALS AND METHODS

The present investigation was undertaken to the study 'Effect of iron and zinc nutrition on seed yield, nutrient uptake and quality of fenugreek (*Trigonella foenum – graecum* L.) in Inceptisol in *rabi* season during 2017 on the research farm at National Agriculture Research Project, Ganeshkhind, Pune. The details regarding the materials used and methods followed during the course of investigation are presented in this chapter.

## 3.1 Materials

### 3.1.1. Selection of Experimental Site

The selection of experimental site was done on the basis of suitability of land for the cultivation of fenugreek. The land was uniformly levelled with good drainage.

## 3.2 Experimental Details

| | | | |
|---|---|---|---|
| **1.** | **Crop** | **:** | Fenugreek |
| **2.** | **Variety** | **:** | Phule Kasturi (GKF-3) |
| **3.** | **Spacing** | **:** | 30 cm X 20 cm row length |
| **4.** | **Net Plot size** | **:** | 3.00 m X 2.40 m |
| | **Gross Plot size** | **:** | 3.60 m X 3 m |
| **5.** | **Season** | **:** | *Rabi* (2017) |
| **6.** | **Design** | **:** | Randomized Block Design |
| **7.** | **Number of treatments** | **:** | 11 |
| **8.** | **Number of replications** | **:** | 3 |
| **9.** | **Sowing date** | **:** | 29 /10/ 2017 |
| **10** | **Recommended dose of fertilizer** | **:** | 40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$ + FYM 10 t $ha^{-1}$ |
| **11** | **Harvesting date** | **:** | 12 / 3 /2018 |

## 3.3 Soil

The field experiment was conducted on Inceptisol soil. The soil was deficient in DTPA extractable iron and zinc content. A composite soil sample from the experimental site was collected and processed for analysis of soil properties and fertility. Initial physio-chemical properties of soil are presented below (Table 3.1).

**Table 3.1:Initial physico-chemical properties of soil**

| Sr. No. | Soil properties | Value |
|---|---|---|
| **A.** | **Physical properties** | |
| 1. | Particle size distribution | |
| | i. Sand (%) | 26.08 |
| | ii. Silt (%) | 27.11 |
| | iii. Clay (%) | 46.15 |
| 2. | Textural class | Clay loam |
| **B.** | **Chemical properties** | |
| 1. | pH (1:2.5) | 8.15 |
| 2. | Electrical conductivity (dS $m^{-1}$) | 0.14 |
| 3. | Organic carbon (g $kg^{-1}$) | 6.60 |
| 4. | Calcium carbonate (%) | 3.25 |
| 5. | Available N (kg $ha^{-1}$) | 313.60 |
| 6. | Available P (kg $ha^{-1}$) | 30.19 |
| 7. | Available K (kg $ha^{-1}$) | 752.64 |
| 8. | DTPA-extractable micronutrients (mg $kg^{-1}$) | |
| | i. Iron | 4.10 |
| | ii. Zinc | 0.40 |
| | iii. Manganese | 12.70 |
| | iv. Copper | 5.00 |

**Table 3.2 : Chemical properties of FYM**

| Sr. No. | FYM properties | Value |
|---|---|---|
| 1. | Nitrogen (%) | 0.54 |
| 2. | Phosphorous (%) | 0.24 |
| 3. | Potassium (%) | 0.51 |
| 4. | Iron (mg $kg^{-1}$) | 619 |
| 5. | Zinc (mg $kg^{-1}$) | 26 |
| 6. | Manganese (mg $kg^{-1}$) | 41 |
| 7. | Copper (mg $kg^{-1}$) | 08 |

### 3.4 Treatment Details

$T_1$ - GRDF (40:80:80 kg $ha^{-1}$, $N:P_2O_5:K_2O$ + FYM 10 t $ha^{-1}$)

$T_2$ - GRDF + Water spray

$T_3$ - GRDF + Foliar spray of chelated Fe @ 0.1%

$T_4$ - GRDF + Foliar spray of chelated Fe @ 0.2%

$T_5$ - GRDF + Foliar spray of chelated Zn @ 0.1%

$T_6$ - GRDF + Foliar spray of chelated Zn @ 0.2%

$T_7$ - GRDF + Foliar spray of chelated Fe + Zn @ 0.1% each

$T_8$ - GRDF + Foliar spray of chelated Fe + Zn @ 0.2% each

$T_9$ - GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$

$T_{10}$ - GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$

$T_{11}$ - GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$

**Note:**

1.Source of elements- i) Iron- Chelated iron 12% ii) Zinc- Chelated zinc 12%

2. Three foliar sprays of chelated micronutrients at 8 days of interval after germination.

3. Soil application of micronutrients was done at the time of sowing.

4. The $FeSO_4$ (12 % iron) and $ZnSO_4$ (12% zinc) were incubated for 15 days in FYM before application in soil.

### 3.5 Details of Operation

#### 3.5.1 Field Experiment Operations

The various field operations were carried out timely during the course of investigations are presented below.

#### 3.5.2 Preparation of Experimental Plots

The land was brought to a good tilth by ploughing and harrowing, a spacing of 0.5m between two replications and 0.5 m between two plots were provided for laying out the irrigation channel and bunds respectively.

#### 3.5.3 Sowing

The sowing of fenugreek seeds cv Phule Kasturi (GKF-3) was done in *rabi* 2017 on 25/10/2017.

#### 3.5.4 Manures and Fertilizers

Urea, SSP, MOP, zinc sulphate and iron sulphate were obtained from Zonal Agricultural Research Station Ganeshkhind, Pune, Maharashtra, India. Half dose of nitrogen and total $P_2O_5$ and $K_2O$ was applied at the time of sowing and remaining half dose of N was given 30 days after sowing. Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$ and $FeSO_4$ @ 15 kg $ha^{-1}$ was done separately and in combination at the time of sowing.

**3.5.5 Gap Filling**

Gap filing was done with fresh seeds after seven to ten days of sowing to maintain plant population in the field.

**3.5.6 Irrigation**

First irrigation was done immediately after sowing and thereafter every eight days interval. Normal cultural practices i.e. weeding, irrigation etc. were carried out as and when required.

**3.5.7 Foliar Application of Chelated Zinc and Chelated Iron**

Three foliar applications of Chelated zinc 12 per cent and Chelated iron 12 per cent were done @ 0.1 per cent and 0.2 per cent respectively, alone and in combination in 8 days interval after germination.

**3.5.8 Harvesting**

The succulent pods were harvested. The harvested pods were further used for different observations and analysis purpose. The fenugreek plants were uprooted carefully for yield and nutrient uptake studies.

**3.6 Field Studies**

Ten plants were selected at random and tagged in each treatment and replication. The observations were recorded on various parameters of plant growth of fenugreek at different crop growth stages. The mean value of the data observed was taken to represent a particular treatment with respect to character.

**3.6.1 Observations Recorded**

**A] Plant:**

1. **Plant height (cm):** Plant height of tagged plants was measured by wooden scale.
2. **Number of branches per plant:** Number of primary branches produced per plant were recorded from tagged plants by counting the number of branches at the time of flowering.
3. **Number of trifoliate leaves:** Number of trifoliate leaves were counted from tagged plants.
4. **Germination of seeds:** 100 seeds were taken and kept for germination purpose on germination paper (crape craft paper) in germinator i.e. towel paper method. After 15 days, germinated seeds were counted to obtain germination percentage. (ISTA Rules for Seed Testing, 1993).

5. **Viability of seeds:** It was calculated in the seed testing laboratory by using 1 per cent tetrazolium solution (the topographical tetrazolium test) (ISTA Rules for Seed Testing, 2009a).
6. **Seed vigour index:** It was calculated by multiplying germination percentage with average seedling height. (Abdul Baki and Anderson, 1973)
7. **Number of pods per plant:** The number of pods produced by the tagged plants were recorded and the average number of pods produced per plant were worked out
8. **1000 grains weight:** The weight of 1000 grain seeds were counted from the sample drawn randomly from the finally winnowed and cleaned produce of plot.
9. **Seed yield plot$^{-1}$:** After complete sun drying, fenugreek pods were picked up and harvested bundles of each plot were weighed for seed yield .
10. **Nutrient uptake** : The uptake of N, P, K and micronutrients *viz*. Fe, Zn, Cu and Mn at harvest in plant samples were estimated by estimating concentration of each nutrient and dry matter yield of fenugreek.
11. **Protein content:** The per cent crude protein content in seed was calculated by multiplying per cent nitrogen content of seed with a factor 6.25.
12. **Total chlorophyll content :** It was calculated from leave samples at 50% flowering by colorimetry method using 80% acetone (Arnon, 1949).
13. **Iron and Zinc content in seed** : Fe and Zn content in seed samples were obtained by using atomic absorption spectrophotometer after wet diacid digestion by nitric acid and perchloric acid.
14. **Plant weight at harvesting :** Single plant from each plot was carefully uprooted and used to calculate plant weight.

**B] Soil**

A composite soil sample was collected from experimental field (0-30 cm depth) before sowing of fenugreek. The soil samples (0-30 cm depth) were collected after harvest of fenugreek from all the treatments. The soil samples were air dried, ground in wooden pestle and mortar and sieved to pass through a 2 mm sieve. The processed soil samples were used for determination of various parameters by adopting standard methods of analysis.

i) Initial soil analysis was carried for estimation of pH, electrical conductivity, $CaCO_3$, organic carbon, soil available N, P, K and DTPA micronutrients.
ii) Soil analysis at harvest was carried for estimation of pH, electrical conductivity, soil available N, P, K, organic carbon and DTPA micronutrients.

## 3.7 Preparation of Plant Samples for Analysis

### 3.7.1. Plant Sampling

The pods and leaf samples were collected at harvest. These samples were dried in diffuse sunlight under laboratory condition then in oven at 70°C temperature till constant weight was obtained. The leaves and seeds were ground to fine powder. This fine powder was used for chemical analysis. The oven dried samples were digested for analysis of N, P, K and micronutrients by wet diacid digestion by nitric acid and perchloric acid.

### 3.7.2. Chemical Analysis

The soil and plant samples were analysed for different parameters in the laboratory by standard analytical methods (Table 3.2).

**Table 3.3: Method used for soil, FYM and plant analysis**

**A. Soil analysis:**

| Sr.No. | Parameters | Methods | References |
|---|---|---|---|
| 1. | Textural class | Hydrometer method | Bouyoucos (1962) |
| 2. | pH (1:2.5) | Potentiometric | Jackson (1973) |
| 3. | EC (1:2.5) | Conductometric | Jackson (1973) |
| 4. | Organic carbon | Wet oxidation | Nelson and Sommer (1982) |
| 5. | $CaCO_3$ | Acid neutralization | Piper (1966) |
| 6. | Available N | Alkaline permanganate method | Subbiah and Asija (1956) |
| 7. | Available P | 0.5 M $NaHCO_3$ (pH 8.5) | Watanabe and Olsen (1965) |
| 8. | Available K | 5 N $NH_4OAc$ | Knudsen *et. al.* (1982) |
| 9. | DTPA-micronutrients | Atomic Absorption Spectrophotometer | Lindsay and Norvell (1978) |

**B. Methods used for FYM analysis**

| Sr. No. | Parameters | Methods | References |
|---|---|---|---|
| 1. | Total N | Micro Kjeldahl | Jackson (1973) |
| 2. | Total P | Vandomolybdate yellow method colour in nitric acid system | Jackson (1973) |
| 3. | Total K | Flame Photometer | Chapman and Pratt (1961) |
| 4. | DTPA Micronutrients | Atomic Absorption Spectrophotometer | Zoroski and Burau (1977) |

**B. Plant analysis:**

| Sr. No. | Parameters | Methods | References |
|---|---|---|---|
| 1. | Total N | Micro – Kjeldahl | Jackson (1973) |
| 2. | Total P | Vandomolybdate yellow method colour in nitric acid system | Jackson (1973) |
| 3. | Total K | Flame photometer | Chapman and Pratt (1961) |
| 4. | Chlorophyll content | 80% acetone Colorimetry | Arnon (1949) |
| 5. | DTPA Micronutrients | Atomic Absorption Spectrophotometer | Zoroski and Burau (1977) |

**3.8 Statistical Analysis**

The data on various biometrical parameters recorded during the period of investigation was tabulated and subjected to statistical analysis using randomized block design (RBD) described by Panse and Sukhatme (1967). The test of significance (‘f’-test) and critical difference (CD) were read at five per cent probability.

