EFFECT OF FOLIAR APPLICATION OF NANO NITROGEN AND IRON ON GROWTH, YIELD AND QUALITY OF MULBERRY IN EASTERN DRY ZONE OF KARNATAKA

SRINIVAS BONDADE

PALB 9377

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

UNIVERSITY OF AGRICULTURAL SCIENCES

BANGALORE

2021

EFFECT OF FOLIAR APPLICATION OF NANO NITROGEN AND IRON ON GROWTH, YIELD AND QUALITY OF MULBERRY IN EASTERN DRY ZONE OF KARNATAKA

SRINIVAS BONDADE

PALB 9377

Thesis submitted to the

UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE

in partial fulfilment of the requirement

for the award of the Degree of

MASTER OF SCIENCE (Agriculture)

in

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

BENGALURU NOVEMBER, 2021

Affectionately dedicated

to my Beloved Parents

Smt. Parvathi

& Sri Ambajiro bondade

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
UNIVERSITY OF AGRICULTURAL SCIENCES BANGALORE

CERTIFICATE

This is to certify that the thesis entitled "**EFFECT OF FOLIAR APPLICATION OF NANO NITROGEN AND IRON ON GROWTH, YIELD AND QUALITY OF MULBERRY IN EASTERN DRY ZONE OF KARNATAKA**" submitted by **Mr. SRINIVAS BONDADE ID No. PALB 9377** for the degree of **MASTER OF SCIENCE (Agriculture)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the University of Agricultural Sciences, Bangalore, is a record of *bonafide* research work carried out by him during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru
November, 2021

J. SARALAKUMARI
MAJOR ADVISOR

Approved by :

CHAIRPERSON : ______________________
(J. SARALAKUMARI)

MEMBERS : **1.** ______________________
(D. V. NAVEEN)

2. ______________________
(N. AMARNATHA)

3. ______________________
(N. NAGESHA)

ACKNOWLEDGEMENT

With regardful memories……...

The gratitude has been a courtesy of rich culture towards all who shares burden of my work and help to succeed in my endeavour. Hence, it is a matter of pleasure and sincere duty to acknowledge all the persons and spirits in the form of teachers, friends, near or dear ones who directly or indirectly gave their supporting hands while doing the research or preparation of this manuscript.

*With immense pleasure and deep respect, I express my heartfelt gratitude to my revered teacher, guide and chairman of the advisory committee, **Dr. J. Saralakumari**, Professor, Department of soil science and agricultural chemistry, UAS, GKVK, Bangalore for his excellent guidance, constant support, close counsel and valuable suggestions throughout the period of my study. I honestly confess with gratitude that it has been a rare privilege to be under his guidance.*

*With a sense of pride and dignity, I sincerely thank the members of my Advisory Committee **Dr. D. V. Naveen,** Assistant Professor (SS & AC), College of Sericulture Chintamani, **Dr. N. Amarnatha** Assistant Professor (Sericulture), College of Sericulture Chintamani and **Dr. N. Nagesha** Assistant Professor (Plant Biotechnology), UAS, Bangalore for their everlasting patience, optimism, timely help, continuous encouragement, valuable suggestions, inspiration and constant support during my research work.*

*My sincere and profound thanks to **Dr. D. V. Naveen** for providing all the facilities for conduction and completion of research work. I am grateful to teachers, Dr. H. C. Prakasha, Dr. C. T. Subbarayappa, Dr. N. B. Prakash, Dr. chikkaramappa, Dr. Satish, Dr. G. G. Kadalli, Dr. Krishnamurthy, Dr. Mamtha, Dr. B. G. Vasnti and non-teaching staff Mr. Srinivasmurthy, Mrs. Suma, Mr. Subbramanya Shetty and others staff members of the Department of Soil Science and Agricultural Chemistry for their valuable suggestion support and encouragement during my study period.*

Gratitude cannot be seen or expressed; it can only be felt and it is beyond description. Although thanks are poor expression of depth of gratitude one feels, yet there is no better way to express it I acknowledge my parents **Smt. Parvathi and Sri Ambajirao Bondade,** my brother **Rajeshbabu Bondade**, **Naveen,** sisters **Bhagya, Bhavani, sister-in-law Annapurna,** friend **Mamta** and brother-in-law**s DR. Naveen Havle, Shankar Sutrave** for their sacrifice, faith, unconditional love and everything that made me come so far.

Anything is possible when you have the right people there to support you. My special thanks for a special persons **Pagala Sai Krishna**, **DR. B. R. Harsha and laxman navi** a very dearest friends of mine and my heartfelt thanks to my seniors **Avinash Gopa, Arun Patlekar, Channabasava** and friends **Shruti gowda, Megharaj, Sharanappa, Manja, Santosh, Rakesh Janadri, Vinayak, Naveen kodbal, Sameer, Digambar, Manoj** for their mental support and encouragement throughout my M.Sc. Degree. without their timely help my research work was incomplete.

My sincere thanks to farmer **Surendra gowda's** family, **Nandeesh and Naveen** for their valuable support at the time of reseach work. I also thank my beloved seniors **Vishal, Suhas, Rohit, Gagan, Hanumanth** for their help, motivation and encouragement which helped me in the successful completion of my research work.

It is my pleasure to acknowledge a heartful thanks to my Department mates **Ruban, Samreen, Hamna, Spoorthi, Mani, Annu, Amurtha, Swetha, Shruthi, Bramara, Chethana, Apoorva** for their timely help, motivation and encouragement.

Finally, I express my sincere gratitude to **University of Agricultural Sciences, GKVK, Bangalore,** for providing an opportunity for completing my Master degree programme.

Any omission in this brief acknowledgement doesn't mean lack of gratitude.

Bengaluru

November, 2021 **(Srinivas bondade)**

EFFECEFFECT OF FOLIAR APPLICATION OF NANO NITROGEN AND IRON ON GROWTH, YIELD AND QUALITY OF MULBERRY IN EASTERN DRY ZONE OF KARNATAKA

SRINIVAS BONDADE

ABSTRACT

A field experiment was conducted in farmer's field at Kurboor village, Chintamani, Chikkaballapur district during *Rabi 2020*, to study the effect of foliar application of nano nitrogen and iron on growth, yield and quality of mulberry in Eastern Dry Zone of Karnataka. The experiment was laid out in randomized complete block design with 9 treatments replicated thrice. The experimental results indicated that significantly higher plant height (124.18 cm), number of shoots per plant (24.80), number of leaves per shoot (22.86), number of leaves per plant (441.26) and leaf yield (8.69 t/ha/crop) was recorded in the treatment receives combination of 50 % N + 25 t FYM + Foliar spray of nano nitrogen @ 0.4 % and nano iron @ 1000 mg/L. Higher leaf protein (37.55 %), crude fibre (14.22 %), chlorophyll content (47.13 SPAD), major and micronutrient uptake, higher net returns per hectare of mulberry (Rs. 62,687) and B: C ratio (2.39) were recorded in treatment comprising a combination of 50 % N + 25 t FYM + Foliar spray of nano nitrogen @ 0.4 % and nano iron @ 1000 mg/L. Lower growth, yield and quality of mulberry leaf was observed in control plot. Application of nano nitrogen and iron fertilizer improved the nitrogen use efficiency by 22 to 65 per cent compared to conventional fertilizers. An overview of the study revealed that foliar application of nano nitrogen and iron fertilizer saved 50 per cent of conventional urea fertilizer with better leaf quality with improved growth characteristics.

November, 2021 **(J. SARALAKUMARI)**

Department of Soil science and agricultural chemistry Major Advisor

UAS, GKVK, Bengaluru - 65

ಕರ್ನಾಟಕದ ಪೂರ್ವ ಒಣ ವಲಯ ಪ್ರದೇಶದಲ್ಲಿ ನ್ಯಾನೋ ಸಾರಜನಕ ಮತ್ತು ಕಬ್ಬಿಣವನ್ನು ಎಲೆಗಳ ಮೇಲೆ ಸಿಂಪರಣೆ ಮಾಡಿದಾಗ ಹಿಪ್ಪುನೇರಳೆ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗೂ ಗುಣಮಟ್ಟದ ಮೇಲೆ ಬೀರುವ ಪರಿಣಾಮ

ಶ್ರೀನಿವಾಸ ಬೊಂದಾಡೆ

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ಕರ್ನಾಟಕದ ಪೂರ್ವ ಒಣ ವಲಯ ಪ್ರದೇಶದಲ್ಲಿ ನ್ಯಾನೋ ಸಾರಜನಕ ಮತ್ತು ಕಬ್ಬಿಣವನ್ನು ಎಲೆಗಳ ಮೇಲೆ ಸಿಂಪರಣೆ ಮಾಡಿದಾಗ ಹಿಪ್ಪುನೇರಳೆ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗೂ ಗುಣಮಟ್ಟದ ಮೇಲೆ ಬೀರುವ ಪರಿಣಾಮ ಬಗ್ಗೆ ತಿಳಿಯಲು ಒಂದು ಕ್ಷೇತ್ರ ಪ್ರಯೋಗವನ್ನು 2020 ರ ಹಿಂಗಾರಿನಲ್ಲಿ, ಚಿಂತಾಮಣಿ ತಾಲ್ಲೂಕಿನ ಕುರುಬುರು ಗ್ರಾಮದ ರೈತರ ಜಮೀನಿನಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಒಂಬತ್ತು ಉಪಚಾರಗಳನ್ನೊಳಗೊಂಡ ಪ್ರಯೋಗವನ್ನು ಆರ್. ಸಿ. ಬಿ. ಡಿ ಮಾದರಿಯಲ್ಲಿ ಮೂರು ಭಾರಿ ಪುನರಾವರ್ತಿಸಲಾಯಿತು. ಕ್ಷೇತ್ರ ಪ್ರಯೋಗದಿಂದ ಕಂಡು ಬಂದಿದ್ದೇನೆಂದರೆ, ಶಿಫಾರಸ್ಸಿನ ಪ್ರಮಾಣದಲ್ಲಿ ಸಂಯೋಜನೆಯ ಶೇ. 50 ಸಾರಜನಕ + 25 ಟನ್/ಹೇ. ಕೊಟ್ಟಿಗೆಗೊಬ್ಬರ + ಶೇ. 0.4 ನ್ಯಾನೋ ಸಾರಜನಕ ಮತ್ತು 1000 ಮಿಲಿಗ್ರಾಂ/ಲೀ. ನ್ಯಾನೋ ಕಬ್ಬಿಣ ಬಳಸಿದ ಉಪಚಾರದಲ್ಲಿ, ಗಿಡದ ಎತ್ತರ (124.18 ಸೆಂ.ಮೀ.), ಪ್ರತಿ ಗಿಡಕ್ಕೆ ರೆಂಬೆಗಳ ಸಂಖ್ಯೆ (24.80), ಪ್ರತಿ ರೆಂಬೆಯ ಎಲೆಗಳ ಸಂಖ್ಯೆ (22.86), ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಎಲೆಗಳ ಸಂಖ್ಯೆ (441.26) ಮತ್ತು ಎಲೆಗಳ ಇಳುವರಿಯು (8.69 ಟನ್/ಹೇ.) ಅಧಿಕವಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಸಸಾರಜನಕ (37.55 %), ಕಚ್ಚಾ ನೀರಿನ ಅಂಶ (14.22 %), ಹಸಿರು ಪತ್ರಹರಿತ್ತು (47.13 SPAD), ಪ್ರಮುಖ ಹಾಗೂ ಸೂಕ್ಷ್ಮ ಪೋಷಕಾಂಶಗಳ ಹಿರುವಿಕೆ, ಹಿಪ್ಪುನೇರಳೆ ಪ್ರತಿ ಹೇ. ಹೆಚ್ಚು ನಿವ್ವಳ ಆದಾಯ (ರೂ. 62,687) ಹಾಗೂ ಖರ್ಚು ವೆಚ್ಚದ ಅನುಪಾತವು (2.39), ಶೇ. 50 ಸಾರಜನಕ + 25 ಟನ್/ಹೇ. ಕೊಟ್ಟಿಗೆಗೊಬ್ಬರ + ಶೇ. 0.4 ನ್ಯಾನೋ ಸಾರಜನಕ ಮತ್ತು 1000 ಮಿಲಿಗ್ರಾಂ/ಲೀ. ನ್ಯಾನೋ ಕಬ್ಬಿಣ ಸಂಯೋಜನೆಯ ಉಪಚಾರವು ಅತ್ಯುತ್ತಮವೆಂದು ಕಂಡುಬಂದಿದೆ. ಕಡಿಮೆ ಹಿಪ್ಪುನೇರಳೆಯ ಎಲೆಗಳ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗೂ ಗುಣಮಟ್ಟದ ಪರಿಕರಗಳು ಯಾವುದೇ ರಸಗೊಬ್ಬರಗಳನ್ನು ಹಾಕದ ನಿಯಂತ್ರಿತ ತಾಕಿನಲ್ಲಿ ಕಂಡುಬಂದಿರುತ್ತದೆ. ಸಾಂಪ್ರದಾಯಿಕ ಫಲೀಕರಣಕ್ಕೆ ಹೋಲಿಸಿದಾಗ, ನ್ಯಾನೋ ಸಾರಜನಕ ಮತ್ತು ಕಬ್ಬಿಣ ರಸಗೊಬ್ಬರವನ್ನು ಉಪಯೋಗಿಸುವುದರಿಂದ, ಸಾರಜನಕದ ಬಳಕೆಯ ದಕ್ಷತೆಯಲ್ಲಿ ಶೇಕಡಾ 22 ರಿಂದ 65 ರಷ್ಟು ಸುಧಾರಣೆ ಕಂಡುಬಂದಿದೆ. ನ್ಯಾನೋ ಸಾರಜನಕ ಮತ್ತು ಕಬ್ಬಿಣ ರಸಗೊಬ್ಬರವನ್ನು ಎಲೆಗಳ ಸಿಂಪರಣೆಯ ಮೂಲಕ ಉಪಯೋಗಿಸುವುದರಿಂದ, ಶೇಕಡ 50 ರಷ್ಟು ಸಾಂಪ್ರದಾಯಿಕ ಯೂರಿಯಾ ಗೊಬ್ಬರದ ಬಳಕೆಯನ್ನು ಉಳಿಸಬಹುದಾಗಿದೆಂದು ಈ ಅಧ್ಯಯನದ ಅವಲೋಕನದಿಂದ ತಿಳಿದುಬಂದಿದೆ.