The quantitative observations in total chlorophyll content at 50% flowering, iron and zinc content in seeds, germination of seeds, viability of seeds and seed vigour index were recorded. Hence statistical analysis was not done for these parameters.

# 4. RESULTS AND DISCUSSION

The micronutrients play a vital role in crop production. These micronutrients not only helpful for higher production but they play important role in improvement in quality of produce. The study on effect of micronutrients on seed yield, nutrient uptake and quality of fenugreek was undertaken. The results obtained under this study are presented in this chapter.

## 4.1 Influence of Iron and Zinc Application on Growth Parameters of Fenugreek.

The data pertaining to the influence of iron and zinc on growth parameters of fenugreek viz., plant height, number of branches and number of trifoliate leaves presented in the Table 4.1.

### 4.1.1 Plant Height (cm)

The application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ at the time of sowing showed significantly higher plant height (29.83 cm) which was at par with $T_8$ (GRDF + Foliar spray of chelated Fe + Zn @ 0.2% each) (29.60 cm), $T_6$ (GRDF + Foliar spray chelated Zn @ 0.2%) (28.63 cm), $T_7$ (GRDF + Foliar spray of chelated Fe+Zn @ 0.1% each), $T_5$ (GRDF + Foliar spray of chelated Zn @ 0.1%) (27.70 cm) and $T_{10}$ (GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$) (27.33 cm). Further, it was also observed that each micronutrient either foliar spray or soil application significantly increased plant height as compared to water spray. (Table 4.1).

The foliar application of chelated iron @ 0.2% increased plant height significantly over the treatment $T_1$ (GRDF) (24.23 cm). Further it was also noticed that foliar application of chelated zinc at both concentrations i.e. 0.1% and 0.2% could increase plant height significantly over $T_1$ (GRDF). The combined application of chelated iron and zinc to fenugreek had also significant effect on plant height.

The increase in height of plant might be due to effective role of micronutrients. The plant treated with Zn shows increase in plant height due to its role in synthesis of tryptophan (Shukla *et. al*., 2009), which is a precursor of auxin (IAA) and essential in nitrogen metabolism, stimulates growth. The findings discussed above are in conformity with reports made by Barman and Pal (1993), Jauhari *et al*. (2005) and Halder *et. al*. (2007) and Choudhary *et. al*. (2015) on fennel. On the other hand, Iron is a component and ferrodoxine an electron transferring protein and is associated with chloroplast. It helps in photosynthesis might have resulted in better vegetative growth. These results confirms the findings reported by Hatwar *et. al*. (2003).

**Table 4.1: Influence of iron and zinc application on growth parameters of fenugreek.**

| Treatment No. | Treatments | Plant height (cm) | Number of branches plant$^{-1}$ | No. of Trifoliate leaves |
|---|---|---|---|---|
| $T_1$ | GRDF | 24.23 | 2.80 | 44.63 |
| $T_2$ | GRDF + Water spray | 25.17 | 2.87 | 44.17 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 26.70 | 3.13 | 46.10 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 26.87 | 3.30 | 48.33 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 27.70 | 3.20 | 50.40 |
| $T_6$ | GRDF + Foliar spray of chelated zinc (0.2%) | 28.63 | 3.27 | 52.23 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 27.70 | 3.33 | 56.37 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2 %) + Foliar spray of chelated zinc (0.2%). | 29.60 | 3.47 | 63.73 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ | 26.13 | 3.33 | 57.30 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg ha$^{-1}$ | 27.33 | 3.50 | 58.13 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ + $ZnSO_4$ @ 10 kg ha$^{-1}$ | 29.83 | 3.53 | 66.70 |
| | **SEM $\pm$** | 0.87 | 0.08 | 0.73 |
| | **CD (0.05)** | 2.59 | 0.25 | 2.17 |

### 4.1.2 Number of Branches per Plant

The number of branches per plant was significantly higher in $T_{11}$ (GRDF + soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ + $ZnSO_4$ @ 10 kg ha$^{-1}$) treatment (3.53) closely followed by and at par with $T_{10}$ (GRDF + Soil application of $ZnSO_4$ @ 10 kg ha$^{-1}$) (3.50), $T_8$ (GRDF + Foliar spray of chelated of Fe + Zn @ 0.2% each) (3.47) and $T_9$ (GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$), $T_7$ (GRDF + Foliar spray of chelated Fe + Zn @ 0.1% each) (3.33) and $T_4$ (GRDF + Foliar spray of chelated iron (0.2%) (3.30) (Table 4.1).

The numbers of branches were significantly increased due to application of iron and zinc either applied through foliar sprays or soil application to fenugreek crop.

The increase in number of branches per plant might be due to zinc and iron act as the activator of several enzymes, alcoholic dehydrogenase, pyridine zinc and iron also favour the storage of more carbohydrates through photosynthesis, which may in turn be the attributing factor for the positive effect on growth attributes (Senthamizhselvi, 2000). The finding discussed above are in conformity with report made by Kuldeep *et. al.* (2018) in chickpea.

**4.1.3 Number of Trifoliate Leaves**

In case of trifoliate leaves the treatment $T_{11}$, (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) registered significantly higher trifoliate leaves (66.70) over rest of the treatments, (Table 4.1).

The trifoliate leaves were registered significantly higher due to micronutrients application as compared to $T_1$ (GRDF). The combined application of micronutrients showed higher response in respect of trifoliate leaves of fenugreek.

Higher number of trifoliate leaves are observed because micronutrients activate several enzymes and involved themselves in chlorophyll synthesis and various physiological activities by which plant growth and development are encouraged (Kumar and Aurora, 2000). These findings are in accordance with the results of Deshmukh and Wavhal (1999), Barman and pal (1999) and Kumar *et al.*(2003), Saleha Tawab *et. al.* (2015) on brinjal, Ghritlahare *et. al.* (2015) on okra and Veer *et. al*. (2018) on onion.

In general, the application of micronutrients *viz.* iron and zinc to fenugreek grown in iron and zinc deficient soils found beneficial for growth of fenugreek crop.

**4.2 Influence of Iron and Zinc Application on Yield Parameters of Fenugreek.**

The data pertaining to yield parameters as influenced by micronutrient application are presented in Table 4.2.

**4.2.1 Plant Weight at Harvest**

The plant weight at harvest was also recorded (Table 4.2). It was clearly indicated that the GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ recorded significantly higher plant weight at harvest over rest of the treatments.

The application of iron and zinc showed promising response in case of plant weight at harvest as compared to treatment $T_1$ (GRDF). The increase in plant weight at harvest ranged from 11.65 g to 18.35 g due to various treatments.

Among foliar sprays, 0.2% concentration of chelated iron *i.e.* $T_4$ treatment (13.35 g) and chelated zinc *i.e.* $T_6$ treatment (13.39 g) found superior. The combined application of chelated iron and chelated zinc showed significantly higher values of plant weight at 0.2% foliar sprays (14.33 g). Soil application of $FeSO_4$ and $ZnSO_4$ registered at par plant weight at harvest.

Increased plant weight due to micronutrients application may be attributed to enhanced photosynthesis activity and increased in production and accumulation of carbohydrates and favorable effect on vegetative growth. Kumbhar and Deshmukh (1993) and Bose and Tripathi (1996) revealed that the increased in dry matter production may be attributed to greater accumulation of photosynthates by vegetative parts. The presence of zinc activates the synthesis of tryptophan, precursor of IAA and it is responsible to stimulate plant growth. Fe plays vital role in promoting growth characters being a component of ferrodoxin and electron transport protein and is associated with chloroplast, helps in photosynthesis might have caused better vegetative growth. It was reported that use of iron increases plant weight by Saimbhi *et. al.* (1979) on okra.

**4.2.2 1000 Grain Weight**

The observation on 1000 grain weight showed that treatment $T_{11}$ (GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) reported significantly higher 1000 grain weight (12.85 g) closely followed by and at par with $T_8$ (GRDF + Foliar spray of chelated Fe + Zn @ 0.2% each) (12.71 g ), $T_7$ (GRDF + Foliar spray of chelated Fe + Zn @ 0.1% each) (12.35 g) and $T_6$ (GRDF + Foliar spray of chelated Zn @ 0.2%) (12.10 g) compared among all rest of the treatments (Table 4.2). These findings are in confirmatory with reports recorded by (Zou *et. al*. 2007) and Abid Ali *et. al.* (2017) on lentil.

**4.2.3 Number of Pods per Plant**

It could be observed from the data, that the soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ along with GRDF registered significantly higher number of pods (32.27). However, this was at par with treatment $T_8$, GRDF + foliar sprays of chelated iron (0.2%) + chelated zinc (0.2%) (31.23) (Table 4.2).

Application of zinc and iron produces healthy green plants by synthesizing chlorophyll, growth promoting substances and mobility of minerals, water, photosynthesis and amino acids from the source to sink which may in turn increase the pod production and ultimately pod yield. Similar findings were also reported by Nag and Biswas (2002) Balkrishnan *et. al.* (2007) and Naveenkumar *et. al.* (2009), Abid Ali *et. al.* (2017) on lentil and Mahobiya (2016) on fenugreek.

**4.2.4 Seed Yield**

The soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ recorded significantly higher seed yield (9.12 ql $ha^{-1}$). This was closely followed by treatments $T_8$ (GRDF + Foliar spray of chelated Fe + Zn @ 0.2% each) (8.98 ql $ha^{-1}$) and $T_{10}$ (GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$) (8.85 ql $ha^{-1}$) (Table 4.2).

Further it is interesting to note that the foliar sprays of chelated zinc found significantly superior for increasing seed yield of fenugreek. The seed yield was increased from 8.46 ql $ha^{-1}$ to 9.12 ql $ha^{-1}$.

Increased yield might be due to micronutrients helps in nitrogen assimilation and synthesis of protein and also because of catalytic role in activation of enzymes (Chaturvedi *et. al.* 1986). Mahesh Kumar and Sen (2005) reported that the increase in yield of okra due to application of zinc through soil. These results were in agreement with findings of Jhon *et al.* (1997) and Mukherjee *et. al*. (1998), Choudhary *et. al.(*2015) on fennel, Abid Ali *et. al.*(2017) on lentil and Kuldeep *et. al.* (2018) on chickpea.

In general, the application of iron and zinc found promising for increasing yield parameters of fenugreek.

**Table 4.2: Influence of iron and zinc application on yield parameters of fenugreek.**

| **Treatment No.** | **Treatments** | **Plant weight at harvest (g)** | **1000 grain weight (g)** | **No. of pods per plant** | **Seed yield (ql ha$^{-1}$)** |
|---|---|---|---|---|---|
| $T_1$ | GRDF | 11.65 | 11.37 | 16.63 | 8.46 |
| $T_2$ | GRDF + Water spray | 11.15 | 11.27 | 17.30 | 8.49 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 12.25 | 11.67 | 21.00 | 8.56 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 13.35 | 11.75 | 24.20 | 8.62 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 12.55 | 11.88 | 22.57 | 8.73 |
| $T_6$ | GRDF + Foliar spray ofchelated zinc (0.2%) | 13.39 | 12.10 | 25.97 | 8.77 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 14.33 | 12.35 | 24.23 | 8.78 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2 %) + Foliar spray of chelated zinc (0.2%). | 16.52 | 12.71 | 31.23 | 8.98 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ | 15.71 | 11.58 | 26.87 | 8.74 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg ha$^{-1}$ | 14.95 | 11.84 | 27.33 | 8.85 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ + $ZnSO_4$ @ 10 kg ha$^{-1}$ | 18.35 | 12.85 | 32.27 | 9.12 |
| | **SEM ±** | 0.50 | 0.26 | 0.79 | 0.06 |
| | **CD (0.05)** | 1.50 | 0.77 | 2.33 | 0.22 |

### 4.3 Influence of Iron and Zinc Application on Qualitative Parameters of Fenugreek

The data pertaining to Influence of iron and zinc application on qualitative parameters of fenugreek are presented below.

The quantitative observations in total chlorophyll content at 50% flowering, iron and zinc content in seeds, germination of seeds, viability of seeds and seed vigour index were recorded. Hence statistical analysis was not done for these parameters.

#### 4.3.1 Total Chlorophyll Content at 50% Flowering

The data on influence of iron and zinc on chlorophyll content at 50% flowering of fenugreek are presented in table 4.3. Total chlorophyll content was significantly higher in $T_{11}$ (GRDF + Soil application $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) (31.11 mg 100 $g^{-1}$ fresh weight ) closely followed by $T_9$ (GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$) (30.75 mg 100 $g^{-1}$ fresh weight) and $T_8$ (GRDF + Foliar spray chelated Fe + Zn @ 0.2% each) (30.55 mg 100 $g^{-1}$ fresh weight).

There was higher magnitudes of total chlorophyll where iron application was done as compared to zinc application. The soil application of $FeSO_4$ recorded higher value of total chlorophyll content (30.75 mg 100 $g^{-1}$ fresh weight). Increase in chlorophyll content was from 26.23 to 31.11 mg 100 $g^{-1}$ fresh weight.

Increase in total chlorophyll content might be due to iron plays vital role in promoting growth characters being a component of ferrodoxin, and electron transport protein and is associated with chloroplast. It helps in photosynthesis might have helped in better chlorophyll content. Zinc is associated with 59 kinds of enzymes which regulates several vital physiological functions in plants it also governs the synthesis of chlorophyll tryptophan and ascorbic acid in plants. The increase in total chlorophyll content either through soil or foliar application of iron and zinc might have associated with saccharide metabolism, photosynthesis and protein synthesis. Iron has important function in plant mechanism such as photorespiration, the glycolate pathway and chlorophyll content Miller *et. al*. (1995). Similar findings were reported by Karuppaiah (2006) and Arif *et. al*. (2016) on garlic.

#### 4.3.2 Protein Content

The treatment $T_{11}$ *i.e.* soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ recorded significantly higher protein content (25.92%). This was closely followed by treatments $T_{10}$ (GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$ and $T_8$ (GRDF + Foliar spray of chelated Fe + Zn @ 0.2% each) (25.46%). (Table 4.3). However the treatment $T_{11}$ was significantly superior over rest of the treatments.

The increase in protein content content either through soil or foliar application of iron and zinc might have associated with increase in nitrogen content. As iron plays important role in nitrogen fixation and energy transfer. Zinc regulates several vital physiological functions in plants. There are 59 kinds of zinc containing enzymes. Zinc is a constituent of metalloenzymes and an activator of metalloenzyme complexes as well as being involved in the allosteric regulation of enzymes by virtue of its ability to modify enzyme conformation. The protein synthesis suffers due to the reduced activity of nitrate reductive and other enzymes. Hence application of zinc has showed positive effect on the protein content. Similar findings were also reported by Ghritlahare *et. al.* (2015) on okra and Jat *et. al.* (2017) on amaranth.

**Table 4.3: Influence of iron and zinc application on chlorophyll content and protein content of fenugreek.**

| Treatment No. | Treatments | Total chlorophyll content (mg 100 $g^{-1}$ fresh weight) | Protein content (%) |
|---|---|---|---|
| $T_1$ | GRDF | 26.23 | 25.09 |
| $T_2$ | GRDF + Water spray | 27.62 | 25.11 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 29.25 | 25.21 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 29.29 | 25.21 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 28.25 | 25.29 |
| $T_6$ | GRDF + Foliar spray ofchelated zinc (0.2%) | 28.90 | 25.21 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 29.79 | 25.25 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2 %) + Foliar spray of chelated zinc (0.2%). | 30.55 | 25.46 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ | 30.75 | 25.29 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$ | 28.75 | 25.46 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ | 31.11 | 25.92 |
| | **SEM $\pm$** | | 0.08 |
| | **CD (0.05)** | | 0.22 |

### 4.3.3 Iron and Zinc Content in Seed

The data pertaining to iron and zinc content in seeds are presented in Table 4.4. It was clearly noticed that there was remarkable increase in iron content in seed due to application of iron to fenugreek. The treatment $T_{11}$ (GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ +$ZnSO_4$ @ 10 kg $ha^{-1}$) registered higher iron content in seed (34.90 mg $kg^{-1}$) followed by $T_9$ (GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$) (34.20 mg $kg^{-1}$). The application of iron either through soil or foliar could increase iron content in seed. Values ranged from 25.20 to 34.90 mg kg$^{-1}$. Application of zinc either through foliar or soil could helped to improve zinc content in seed. The higher content of zinc in seed was observed in treatment $T_{11}$ (GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ +$ZnSO_4$ @ 10 kg ha$^{-1}$) (71.20 mg kg$^{-1}$) followed by $T_{10}$ (GRDF + Soil application of $ZnSO_4$ @ 10 kg ha$^{-1}$) (69.90 mg kg$^{-1}$) (Table 4.4).

The increase in content of iron due to $FeSO_4$ might be attributed to easy availability of iron from $FeSO_4$. The $ZnSO_4$ plays synergetic effect for availability of iron. Pahlvan-Rad and Pessarakli (2009) reported that foliar application of Zn increased Zn concentration and Fe concentration in wheat grains 99 % and 8 % respectively. Hossain *et. al.* (2008) reported that the Zn and N concentrations of grains were significantly increased with Zn application.

In general application of iron and zinc to fenugreek promises to increase iron and zinc content in seed respectively.

**Table 4.4: Influence of iron and zinc application on iron and zinc content in fenugreek seed.**

| Treatment No. | Treatments | Iron content in seed (mg kg$^{-1}$) | Zinc content in seed (mg kg$^{-1}$) |
|---|---|---|---|
| $T_1$ | GRDF | 25.20 | 40.30 |
| $T_2$ | GRDF + Water spray | 26.80 | 48.20 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 30.80 | 55.40 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 31.50 | 55.30 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 28.50 | 60.20 |
| $T_6$ | GRDF + Foliar spray of chelated zinc (0.2%) | 29.00 | 67.70 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 31.10 | 61.40 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2 %) + Foliar spray of chelated zinc (0.2%). | 33.40 | 69.50 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ | 34.20 | 60.20 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg ha$^{-1}$ | 32.10 | 69.90 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ + $ZnSO_4$ @ 10 kg ha$^{-1}$ | 34.90 | 71.20 |

**4.3.4 Germination of Seeds**

The data on iron and zinc application on seed quality of fenugreek (Table 4.5) showed that there was 89% germination of seeds due to treatment GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ closely followed by $T_{10}$ (GRDF + Soil application $ZnSO_4$ @ 10 kg $ha^{-1}$) (3.50) (87%) and $T_8$ (GRDF + Foliar spray chelated Fe + Zn @ 0.2% each) (86%) which was higher over $T_1$ (GRDF (40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$) + FYM 10 t $ha^{-1}$) (76%) (Table 4.5).

The germination of fenugreek seed was increased due to iron and zinc application either through foliar spray or through soil. However the zinc application to fenugreek showed significantly higher values of germination of fenugreek seeds.

The increase in seed germination may be due to the participation of micronutrients in catalytic activity and breakdown of complex substances into simple forms like glucose, amino acids and fatty acids. Due to active role of different micronutrients in meristimatic growth, nitrogen assimilation, hormonal biosynthesis, protein synthesis and photosynthetic process. Similar results were also recorded by Rajput *et. al*. (2003) and Girwani *et. al*. (1990). Plant needs iron to produce chlorophyll and to activate several enzymes including those involved in the oxidation / reduction processes of photosynthesis and respiration. Zinc is an important for the formation and activity of chlorophyll and in the functioning of several enzymes and growth hormone auxin. These results confirms the findings reported by Hatwar *et. al*. (2003) and Suryawanshi (2010).

**4.3.5 Viability of Seeds**

The viability of seed was higher in $T_{11}$ (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) (93.62%) treatment closely followed by $T_{10}$ (GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$) (89.26%) and $T_8$ (GRDF + Foliar spray chelated Fe+Zn @ 0.2% each) (87.78%) compared to $T_1$ (GRDF (40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$) + FYM 10 t $ha^{-1}$) (81.38%) (Table 4.5).

The viability of seed was also influenced due to iron and zinc application. Among different foliar treatments the application of zinc showed promising results over foliar application of iron as far as viability of seeds is concerned. The increase in viability of fenugreek due to micronutrients might be due to their role in fundamental processes involved in cellular mechanism and respiration. These findings confirms the results reported by Srihari *et. al*. (1987), Medhi and Kakati (1994), Singh and Hooda (1992) and Suryawanshi (2010).

**Table 4.5: Influence of iron and zinc application on seed quality of fenugreek.**

| Treatment No. | Treatments | Germination of seeds (%) | Viability of seeds (%) | Seed vigour index |
|---|---|---|---|---|
| $T_1$ | GRDF | 76 | 81.38 | 1195 |
| $T_2$ | GRDF + Water spray | 79 | 84.35 | 1232 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 81 | 86.96 | 1288 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 82 | 85.74 | 1394 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 84 | 87.56 | 1463 |
| $T_6$ | GRDF + Foliar spray of chelated zinc (0.2%) | 85 | 89.32 | 1471 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 83 | 86.66 | 1427 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2%) + Foliar spray of chelated zinc (0.2%). | 86 | 87.78 | 1564 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ | 81 | 84.56 | 1328 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$ | 87 | 89.26 | 1556 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ | 89 | 93.62 | 1618 |

**4.3.6 Seed Vigour Index**

The seed vigour index was higher in $T_{11}$ (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) (1618) closely followed by $T_8$ (GRDF + Foliar spray chelated Fe + Zn @ 0.2% each) (1564) compared over $T_1$ (GRDF (40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$) (1195). It was ranged from 1195 to 1617 (Table 4.5).