ನವೆಂಬರ್, 2021

ಮಣ್ಣು ವಿಜ್ಞಾನ ಮತ್ತು ಕೃಷಿ ರಸಾಯನ ಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃಷಿ ಮಹಾವಿದ್ಯಾಲಯ, ಗಾ.ಕೃ.ವಿ.ಕೇ. ಬೆಂಗಳೂರು-65

(ಜೆ. ಸರಳಕುಮಾರಿ)
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

Effect of foliar application of nano nitrogen and iron on growth, yield and quality of mulberry in Eastern dry zone of Karnataka

SRINIVAS BONDADE, PALB 9377

Department of Soil Science and Agricultural Chemistry, CoA, GKVK, Bengaluru

INTRODUCTION

Mulberry sericulture is back bone of industry as it occupies nearly 72 per cent of total raw silk production in India. Mulberry leaf is sole food material for silkworm (*Bombyx mori*. L) and also major source of silk protein, Nutritional qualities of mulberry leaves supplied as food material to silkworm have great influence on quality of cocoon.

Foliar application in the form of composite formulation of different nutritional resources is found to be an efficient approach in terms of reducing the quantity of nutrient inputs along with enhancing nutrient assimilation by the plant.

Excessive and improper usage of conventional fertilizer causes problems on human and environment. Nano nitrogen and iron fertilizers are alternative to conventional (N and Fe) fertilizers with slow and control release of nitrogen and iron. The application of Nano-N and Fe fertilizer can reduce harmful effects to the environment by reducing harmful nitrogen and iron inputs and increase the nutrient use efficiency.

OBJECTIVE

To study the effect of foliar application of nano nitrogen and iron on quality and yield parameters of mulberry leaves.

MATERIAL AND METHODS

The experiment was conducted during November to December of *Rabi* season 2020 in a well-established mulberry garden in the farmer's field at Kurboor Village, Chintamani Taluk, Chikballapur District. The details of the experiment are given below,

Treatment : Nine
Replications : Three
Design : RCBD
Plot size : 4 m × 4 m
Variety : Victory-1 (V-1)

Treatment details:

- T_1 : Absolute Control
- T_2 : RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha)
- T_3 : T_2 + soil application of $FeSO_4$ @ 5 kg/ha
- T_4 : T_2 + nano iron @ 500 mg/L as foliar spray
- T_5 : T_2 + nano iron @ 1000 mg/L as foliar spray
- T_6 : RDF (50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha)
- T_7 : T_6 + nano nitrogen @ 0.4% as foliar spray
- T_8 : T_6 + nano Nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray
- T_9 : T_6 + nano Nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray

Note: spray @30 DAP (Days After Pruning)

RESULTS

- Significantly higher leaf yield (0.52 kg/plant and 8.69 t/ha/crop) was recorded in T_9 treatment which received T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray followed by T_8 and T_5. The lower leaf yield was recorded in treatment T_1 (0.26 kg/plant and 5.89 t ha^{-1} $crop^{-1}$). (Fig.1)
- Significantly higher protein content of leaves (37.55 %) was recorded in treatment T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000 mg/L as foliar spray) followed by T_8 (36.81 %) and T_5 (35.60 %) which were on par with each other. Significantly lower content of protein (28.49 %) was recorded in the leaves of treatment T_1 (Absolute control). (Table 1)
- Significantly higher Crude fiber content (14.22 %) was recorded in leaves of treatment T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray) followed by 14.14 per cent T_8 and 14.06 per cent in treatment T_5 which were on par with each other. Significantly lower content of crude fiber (11.28 %) in leaf was recorded in treatment T_1 (Absolute control).
- Significantly higher nitrogen content of 4.10 per cent was recorded in leaves obtained from the treatment T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @1000 mg/L as foliar spray) which was on par with treatment T_8 (3.96 %). Significantly lower nitrogen content of 3.17 per cent was recorded in leaves harvested from treatment T_1 (Absolute control).
- Significantly higher content of Fe (199.47 mg/kg) was recorded in leaves obtained from T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray) followed by T_8 (186.02 mg/kg) which received T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray and significantly lower Fe (100.18 mg/kg) content was recorded in leaves of treatment T_1 (Absolute control).

Table 1: Effect of foliar application of nano nitrogen and iron on nitrogen, iron content, quality and yield of mulberry leaves.

Treatment	N (%)	Fe (mg/kg)	Protein (%)	Crude fibre (%)	Yield per plant (kg)	Yield per hectare (tons/ha/crop)
T_1	2.9	100.18	28.49	11.28	0.26	5.89
T_2	3.33	120.94	31.42	12.74	0.30	6.66
T_3	3.49	126.91	31.81	13.62	0.31	6.9
T_4	3.78	155.88	32.72	13.86	0.37	7.37
T_5	3.93	179.84	35.60	14.06	0.44	8.11
T_6	3.29	109.04	30.13	12.18	0.28	6.24
T_7	3.84	174.49	34.19	13.97	0.40	7.74
T_8	3.96	186.02	36.81	14.14	0.47	8.44
T_9	4.1	199.47	37.55	14.22	0.52	8.69
SEM ±	**0.1**	**1.04**	**1.48**	**0.45**	**0.005**	**0.51**
CD at 5 %	**0.32**	**3.12**	**4.45**	**1.36**	**0.017**	**1.53**

DISCUSSION

- Foliar application of nano nitrogen and iron significantly influenced the nitrogen and iron content, quality and yield of mulberry leaves.
- Higher leaf yield due to foliar application of nano nitrogen and iron was mainly because of better supply of nutrients to the target area where in higher concentration of nitrogen and iron in the form of nano particles would have entered through the stomata or vascular systems helping higher metabolic activity leading to higher leaf yield. (Sheykhbaglou *et al*., 2010)
- Foliar application of nano fertilizer improved the yield attributes due to enhanced availability of nutrients by easy penetration of nano formulation through stomata of leaves via gas uptake. (Aziz *et al.*,2018)
- Nano-fertilizers have small size and large surface area, resulting high reactivity that increases the contact of fertilizer with plant and leading to increase in nutrient uptake, leaf chlorophyll content and fertilizer use efficiency (Herrera *et al*., 2016).

Plate 1: General view of the field experiment

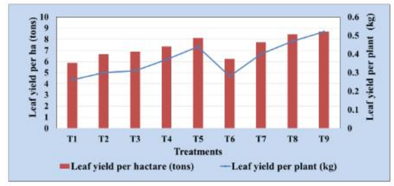

Fig.1: Effect of foliar application of nano nitrogen and iron on leaf yield of mulberry.

SUMMARY

- Significant increase in yield and quality of mulberry leaf was recorded in all the treatments compared to control.
- Among the treatments, foliar application of nano nitrogen @ 0.4 % and nano iron @ 1000 mg/L combined with 50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha recorded significantly higher leaf yield.
- Protein (%) and Crude fibre (%) recorded significantly higher content in treatment (T_9) 50 % N: 100% P_2O_5: 100% K_2O + 25 t FYM/ha + nano Nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray.

REFERENCE

AZIZ, A. H., HASANEEN, M. N. AND OMAR, A., 2018, Effect of foliar application of nano chitosan NPK fertilizer on the chemical composition of wheat grains. *Egypt. J. Bot*., **58**(1): 87-95.

HERRERA, C. M. AND BAZAGA, P., 2016, Genetic and epigenetic divergence between disturbed and undisturbed subpopulations of a Mediterranean shrub: A 20-year field experiment. *Ecol. Evol*., **6**(11): 3832-3847.

SHEYKHBAGLOU, R., SEDGHI, M., SHISHEVAN, MT. AND SHARIFI, SR., 2010, Effects of Nano iron oxide particles on agronomic traits of soybean. *Not. sci. biol*., **2**: 112-113.

Advisory Committee

Chairperson
Dr. J. Saralakumari

Members
Dr. D. V. Naveen
Dr. N. Amarnatha
Dr. N. Nagesha

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVATIONS

Abbreviation	Full form
%	Per cent
@	At the rate of
BD	Bulk Density
CD	Critical Difference
Cu	Copper
DAP	Days After Pruning
ds m^{-1}	Deci Simens per meter
DTPA	Diethylene Triamine Penta aceticacid
EC	Electrical Conductivity
et al.,	Coworkers
Fe	Iron
FYM	Farm Yard Manure
Kg ha^{-1}	Kilogram per hectare
mg kg^{-1}	Milligram per kilogram
MWHC	Maximum water holding capacity
NPK	Nitrogen, phosphorus and potassium
NS	Non-significant
OC	Organic carbon
P_2O_5	Phosphorus pentoxide
PD	Particle Density
RDF	Recommended dose of fertilizer
S. Em ±	Standard error of mean
SPAD	Soil Plant Analysis Development
t ha^{-1}	Tonnes per hectare
Zn	Zinc

I INTRODUCTION

Sericulture is an agro based industry are well known heritage of Indian culture and tradition both economically and traditionally. This agro-based industry play an vital role in nurturing the rural economy by providing opportunity to better livelihood among millions of people through pre to post cocoon technology. Mulberry sericulture is back bone of industry as it occupies nearly 72 per cent of total raw silk production in India.

Mulberry leaf is the sole food material of silkworm (*Bombyx mori*. L) and also major source of silk protein, Nutritional qualities of mulberry leaves supplied as food material to silkworm have great influence on quality of cocoon because, the silk produced by the silk worm are directly derived from the protein of mulberry leaves. Feeding of nutritious mulberry leaves to silkworm larvae also lowers the mortality rate of silkworms. Mulberry nutritional quality has also been found to significantly affect silkworm cocoon production by researchers around the world.

Several factors contributes for production of quality of mulberry leaves viz., soil health, nature of mulberry variety, INM, agronomic practices, environmental condition and protection measures for disease and pest. Among these, soil health, environmental condition and nutrient management have greater influence on mulberry leaf production. Soil application of fertilizers is a common practice followed by the farmers cultivating mulberry, but such application has certain disadvantages including their high cost, less nutrient uptake in rain fed condition, has excess use of these fertilizers in soil along with other insecticide and pesticides pose threat not only to mulberry crop but also to environment. Hence, there is a serious need of alternative approach to enhance the mulberry leaf production without affecting the ecosystem.

Foliar application in the form of composite formulations of different nutrients has been found to be an efficient way to provide nutritional support in terms of reducing the quantity of nutrient inputs along with enhancing nutrient assimilation by the plant. Besides, it has also much effect on physiological growth and development of mulberry plants. Plant nutrients like Mg, Mn, Fe, Zn and B provided to mulberry as foliar nutrients has enhanced its growth and yield as well as quality of leaf and cocoon yield (Mahesh 2014). Application of several plant growth regulators in combination with inorganic fertilizers has a significant influence on growth and development several crops including mulberry.

Recently, the introduction of nanotechnology application in agriculture playing an important role in application of water soluble and liquid nano fertilizers are available in market have been sprayed with these products as well as applied to the soil. There are various scientists who reported that foliar sprays of nano fertilizers positively affect growth and yield parameters crops like wheat, tomato, cucumber and other crops (Rajonee *et al.,* 2016, Nithya *et al.*, 2018 and Kasivelu *et al*. 2020). Currently, little information is available regarding the application of nano fertilizers to foliage crops.

A survey conducted in selected mulberry growing farmers field from eastern dry zone of Karnataka showed that nutrient management adopted was only conventional soil application and there was no nutrient foliar spray. It was observed that application of recommended nitrogen through soil application recorded lower nutrient use efficiency (30-35 %), which was attributed to various losses like leaching and denitrification under irrigation practices. Iron deficiency symptom that is iron like chlorosis is a common nutrient disorder in plants grown in high pH and calcareous soils which results in poor yield and quality of the crop due to decreased leaf photosynthetic pigment concentration especially chlorophyll (Chen *et al*., 2016).

There are a number of studies related to use of nano fertilizers as foliar spray (N, Zn, Fe and B) resulting have been in higher nutrient use efficiency in various crops and less reports with respect to mulberry. In this regard an attempt was made to study the effect of foliar application of nano nitrogen and iron on mulberry growth and development in Eastern Dry Zone of Karnataka with following objectives.

a) To study the effect of nano nitrogen and iron on growth and yield of mulberry leaf.

b) To study the impact of nano nitrogen and iron on soil properties.

c) To study the effect of nano nitrogen and iron on quality and nutrient status of mulberry leaf.

II. REVIEW OF LITERATURE

Literature related to study "Effect of foliar application of nano nitrogen and iron on growth, yield and quality of mulberry in Eastern Dry Zone of Karnataka" is presented in this chapter below under the suitable headings.

2.1 Effect of nano nitrogen fertilizer on growth and yield parameters.

2.2 Effect of nano nitrogen fertilizer on quality parameters.

2.3 Effect of nano iron fertilizer on growth and yield parameter.

2.4 Effect of nano iron fertilizer on quality parameter.

2.5 Effect of nano fertilizer on soil properties.

2.6 Effect of foliar application of fertilizers on nutrient uptake and soil available nutrients status after harvest of the crop.

2.1 EFFECT OF NANO NITROGEN FERTILIZER ON GROWTH AND YIELD PARAMETER.

Subbaiya *et al.* (2012) in a study effect of formulation of nano nitrogen to enhance the plant growth through slow and sustained release of nitrogen in green gram revealed that modified nano urea particle treated seeds of green gram recorded 100 per cent germination while urea alone gave 70 per cent seed germination, further plant height recorded was highest with HA treatment plot at 5 days time interval.

A pot experiment conducted in China to study the effect of nanoparticle application on growth characteristics and nutrient accumulation in tobacco plants by Liang *et al.* (2013) with four treatments having different concentration of nano nitrogen (0, 25, 75 and 125 mg/pot). They have reported that per cent increase in plant height with application of different concentration of nano nitrogen compared to control plot (6.33, 10.56 and 10.00 per cent), a similar increased in leaf area was noticed with the same treatment at maturity stage.

An investigation carried out by Junxi *et al.* (2013) on feasibility of using ammonium and potassium loaded Nano Zeolite (NK-Z) as carriers for fertilizer and for slow release of nitrogen (N) and potassium (K) in kale (*Brassica alboglabra* cv. bailey) crop in China observed that the leaf fresh weight of kale in the fertilizer treatments including NK-Z were 2118.4 and 2111.3 g/plant, while, the leaf fresh weights of kale in the treatment without NK-Z was 2018.0 g/plant (control).

Ekinci *et al.* (2014) studied the effects of nano liquid fertilizer on plant growth and yield of cucumber (*Cucumis sativus*) in Turkey. The doses of 2.0, 3.0 and 4.0 L/ha of Nanonat and Ferbanat were used as fertilizer source. The results showed that the fertilizer treatments significantly improved the yield compared to control. The highest yield (149.17 t/ha) was observed with Ferbanat 4.0 L/ha application.

Liu and Lal (2014) conducted a greenhouse experiment, to assess the fertilizing effect of synthetic apatite nanoparticles on soybean (*Glycine max*). The result showed that application of nanoparticles increased the growth rate and seed yield by 32.6 and 20.4 per cent, respectively, compared to regular P fertilizer applied plot.

Mukhopadhyay and De (2014) conducted an experiment to study the effect of nano clay polymer composite on growth and yield of lentil in a long-term trial under rainfed condition. The treatments were *viz*, control (no nutrient supplemented), T_1- 100% Recommended Dose of Fertilizer (RDF) *i.e*. 80-40- 30 kg/ha N: P: K., T_2- 100% N through farm yard manure (FYM), T_3- 50% N through FYM, T_4- 50% RDF + 50% N through FYM, T_5- farmers general practice (20 kg N ha^{-1}), T_6- Nano Clay Polymer Composite (NCPC) was applied @ 20 kg/ha in each soil. They revealed that NCPC applied in combination with 100 per cent N through farm yard manure (FYM) successfully increased the grain yield of lentil from 833.6 kg/ha to 845.3 kg/ha. Besides grain yield, stubble yield also varied from 4.3 to 38.5 per cent over control. Nano clay polymer composite enhanced the other growth parameters like root length, plant dry weight, number of pods, primary branches.

Zareabyaneh and Bayatvarkeshi (2015) conducted experiment to study the effect of slow release fertilizers on nitrate leaching, its distribution in soil profile, N-use efficiency (NUE), and yield in potato cultivation. The treatments included nano-nitrogen chelate (NNC), sulfur-coated nano-nitrogen chelate (SNNC), sulfur-coated urea (SCU), and urea (U). The results revealed that potato yield increased by 56.10, 59.61, and 49.76 per cent with NNC, SNNC, and SCU fertilizers, respectively compared to urea fertilizer application.

Manikandan and Subramanian (2016) carried out an experiment with intercalated N nano fertilizer to study the effect of nano fertilizer in maize. Nano-zeourea registered a plant height of 144.8 cm while conventional urea fertilization produced 131.8 cm at 90 DAS, that is 20 per cent higher than the conventional urea. Nano-zeourea registered 38 per cent higher maize yield than conventional urea fertilization.

Kaviani and Negahdar (2016) studied the effect of different concentration of nitrogen nano fertilizers on improving quality of ornamental plants box tree (*Buxus hyrcana Pojark.*). Treatments were biological nitrogen nano fertilizers 0.00, 0.60, 1.20, 1.80, 2.40 and 3.00 g/pot as drench and 0.00, 1.00, 2.00, 3.00, 4.00 and 5.00 gram as leaf spray. The maximum node number (19.33), root length (6.83 cm), leaf number (133.30) and proliferation rate (133.53) were obtained in plants treated with 3.00 g/pot drench + 2.00 g spray of nano fertilizer especially for ornamental plants.

Hasaneen *et al.* (2016) studied the two different types of engineered nano fertilizers namely, carbon nanotubes coated nitrogen and chitosan nanoparticles-N on french bean (*Phaseolus vulgaris.* L). The combined morphological and anatomical analysis indicated that after about 30 days from the date of planting, nano materials either alone or in combination significantly enhanced plant growth and biomass when compared to control. They concluded that low dose of nano fertilizers have been to be beneficial, improving water absorption and nutrients uptake and enhanced the growth of the plants.

A pot culture experiment was conducted by Rajonee *et al.* (2016) to study the efficacy of the nano nitrogen fertilizer on the growth promotion of *Ipomoea aquatic* (Kalmi) plant. The fresh weight production with nano N fertilizer treated soil was more or less same as that of conventional fertilizer. In case of dry weight the production was higher with the nano fertilizer treated soil than the untreated soil.

An experiment was conducted by Khospeyak *et al.* (2016) to investigate the effect of application of nano organic fertilizer at (0, 10, 20 and 30 t/ha) and chemical nitrogen fertilizer (0, 25, 50 and 75 kg/ha) on yield and yield components of fennel. Results revealed that the plant height, number of lateral branches, dry weight, seed yield, straw yield, biological yield, harvest index and essential oil yield were influenced by Nano fertilizer treatments compared to chemical nitrogen fertilizers.

The effect of chemical and nano fertilization on the yield of pinto bean (*Phaseolus vulgaris* L.) was investigated under drought stress (water deficit) conditions by Aghajani and Soleymani (2017). Fertilization treatments where T_1: control (0), T_2: Nano fertilizer, T_3: Nano fertilizer with 75 kg pure N (urea, surface broadcast), T_4: 150 kg pure N (urea), T_5: 75 kg pure N with Nano Zn Fe Mn (foliar applied), and T_6: 75 kg pure N with Zn, Fe and Mn (foliar applied). It was found that nano-fertilization recorded the highest rate of yield and yield components under water sufficient condition and drought condition.

Jyothi and Hebsur (2017) conducted an experiment in Karnataka to study the effect of nano fertilizers on growth and yield of rice and wheat. They reported that full recommended rate of conventional and nano fertilizer (FRRCF+ FRR-NF) enhanced the plant height, chlorophyll content, number of reproductive tillers, panicles, and spikelets in both rice and wheat. Maximum number of grains per spike was recorded with 25 ppm followed by 50 ppm nanoparticles applied in soil, whereas the maximum 100-grain weight was observed with 25 and followed by 125 ppm soil applied nanoparticles in wheat.

Mala *et al.* (2017) studied the influence of nano structured slow release fertilizer on the biochemical characteristics, soil properties and yield attributes of *Vigna radiata.* They studied by the treatments used in this experiment was *viz*. control (without any fertilizer), neem cake, chemical fertilizer, PGPR and nano Slow Release Fertilizers (SRF). They found that both fertilizers increased yield with application of nano SRF compare to application of chemical fertilizers and control.

Aziz *et al*. (2018) investigated the effect of nano chitosan-NPK fertilizer on growth and productivity of wheat. Chitosan-NPK nanoparticles were easily applied to leaf surfaces and entered the stomata via gas uptake, avoiding direct interaction with soil systems. The uptake and translocation of nanoparticles inside wheat plants was investigated by transmission electron microscopy. The result showed that wheat plants grown on sandy soil with nano chitosan-NPK fertilizer induced significant increases in harvest index, crop index and mobilization index of the determined wheat yield variables, as compared with control. The life cycle of the nano-fertilized wheat plants was shorter than normal-fertilized wheat plants with the ratio of 23.5 per cent (130 days compared with 170 days for yield production from date of sowing).

Behboudi *et al.* (2018) reported application of chitosan nanoparticles at 60 and 90 ppm significantly increased the leaf area, leaf color, grain yield, number of grains per spike in barley plants.

Al-Juthery *et al*. (2019) carried out a field experiment to study the effect of foliar application of different sources of nano-fertilizers on growth and yield of wheat. Results indicated that positive response to spraying of Super micro plus nano-fertilizer followed by spraying combined of tri (N+P+K), di (N+P), (N+K) and (P+K) nano-fertilizer compared to control and traditional (NPK) fertilizer treatments respectively in all growth and yield parameters of wheat. Further with an increment of the foliar spray, higher plant height with wheat recorded of 87.77 cm, 12.22 cm, and SPAD value 58.22 (3.17 %, 0.66 % and 2.88 %) for plant height, length of spike, total chlorophyll, concentration of N, P and K respectively compared to control treatment. Yield and protein content parameter followed similar trend in nano NPK fertilizers compared to control.

A pot culture experiment was conducted by Rani *et al.* (2019) to study the effect of chemical and nano nitrogenous fertilizer on growth, yield and yield attributes by sorghum (*Sorghum bicolor* L.). The results revealed that the application of 2.5 time reduction of RDN through nano fertilizer significantly increased growth parameters, yields and quality characters of sorghum.

2.2 EFFECT OF NANO NITROGEN FERTILIZER ON QUALITY PARAMETER

Boonlertnirun *et al.* (2008) reported that application of chitosan by seed soaking before planting and four times of soil application throughout cropping season increased fiber percentage in rice plants greater than the other treatments. Chitosan in combination with urea fertilizer enhanced chlorophyll content and promoted yield in rice.

Dzung *et al.* (2011) reported that under field conditions applications nano chitosan oligomer in coffee seedling increased chlorophyll content up to 15.3 per cent.

Hokmalipour and Maryam (2011) conducted an experiment on the application of increased in dosage of nitrogen fertilizers in maize compare to conventional urea increased the chlorophyll content. They reported that it might be due to better assimilation of nitrogen fertilizer in meristematic tissues and increase metabolic activates enhance chlorophyll content.

Manikandan and Subramanian (2016) carried out an experiment with intercalated N nano fertilizer to study the effect of nano fertilizer in maize. The SPAD readings of urea-fertilized maize plants compared with urea blended with Zeolite or nano-zeolite showed that all plants had comparable in SPAD meter readings and were statistically non-significant.

Mala *et al.* (2017) reported that enhancement in chlorophyll content and photosynthetic pigments by the application of slow release nano urea fertilizer as compared to control in *Vigna radiata.*

NPK nano-fertilizer was prepared by Ha *et al.* (2019) loading nitrogen (N), phosphorous (P) and potassium (K) into chitosan nanoparticles. The results showed that the nano-fertilizer enhanced uptake of nutrients, photosynthesis and growth of coffee plants. Application of the nano-fertilizer improved 17.04, 16.31 and 67.50 per cent of nitrogen, phosphorous and potassium content respectively in the leaves of treated plots compared to the control; total chlorophyll content increased up to 30.68 per cent and 71.7 per cent of photosynthesis net rate.

2.3 EFFECT OF NANO IRON FERTILIZER ON GROWTH AND YIELD PARAMETER

Lokanath and Shivashankar (1986) indicated that number of branches of mulberry differed significantly in the treatments of zinc at 5 kg, iron and magnesium at 2.5 kg, boron at 2 kg and water spray. Iron and magnesium at 2.5 kg/ha and zinc at 5 kg/ha produced significantly higher number of branches (15 to 17.7) compared to other treatments. Leaf area per plant did not differ significantly in the 1st cutting. While in the 2nd cutting, significantly higher leaf area was observed in magnesium and iron at 2.5 kg/ha (3918 and 3266 cm^2) than other treatments.

Narayanaswamy and Shankar (2003) revealed that micronutrient foliar spray influenced the quality of mulberry positively hence the use of foliar sprays particularly Zn may be beneficial in Sericulture. In the present study it was evident from the data that 0.5 % $ZnSO_4$ + (1.0 % $FeSO_4$ + 0.1 % citric acid) + 0.2 % boric acid + 0.5% $MnSO_4$ + 0.01% of Na_2MoO_4 influenced the growth of mulberry.

Bose and Bindroo (2009) reported that all micronutrients significantly increased the leaf yield of mulberry. Zinc @ 10.0 kg/ha/year recorded maximum yield and there was an increase of 34.76 % over the control followed by 33.72 % with the application of boron at 10 kg/ha/year. The leaf yield was attributed by an increase in plant height, number of shoots/plant, length of leaf bearing shoot and leaf area.

Sheykhbaglou *et al*. (2010) examined the effect of nano ferrous oxide particles on physiological traits and nutritional compounds of soybean. Treatments were 5 concentrations of ferrous nano-oxide particles including 0, 0.25, 0.5, 0.75 and 1 g/L which were sprayed 3 times at 4 and 8 leaves stage and pod initiation. Results showed that solution containing ferrous nano-oxide particles had significant effect on nutritional compounds of soybean seed reported that an increase in the content of lipid and protein observed by applying 0.75 g.

Bozrogi (2012) studied the effect of nitrogen fertilizer management and nano Fe chelate foliar spraying on yield and yield component of eggplant. They reported that the highest fruit yield with 46.30 t/ha was recorded under 2 g/L nano iron chelate spraying and 60 kg/ha nitrogen fertilizer treatment and the lowest amount (14.57 t/ha) was obtained under without nano iron chelate and nitrogen fertilizer application treatment. The highest plant height and number of branches per plant were observed 122.6 cm and 3.13 branches under 2 g/L nano iron chelate spraying and 60 kg/ha nitrogen fertilizer treatment, respectively. On the other hand, the lowest plant height and number of branches per plant were 68.83 cm and 2.26 branches under without nano iron chelate and nitrogen fertilizer application treatment, respectively.

Moghadam *et al*. (2012) observed a positive effect of iron chelate nano fertilizer on spinach (*Spinacia oleracea* L.) wet weight by enhancing the growth parameters like leaf area index, crop growth rate and leaf numbers of treated plants.

Prasad *et al.* (2012) observed that ZnO nanoparticles at a concentration of 1000 ppm improved the germination (99 %), root growth (11.81 cm), shoot growth (8.71 cm) and pod yield (3121 kg ha^{-1}) in groundnut significantly as compared to chelated $ZnSO_4$ (90.32 %, 6.71 cm, 4.32 cm and 2410 kg ha^{-1}) but higher concentration of ZnO nanoparticles (2000 ppm) had inhibitory effect on growth and pod development.

Mahajan *et al.* (2013) reported that among different nanoparticle suspensions the maximum growth was found at 50 ppm Zn, Fe, Cu-oxide followed by 50 ppm Fe oxide and lowest were at 20 ppm Zn oxide over control in Mung bean.

Ghafari and Razmjoo (2013) found that wheat harvest index, 1000-grain weight and chlorophyll content increased as the rate of iron sulphate and iron chelate increased but these parameters decreased at the higher rate of nano iron oxide. Significantly higher 1000-grain weight, harvest index, grain and grain carbohydrate yields were produced by application of 8 g L^{-1} iron sulphate followed by application of 2 g L^{-1} of nano iron oxide.

Shailesh *et al.* (2013) studied the effect of nano ZnO, nano FeO, nano Zn, Cu, Fe oxide particles on growth of mung bean seedlings and reported the positive effect of these nanoparticles on growth of mung bean seedlings over the control. The best performance was observed for nano Zn, Cu, Fe oxide particles followed by nano FeO and nano ZnO particles.

Rezaei and Abbasi (2014) depicted that application of nano chelate of zinc increased the fresh weight and dry weight of cotton due to improved physiological processes like chlorophyll content and antioxidant activity.

Field experiment was conducted by Khaledian *et al.* (2014) found that nano iron chelate nitrogen increased growth and yield parameters compared to either only chemical fertilizers or FYM and control. The pod number and seed number per pod were significantly affected by fertilization. The highest grain yield was observed with F_3N_1 treatment (FYM + seed treatment with nano-iron chelate fertilizer). It seems that the significant variation in seed number per pod and pod number per plant were finally led to positive effect on seed yield. The highest pod number and seed number per pod was observed with co application of farmyard manure and chemical fertilizers.

Harsinia *et al*. (2014) reported that foliar application of nano iron chelate at tillering stage of wheat was more effective compare to conventional fertilizers applications. Foliar application in this stage had the effective impact on quantitative characteristics of wheat. Maximum dry matter, crude protein and crude fiber percentage also increased in nano Fe-chelate fertilizers plot.