Micronutrients application have a great influence on vegetative growth, because they enhance the availability of micronutrients and also activate the plant defence mechanism result in vegetative growth (Bashir *et. al.* 2013). The obtained results are in conformity with those of El-Khayat (1999), Gomaa, (2001), Yadav *et. al.* (2002) and Samia and Mahmoud (2009) also Nahed and Laila (2007), Farahat *et. al.* (2007) and Rawia *et. al.* (2010).

In general, the qualitative parameters *viz.* germination of seeds, viability of seeds and seed vigour index found to be increased due to application of iron and zinc to fenugreek.

## 4.4 Influence of Iron and Zinc Application on Macronutrient Nutrient Uptake of Fenugreek

The N, P and K uptake by fenugreek was influenced significantly by the different treatments (Table 4.6).

### 4.4.1 Nitrogen Uptake

There was significant increase in nitrogen uptake (112.82 kg ha-1) due to application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$. The uptake of nitrogen was ranged from 87.93 kg $ha^{-1}$ to 112.82 kg $ha^{-1}$ (Table 4.6).

The increase in nitrogen uptake through soil application of iron and zinc might have associated with increase in nitrogen content. As iron plays important role in nitrogen fixation and energy transfer. These findings are in supportive to earlier results reported by Samui *et. al.* (1981), Balasubramanium *et. al.* (1998), Bhatt and Srivastava (2006), Radder *et. al.* (2008) and Ravi (2008). The synergistic effect of zinc with nitrogen might have attributed to increase in nitrogen uptake by fenugreek. These findings are in accordance with the results of Savitha (2008) on red chilli and Jadhav *et. al*. (2017) on coriander.

### 4.4.2 Phosphorus Uptake

In case of uptake of phosphorous, significantly higher uptake was registered in $T_{11}$ (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) (4.66 kg $ha^{-1}$) and at par with $T_7$ (GRDF + Foliar spray of chelated Fe + Zn @ 0.1% each) (4.52 kg $ha^{-1}$), $T_4$ (GRDF + Foliar spray of chelated Fe@ 0.2%) (4.51 kg $ha^{-1}$), $T_8$ (GRDF + Foliar spray of chelated Fe + Zn @ 0.2% each) (4.48 kg $ha^{-1}$) and $T_3$ (GRDF + Foliar spray of chelated Fe @ 0.1%) (4.21 kg $ha^{-1}$) (Table 4.6).

It indicated that soil application of $ZnSO_4$ showed antagonistic effect in respect of uptake of phosphorus. Similar antagonistic effect of Zn in respect of P uptake has been reported by Hossain *et. al.* (2008) and Chandra Deo and Khandelwal (2009). The amounts of NPK content in leaf material were slightly increased by spraying plants (*Visica faba*) with iron (EI-Naggar and Awad 1986). The application of sulphur, zinc and iron increased uptake of NPK significantly over control (Ravi *et. al.* 2008).

**Table 4.6: Influence of iron and zinc application on macronutrient uptake by fenugreek.**

| Treatment No. | Treatments | Nitrogen | Phosphorous | Potassium |
|---|---|---|---|---|
| | | (kg ha$^{-1}$) | | |
| $T_1$ | GRDF | 87.93 | 3.94 | 30.62 |
| $T_2$ | GRDF + Water spray | 88.50 | 3.74 | 33.02 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 94.97 | 4.21 | 37.43 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 95.42 | 4.51 | 37.98 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 91.72 | 4.31 | 38.60 |
| $T_6$ | GRDF + Foliar spray of chelated zinc (0.2%) | 93.07 | 4.17 | 34.73 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 95.64 | 4.52 | 38.07 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2%) + Foliar spray of chelated zinc (0.2%). | 101.67 | 4.48 | 37.38 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ | 90.82 | 3.82 | 33.72 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg ha$^{-1}$ | 97.07 | 4.04 | 35.69 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ + $ZnSO_4$@ 10 kg ha$^{-1}$ | 112.82 | 4.66 | 49.29 |
| | **SEM $\pm$** | 3.47 | 0.16 | 1.34 |
| | **CD (0.05)** | 10.30 | 0.46 | 3.97 |

### 4.4.3 Potassium Uptake

The uptake of potassium was significantly higher in $T_{11,}$ GRDF + soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ + $ZnSO_4$ @ 10 kg ha$^{-1}$ (49.29 kg ha$^{-1}$) over all rest of treatments. The uptake of potassium ranged from 30.62 to 49.29 kg ha$^{-1}$(Table 4.6).

The combined application of $FeSO_4$ + $ZnSO_4$ showed significantly higher uptake of potassium than individual application of $FeSO_4$ and $ZnSO_4$ either through foliar spray or through soil. All treatments exhibited significant increase in uptake of potassium over water spray. Samui *et. al.* (1981) reported that potassium uptake was increased due to Fe application.

In general, the uptake of macronutrients *viz.* NPK were greatly influenced by soil application of $FeSO_4$ and $ZnSO_4$ to fenugreek. The application of iron and zinc when applied under deficient condition might have helped for better uptake of NPK by fenugreek crop. The synergistic effect of zinc with potassium might have attributed to increase in potassium uptake by fenugreek. These findings are in accordance with the results of Savitha (2008) on red chilli, by Jadhav *et. al*. (2017) on coriander.

**4.5 Influence of Iron and Zinc Application on Micronutrient Uptake by Fenugreek.**

The data on influence of iron and zinc on nutrient uptake of fenugreek is presented in table 4.7.

**4.5.1 Iron Uptake**

There was significant increase in uptake of iron by fenugreek due to application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ (389 g $ha^{-1}$) and another treatment GRDF + foliar sprays of chelated iron and zinc @ 0.2% each (356 g $ha^{-1}$). These treatments were at par with each other and superior over rest of the treatments (Table 4.7).

The application of chelated iron to fenugreek when applied through foliar sprays significantly increased iron uptake. It was also noticed that the foliar sprays of chelated zinc could also helped to increase iron uptake. It might be due to complimentary influence of zinc for iron uptake. The combined application of chelated iron and zinc showed beneficial effect for iron uptake by fenugreek.

The increase in uptake of iron due to $FeSO_4$ might be attributed to easily availability of iron from $FeSO_4$. The $ZnSO_4$ plays synergetic effect for availability of iron. The uptake of Fe by the crop significantly increased up to 5 ppm, and decreased at higher level of Zn application (Subrahmanyam *et. al.* 1991).

**4.5.2 Zinc Uptake**

There was significant influence of micronutrients application on uptake of zinc by fenugreek. The treatment $T_{11}$ (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) showed significant increase in zinc uptake (159 gm $ha^{-1}$) over all rest of the treatments (Table 4.7).

Foliar sprays of chelated zinc registered significantly higher uptake of iron when compared to treatment $T_1$ (GRDF) (114 g $ha^{-1}$) and $T_2$ (GRDF + Water spray) (114 g $ha^{-1}$).

Chandra Deo and Khandelwal (2009) noticed that application of Zn and P significantly increased the P and Zn uptake. The application of $ZnSO_4$ might have supplied sufficient quantity of zinc to the crop resulting in its better uptake. The addition of $ZnSO_4$ along with $FeSO_4$ found beneficial.

The soil application of $FeSO_4$ and $ZnSO_4$ increased the uptake of iron and zinc respectively. This might be due to supply of iron and zinc to fenugreek immediately after it started vegetative growth.

### 4.5.3 Manganese Uptake

The application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ recorded significantly higher uptake of manganese (263 g $ha^{-1}$). This was closely followed by two treatments $T_8$ (GRDF + Foliar spray chelated Fe + Zn @ 0.2% each) (239 g $ha^{-1}$ ). Both these treatments significantly superior over rest of the treatments (Table 4.7).

**Table 4.7: Influence of iron and zinc application on micronutrients uptake by fenugreek.**

| Treatment No. | Treatments | Fe (g $ha^{-1}$) | Zn (g $ha^{-1}$) | Mn (g $ha^{-1}$) | Cu (g $ha^{-1}$) |
|---|---|---|---|---|---|
| $T_1$ | GRDF | 306 | 114 | 208 | 48 |
| $T_2$ | GRDF + Water spray | 310 | 114 | 209 | 53 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 334 | 121 | 224 | 56 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 339 | 123 | 228 | 57 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 320 | 127 | 218 | 56.67 |
| $T_6$ | GRDF + Foliar spray ofchelated zinc (0.2%) | 327 | 130 | 220 | 58 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 338 | 133 | 228 | 57.33 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2 %) + Foliar spray of chelated zinc (0.2%). | 356 | 140 | 239 | 62.33 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ | 321 | 122 | 213 | 56.33 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$ | 338 | 138 | 228 | 59.33 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ | 389 | 159 | 263 | 68.67 |
| | **SEM ±** | 12.15 | 4.66 | 8.20 | 2.14 |
| | **CD (0.05)** | 36.09 | 13.86 | 24.38 | 6.34 |

### 4.5.4 Copper Uptake

The application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ (68.67 gm $ha^{-1}$) and treatment $T_8$ (62.33 gm $ha^{-1}$ ) (GRDF + Foliar spray chelated Fe + Zn @ 0.2% each) registered at par uptake of copper and significantly superior over rest of the treatments.

Foliar feeding of nutrients have become an established procedure to increase yield and quality of produce (Romemheld, 1999). It may actually promote root absorption of the same nutrients or other nutrients through improving root growth and increasing nutrient uptake (Saqib *et. al.* 2006).

In general, the iron and zinc application to fenugreek helped to increase uptake of nutrients.

**4.6 Influence of Iron and Zinc on Soil Chemical Properties after Harvest of Fenugreek.**

**4.6.1 Soil pH**

The data pertaining to soil pH as influenced due to micronutrient application to crop fenugreek differed non-significantly. The pH values after harvest of crop ranged between 8.15 to 8.16 (Table 4.8).

**4.6.2 Electrical Conductivity of Soil**

The electrical conductivity of soil showed non-significant effect of various treatments. The electrical conductivity of soil was registered within 0.16 to 0.17 dS $m^{-1}$ after harvest of the crop (Table 4.8).

**Table 4.8: Influence of iron and zinc application on soil chemical properties after harvest of fenugreek.**

| Treatment No. | Treatments | pH | EC (dS $m^{-1}$) | Organic carbon (g $kg^{-1}$) |
|---|---|---|---|---|
| $T_1$ | GRDF | 8.16 | 0.16 | 6.30 |
| $T_2$ | GRDF + Water spray | 8.16 | 0.17 | 6.30 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 8.16 | 0.17 | 6.20 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 8.15 | 0.16 | 6.30 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 8.16 | 0.17 | 6.30 |
| $T_6$ | GRDF + Foliar spray of chelated zinc (0.2%) | 8.15 | 0.17 | 6.20 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 8.16 | 0.17 | 6.10 |
| $T_8$ | GDRF + Foliar spray of chelated iron (0.2 %) + Foliar spray of chelated zinc (0.2%). | 8.16 | 0.17 | 6.20 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ | 8.15 | 0.16 | 6.30 |
| $T_{10}$ | GDRF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$ | 8.16 | 0.17 | 6.30 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ | 8.15 | 0.17 | 6.40 |
| | **SEM $\pm$** | **0.004** | **0.006** | **0.06** |
| | **CD (0.05)** | **NS** | **NS** | **NS** |

**4.6.3 Soil Organic Carbon Content**

The organic carbon of the soil remained unaffected due to iron and zinc application to fenugreek crop. The organic carbon was observed in the range of 6.10 g $kg^{-1}$ to 6.40 g $kg^{-1}$ due to different treatments (Table 4.8).