Dimkpa *et al*. (2015) observed the response of bean (*Phaseolus vulgaris*) to commercial ZnO nanoparticles (NPs). Application of ZnO nano particles ranging from 250-1000 mg Zn kg^{-1} had significant impact on root elongation after 7 days. Whereas, shoot growth was significantly inhibited at 1000 mg kg^{-1}.

Alam *et al*. (2015) reported that wheat seed germination and seedlings growth was regularly affected with 1.0 to 2.0 ppm (shoot length and root length for 0, 1.0, 1.5 and 2.0, 2.5 ppm Fe nanoparticles were 2.7, 3.7, 5.2, 6.7 cm and 3.7, 5.1, 7.02, 7.96 cm respectively) but decreased significantly at 2.5 ppm of iron nanoparticles (shoot length was 1.9 cm and root length 2.3 cm).

The spinach plants were sprayed with the graded concentration of zinc oxide nano particles after 14 days of sowing. The plants sprayed with ZnO nano particles at the concentration of 500 and 1000 ppm showed the increased growth and quality parameters like leaf length, width, surface area and colour of the leaf samples when compared to the control leaf samples. Hence, study suggests that the nano zinc oxide sprayed spinach is more nutritious to vegetarian diet by providing protein, fiber and required amount of vegetarian fat to diet (Kisan *et al*. 2015).

Rui *et al.* (2016) conducted an experiment on iron oxide nanoparticles as a potential iron fertilizer for peanut. The aim of this study was to evaluate the effectiveness of iron oxide nanoparticles (Fe_2O_3 NPs) as a fertilizer to replace traditional Fe fertilizers, which have various shortcomings. Results revealed that Fe_2O_3 NPs increased root length, plant height, biomass and SPAD values of peanut plants and can traditional Fe fertilizers in the cultivation of peanut plants.

Siva and Benita (2016) compared effect of EDTA chelated iron and iron oxide nanoparticles on ginger and concluded that ginger roots supplemented with iron oxide nanoparticles showed an enhanced plant growth, *i.e.*, increased plant height, number of leaves, chlorophyll, carotenoid, protein and iron content and was an efficient solution to avoid chlorosis compared to chelated form.

Sharifi *et al.* (2016) found that foliar application of nano-iron fertilizer increased the growth of forage corn because of enhanced levels of crude protein and soluble carbohydrates.

Drostkar *et al.* (2016) conducted a field experiment to study the effects of foliar application of Zn, Fe and NPK as nano fertilizers on chickpea at dryland conditions. The results revealed that plant height, number of branches, seed weight, biological yield and seed yield were significantly increased as compared to plants grown in control condition. Highest seed yield (137.3 g/m^2) was obtained by Fe + Zn foliar application and caused 34% increase in the seed yield. The most increase in seed weight (12 %) was obtained by the foliar application of NPK and Fe + Zn.

Raju and Prashant (2017) analyzed the studies on effect of polymer seed coating, nanoparticles and hydro priming on seedling characters of pigeon pea and revealed that to know the effect of seed polymer coating, nanoparticles (NPs) Zn, Fe at different concentration (10 and 25 ppm), $ZnSO_4$, $FeSO_4$ (100 and 500 ppm). Results showed that seed polymer coating with Fe NPs at 25 ppm recorded significantly higher seed germination (94.75 %), speed of germination (94.75 %), seedling root length (12.58 cm), seedling shoot length (19.58 cm), seedling length (32.15 cm), seedling dry weight (0.43 g), seedling fresh weight (0.74 g), seedling vigour index I (2953.70), seedling vigour index II (407.00) and lowest abnormal seedlings (2.50 %) over their bulk forms and control followed by Fe and Zn NPs at 25 ppm.

Karunakaran *et al*. (2017) experiment conducted on Green synthesized iron oxide nanoparticles: A nano-nutrient for the growth and enhancement of flax (*Linum usitatissimum* L.) plant. It was observed that the seedling length (cm), average number of seedling with leaves and root length (cm) were increased with an increase in the concentration of the nanoparticles when compared to control.

Nithya *et al.* (2018) conducted field experiment to study the influence of nano zinc application on mulberry and cocoon productivity at College of Sericulture, Chintamani. The experiment consisted of seven treatment combinations with three replications (RCBD). Field experiment recorded significantly higher shoot height (96.63cm), number of branches/plant (8.47), number of leaves/ shoot (18.60), number of leaves/ plant (157.15), higher leaf area (96.90 cm^2) and leaf yield (0.46 kg/plant) were recorded in nano zinc oxide of 50 ppm as foliar spray when compare to other treatment.

Shebl *et al*. (2019) experiment conducted to study the effect of micronutrient oxide nanoparticles of zinc, iron and manganese, as well as combination between these oxide as a foliar application on the growth and quality of squash plants. These oxide nanoparticles recorded a significant increase in vegetative growth characters of the squash plant. Plant length, number of leaves per plant, leaf area per plant and plant fresh weight of squash plant were significantly increased by spraying plants with Mn nano oxide as compared to other treatments. On the contrary, plant dry weight is enhanced with Fe nano oxide and followed by Fe+Mn nano oxides.

Kasivelu *et al*. (2020) conducted experiment on demonstrated on green preparation of Nano-micronutrients γ- iron (Fe_2O_3) and zinc (ZnO), characterization, agro-morphological characteristics and crop productivity studies in two crops (rice and maize). The highest seed germination percentage (100 %) and seedling vigor index (27500 & 36500) were observed at the 500 ppm of nano scale γ- Fe_2O_3 treated in rice and maize respectively. In the case of nano scale ZnO, the highest seed germination percentage of (100 % & 99 %) and seedling vigor index (32400 & 33660) were observed at 1000 and 2000 ppm in rice and maize seeds, respectively. The results of micro plot field studies revealed that yield attributes like total grain weight (g/m^2), 1000 grain weight, seed length, seed thickness, seed width and yield (kg/ha) were also highly influenced by the foliar application of nano scale γ- Fe_2O_3 and ZnO (500 and 750 ppm) in rice and maize, respectively.

2.4 EFFECT OF NANO IRON FERTILIZER ON QUALITY PARAMETERS.

Weisany *et al*. (2011) conducted an experiment to investigate the effects of nano-zinc application and salinity stress on some morphological and physiological parameters of soybean. Nano-chelate zinc fertilizer application proved to enhance the activity of peroxidase, catalase, and polyphenol oxidase enzymes in soybean crops which increases the shoot and root growth.

A field experiment was carried out by Tarafdar *et al.* (2014) to find the impact of Nano zinc fertilizers on the growth and yield of pearl millet. Results indicate that significant improvement in chlorophyll content (24.4 %), total soluble leaf protein (38.7 %), and enzyme activities of acid phosphatase (76.9 %), alkaline phosphatase (61.7 %), phytase (322.2 %), and dehydrogenase (21 %) were observed over control in 6 weeks old plants.

Pirvulescu *et al*. (2015) reported that biocompatible magnetic nano fluid (Fe_3O_4/H_2O) had positive influence on the total chlorophyll content (a and b) in sunflower leaves. However, with higher concentrations (> 0.75 %) the growth rate of the chlorophyll content is negative.

Karunakaran *et al*. (2017) reported that metabolic activity due to nanoparticle treatment, peroxidase and catalase activities were measured. The result showed that higher concentration of iron oxide nanoparticles (Fe_2O_3NPs 1000 mg/L) has enhanced the activity of both the enzymes indicating the inhibition of ROS (Reactive Oxygen Species) generation and hence promoted plant growth.

Nithya *et al.* (2018) conducted field experiment to study the influence of nano zinc application on mulberry and cocoon productivity at College of Sericulture, Chintamani. Higher total chlorophyll (2.44 mg/g), crude protein (39.00 %) and crude fiber (14.19 %) of mulberry leaves in nano zinc oxide of 50 ppm used as foliar spray.

Shebl *et al*. (2019) reported that foliar application of nano oxides increased the content of photosynthetic pigments expressed as chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids in squash leaves as compared to control. The application of manganese nano oxide as foliar on squash plants enhanced the content of chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids in the leaves followed by plants supplied with iron and zinc nano oxides compared with other treatments.

2.5 EFFECT OF NANO FERTILIZER ON SOIL PROPERTIES.

Subbramanian and Kumaraswamy (1989) observed that there was no effect of adding 100 per cent NPK +FYM on electrical conductivity of soils.

Bharadwaj and Omanwar (1994) studied the effect of crop rotation and fertilization on soil properties and reported that EC of soil was not affected by any of the treatments.

Basumantary and Talukdar (1998) opined that continuous application of chemical fertilizers alone let to decrease in soil pH, where as an improvement over initial value resulted under integrated treatments which received both inorganic and organic source of fertilizers in a long term experiment.

The most important reaction pathways which may affect fate and behaviour of nanoparticles in soil are dissolution, aggregation, partitioning between solution and solid phase and mobility. Soil properties such as pH, ionic strength, clay and organic matter content affect the dissolution of nanoparticles through their effect on aggregation. High surface area and charge of manufactured nanoparticles result in strong adhesion of nanoparticles to the reactive surface of soil (Milani, 2011).

Kim *et al.* (2011) revealed that concentration of zinc in the soil treated with zinc nanoparticles were more than that of treated with soluble zinc. This indicated that in soil there would be better retention of nanoparticles which reduces phototoxicity and increases the reserve of zinc nutrient in the soil.

Du *et al.* (2011) investigated the effect of TiO_2 and ZnO nanoparticles on wheat growth and soil enzyme activities under field conditions. The nanoparticles induced significant changes in soil enzyme activities, soil quality and health. Soil protease, catalase and peroxidase activities were inhibited in the presence of the nanoparticles while urease activity was unaffected.

Moshe *et al.* (2012) studied effect of metal oxide nanoparticles (CuO and Fe_3O_4) on various soil properties. It was found that the nanoparticles did not change the total amount of organic materials in the soil or the total organic carbon in the soil extract. Denaturing gradient gel electrophoresis (DGGE) fingerprinting revealed that nanoparticles affected the soil bacterial community composition, but had little impact on the macroscopic properties of the soil

Kim *et al.* (2013) investigated effects of CuO and ZnO nanoparticles (NPs) and microparticles (MPs) on soil microbial toxicity, phytotoxicity and bioaccumulation in two crops (*Cucumis sativus* and *Zea mays*) and found that NPs were more toxic than MPs to microbes and plants in the soil ecosystem. They also found that the soil enzyme activity and plant biomass were inhibited to the greatest extent by CuO NPs than ZnO NPs.

Subbaiah (2014) reported that the postharvest nutrient availability of zinc in the soil increased due to the foliar nano ZnO spray and maximum content was recorded with the application of nanoparticles @ 1,000 ppm indicating that the translocation of zinc from the leaves to the soil through the plant body system and accumulated in the soil. The soil zinc content had shown high significant differences among treatment.

Shen *et al.* (2015) investigated the eco-toxicological effect of ZnO-NPs on soil microorganisms testing respiration, ammonification, dehydrogenase activity, and fluorescent diacetate hydrolase activity in soil. The study revealed that soil type determines the toxicity of ZnO NPs in soil and toxicity was highest in the acid soil, followed by the neutral soil. The toxicity was relatively low in the alkaline soil. The toxicity was not accounted for by the Zn^{2+} released from the ZnO-NPs but due to the direct interaction of ZnO-NPs with biologic targets.

Watson *et al.* (2015) studied the effects of soil properties on phytotoxicity and Zn bioavailability from the NPs in an acidic and a calcareous alkaline soil and concluded that in the acid soil, ZnO NPs caused dose-dependent phytotoxicity while no phototoxicity in calcareous soil showing that ZnO NPs formulations to be used as a soil amendment need to be tuned to soil properties to avoid phytotoxicity.

Schlich and Hund-Rinke (2015) investigated the effects of silver nanomaterials (Ag-NMs) on five well-characterized soils with distinct physico-chemical properties using two standardized test systems. The carbon transformation test (OECD 217) showed minimal sensitivity whereas the ammonia oxidizing bacteria test (ISO 15685) showed extreme sensitivity over 28 days of exposure. Ag-NM toxicity was compared with the physico-chemical properties of the soils, revealing that toxicity declined with increasing clay content and increasing pH. Ag-NM toxicity did not appear to be affected by the organic carbon content of the soil.

Simonin *et al.* (2016) reported that soil exposed to TiO_2-NPs (1 and 500 mg kg^{-1} dry soil) showed a decrease in nitrification enzyme activities and abundance of ammonia oxidizing microorganism and concluded it as emerging pollutant to affect the soil health.

Rui *et al.* (2016) studied the effectiveness of iron oxide nanoparticles (Fe_2O_3 NPs) on the growth and development of peanut to replace traditional chelated Fe-fertilizers. The results showed that Fe_2O_3 NPs promoted the growth of peanut by increasing root length, plant height, biomass and SPAD values and regulating phytohormone contents and antioxidant enzyme activity. The iron content in the soil was quantitatively determined by energy dispersive X-ray spectroscopy (EDS) showed that the Fe_2O_3 NPs adsorbed on to sandy soil improved the availability of Fe to the groundnut plants.

You *et al.* (2017) suggested that metal oxide nanoparticle incubation could influence soil enzyme activities and change soil bacterial community. ZnO NPs had a stronger effect on soil enzymatic activities than $nTiO_2$, $nCeO_2$, and nFe_3O_4 and saline-alkali soil was more susceptible to metal oxide nanoparticles than black soil.

Kwak *et al.* (2017) investigated the long-term effects of ZnO NPs at concentrations of 50 and 500 mg kg^{-1} on the activities of six exo-enzymes in planted soils such as dehydrogenase, fluorescein diacetate (FDA) hydrolase, urease, acid phosphatase, aryl-sulfatase, and β-glucosidase. These effects included both decrease and increase in enzyme activity. However, results suggested that ZnO NP treatments of 50 and 500 mg kg^{-1} can adversely affect soil enzymes, particularly acid phosphatase and urease and thus have implications for phosphorous and nitrogen cycles in the soil.

2.6 EFFECT OF FOLIAR APPLICATION OF FERTILIZERS ON SOIL AVAILABLE NUTRIENTS STATUS AND NUTRIENT UPTAKE AFTER CROP HARVEST.

Boote *et al.* (1977) observed foliar application of N, P, K, and S increased the N, P and K concentration of total canopy leaves from 3.28, 0.24, and 0.92 per cent to 3.48, 0.29, and 1.32 per cent respectively in soybean. Foliar fertilization significantly increased upper leaf Pg (gross leaf photosynthesis) only at two late sample dates when seed growth was nearly complete and most leaves had already started senescence and dropped. Maximum Pg was predicted at 4.6 to 6.0 per cent leaf N. Leaf Pg and per cent P were also positively correlated. The relationship of Pg to leaf N during N removal from leaves can potentially be used to model photosynthetic decline during seed filling stage.

Muthuvel *et al.* (1985) reported that, foliar spray of 2 per cent DAP and 1 per cent urea at flowering stage, soil nutrient status was increased with the available N, P and K status of soil (131, 6.3 and 134 kg ha^{-1}, respectively) of rainfed black gram compared to no foliar spray. Singh and Kamath (1989) found that foliar application of 1.5 kg P_2O_5 in two sprays significantly increased the P uptake (20.5 mg $plot^{-1}$) and dry matter (7.71 gm $plot^{-1}$) of Mustard.

Elayaraja and Angayarkanni (2005) concluded that, foliar application of 2 per cent DAP at 20, 30 and 45 DAS resulted in higher NPK uptake in both seed (43.03, 46.22 and 6.85 kg ha^{-1}, respectively) and haulm (5.39, 8.18 and 15.01 kg ha^{-1}, respectively) of black gram.

Nelson *et al.* (2005) reported that foliar application of potassium sulphate @ 36 kg ha-1 on soybean leaves acts as an excellent method of supplementary fertilization when edaphic climatic condition do not favor the satisfactory uptake of potassium from soil thus resulting in increased yield. Nasef *et al.* (2006) observed foliar spraying with 200 ppm boron and inoculated with rhizobium increased significantly the uptake of N, P, K, Fe, Mn, Zn and B by straw and seeds of groundnut in both seasons as compared without biofertilizer.

Raman and Venkataramana (2006) studied the effect of foliar nutrients on NPK uptake, yield attributes and yield of green gram in *Inceptisols*. The results revealed that foliar spray of 2 per cent DAP with 30 ppm NAA recorded higher NPK (69.01, 18.19 and 65.71 kg ha^{-1}, respectively) uptake over control (58.66, 12.97 and 53.68 kg ha^{-1}, respectively).

Jyothi *et al.* (2013) reported that foliar spray of 2 % urea at pod development and flowering stage significantly increased uptake of Zn, N by soybean and also soil application of NPK fertilizer was found to be more beneficial to improve the productivity of soybean than NPK application alone in soybean. Kumar (2013) reported that the foliar application of soluble starter NPK @ 2 per cent + sulphur spray 2 per cent at 45 DAS and soluble booster NPK 2 per cent + boron spray 0.15 per cent at 65 DAS resulted in significantly higher oil content, oil yield, protein content.

Significantly higher phosphorus and potassium uptake (88.32, 10.72 and 35.09 kg ha^{-1} respectively) and available N and P2O5 content of soil (278.13 kg ha^{-1} and 28.55 kg ha^{-1} respectively) was noticed in RDF + foliar spray of 40 ppm NAA + 0.5 % chelated micronutrient + 2% DAP. Which was at par with RDF + foliar spray of 2 per cent DAPS + 0.5 % chelated micronutrient of black gram (Rezaei *et al*. 2013).

Manikandan and Subramanian (2016) reported that grain N content of nanozeourea on *Inceptisol* (Control: 0.26%; Treated: 0.32%) and *Alfisols* (Control 0.48; Treated 0.76%) were higher consistently compared to control plot.

Rajoniee *et al*. (2016) reported that uptake and concentration of nitrogen (N) was better with Nano fertilizer treatments than the conventional fertilizer treatments.

Azizah *et al*. (2017) studied the use of Multi Walled Carbon Nanotubes (MWCNTs) enhancing the nitrogen uptake and use efficiency of urea fertilizer by paddy and revealed that during the 11^{th} week of paddy growth, remarkable increases in N fertilizer uptake was recorded for UF-MWCNTs treatment which recorded 1363.6 mg/pot which was higher than that of control (455 mg/pot). The results also revealed significant increase in NUE in treatment receiving UF-MWCNTs (88.72 %) compared to control (50 %) during 11^{th} week.

III MATERIAL AND METHODS

The details of materials used and the methodologies adopted during the course of investigation on “Effect of foliar application of nano Nitrogen and Iron on growth, yield and quality of mulberry in eastern dry zone of Karnataka” during *rabi* season 2020 carried at Department Soil Science and Agriculture Chemistry are described in this chapter.

3.1 Location of the experimental site

The field experiment was conducted during November to December of *rabi* season in a well-established mulberry garden in the farmer’s field at Kurboor Village, Chintamani Taluk, Chikballapur District. The experimental plot is geographically situated in the Eastern dry zone (Zone - 5) of Karnataka and located between latitude of 13°18ˈ25ˈˈ North, a longitude of 78°5ˈ27ˈ East, with an altitude of 865 m above sea level.

3.2 Climate

Monthly mean meteorological data was recorded at the observatory, College of Sericulture, Chintamani during the year 2020. The actual weather parameters for the year 2020 (April 2020 to December 2020) such as total rainfall, temperature (maximum and minimum), relative humidity and sunshine hours are presented in Table 3.1 and Fig 3.1.

3.2.1 Actual climatic conditions during the period of experimentation

The maximum monthly rainfall was received during September 2020 (259.6 mm) and the minimum was in December 2020 (15.9 mm). During the cropping season (November 2020 - December 2020), a total of 126.3 mm rainfall was received. The average maximum air temperature was 37.01 °C in the month of May 2020 and minimum temperature was 15.69 °C during the month of December 2020 was recorded. The mean monthly minimum relative humidity (56.5 %) in evening was registered in April 2020 and maximum relative humidity (84.03 %) in morning was recorded in December 2020. Mean maximum sunshine hours (8.35) was registered in April 2020 and minimum sunshine hours (2.68) was recorded in August 2020.

Table 3.1: Meteorological data of experimental site for the cropping season at College of Sericulture, Chintamani

Month	Total Rain Fall (mm)	No. of rainy days	Temperature (^{0}C)		Relative Humidity (%)		Sunshine Hrs.
			Max.	Min.	Morn.	Even.	
April	125.8	5	36.65	20.98	69.27	56.5	8.35
May	57	6	37.01	21.35	64.06	58.03	8.27
June	118.2	6	32.2	20.34	76.63	67.33	6.33
July	113.4	10	29.81	19.5	80.03	73.65	4.18
August	87.1	9	29.45	19.21	80.52	77.06	2.68
September	259.6	11	28.71	18.99	83.2	80.43	4.52
October	161	8	28.66	18.71	78.74	76.68	4.94
November	110.4	7	28.23	17.97	79.6	76.67	5.14
December	15.9	3	26.74	15.69	84.03	80.61	5.55
Total	**1048.4**	**65**					

3.3 Soil characteristics of experimental site

A composite soil sample (0 - 30 cm depth) was drawn from the experimental site before initiation of the experiment. Composite soil sample were drawn from experimental site and analyzed for physical and chemical properties. The data are presented in Table 3.2.

3.4 Experimental details

3.4.1 Experimental design

The experiment was laid out in Randomized Completely Block Design (RCBD) during *rabi* 2020 with nine treatments replicated thrice. The whole experimental area was divided into three blocks. Each block was subdivided into 9 plots. Thus, the total numbers of plots were 27 (9 treatments x 3 replications). The size of each plot was 4 m x 4 m. Treatments were distributed randomly in the plots within the blocks. The layout plan of the field experiment is presented in Fig. 3.2.

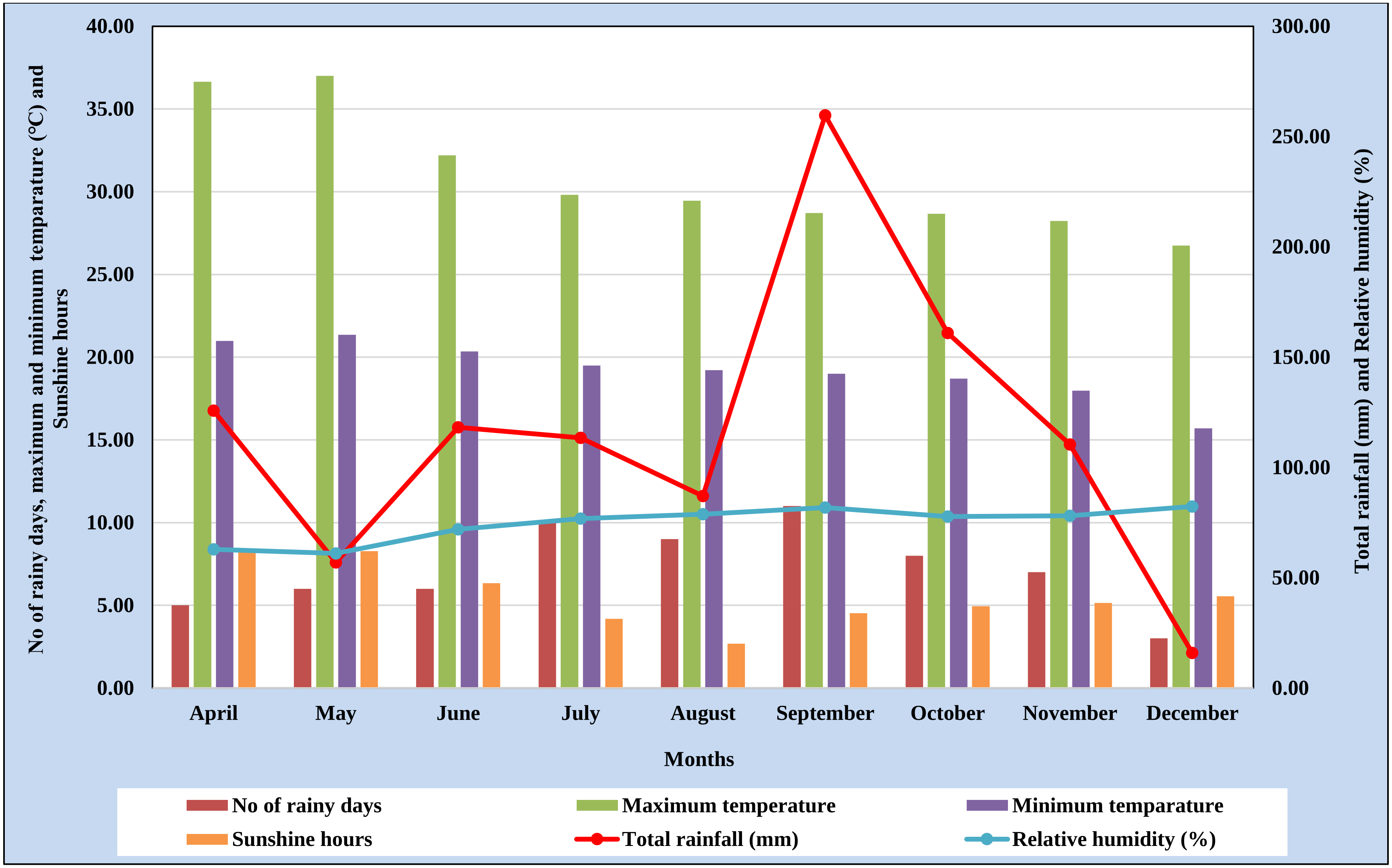

Fig. 3.1 Meteorological data of experimental site for the cropping season at college Sericulture, Chintamani

The experimental details are as follows;

Design	:	Randomized complete block design
Replications	:	Three
Treatment	:	Nine
Plot size	:	4 m × 4 m (16 m^2)
Crop	:	Mulberry (*Morus alba*. L)
Variety	:	Victory -1 (V-1)
RDF	:	360:140:140 (N: P_2O_5: K_2O, respectively) kg ha^{-1}
Date of pruning	:	03-11-2020
Date of harvesting	:	03-01-2021

Table 3.2: Initial physical and chemical properties of soil at the experimental site

SI. No.	Parameter	Value
Physical properties		
1	Sand (%)	43.70
2	Silt (%)	27.19
3	Clay (%)	29.10
	soil Texture	Clay loam
4	Bulk density (g/cc)	1.24
5	Particle density (g/cc)	2.33
6	Maximum water holding capacity (%)	48.95
7	Porosity (%)	46.98
Chemical properties		
1	pH (1:2.5)	6.90
2	EC (dsm^{-1})	0.120
3	Organic carbon (%)	0.65
4	Available N (kg ha^{-1})	390.35
5	Available P_2O_5(kg ha^{-1})	54.78
6	Available K_2O (kg ha^{-1})	286.5
7	Exchangeable Ca (Cmol kg^{-1})	10.52
8	Exchangeable mg (Cmol kg^{-1})	7.85
9	Available S (mg kg^{-1})	13.78
10	DTPA Fe (mg kg^{-1})	14.05
11	DTPA Mn (mg kg^{-1})	10.19
12	DTPA Zn (mg kg^{-1})	2.12
13	DTPA Cu (mg kg^{-1})	0.60
14	Hot water soluble Boron (mg kg^{-1})	0.77

3.4.2 Treatment details

Totally nine treatment combinations of nano nutrients along with recommended dose of fertilizer (RDF) was adopted. The RDF and nano fertilizers were applied as per the treatments given below:

Treatments:

T_1 : Absolute control

T_2 : RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha)

T_3 : T_2 + soil application of $FeSO_4$ @ 5 kg/ha

T_4 : T_2 + nano iron @ 500 mg/L as foliar spray

T_5 : T_2 + nano iron @ 1000 mg/L as foliar spray

T_6 : RDF (50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha)

T_7 : T_6 + nano nitrogen @ 0.4% as foliar spray

T_8 : T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray

T_9 : T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray

Note: spray @30 DAP (Days After Pruning)

3.4.3 Chemical Composition of nano fertilizers used for foliar application.

Chemicals	Concentration
Nano nitrogen	0.4 % - 4 ml of nano nitrogen in 1litre of water.
Nano iron	500 ppm – 500 mg of nano iron in 1 litre of water. 1000 ppm – 1000 mg of nano iron in 1 litre of water.

3.4.4 Crop husbandry

3.4.4.1 Varietal description of mulberry (Victory-1)

The variety Victory-1 (V-1) is a diploid mulberry variety, developed from F1 hybrids obtained from the cross S30 X C776 by Central Sericultural Research and Training Institute, Mysore. The leaves of V-1 are large, thick, smooth, glossy dark green and ovate. Average leaf yield is around 70 MT/ha/year under assured irrigated conditions.