The soil organic carbon was decreased in all treatments when compared with initial soil organic carbon (6.60 g $kg^{-1}$). The decrease in organic carbon might be attributed to better mineralization of organic matter. Akbari *et. al.* (2003) noticed that under various levels of zinc, iron, manganese and copper the soil pH and organic carbon content of soil after harvest of crop were remained unchanged.

**4.6.4 Available Nitrogen**

The data on influence of iron and zinc on available nutrients *viz*, N, P and K are presented in table 4.9. The perusal of data indicated that there was significantly higher available nitrogen content in all the treatments over $T_1$ (GRDF (40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$) + FYM 10 t $ha^{-1}$) and $T_2$ (GRDF + Water spray) The available N content was ranged from 334 to 361.33 kg $ha^{-1}$.

The increase in soil available nitrogen content might be due to effect of soil test with progressive inclusion of deficient nutrients, Rao Subba *et. al*. (2009). The results are in confirmity with the findings of Bhattacharyya *et. al*. (2004).

**4.6.5 Available Phosphorous**

There was not significant effect of iron and zinc application to fenugreek on available phosphorous in soil. The values ranged from 32.00 to 37.67 kg $ha^{-1}$ (Table 4.9).

**4.6.6 Available Potassium**

The available potassium was also observed significantly higher in all treatments over $T_1$ (GRDF (40:80:80 kg $ha^{-1}$ $N:P_2O_5:K_2O$ + FYM 10 t $ha^{-1}$) and $T_2$ (GRDF + water spray). The magnitude of available potassium ranged from 745.33 kg $ha^{-1}$ to 777.33 kg $ha^{-1}$ (Table 4.9).

The increased availability of K with FYM application might be due to solubilisation action of certain organic acids produced during decomposition of organic manures and its greater capacity to hold K in available form in soil. Similar beneficial effect of organic manures in increasing soil K were reported earlier Pawar *et. al*. (1997) and Sharma *et. al*. (2001).

**Table 4.9: Influence of iron and zinc application on available nutrients after harvest of fenugreek.**

| Treatment No. | Treatments | Available nutrients (kg $ha^{-1}$) | | |
|---|---|---|---|---|
| | | Av. N | Av. P | Av. K |
| $T_1$ | GRDF | 334 | 34.00 | 745 |
| $T_2$ | GRDF + Water spray | 337 | 32.00 | 747 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 345 | 34.33 | 767 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 352 | 35.67 | 765 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 357 | 37.67 | 761 |
| $T_6$ | GRDF + Foliar spray of chelated zinc (0.2%) | 358 | 36.33 | 764 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 362 | 34.67 | 771 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2 %) + Foliar spray of chelated zinc (0.2%). | 361 | 35.67 | 769 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ | 353 | 33.00 | 777 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$ | 354 | 34.33 | 768 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$@ 10 kg $ha^{-1}$ | 361 | 34.33 | 759 |
| | **SEM ±** | **4.00** | **1.73** | **6.02** |
| | **CD (0.05)** | **12** | **NS** | **18** |

**4.6.7 DTPA Iron**

The data on available DTPA micronutrients are presented in table 4.10. The DTPA iron in soil after harvest of fenugreek influenced by iron and zinc application to fenugreek clearly showed that there was significant increase in DTPA iron in $T_9$ (GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$) (4.73 mg $kg^{-1}$) and $T_{11}$ (GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) (4.87 mg $kg^{-1}$) where GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ was done. It was interesting to note that the soil which was deficient in DTPA iron content before experimentation was found sufficient in DTPA iron content after harvest of the crop when soil application of $FeO_4$ @ 15 kg $ha^{-1}$ was done to fenugreek.

Meena *et. al.* (2006) reported that the Zn and Fe enriched FYM enhanced DTPA extractable Zn and Fe content of soil. These results are in accordance with the results recorded by Teke (2009).

**Table 4.10: Influence of iron and zinc application on available DTPA micronutrients after harvest of fenugreek.**

| Treatment No. | Treatments | Fe ( mg kg$^{-1}$) | Zn (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) | Cu (mg kg$^{-1}$) |
|---|---|---|---|---|---|
| $T_1$ | GRDF | 4.20 | 0.40 | 11.67 | 4.37 |
| $T_2$ | GRDF + Water spray | 4.13 | 0.41 | 12.43 | 4.40 |
| $T_3$ | GRDF + Foliar spray of chelated iron (0.1%) | 4.37 | 0.41 | 12.73 | 5.20 |
| $T_4$ | GRDF + Foliar spray of chelated iron (0.2%) | 4.37 | 0.42 | 12.57 | 4.73 |
| $T_5$ | GRDF + Foliar spray of chelated zinc (0.1%) | 4.13 | 0.43 | 12.43 | 5.17 |
| $T_6$ | GRDF + Foliar spray of chelated zinc (0.2%) | 4.13 | 0.44 | 12.57 | 4.93 |
| $T_7$ | GRDF + Foliar spray of chelated iron (0.1%) + Foliar spray of chelated zinc (0.1%) | 4.30 | 0.44 | 12.37 | 4.90 |
| $T_8$ | GRDF + Foliar spray of chelated iron (0.2 %) + Foliar spray of chelated zinc (0.2%). | 4.37 | 0.44 | 12.27 | 4.93 |
| $T_9$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ | 4.73 | 0.43 | 12.30 | 4.933 |
| $T_{10}$ | GRDF + Soil application of $ZnSO_4$ @ 10 kg ha$^{-1}$ | 4.20 | 0.67 | 12.47 | 5.03 |
| $T_{11}$ | GRDF + Soil application of $FeSO_4$ @ 15 kg ha$^{-1}$ + $ZnSO_4$ @ 10 kg ha$^{-1}$ | 4.87 | 0.66 | 12.43 | 5.07 |
| | **SEM ±** | **0.09** | **0.01** | **0.45** | **0.26** |
| | **CD (0.05)** | **0.27** | **0.04** | **NS** | **NS** |

**4.6.8 DTPA Zinc**

Significant increase in DTPA zinc in soil was recorded where soil application of $ZnSO_4$ @ 10 kg ha$^{-1}$ with GRDF was done in $T_{10}$ (GRDF + Soil application $ZnSO_4$ @ 10 kg ha$^{-1}$) (0.67 mg kg$^{-1}$) and $T_{11}$ (GRDF + Soil application $FeSO_4$ @ 15 kg ha$^{-1}$ + $ZnSO_4$ @ 10 kg ha$^{-1}$) (0.66 mg kg$^{-1}$) (Table 4.10). Treatment $T_{10}$ (0.67 mg kg$^{-1}$) and $T_{11}$ (0.66 mg kg$^{-1}$) brought zinc to sufficient level in soil. This increase in Fe and Zn content of soil might be due to addition of $FeSO_4$, $ZnSO_4$ and FYM. FYM might have also contributed in addition of Fe and Zn content in soil.

It indicated that there was improvement of soil iron and zinc content in soil due to application of $FeSO_4$ and $ZnSO_4$ respectively in soil.

In general, it was clearly noticed that foliar application of chelated iron and chelated zinc mitigated the need of iron and zinc of crop. However, the soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ and $ZnSO_4$ @ 10 kg $ha^{-1}$ had not only mitigated the need of iron and zinc of fenugreek but improved the DTPA iron and DTPA zinc status in soil.

Meena *et. al.* (2006) reported that the Zn and Fe enriched FYM enhanced DTPA extractable Zn and Fe content of soil. These results resemble the results reported by Teke (2009). The application of FYM in addition to foliar or soil application of Fe and Zn mitigate the requirement of crop and resulted increase in Fe and Zn content of soil after harvest of fenugreek. This could be attributed to the direct contribution of FYM to nutrient pool and its beneficial effect either through complexation or metabolism of native Fe and Zn (Nand Ram and Verloo, 1985). Similar finding have also been reported by Singh *et. al*. (2009).

**4.6.9 DTPA Manganese**

The content of manganese remained significantly unchanged due to iron and zinc application to fenugreek (Table 4.10).

**4.6.10 DTPA Copper**

The content of copper remained significantly unchanged due to iron and zinc application to fenugreek (Table 4.10).

# 5. SUMMARY AND CONCLUSION

The field experiment was conducted on Inceptisol to study the response of fenugreek to iron and zinc during *rabi* season of 2017. The results obtained during this investigation are summarized and presented in following subheads:

## 5.1 Growth Parameters

The application of micronutrient either through foliar spray or soil significantly influenced the growth parameters of fenugreek as compared to water spray. Among various treatments, application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ at the time of sowing show significantly higher plant height (29.83 cm) , The number of branches per plant (3.53) and trifoliate leaves (66.70) over rest of the treatments.

## 5.2 Yield Parameters

It was clearly indicated that GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ recorded significantly higher plant weight (18.35 g), 1000 grain weight (12.85 g), seed yield (9.12 ql $ha^{-1}$) and higher no. of pods per plant (32.27) over rest of all treatments.

## 5.3 Qualitative Parameters

The total chlorophyll content @ 50% flowering (31.11 mg 100 $g^{-1}$ fresh weight) and protein content (25.92%) were significantly higher in $T_{11}$ treatment (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$).

The treatment $T_{11}$ registered higher iron content in seed (34.9 mg $kg^{-1}$) followed by $T_9$ (GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$) (34.2 mg $kg^{-1}$). The application of iron either through soil or foliar could increase iron content in seed.

The application of zinc either through foliar or soil could helped to improve zinc content in seed. Remarkably higher content of zinc in seed was observed in treatment $T_{11}$ (71.2 mg $kg^{-1}$) followed by $T_{10}$ (GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$) (69.9 mg $kg^{-1}$).

Also higher (89%) germination of seeds was observed, due to treatment $T_{11}$, (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$). The viability of seed (93.62%) and seed vigour index (1618) were higher in $T_{11}$ (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) over rest of the treatments.

## 5.4 Nutrient Uptake

### 5.4.1 Macronutrient Uptake

The data in respect of nutrients uptake revealed that significant increase in nitrogen uptake (112.82 kg $ha^{-1}$) due to application of treatment $T_{11,}$ GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$. In case of uptake of phosphorous (4.66 kg $ha^{-1}$) and uptake of potassium (49.29 kg $ha^{-1}$) were significantly higher in $T_{11}$ over all rest of treatments.

It is observed that treatment $T_{11}$ (GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$) showed significantly higher uptake of macronutrients.

### 5.4.2 Micronutrient Uptake

The application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ recorded significantly higher uptake iron (389 mg $kg^{-1}$), zinc uptake (159 mg $kg^{-1}$), uptake of manganese (263 mg $kg^{-1}$) and copper (68.67 mg $kg^{-1}$). This treatment significantly superior over rest of the treatments.

## 5.5 Soil Chemical Properties after Harvest of Fenugreek

### 5.5.1 Soil Properties

There was no significant influence of iron and zinc application either through foliar or soil on soil pH, electrical conductivity and organic carbon content in soil.

### 5.5.2Soil Available Macronutrients

There was significantly higher available nitrogen in all the treatments over $T_1$ (GRDF) and $T_2$ (GRDF + Water spray). There was not significant effect of iron and zinc application to fenugreek on available phosphorous in soil. Available potassium was also observed significantly higher in all treatments over $T_1$ (GRDF) and $T_2$ (GRDF+ Water spray).