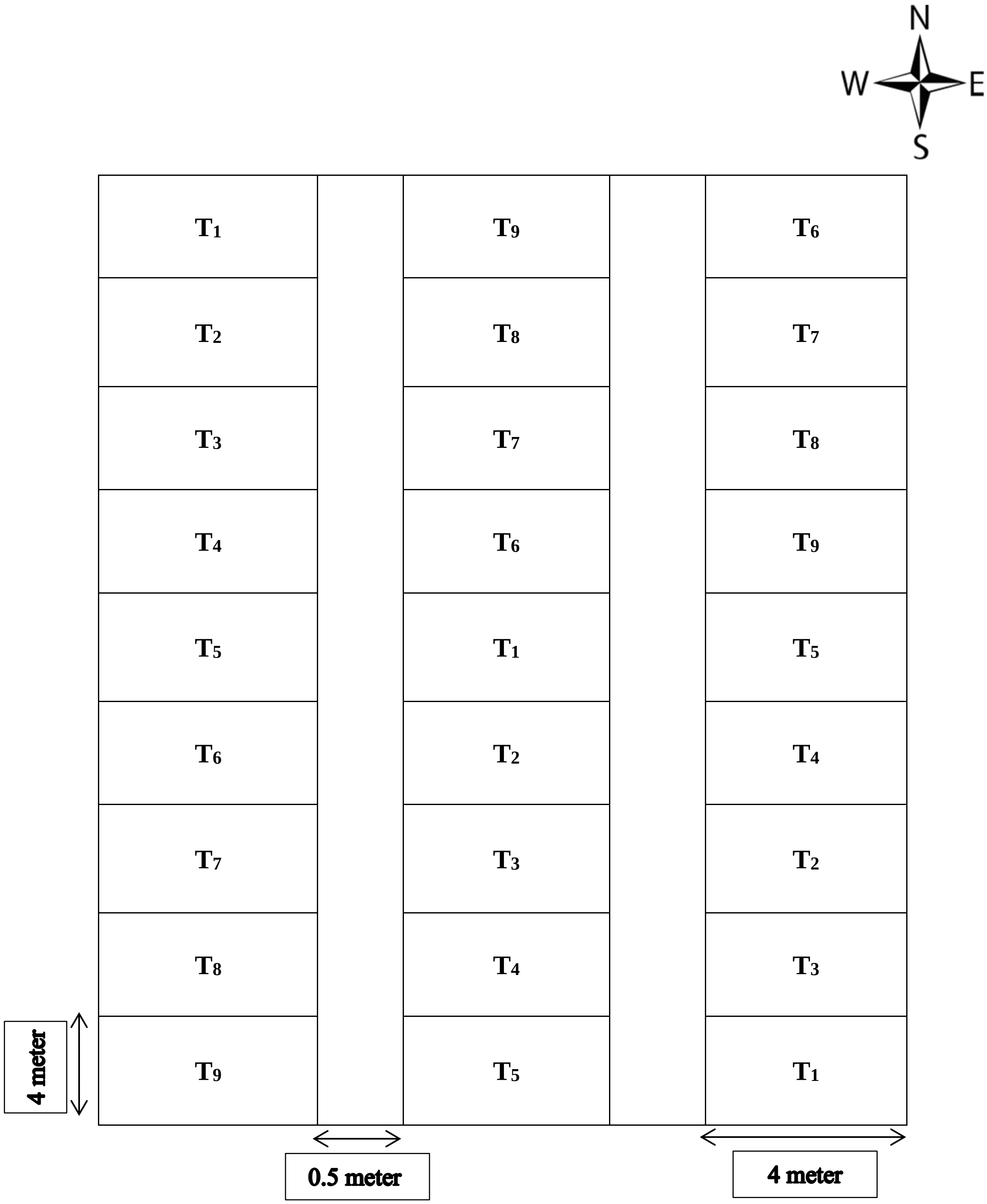

Fig. 3.2: Layout of experimental site

The moisture content of mulberry leaves is 78.9 and 72.5 per cent in young and matured leaves respectively, protein content is 24.6 per cent and total sugar content is 16.98 per cent. It is highly resistant to leaf spot and moderately resistant to leaf rust and tukra infestation. It has quick sprouting ability and very high rooting ability (more than 94%) high photosynthetic rate and higher water use efficiency. Moreover, leaves are suitable for rearing both young and grown bivoltine silkworms.

3.4.4.2 Land preparation

Before initiation of the experiment, mulberry plants were pruned, and land was ploughed with a bullock drawn MB plough and made weed free. The experimental area was laid out as per the plan with small bunds on four sides of each plot. The plots were leveled and irrigation was facilitated through drip system.

3.4.4.3 Application of fertilizers

The furrows were opened according to row spacing and FYM was applied at the rate of 25 tons/ha/year and recommended dose of N, P and K was applied through urea, single super phosphate and murate of potash (350:140:140 kg ha^{-1} yr^{-1} for 6 crops) to all the plants in each treatment plot. The required dose of $FeSO_4$ was calculated according to recommended dose (5 kg/ha) and applied to the soil as per respective treatments. Irrigation was provided at 10 days interval depending upon the climatic conditions. Foliar spray of nano nitrogen and iron was given to the respected treatments by using Knap sack sprayer on 30th day after pruning.

3.4.4.4 After care

a) Irrigation

Common irrigation was given to all the treatments during the dry spell using portable dripper. Totally three irrigations were given during the cropping period.

b) Weeding

Two hand weedings at 20 and 45 Days After Pruning (DAP) were carried out to control weeds.

d) Plant protection

Mulberry crop was sprayed with Nuvan (@ 1.0 ml L^{-1}) as a preventive measure for sucking pest.

e) Harvesting of leaves

Five plants were maintained for recording the observations and the mulberry leaves were harvested at 60 days after pruning. The leaves were picked manually and the amount of leaves harvested in each net plot was recorded and converted to hectare for comparison of the yield.

3.4.5 Growth parameters of mulberry

Five plants were randomly selected and labelled in each row to record the observation on growth parameter periodically at 30, 45 and 60 Days After Pruning (DAP).

3.4.5.1 Growth parameters

The growth parameters such as shoot height, number of leaves per plant and number of shoots were recorded on 30^{th}, 45^{th} and 60^{th} days after pruning.

3.4.5.1.1 Plant height

The observation on plant height was recorded in five randomly labelled plants from the base to the tip of the top-most fully opened leaf. The mean plant height was calculated using the formula,

$$\text{Plant height (cm)} = \frac{\text{Total shoot height}}{\text{Number of shoots}}$$

3.4.5.1.2 Number of shoots per plant

The number of shoots per plant in all the five plants were counted and mean shoots per plant was calculated by using the formula,

$$\text{Number of shoots per plant} = \frac{\text{Total number of shoots}}{\text{Number of plants}}$$

Plate 1. Layout of experimental site

Plate 2. General view of the experimental site

3.4.5.1.3 Number of leaves per plant

The number of leaves from the five labelled plants was counted and mean number of leaves per plant was computed using the following formula,

$$\text{Number of leaves per plant} = \frac{\text{Total number of leaves}}{\text{Number of plants}}$$

3.4.5.1.4 Leaf area (cm^2)

The area of third fully opened leaf from top was determined by using the formula

$$\text{Leaf area} = \text{Length} \times \text{Breadth} \times 0.6898$$

3.4.5.2 Yield parameter of mulberry

3.4.5.2.1 Leaf yield per plant (kg)

The leaves were harvested from each plant treatment wise and fresh leaf weight was recorded separately.

3.4.5.2.2 Leaf yield per hectare (tons/crop)

The leaf yield per hectare was computed based on the leaf yield in the respective treatments.

3.4.5.3 Leaf quality parameter

3.4.5.3.1 Chlorophyll content (SPAD value)

A chlorophyll meter (SPAD-502, Soil Plant Analysis Development) was used for chlorophyll measurement on ten top fully expanded leaves (*i.e.* index leaves). The average of 30 SPAD readings were used to represent the mean SPAD readings of each plot.

3.4.5.3.2 Relative Water Content (RWC) (%)

The leaf samples were collected from plants as per replicated treatments and the fresh weight was determined. Discs were made and further floated on deionised water for 5hr, the turgid tissue was then quickly blot dried with tissue paper prior to determining turgid weight. Dry weight was determined after drying in oven at 70˚C for 48 hours (Anonymous, 1970). The relative water content was calculated using the formula,

$$\text{RWC (\%)} = \frac{\text{(Fresh weight – Dry weight)}}{\text{(Turgid weight – Dry weight)}} \times 100$$

3.4.5.3.3 Protein (%)

The crude protein content of mulberry leaves was estimated and described as per the procedure described by Lowry (Lowry *et al*., 1951). 0.5 g of mulberry leaf sample and add 15 ml of 1% phosphate buffer crush in pestle and morter and transfered to a centrifuge tube. Collect the supernatant solution add 5 ml of solution C (alkaline cupric tartarate solution) and add 0.5 mL Folin-Ciocalteau reagent mixed thoroughly and incubated in dark for 10 min. the intensity of blue colour was measured at 660 nm and absorbance was recorded.

3.4.5.3.4 Crude fibre (%)

The crude fiber content of mulberry leaf was estimated as described by Sadashivam and Manickam (1996) *i.e* by taking 2 g of sample followed by boiling with 200 ml sulphuric acid (0.005 %) for 30 minutes with bumping chips and it was filtered through muslin cloth and washed with boiling water until washings were no longer acidic. Then boiled with 200 ml of sodium hydroxide solution (0.005 %) for 30 min and filtered through muslin cloth again and washed with 25 ml alcohol. It was then transferred to crucible (pre weighed) W_1, the residue was dried for 2 hours at 130±2℃, the dish was cooled and weighed (W_2) then ignited for 30 minutes at 600±15℃ and weight was taken (W_3). It was calculated using the formula,

$$\text{Crude fibre (\%)} = \frac{\text{Loss of weight on ignition } (W_2 – W_1) – (W_3 – W_1)}{\text{Weight of plant sample (g)}} \times 100$$

3.4.6 Soil sampling

Representative soil sample from 0-30 cm depth was collected before land preparation from experimental site. Similarly, after harvest of crop, representative samples

Plate 3. Application of conventional and nano fertilizer to mulberry during experimentation

(0-30 cm) were collected by taking samples from four spots in each treatment plot. The samples were dried under shade in the laboratory. The air dried sample was processed by gently pounding using wooden pestle and mortar. The ground sample was sieved using 2 mm sieve and stored in PVC bottles for further analysis.

3.4.7 Soil analysis

The initial and postharvest soil samples collected were analysed for pH, electrical conductivity (EC), organic carbon, available nutrient status (N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B) by following standard procedure used for soil and plant analysis are furnished in Table 3.4.

3.4.8 Plant analysis

Plant samples were randomly collected from labeled plants in each treatments, air dried and followed by oven dried at 60 ºC for 18 hours. The samples were then powdered and stored in the polythene containers. These samples were analyzed for nitrogen, phosphorus, potassium, calcium, magnesium, Sulphur and micronutrients like zinc, iron, manganese, copper and boron by standard procedures.

3.4.9 Nutrient uptake by crop

After estimating the nutrient content of mulberry leaves nutrient uptake (kg ha^{-1}) by crop was calculated for each treatment separately using the following formula,

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%) x dry matter (kg ha}^{-1}\text{)}}{100}$$

3.4.10 Nutrient use efficiency (NUE)

Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. NUE was calculated by using partial factor productivity (Dobermann, 2007).

$$\text{Partial factor productivity} = \frac{\text{Total yield}}{\text{Amount of nutrient applied (kg ha}^{-1}\text{)}}$$

Table 3.4: Methodology adopted for soil and plant analysis

Parameters	Procedure	Method and References
Soil analysis		
Particle size Analysis	Soil was treated with H_2O_2, dispersed with sodium hexametaphosphate, sand with decantation procedure, silt and clay in the suspension was measured after pipetting with Robinson pipette.	International pipette, Jackson (1973)
Determination of B.D, P.D, MWHC and Porosity	Keen's cup method	Keen Rackzowski, Baruah and Barthakur (1997)
Soil reaction	Soil:water suspension (1:2.5) was measured for pH using potentiometer after standardizing with appropriate buffers.	Potentiometry, Jackson (1973)
Electrical Conductivity (dsm^{-1})	Soil:water extract (1:2.5) was measured for EC using conductivity bridge	Conductometry, Jackson (1973)
Organic carbon (%)	Soil was digested with $K_2Cr_2O_7$ and conc. H_2SO_4. The unutilized $K_2Cr_2O_7$ was back titrated against ferrous ammonium sulphate using ferrion.	Wet oxidation, Walkely and Black (1934)
Available N ($kg\ ha^{-1}$)	Soil was oxidised and distilled with alkaline potassium permanganate and then titrated against standard acid using mixed indicator.	Subbiah and Asija,1956
Available P_2O_5 ($kg\ ha^{-1}$)	Soil was extracted with Brays-1 and estimated by chloromolybdate acid method using spectrophotometer and intensity of blue colour measured at 660 nm.	Brays–I, Brays and Kurtz (1945)
Available K_2O ($kg\ ha^{-1}$)	Extracted the soil with 1 N (pH 7) ammonium acetate and estimated with flame photometer.	Flame photometry, Jackson (1973)
Exchangeable calcium and magnesium	The soil was extracted with 1 N (pH 7) ammonium acetate and Ca and Mg was estimated by complexometric titration method.	Complexometric titration, Baruah and Barthakur (1997)
Avail. S ($mg\ kg^{-1}$)	Extract the soil with 0.15 % $CaCl_2$ then sulphur was precipitated with $BaCl_2$, and the turbidity was measured at 420 nm.	Turbidometry, Jackson (1973)
DTPA extractable Fe, Mn, Zn and Cu ($mg\ kg^{-1}$)	Extracted the soil with DTPA and estimated with atomic absorption spectrophotometer	Lindsay and Norvell, 1978
Available boron method ($mg\ kg^{-1}$)	Azomethine–H reagent method	Gupta (1979)

Plate 4. Chemical analysis of soil and mulberry leaves

Parameters	Procedure	Method and References
Method used for analysis of plant sample		
Total nitrogen (%)	Plant sample digested in concentrated sulphuric acid and digestion mixture (K_2SO_4:$CuSO_4$: Selenium at 100:20:1 proportion). The digested sample was distilled by micro Kjeldhal distillation method. The liberated ammonia was trapped in boric acid and estimated by titration against standard sulphuric acid.	Piper (1966)
Total phosphorus (%)	Phosphorus in di acid digested plant sample estimated by forming yellow colour phosphovanadomolybdate complex using spectrophotometer at 430 nm.	Phosphovanado molybdate complex, Baruah and Barthakur (1997)
Total potassium (%)	Potassium in diacid digested plant sample was estimated with flame photometer	Flame photometry, Jackson (1973)
Total calcium and magnesium (%)	Calcium and magnesium in diacid digested plant sample were estimated by complexometric titration method.	Complexometric titration, Baruah and Barthakur (1997)
Total sulphur (%)	Sulphur in diacid digested plant sample was estimated by precipitating with $BaCl_2$, and the turbidity was measured at 420 nm.	Turbidometry, Bardsley and Lancaster(1965)
Total micronutrients (mg kg^{-1})	Micronutrients in diacid digested plant samples were determined using Atomic Absorption Spectrophotometer	Lindsay and Norvell (1978)
Boron (mg kg^{-1})	The diacid digested plant samples were treated with Azomethine–H reagent and colour was measured at 420 nm using Spectrophotometer	Azomethine–H, Jones and Case (1990)

3.4.11 Economics

Based on the prevailing price of inputs used and produce obtained during the year, the gross returns, net returns and benefit cost ratio were worked as follows:

Net returns per hectare (Rs.) = Gross returns per hectare (Rs.) – Cost of cultivation (Rs.)

$$\text{Benefit: Cost ratio} = \frac{\text{Net returns ha}^{-1} \text{ (Rs.)}}{\text{Cost of cultivation (Rs.)}}$$

3.4.12 Statistical analysis

The experiment data obtained was subjected to statistical analysis adopting Fisher's method of analysis of variance (ANOVA) as out lined by Gomez and Gomez (1984). The level of significance used was given at 5 % Critical Difference (C.D) valve are given in the table at 5 % level of significance, where F test value was significant @ 5 % level of significance.

IV RESULTS AND DISCUSSION

The results of the investigation on “Effect of foliar application of nano Nitrogen and Iron on growth, yield and quality of mulberry in Eastern Dry Zone of Karnataka” conducted at farmer’s field in Kurboor village, Chintamani, Chikkaballapur district during *rabi* 2020 are presented in this chapter with different sub-headings.

Initial characteristics of soil samples at experimental site

The soil was clay loam in texture with neutral in pH (6.9), non-saline (EC 0.12 dSm^{-1}), medium in organic carbon content (0.65 %), medium in available nitrogen (390.35 kg ha^{-1}), phosphorus (54.78 kg P_2O_5 ha^{-1}), potassium (286.5 kg K_2O ha^{-1}) and sulphur (13.78 mg kg^{-1}) status, sufficient with exchangeable calcium and magnesium (12.12 and 7.85 C mol (p+) kg^{-1}) and DTPA extractable micronutrients iron, zinc, copper and manganese status (14.05, 2.12, 0.60 and 10.19 mg kg^{-1}, respectively). The hot water soluble boron concentration was 0.77 mg kg^{-1}.

4.1 Effect of foliar application of nano nitrogen and iron on growth components of mulberry

The data on plant height, number of shoots per plant, number of leaves per shoot, number of leaves per plant and leaf area per plant at different intervals of crop growth period (30, 45 and 60 DAP) as influenced by foliar application of nano nitrogen and iron on mulberry are presented in Tables 4.1, 4.2, 4.3, 4.4 and 4.5.

4.1.1 Plant height (cm)

No significant difference was found in plant height recorded due to foliar application of nano nitrogen and iron at 30 Days After Pruning (DAP). However, highest plant height (50.60 cm) was recorded in treatment T_3 (RDF + FYM + $FeSO_4$ at 5 kg/ha) followed by T_2 (49.57 cm). Lowest plant height (45.13 cm) was recorded in treatment T_1 (control) are presented in Table 4.1 and Fig. 4.1.

Significant difference in plant height was noticed due to foliar application of nano nitrogen and iron was observed at 45 and 60 Days After Pruning (DAP). Significantly higher plant height of 74.10cm at 45 DAP and 124.18 cm at 60 DAP was recorded in T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000 mg/L as foliar spray) followed by T_8 (71.89 cm at 45 DAP and 116.55 cm at 60 DAP). Significantly lower pant height 53.70 cm at 45 DAP and 90.72 cm at 60 DAP was observed in the T_1 treatment (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, there was a significantly increases plant height in treatment T_5 (65.98 cm at 45 DAP and 106.68 cm at 60 DAP) which received T_2 + nano iron @ 1000 mg/L as foliar spray fallowed by T_4 (64.27 cm at 45 DAP and 104.64 cm at 60 DAP) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (62.39 cm at 45 DAP and 98.18 cm at 60 DAP) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

The increase in the plant height may be due to application of RDF along with nano fertilizers. Similar findings to increase in plant height was reported by Jyothi and Hebsur (2017). Further the nutrients NPK helped in sugar translocation in plant for maintenance of turgor pressure in plant cell which led to increase in plant height. Lower plant height was attributed to the treatment without application of nano fertilizers Bozorgi (2012).

4.1.2 Number of shoots per plant

The number of mulberry shoots per plant recorded at 30 DAP due to foliar application of nano nitrogen and iron did not show any significant difference among the treatments. Highest number of shoots was recorded in treatment T_3 which received RDF + $FeSO_4$ at 5 kg/ha (18.53) which was on par with treatment T_2 which received RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha). Lowest number of shoots (14.60) was recorded in treatment T_1 (control) are presented in Table 4.2 and Fig. 4.2.

Significant difference in number of shoots per plant due to foliar application of nano nitrogen and iron at 45 and 60 Days After Pruning was registered. Significantly higher number of shoots at 45 DAP and 60 DAP was recorded in T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000 mg/L as foliar spray) the values where 24.53 and 24.80 respectively followed by T_8 (23.73 at 45 DAP and 24.06 at 60 DAP). Lowest number of shoots was observed in the T_1 treatment (16.66 at 45 DAP and 17.06 at 60 DAP). Comparison of nano iron over conventional iron sulphate fertilizers, there was significantly increases number of shoots in treatment T_5 (22.86 at 45 DAP and 23.06 at 60 DAP) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (21.8 at 45 DAP and 22.13 at 60 DAP) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (19.46 at 45 DAP and 19.80 at 60 DAP) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

Table 4.1 Effect of foliar application of nano nitrogen and iron on plant height (cm) at 30, 45 and 60 DAP of mulberry

Treatments	30 DAP	45 DAP	60 DAP
T_1= Absolute control	45.13	53.70	90.72
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	49.57	61.38	96.39
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	50.60	62.39	98.18
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	48.60	64.27	104.64
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	49.42	65.98	106.68
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	47.33	55.58	93.65
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	47.87	64.32	107.54
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	47.60	71.89	116.55
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	46.87	74.10	124.18
SEM	**1.31**	**0.27**	**0.22**
CD at 5% level of significance	**NS**	**0.83**	**0.67**

Note: DAP: Days After Pruning, NS: non-significant

Among the treatments which received nano fertilizer along with RDF would have facilitated in mineralization of nutrients for uptake by mulberry plant there by increasing in the number of shoots of mulberry. Nano fertilizers are found to release to on demand and helps in regulating the plant growth with help of several enzymes released from organic source and contributing to RNA synthesis which improves the photo systems making the plant to observe and assimilate more amount of nutrients resulting in significant increase in number of shoots compare to treatments without nano fertilizers application and soil alone. These results are in agreement with the findings of Sheykhbaglou *et al*. (2010), Rosa *et al.* (2010) and Nair *et al.* (2010).

4.1.3 Number of leaves per shoot

No significant difference was found in number of leaves per shoot recorded due to foliar application of nano nitrogen and iron at 30 Days After Pruning. However, highest (8.33) number of leaves per shoot was recorded in treatment T_3 (T_2 + $FeSO_4$ at 5 kg/ha) which was on par with T_2 (8.20). Lower number of leaves per shoot (6.93) was recorded in treatment T_1 (Absolute control) which are presented in Table 4.3 and Fig 4.3.

Significant difference in number of leaves per shoot recorded due to foliar application of nano nitrogen and iron at 45 and 60 Days After Pruning was observed. Significantly higher number of leaves per shoot 15.80 at 45 DAP and 22.86 at 60 DAP was recorded in treatment T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000mg/L as foliar spray) which was on par with T_8 (15.06 at 45 DAP and 21.80 at 60 DAP). Lowest number of leaves per shoot was observed in the treatment T_1 (8.06 at 45 DAP and 15.86 at 60 DAP). Comparison of nano iron over conventional iron sulphate fertilizers, there was significantly increases number leaves per shoot in treatment T_5 (14.13 at 45 DAP and 20.86 at 60 DAP) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (13.06 at 45 DAP and 19.53 at 60 DAP) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (11.00 at 45 DAP and 18.00 at 60 DAP) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

Increasing in the number of leaves per shoot showed an increase trend which may be due to application of nano iron and nano nitrogen. Nitrogen contributes for plant growth and development, quality being required for chlorophyll and enzyme synthesis. Iron acts as co-factor for enzymes and being component of ferrodoxin which involves in electron transport protein associated with chloroplast contributes to increasing in the growth characters of plant Hazra *et al.* (1987), Rostami *et al*. (2017) and Rajonee *et al.* (2016).

Table 4.2 Effect of foliar application of nano nitrogen and iron on number of shoots per plant at 30, 45 and 60 DAP of mulberry

Treatments	30 DAP	45 DAP	60 DAP
T_1= Absolute control	14.60	16.66	17.06
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	18.50	19.20	19.46
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	18.53	19.46	19.80
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	18.20	21.8	22.13
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	18.47	22.86	23.06
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	16.80	18.20	18.46
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	16.33	21.33	21.60
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	17.20	23.73	24.06
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	17.33	24.53	24.80
SEM	**1.02**	**0.29**	**0.29**
CD at 5% level of significance	**NS**	**0.87**	**0.87**

Note: DAP: Days After Pruning, NS: non-significant

4.1.4 Number of leaves per plant

No significant difference was found in number of leaves per plant recorded due to foliar application of nano nitrogen and iron at 30 DAP. However, higher (147.63) number of leaves per plant was recorded in treatment T_3 (RDF + FYM + $FeSO_4$ at 5 kg/ha) which were on par with T_2 (146.58). Lower number of leaves per plant (113.00) was recorded in treatment T_1 (control) are presented in Table 4.4 and Fig 4.4.

Table 4.3 Effect of foliar application of nano nitrogen and iron on number of leaves per shoot at 30, 45 and 60 DAP of mulberry

Treatments	30 DAP	45 DAP	60 DAP
T_1= Absolute control	6.93	8.06	15.86
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	8.20	10.80	17.60
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	8.33	11.00	18.00
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	8.10	13.06	19.53
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	8.13	14.13	20.86
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	7.73	9.46	17.00
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	7.70	13.80	20.26
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	7.67	15.06	21.80
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	7.60	15.80	22.86
SEM	**0.27**	**0.11**	**0.09**
CD at 5% level of significance	**NS**	**0.33**	**0.28**

Note: DAP: Days After Pruning, NS: non-significant

Significant difference in number of leaves per plant recorded due to foliar application of nano nitrogen and iron at 45 and 60 Days After Pruning. Significantly higher number of leaves per plant 264.60 at 45 DAP and 441.26 at 60 DAP was recorded in T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @1000 mg/L as foliar spray) which were on par with T_8 (257.06 at 45 DAP and 415.26 at 60 DAP). Lowest number of leaves per plant was observed in the T_1 treatment (144 at 45 DAP and 257.26 at 60 DAP). Comparison of nano iron over conventional iron sulphate fertilizers, there was a significantly increases number leaves per plant in treatment T_5 (262.46 at 45 DAP and 406.73 at 60 DAP) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (241.46 at 45 DAP and 387.06

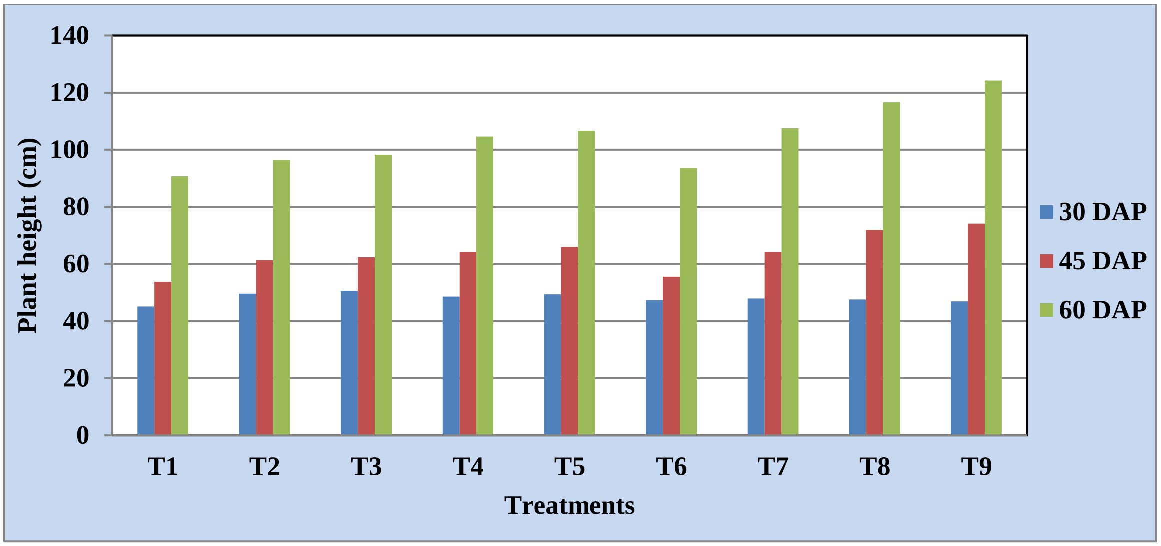

Fig. 4.1 Effect of foliar application of nano nitrogen and iron on plant height (cm) at 30, 45 and 60 DAP of mulberry

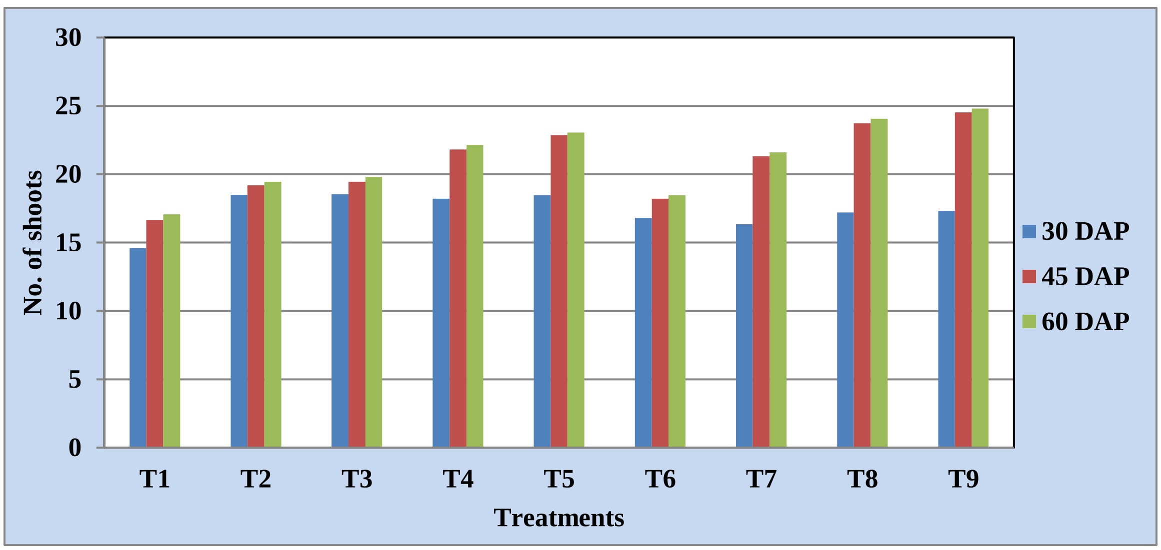

Fig. 4.2 Effect of foliar application of nano nitrogen and iron on number of shoots per plant at 30, 45 and 60 DAP of mulberry