### 5.5.3 Soil Available Micronutrients

The soil application of Fe and Zn fertilizers significantly altered the DTPA extractable Fe and Zn content in soil after harvest of fenugreek. There was significant increase in DTPA iron in $T_9$ (GRDF + Soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ (4.73 mg $kg^{-1}$) and $T_{11}$ (4.87 mg $kg^{-1}$) where GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ was done. Similar increase in DTPA zinc in soil was recorded where soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$ along with GRDF was done in $T_{10}$ (GRDF + Soil application of $ZnSO_4$ @ 10 kg $ha^{-1}$) (0.67 mg $kg^{-1}$) and $T_{11}$ (0.66 mg $kg^{-1}$). The content of manganese and copper remained significantly unchanged due to iron and zinc application to fenugreek.

## CONCLUSION

The field experiment was conducted on Inceptisol to study the response of fenugreek cv. Phule Kasturi **(**GKF-3) to iron and zinc during *Rabi* season of 2017-2018. The results obtained during this investigation are summarized as:

The foliar application of iron and zinc could helped to increase growth, yield and quality parameters of fenugreek grown in iron and zinc deficient soil. However, the application of GRDF + soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ + $ZnSO_4$ @ 10 kg $ha^{-1}$ to fenugreek not only helped to improve growth, yield and quality parameters of fenugreek but it helped to built up iron and zinc content respectively in iron and zinc deficient soil.

# 6. LITERATURE CITED


Abid Ali, Bashir Ahmad, Iqbal Hussain, Akhtar Ali and Fawad Ali Shah (2017) Effect of Phosphorus and zinc on yield of lentil. *Pure Applied Biology* **6,** 1397-140

Abou-Hadid, A. F., El-Behairy, U. A., El-Beltagy, A. S. and Burrage, S. W. (1994) Effect of different zinc concentrations in the nutrient solution on uptake and translocation of macro and micro nutrients in cucumber. *Acta Horticulturae*, International Society for Horticultural Science **361,** 325-33.

Abdul Baki and Anderson (1973) Vigour determination in soybean seed by multiple criteria. *Crop Science* **13,** 630-633.

Akbari, K.N., Karan, F., Qureshi, F. M. and Patel, V. N. (2003) Effect of micronutrients, sulphur and gypsum on soil fertility and yield of and gypsum on soil fertility and yield of mustard in red loam soils of Mewar (Rajasthan). *Journal of Indian Society of Soil Science* **37,** 94-99.

Ali, M. R., Mehraj, H. and Jamal Uddin A. F. M. (2015) Effects of foliar application of zinc and boron on growth and yield of summer tomato. *Journal of Bioscience and Agriculture Research* **6,** 512-517.

Anand Swarup (1981) Effect of iron and manganese application on the availability of micronutrients to Rice in Sodic soil. *Plant and Soil* **60,** 481-485.

Anand Swarup (1991) Effect of gypsum, green manure, farm yard manure and zinc fertilization on zinc, iron and manganese nutrition of Wetland Rice on Sodic soil. *Journal of Indian Society of Soil Science* **39,** 530-536.

Arabhavi Shrishail (2014) Studies on zinc sulphate and borax on yield, quality and nutrient uptake by knol-khol (*Brassica oleracea*var. Gonglodes L.) in alfisols under northern transition zone of karnataka. Submitted to University of Agricultural Sciences, Dharwad.

Arnon, D.I. (1949) Copper enzymes in isolated chloroplasts, polyphenoloxidasein *Beta vulgaris*. *Plant Physiology* **24,** 1.

Arif Uzma, Hussain Sayed, Zulfiqar Ali Shah Syed, Abdul Hamid, Abid Yaqoob, Ayaz Ahmed Arif, Ahmed Younis, Saddam Hussain, Andleeb Akbar, Saba Bashir, Iftikhar Azam, Muhammad Zeeshan, Saeed Ahmed, Sajid Majeed, Nagina Muneer (2016) Interactive effect of phosphorus and zinc on the growth,yield and nutrient uptake of Garlic (*Allium sativum* L.) Variety Gulabi.*Asian Journal of Agriculture and Food Sciences* **4,** 279-284.

Balakrishnan, V., Jawaharlal, M., Senthilkumar, T. and Ganga, M. (2007) Response of micronutrients on flowering, yield and xanthophylls content in African marigold. *Journal of Ornamental Horticulture* **10,** 153-156.

Balasubramanium, P., Mani, A. K. Durasiwamy, P. and Kandsawami, M. (1998) Effect of organic and inorganic nutrients on the yield and uptake of tomato (*Lycopersicon esculentum*) in Alfisol. *South Indian Horticulture* **46,** 143-147.

Barman, D. and Pal, P. (1993) Effect of micronutrients on growth and flowering of *Chrysanthemum morifolium cv*. Chandrama. Haryana. *Journal of Horticultural Sci*ence **28,** 78-79.

Bashir, M. A., Ahmad, W., Ahmad, K. S., Shafi, J., Shehzad, M. A., Sarwar, M.A., Ghani, I. and Iqbal, M. (2013) Efficiency of foliar application of micronutrients on growth flowering of*Gerbera jamesonii* L. *Universal Journal Agricultural Research* **1,** 145-149.

Bhamare, R.S., Sawale, D.D., Jagtap, P.B., Jagdhani, A.D. and Nimbalkar, R.U. (2018) Effect of iron and zinc on quality and nutrient uptake of French bean in iron and zinc deficient inceptisol soil. *Journal of Pharmacognosy and Phytochemistry* **7,** 464-467.

Bhatt, L. and Srivastava, B. K. (2006) Effect of foliar application of micronutrients on the nutrient composition of tomato (*Lycopersicon esculentum* Mill).*Indian Journal of Horticulture* **63,** 0972-8538.

Bhattacharyya, T., Mandal, C., D. K. and Gajbhiye, K. S. (2004) Composition of available soil and other data sets for the Indo-Gangetic plains, India. NBSS and LUP, Nagpur

Bogard, L. (1966) The biosynthesis of chlorophyll. In: The chlorophyllus L. P. Vernon and Seeky, G. R. eds. Academic Press. New York and London, 481-510.

Bose, U. S. and Tripathi, S. K. (1996) Effect of micronutrients on growth, yield and quality of tomato.cv. Pusa Ruby. in M. P. *Chromosome Research* **12,** 61-64.

Bouyoucos, G.J. (1962) A recalibration of the hydrometer method for making mechanical analysis of soil. *Argonomy Journal* **43,** 435-438.

Chandra Deo and Khandelwal, R. B. (2009) Effect of zinc and phosphorus on yield, nutrient uptake and oil content of mustard grown on gypsum treated sodic soil. *Journal of Indian Society of Soil Science* **57,** 66-70.

Chapman , H. D. and P. F. Pratt (1961) Methods of analysis for soils, plants and water. *Plant Physiology*, 169-170.

Chaturvedi, O. P., Shukla, I. N. and Singh A. R. (1986) Effect of agromin on growth and flowering in gladiolus. *Progressive Horticulture* **18,** 196-199.

Choudhary Hansa Devi, Sharma S. R., Jat R. S. and Gajanand Jat (2015) Effect of soil and foliar application of zinc and iron on yield, quality and economics of fennel. *Annals of Plant and Soil Research* **17,** 200-203.

Deshmukh, M. R. and Wavhal, K. N. (1999) Effects of zinc on growth and flowering of aster. *Journal of Maharashtra Agricultural Universities* **24,** 224-226.

Diana Aishwarya and Nehru Amitabh (2015) Impact of micronutrient application incoriander (*Coriandrum sativum* L.) cv.CO4. *Advanced Journal of Seed Science and Technology* **2,** 042-046.

Elayaraja, D. and Dhanasekaran, K. (2016) Effect of zinc fertilization on the growth, yield and nutrients uptake by bhendi in coastal sandy soil .*International Journal of Agriculture Innovations and Research* **5,** 2319-1473.

El-Khayat, A. S. (1999) The response of growth and yield of *Antholyza aethiopica* under plants to chilling and foliar potassium and zinc application. *Research Bulletin, Moshtohor, Egypt* **37,** 1915-1934.

El-Naggar, S. M. and Awad, F. (1986) Effect of foliar application of some micronutrients on plant growth in new reclaimed areas. In development in plant and soil science foliar fertilization. AlexzanderMartinus Nijhoff Publisher.142-152.

Esmaeil Rezaei-Chiyaneh, Sajjad Rahimi, Amir Rahimi, Hashem Hadi and Hassan (2018) Response of seed yield and essential oil of black cumin (*Nigella sativa* L.) affected as foliar spraying of nano-fertilizers. *Journal of Medicinal Plants and By-products* **1,** 33-40.

Fageria, V. D. (2001) Nutrient interaction in crop plants. *Journal of Plant Nutrition* **24,** 1269-1290.

Farahat, M. M., Soad Ibrahim, Lobna Taha, S. Fatma, E. M., El-Quesni, (2007) Response of vegetative growth and some chemical constituents of *Cupressus sempervirens* L. to foliar application of ascorbic acid and zinc at Nubaria. *World Journal of Agricultural Sci*ence **3,** 496-502.

Ghasemi-Fasaei, R. and Ronaghi, A. (2008) Interaction of iron with copper, zinc and manganese in wheat as affected by iron and manganese in calcareous soil. *Journal of Plant Nutrition* **31,** 839-848.

Ghritlahare Anjali, P. J., Marsoniaand and H. L. Sakarvadia (2015) Effect of zinc and iron on yield and yield attributes of okra (*Abelmoschus esculentus* L.). *An Asian Journal of Soil Science* **10,** 104-107.

Girwani, A., Babu, R. S. and Chandrashekhar, R. (1990) Response of marigold (*Tagetes erecta* L.) to growth regulators and zinc. *Indian Journal of Agricultural Sciences* **60,** 220-222.

Gomaa, A. O. (2001) Effect of foliar spray with some amino acids and nutrient elements on *Antholyza aethiopica* L. Plants Proceedings, The Fifth Arabian Horticulture Conference, Ismailia, Egypt, March **24-28,** 63-73.

Halder, N. K., Rfiruddin, M. D., Siddky, M. A., Gomes, R., Ara Beghum and Kavita Anjuman. (2007) Performance of gladiolus influenced by boron and zinc Pakistan. *Journal of Biological Sci*ences **10,** 581-585.

Hallur Chidanand (2013) Studies on zinc, iron and boron nutrition on yield, quality and nutrient uptake by cabbage (*Brassica oleracea*var. Capitatal.) in northern transition zone of karnataka. Submitted to University of Agricultural Sciences, Dharwad.

Hatwar, G. P., Gondane, S. U., Urkude, S. M. and Gahukar, O. V. (2003) Effect of micronutrients on growth and yield of chilli. *Journals of Soils and Crops* **13,** 123-125.

Hossain, M. A., Jahiruddin, M., Islam, M. R. and Mian, M. H. (2008) The requirement of zinc for improvement of crop yield and mineral nutrition in the maize-mungbeen-rice system. *Plant and Soil* **306**, 13-22.

ISTA (1993) International Rules for Seed Testing. International Seed Testing Association, Bassersdorf, Switzerland.

ISTA (2009) International Rules for Seed Testing. International Seed Testing Association, Bassersdorf, Switzerland.

Jacbson, L. and Ortali, J. J., (1956) The relation between iron and chlorophyll content in chlorotic sunflower leaves. *Plant physiology* **31,** 199-204.

Jackson , M.L. (1973) Soil Chemical Analysis Prentice Hall of India, New Delhi.

Jadhav, S.C., Pooja, S. Sawant, Devmore J.P., Prabhudesai, S.S., Mahale, A.G. and Snehal, V. (2017) Effect of foliar spray and soil application of micronutrients on major nutrient content and uptake of coriander in lateritic soils of Konkan region. *International Journal of Chemical Studies* **5,** 1669-1672.

Jagtap, P. B., Kadam, M. B., Chalak, S. U. (2016) Response of cabbage to foliar and soil application of iron and zinc in Inceptisol. *Advances in Life Sciences* **5,** 6823-6827.

Jat Girraj Prasad, Vadodaria J. R., Karthick, K. and Sunil Nath (2017) Effect of zinc and iron on growth of amaranth (*Amaranthus spp.*) cv. Pusa Kiran. *International Journal of Current Microbiology and Applied Sciences* **6,** 1006-1009.

Jatav, M. K. and Pankaj Kumar. (2008) Effect of zinc and iron application on nutrients availability in a treated saline soil as influenced by water quality. *Indian Journal of Agricultural Chemistry* **41,** 25-30.

Jauhari, S. R. and Srivastava, P. C. (2005) Effect of Zinc on growth, flowering, corm attributes, post harvest life, leaf and corm nutrients status in gladiolus *cv*. Red Beauty. *Progressive Horticulture* **37,** 423-428.

Jhon, A. Q., Paul, T. M. and Siddique, M. M. A. (1997) Nutritional studies in gladiolus corm and cormels production. *Advances in Plant Sciences* **10,** 45-49.

Karuppaiah, P. (2006) Effect of spacing and nutrient levels on flower yield, carotenoid content, nutrient uptake and residual soil fertility in French marigold (*Tagites patula* L.). *International Journal of Agricultural Sciences* **2,** 375-376.

Kaushal Manisha (2016) Studies on macro and micro nutrients on yield and quality of garlic (*Allium sativum* L.).Submitted to the Dr. Yashwant Singh Parmar University of Horticulture And Forestrysolan (Nauni) Himachal Pradesh.

Khatemenla, Singh V.B., Trudy Tengse, A. Sangma and Maiti C.S. (2018) Effect of zinc and boron on growth, yield and quality of Onion (*Allium cepa* L.) cv. Agrifound Dark Red. *International Journal of Current Microbiology and Applied Science* **7,** 3673-3685.

*Knudsen, D., Peterson, G. A. and Pratt, P. F. (1982) In methods of soil analysis part II chemical and microbiological properties. *American Society of Agronomy and Soil Science society of America, Madison, Wisconsin, USA.*

Kotecha, A.V., Dhruve J.J. And Vihol, N.J. (2011) Effect of foliar application of micronutrients and growth regulators on growth and yield of cabbage (*Brasicca oleracea* L. Var. Capitata) cv. Golden Acre. *The Asian Journal of Horticulture* **6,** 381-384.

Kuldeep, P. D., Kumawat, Vipen Bhadu, H. K. Sumeriya and Vinod Kumar (2018) Effect of Ironand zinc nutrition on growth attributes and yield of chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences* **7,** 2319-7706.

Kumar, P. and Arora, J. S. (2000) Effect of micronutrients on gladiolus. *Journal of Ornamental Horticulture (New Series)* **3,** 91-93.

Kumar, R. and Singh, K. (2003) Effect of growth regulator and shoot tip pinching on carnation. *Journal of Ornamental Horticulture* **6,** 134-136.

Kumbhar, V. S. and Deshmukh, S. S. (1993) Effect of soil application of ferrous sulphate on the uptake of nutrients, yield and quality of tomato. cv. Rupali. *South Indian Horticulture* **41,** 144-147.

Kumawat Ajay (2018) Studies on the effect of plant growth regulators and micronutrients on growth, yield and quality of okra (*Abelmoschus esculentus* L. Moench). Submitted to Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya.

Lindsay, W. L. and Norvell, W. A. (1978) Development of DTPA soil test for zinc, iron, manganese and copper, *Ammerican Journal of Soil Science Society* **42,** 421-428.

Mahesh Kumar and Sen, N. L. (2005) Effect of zinc, boron and gibberellic acid on growth and yield of okra *(Ablmoschus esculentus* L. Moench) *Indian Journal of Horticulture* **62,** 308-309.

Mohammed shahid salam, C.H (2015) Silicon, boron and zinc nutrition of bitter gourd (*Momordica charantia* L.) var. Preethi. Submitted to Kerala Agricultural University.

Mahobiya Vidhya (2016) Response of fenugreek (*Trigonella foenum-graecum* L.) to different micronutrients used as basal and foliar spray. Submitted to Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior.

Mansur, C. P., Hundekar, A. R., Kubsad, V. C., Gawda, D. S. M. (1995) Response of onion to micronutrient farming system. *Advances in Agron*omy **11,** 55-57

Medhi, G. and Kakati, R. N. (1994) Effect of micronutrients in increasing the growth and yield of *bhendi* (*Abelmoschus esculentus* L.). *The Horticulture Journal* **7,** 155-158.

Meena, M. C., Patel, K. P. and Rathod, D. D. (2006) Effect of Zn and Fe enriched FYM on mustard yield and micronutrient availability in Loamy sand soil (Typic Haplustept) of Anand. *Journal of Indian Society of Soil Science* **54,** 495-499.

Miller, G. W., Huang, I. J., Welkie, G. W. and Pushmik, J. C. (1995) Function of iron in plants with special emphasis on chloroplast and photosynthetic activity. In: Abadia J. (Ed.) Iron nutrition in soils and plants. Kluwer Academic Publishers, Dordrecht; DOI: 10.1007/798-94-011-0503-34.

Mohsen Kazemi (2013) Effect of foliar application of iron and zinc on growth and productivity of cucumber. Bulletin of Environment, *Pharmacology and Life Sciences* **2,** 11-14.

Mounika, Y., Thanuja Sivaram, G., Syam Sundar Reddy, P. and Ramaiah, M. (2017) Effect of biofertilizers and micronutrients on growth, leaf yield and quality of Coriander (*Coriandrum sativum* L.) cv. Sadhana. *Journal of Horticulture Science* **12,** 113-117.

Mukherjee, S., Jona, S. C. and Chattterjee, T. K. (1998) Effect of nitrogen and phosphorus dose on production of flowers and corms of gladiolus. *Indian Agriculturist* **36,** 211-213.

Nag, M. R. and Biswas, J. (2002) Studies on effect of boron on vegetative and reproductive growth in tuberose *(Polianthes tuberosa)cv.* Single. Orissa*. Journal of Horticulural Sciences* **30,** 39-42.

Nagare Deepika Bajirao (2014) Effect of iron and zinn on yield, nutrient uptake and quality of onion in inceptisol. Submitted to Mahatma Phule Krishi Vidyapeeth, Rahuri.

Nahed, G., Abd El-Aziz, Balbaa, K. and Laila, (2007) Influence of tyrosine and zinc on growth, flowering and chemical constituents of *Salvia farinacea* plants. *Journal of Applied Sciences Research* **3,** 1479-1489.

Nand Ram and Verloo, M. (1985) Effect of various organic maerials on mobility of heavy metels in soil.*Environmental Pollution* **10,** 241-248.

Naveenkumar, P., Misra, B. L., Ganga, M., Dhiman, S. R. and Kameshwari, Lalitha. (2009) Effect of micronutrients sprays on growth and flowering of chrysanthemum. *Indian Journal of Horticultural Science* **76,** 426-428.

Navrot, J. and Banin, A. (1975) Tomato plant response to iron supply in various carrier forms. *Plant and Soil* **42,** 309-312.

Nelson, D.W. and Sommer, L. E. (1982) Total Carbon, and Organic Carbon and Organic Matter. In A. L. Page (ED.) Methods of Analysis Part II Agronomy. *American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin* **9,** 539-579.

Pahalvan-Rad, Mohammad R. and Pessarakali, Mohammad. (2009) Response of wheat plants to zinc, iron and manganese applications and uptake and concentration of zinc, iron and manganese in wheat grains. *Communications in Soil Science and Plant Analysis* **40,** 1322-1332.

Palankar Gireesh (2014) Effect of major and micronutrients, plant spacing and stages of picking on seed yield and quality of cluster bean (*Cyamopsis tetragonoloba* L.TAUB). Submitted to University of Agricultural Sciences, Dharwad.

Pandav, A. K., Manoj Kumar Nalla, Aslam, T., Rana, M. K. and Bommesh, J. C. (2016) Effect of foliar application of micronutrients on growth and yield parameters in eggplant cv HLB 12. *Environment & Ecology, ISSN 0970-0420* **35,** 1745-1748.

Panse, V. G. and Sukhatme, P. V. (1967) Statistical methods for agricultural workers. ICAER, New Delhi **2,** 99.

Patel, M. M., Patel, I. C., Patel, R. I. and Acharya, S. (2011) Effect of zinc and iron on yield and yield attributes of rainfed cowpea (*Vigna unguiculata* L. Walp). *Annals ofArid Zone* **50,** 17-19.

Pawar, V. P., Khatmali, D. K., Deshmukh, Z. V. and More, J. A. (1997) Effect of fertilizers doses and their application on production of Basrai Banana. *Journal of Maharashtra Agricultural University* **22,** 166-168.

Petropoulos, G. A., (2002) Fenugreek: The genus *Trigonella*. Medicinal and Aromatic Plants – Industrial Profiles, Taylor and Francis.

Piper, C. S. (1966) Soil and Plant analysis. Hans Publication, Bombay. PP. 135-136.

Pratap, M., Amarender, S. Reddy and Reddy, Y. N. (2005) Response of pre-harvest micro nutrient foliar spray on leaf nutrients and corm production in gladiolus. *Journal of Ornamental Horticulture* **8,** 18-22.

Radder, B. M., Patil, P. L., Aladakatti, Y. R. and Patil, S. G. (2008) Response of okra (*Abelmoschus esculentus* L.) to moisture regimes and micronutrients in Vertisols of Malaprabha Command, Karnataka.*Journal of Indian Society of Soil Science* **56,** 276-280.

Raj, G. B., Patnaik, M. C., Reddy, I. P. and Rao, A. P. (2001) Response of brinjal (*Solanum melongena* L.) to zinc and iron. *Vegetable Science* **28,** 80- 81.

Rajput, D. K., Megh Naresh, Srivastava, P. C., Singh, S. K. and Gangawar, M. S. (2003) Effect of S, B and Zn application and their interaction on growth, yield and nutrient uptake of *Tagetes minuta* L. Indian Perfumer **47,** 91-97.

Rao Subba, A. Muralidhar, Y., Lakaria, B. L. and Singh, K. N. (2009) Soil testing and nutrient recommendations. *Journal of Indian Society of Soil Science* **57,** 559-571.

Ravi, S., Channal, H. T., Hebsur, N. S., Patil, B. N. and Dharmatti, P. R. (2008) Effect of sulphur, zinc and iron nutrition on growth, yield, nutrient uptake and quality of safflower (*Carthamus tinctorius* L.) *Karnataka Journal of Agricultural Sci*ence **21,** 382-385.

Rawia, A., Eid, R. Kh. M. Khalifa and S. H. A. Shaaban, (2010) Effect of foliar application of zinc and benzyladenine on growth, yield and chemical constituents of tuberose plants. *Research Journal of Agriculture and Biological Sciences* **6,** 732-743.

Romemheld, V., and El-Fouly., M. M. (1999) Foliar nutrient application, Challenge and limits in crop production, Proc. 2nd International Workshop on Foliar Fertilization April 4-10 Bangkok, Thailand, 1-32.

Rukeiya Begum (2014) Effect of some micronutrients application on seed yield and quality in green gram. Submitted to Orissa University of Agriculture and Technology, Bhubaneswar.

Sahu Seema., Lidder, R. S. and Singh, P. K. (2008) Effect of micronutrients and biofertilizers on growth, yield and nutrients uptake by chick pea (*Cicer aeritinum* L.) in vertisol of Madhya Pradesh. *Advances in Plant Sciences* **21,** 501-503.

Said-Al Ahl H. A. H, Omer, E. A. (2009) Effect of spraying with zinc and / or iron on growth and chemical composition of coriander (*Coriandrum sativum* L.) harvested at three stages of development. *Journal of Medicinal Food Plants* **1,** 30-46.

Saleha Tawab, Gohar Ayub, Faiza Tawab, Owais Khan, Nadia Bostan, Ghazala Ruby, Shawana Ahmad and Ume-Kalsoom Afridi (2015) Response of brinjal (*solanum melongena* L.) cultivars to zinc levels. *ARPN Journal of Agricultural and Biological Science* **10,** 172-178.

Samia, M., El-Bably, Z. and Mohmoud, A. M. A. (2009) Effects of corms storage, zinc application and their interaction on vegetative growth, flowering, corms productivity and chemical constituents of *Tritonia crocata* Ker Gawl Plant. *Journal of Agricultural Research Kafr El-Sheikh University* **35,** 230-255.

Saimbhi, M. S., Jaiswal, S. P., Nandpuri, K. S. and Vig, A. C. (1979) Influence phorate and iron nutrition on plant growth, mineral composition and seed yield of okra(*Abelmoschus esculentus* (L) Moench). *Proceedings of the Indian National Science Academy* **2,** 69-73.

Salam, M. A., Siddique M. A., Rahim, M. A., Rahman, M. A. and Goffar, M. A. (2011) Quality of tomato as influenced by boron and zinc in presence of different doses of cowdung. *Bangladesh Journal of Agriculture Research* **36,** 151-163.

Samui, R. C., Bhattacharyya, P. and Dasgupta, S. K. (1981) Uptake of nutrients by mustard (*Brassica juncea* L.) as influenced by zinc and iron application. *Journal of Indian Society of Soil Science* **29,** 101-106.

*Saqib, M., Zorb, C. and Schubert, S. (2006) Salt-resistant and salt-sensitive wheat genotypes show similar biochemical reaction at protein level in the first phase of salt stress, *Journal of Plant Nutration and Soil Science* **169,** 542-548.

Saravaiya, S.N., Wakchaure, S. S., Jadhav, P. B., Tekale, G. S., Patil, N. B. and Dekhane S. S. (2014) Effect of foliar application of micronutrients in tomato (*Lycopersicon esculentum* Mill.) cv.GUJARAT TOMATO-2. *The Asian Journal Of Horticulture* **9,** 297-300.

Savitha, H. R. (2008) Effect of iron-EDTA on yield and quality of red chilli (*Capsicum annuum* L.) in a calcareous vertisol of zone-8 of karnataka. Submitted to the University of Agricultural Sciences, Dharwad.

Senthamizhselvi, B. (2000) Studies on the flowering and productivity of Gundumalli (*Jasminum sambac* Ait) as influencedby nutrient management technique. Thesis submitted to Tamilnadu Agricultural University, Coimbatore (T.N.) INDIA.

Singh, S. and Hooda, R. S. (1992) Effect of micronutrients on growth, yield and quality of muskmelon. *Agricultural Science Digest* **12,** 196-198.

Singh, Akhilesh kumar, Sarkar, A. K., Kumar, Arvind and Singh, B. P. (2009) Effect of long term use of mineral fertilizers, lime and farm yard manure on the crop yield, available plant nutrient and heavy metal station in acidic loam soil. *Journal of the Indian Society of Soil Science* **57,** 362-365.

Shnain Rawaa Shakir, Prasad V. M., Saravanan, S. (2014) Effect of zinc and boron on growth,yieldand quality of tomato (*Lycopersicon esculentum.* Mill) cv. *Heem Sohna*, under protected cultivation. *European AcademicResearch* **2,** 4572- 4597.

Sharma, R. P., Bali, S. V. and Gupta, D. K. (2001) Soil fertility and productivity of rice-wheat cropping system on Inceptisol an influenced by integrated nutrient management. *Indian Journal of Agricultural Sciences* **71,** 82-86.

Sharma Raunak, Bairwa, L. N., Ola, A. L., Kumari Lata and Atma Ram Meena (2018) Effect of zinc on growth, yield and quality of okra (*Abelmoschus esculentus* L.). *Journal of Pharmacognosy and Phytochemistry* **7,** 2519-2521.

Shivannanavar Basavaraj (2013) Studies on zinc and boron nutrition on yield, quality and nutrient uptake in cauliflower (*Brassica oleracea* var. *botrytis* L.) under northern transition zone of karnataka. Submitted to University of Agricultural Sciences, Dharwad.

Shivappa, M. V. (2005) Effect of micronutrients on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill) cv. Pusa Ruby in Hyderabad conditions. Submitted to Acharya N. G. Ranga Agricultural University Rajendranagar, Hyderabad-500 030, Andhra Pradesh India.

Shukla, A. K., Dwivedi, B. S., Singh, V. K. and Gill, M. S. (2009) Macro role of micronutrients. *Indian Journal of Fertilizers* **5,** 11-12, 15-18, 21-24 and 27-30.

Solanki Mahesh, M., Solanki Manjusha, S., Thakare Gajanan, Pallavi, D. Jogi And Deepak R. Sapkal (2017) Effect of zinc and boron on growth of brinjal (*Solanum melongena* L.) *International Journal Of Plant Sciences* **12,**160-163.

Srihari, D., Singh, B. P. and Rao, D. V. R. (1987) Effect of foliar sprays of zinc andmolybdenumon growth and yield of okra (*Abelmoschus esculentus* (L.) Moench) cv. Pusa Sawani.*Progressive Horticulture* **19,** 31-34.

Subrahmanyam, D., Sah, R. and Rathore, V. S. (1991) Influence of boron deficiency on growth, protein and lipid contents in tomato and okra seedlings. *Acta Physiologiae Plantarum* **15,** 25-30.

Subbiah, B. V. and Asija, G. L. (1956) A rapid procedure for estimation of available nitrogen in soil. *Current Science* **25,** 259-260.

Surywanshi, L. B. (2010) Response of summer okra (cv.*Phule Utkarsha*) to Iron, zinc and boron in inceptisol. M.Sc (Agri) Thesis submitted to Mahatma Phule Krishi Vidyapeeth Rahuri, Maharashtra.

Teke, S. R. (2009) Effect of foliar and soil application of iron, zinc and boron on yield and fruit qualityof fig in Inceptisol. M.Sc. (Agri.) Thesis submitted to Mahatma Phule Krishi Vidyapeeth, Rahuri,(Maharashtra.).

Thingujam Umalaxmi, Sajal Pati1, Rubina Khanam, Arnab Pari1, Krishnendu Ray, Amit Phonglosa and Kallol Bhattacharyya (2016) Effect of integrated nutrient management on the nutrient accumulation and status of post-harvest soil of brinjal (*Solanum melongena* L.) under Nadia conditions (West Bengal), India. *Journal ofApplied and Natural Science* **8,** 321- 328.

Uikey, S., Das, M. P., Ramgiry, P., Vijayvergiya, D., Ghaday, P., Ali, S. A. and Pradhan, J. (2018) Effect of Zinc, Boron and Iron on Growth and Phenological Characters of Brinjal (*Solanum melongena* L.) *International Journal of Current Microbiology and Applied Sciences ISSN* **7,** 2319-7706**.**

Yadav, B. S., Ahlawat, V. P., Sukhbir–Singh, Sehrawat, S. K. and Singh, S., (2002) Effect of nitrogen and zinc on floral characters, bulb production and nutrient content in tuberose (*Polianthes tuberose* Linn.) *cv*. Double. Haryana. *Journal of Horticultural sciences* **31,** 210-212.

Varghese, A. and Duraiswami, V. P. (2005) Effect of boron and zinc on yield, quality and mineral contentof cauliflower. *South Indian Horticulture* **53,** 126-133.

Veer Ishwar, Das, M. P., Vijayvergiya, D., Ghaday P. S., Uikey, P. Ramgiry, J. Pradhan, U. Parmar and S. A., Ali (2018) Effect of zinc, boron and copper on growth characters of onion (*Allium cepa* L.). *International Journal of Chemical Studies* **6,** 3384-3387.

Vyas, M. D., Jain, A. K. and Tiwari, R. J. (2003) Long-term effect of micronutrients and FYM on yield of and nutrient uptake by soyabean on Typic Chromustert . *Journal of Indian Society of Soil Science* **51,** 45-47.

Watanabe, F. S. and Olsen, S. R. (1965) Test of an ascorbic acid method for determining phosphorus in waters and $NaHCO_3$ extracts from soil. *Proceedings of Soil Science Society of Am*erica **29,** 677-678.

Zende, G. K. (1996) Integrated nutrient supply in relation to micronutrients for sustainable agriculture. *Micronutrient News* **10,** 1-9.

*Zoroski, R. J. and Burau, R. G. (1977) A rapid nitric perchloric acid digestion method for multi element tissue analysis. *Communications in Soil Science and Plant Analysis* **8,** 425-436.

Zou, C. Q., Gao, X. P. and Zhang, F. S. (2007) Micronutrient deficiencies in crop production in China. In: Alloway, B. (Ed) Micronutrient Deficiencies in Global Crop Production (in press).

*Originals are not seen.

# VITAE

## RUTUJA BHAIRU CHOUGALE

## MASTER OF SCIENCE (AGRICULTURE)
**IN**
## SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
**2019**

| | | | |
|---|---|---|---|
| **Title of Thesis** | | **:** | **Effect of iron and zinc nutrition on seed yield, nutrient uptake and quality of fenugreek (*Trigonella foenum-graecum* L.) in Inceptisol.** |
| **Major field** | | **:** | Soil Science and Agricultural Chemistry |
| **Biographical information** | | **:** | |
| **Personal** | **Date of Birth** | **:** | 15/10/1993 |
| | **Place of Birth** | **:** | Pune |
| | **Father's Name** | **:** | Shri. Bhairu Dnyandeo Chougale |
| | **Mother's Name** | **:** | Sau. Ujwala Bhairu Chougale |
| **Educational** | **Bachelor Degree Obtained** | **:** | B.Sc. (Agri.) |
| | **Class** | **:** | First Class |
| | **Name of University** | **:** | Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722, Dist.-Ahmednagar (Maharashtra), INDIA |
| | **Master Degree Obtained** | **:** | M.Sc.(Agri.) |
| | **Class** | **:** | Second Class |
| | **Name of University** | **:** | Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722, Dist.-Ahmednagar (Maharashtra), INDIA |
| **Address** | | **:** | Survey No.2/15 C, "Ganesh Prestige", Dhankawadi, Pune-411 043 |
| | **Email-ID** | **:** | rutuchougale@gmail.com |
| | **Contact Number** | **:** | 9096562008 |