Treatment details:

T_1	:	Absolute control
T_2	:	RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha)
T_3	:	T_2 + soil application of $FeSO_4$ @ 5 kg/ha
T_4	:	T_2 + nano iron @ 500 mg/L as foliar spray
T_5	:	T_2 + nano iron @ 1000 mg/L as foliar spray
T_6	:	RDF (50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha)
T_7	:	T_6 + nano nitrogen @ 0.4% as foliar spray
T_8	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray
T_9	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray

at 60 DAP) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (219.86 at 45 DAP and 335.80 at 60 DAP) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

Table 4.4 Effect of foliar application of nano nitrogen and iron on number of leaves per plant at 30, 45 and 60 DAP of mulberry

Treatments	30 DAP	45 DAP	60 DAP
T_1= Absolute control	113.00	144	257.26
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	146.58	216.73	325.60
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	147.63	219.86	335.80
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	146.13	241.46	387.06
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	145.53	262.46	406.73
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	129.20	180.73	292.33
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	125.60	234.06	400.73
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	123.00	257.06	415.26
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	126.80	264.60	441.26
SEM	**8.12**	**1.13**	**0.64**
CD at 5% level of significance	**NS**	**3.39**	**1.94**

Note: DAP: Days After Pruning, NS: non-significant

The results are in line with Benzon *et al*. (2015) who revealed that the full recommended rate of conventional and nano fertilizer enhance the total shoot dry weight (15.3 %) of paddy over the full recommended rate of conventional fertilizer. Hazra *et al.* (1987) Iron acts as a cofactor for approximately more than hundred enzymes and being a component of ferrodoxin, an electron transport protein associated with chloroplast might have helped to increase the growth characters of plants.

4.1.5 Leaf area (cm^2 plant^{-1})

No significant difference was found in leaf area (cm^2 plant^{-1}) was recorded due to foliar of application nano nitrogen and iron at 45 and 60 DAP and no significance difference among treatments in 30 DAP are presented in Table 4.5 and Fig 4.5.

Table 4.5 Effect of foliar application of nano nitrogen and iron on leaf area (cm^2) at 30, 45 and 60 DAP of mulberry

Treatments	30 DAP	45 DAP	60 DAP
T_1= Absolute control	1294.92	8350.00	12120.04
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	2184.12	9149.27	13063.03
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	2233.16	9786.09	13530.37
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	2155.29	10635.15	17048.33
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	2098.23	12245.16	19089.08
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	1667.83	8868.09	12600.55
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	1640.38	11832.26	17745.13
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	1610.60	12936.19	19852.37
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	1746.58	13546.33	21985.76
SEM	**163.61**	**375.90**	**423.92**
CD at 5% level of significance	**NS**	**1126.96**	**1270.91**

Note: DAP: Days After Pruning, NS: non-significant

There is no significant difference was observed among the treatments with leaf area. The maximum leaf area was recorded in T_3 (2233.16 cm^2) which received (100 % RDF + FYM + $FeSO_4$ at 5 kg/ha) which was found be on par with T_2 (2184.12 cm^2) which received

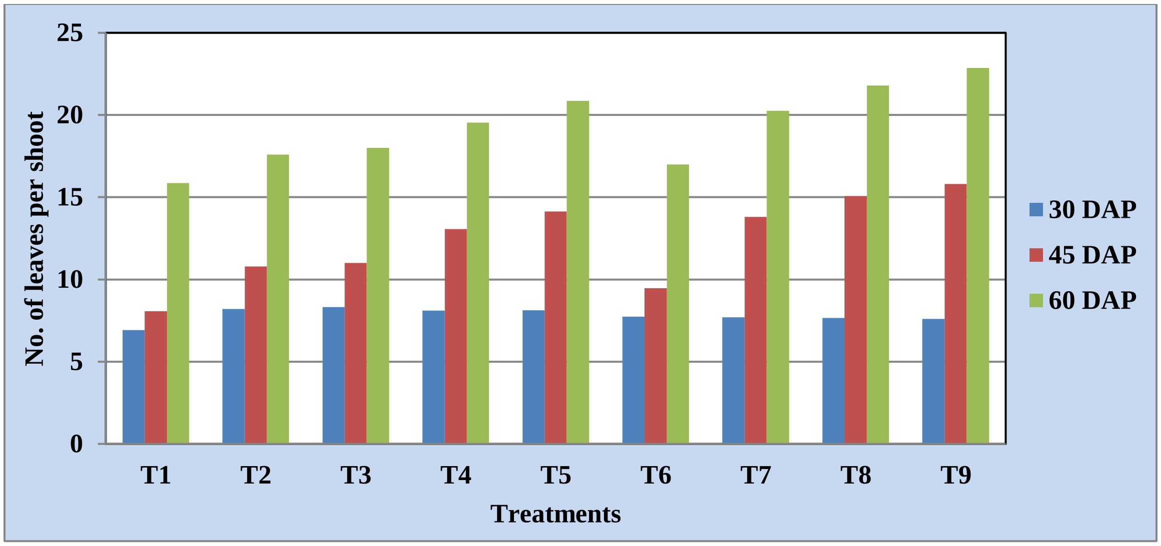

Fig. 4.3 Effect of foliar application of nano nitrogen and iron on number of leaves per shoot at 30, 45 and 60 DAP of mulberry

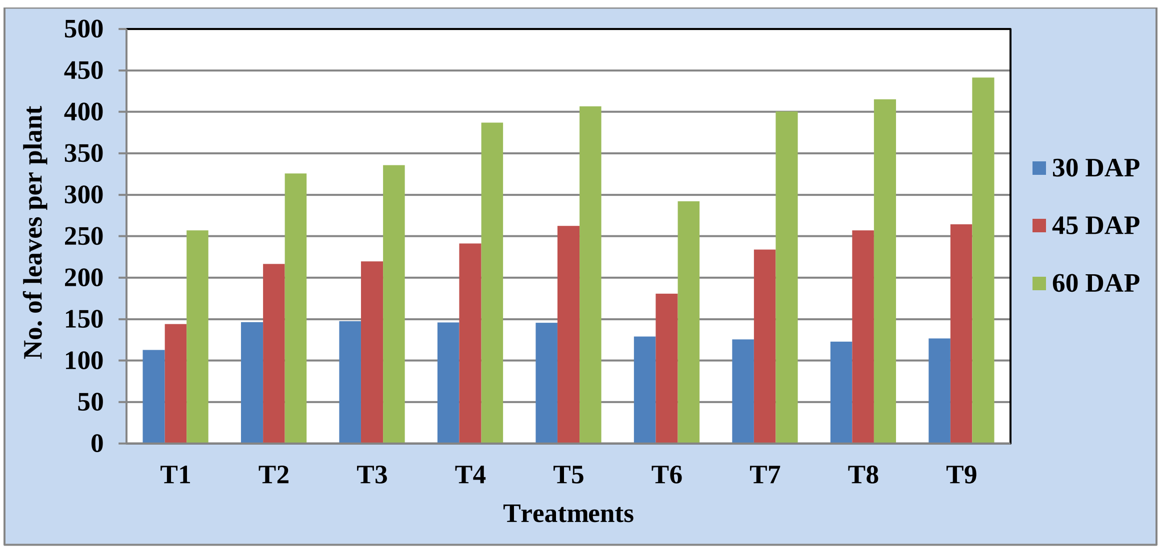

Fig. 4.4 Effect of foliar application of nano nitrogen and iron on number of leaves per plant at 30, 45 and 60 DAP of mulberry

Treatment details:

T_1	:	Absolute control
T_2	:	RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha)
T_3	:	T_2 + soil application of $FeSO_4$ @ 5 kg/ha
T_4	:	T_2 + nano iron @ 500 mg/L as foliar spray
T_5	:	T_2 + nano iron @ 1000 mg/L as foliar spray
T_6	:	RDF (50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha)
T_7	:	T_6 + nano nitrogen @ 0.4% as foliar spray
T_8	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray
T_9	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray

100 % RDF+ FYM at 30 DAP. Minimum leaf area (1294.92 cm^2) was recorded in treatment T_1 (absolute control).

At 45 and 60 DAP comparing the treatments maximum leaf area was recorded in treatment T_9 it was significantly higher than all other treatments except T_8. T_9 and T_8 are on par with each other. Leaf area 13546.33 cm^2 at 45 DAP and 21985.76 cm^2 at 60 DAP was recorded in T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray) which were on par with T_8 (12936.19 cm^2 at 45 DAP and 19852.37 cm^2 at 60 DAP). Minimum leaf area was recorded in the T_1 treatment (8350.00 cm^2 at 45 DAP and 12120.04 cm^2 at 60 DAP). Comparison of nano iron over conventional iron sulphate fertilizers, there was significantly increases leaf area in treatment T_5 (12245.16 cm^2 at 45 DAP and 19089.08 cm^2 at 60 DAP) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (10635.15 cm^2 at 45 DAP and 17048.33 cm^2 at 60 DAP) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (9786.09 cm^2 at 45 DAP and 13530.37 cm^2 at 60 DAP) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

From the data observed the treatments which have received the conventional levels of fertilizers as per package of practice + nutrients as foliar sprays in the form of nano size might have helped in entering the stomata of the leaves enhancing the chlorophyll synthesis and photosytemtic activity attributing to increasing in the leaf area. Similar observation was also reported by Kanjana (2019) stating that iron oxide in the form of nano increase in leaf area.

Nano fertilizers or nano-encapsulated nutrients have properties effectively to release nutrients and chemical fertilizers on demand that regulate plant growth and enhance target activity (Nair *et al.* 2010). Manikandan and Subramanian (2016) recorded that highest dry matter yield obtained from nanozeourea treated soil may be attributed to the increased N availability due to reduced ammonia loss. Kanjana (2019) revealed that highest leaf area (45.4 cm^2 /plant) was recorded in iron oxide (magnetite, Fe_3O_4) nanoparticles and the lowest (41.9 cm^2/plant) was recorded in control.

4.2 Effect foliar application of nano Nitrogen and Iron on yield components of mulberry

4.2.1 Leaf yield/ plant (kg) and leaf yield/ ha (tons)

There was a significant difference was recorded among the treatments with respect to leaf yield of mulberry. Significantly higher leaf yield (0.52 kg/plant and 8.69 t ha^{-1} $crop^{-1}$) was recorded in T_9 treatment which received T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray followed by T_8 (0.47kg/plant and 8.44 t ha^{-1} $crop^{-1}$) and T_5 (0.44 kg/plant and 8.11 t ha^{-1} $crop^{-1}$). The lower leaf yield was recorded in treatment T_1 (0.26 kg/plant and 5.89 t ha^{-1} $crop^{-1}$). Comparison with foliar applied nano iron fertilizers and conventional iron sulphate fertilizers increases yield in treatment T_5 (0.44 kg/plant and 8.11 t ha^{-1} $crop^{-1}$) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (0.37 kg/plant and 7.37 t ha^{-1} $crop^{-1}$) compared to T_3 (0.31 kg/plant and 6.90 t ha^{-1} $crop^{-1}$) are presented in Table 4.6 and Fig. 4.6.

Table 4.6 Effect of foliar application of nano nitrogen and iron on leaf yield of mulberry

Treatment	Yield per plant (kg)	Yield per hectare (tons/hectare/ crop)
T_1= Absolute control	0.26	5.89
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	0.30	6.66
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	0.31	6.90
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	0.37	7.37
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	0.44	8.11
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	0.28	6.24
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	0.40	7.74
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	0.47	8.44
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	0.52	8.69
SEM	**0.005**	**0.51**
CD at 5% level of significance	**0.017**	**1.53**

Note: DAP: Days After Pruning

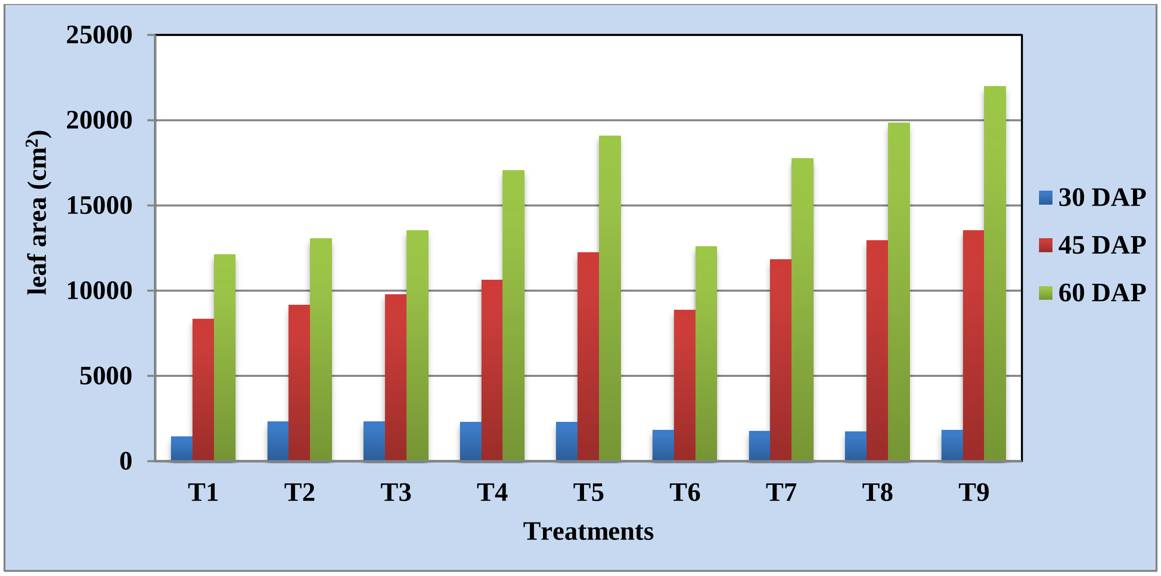

Fig. 4.5 Effect of foliar application of nano nitrogen and iron on leaf area (cm^2) at 30, 45 and 60 DAP of mulberry

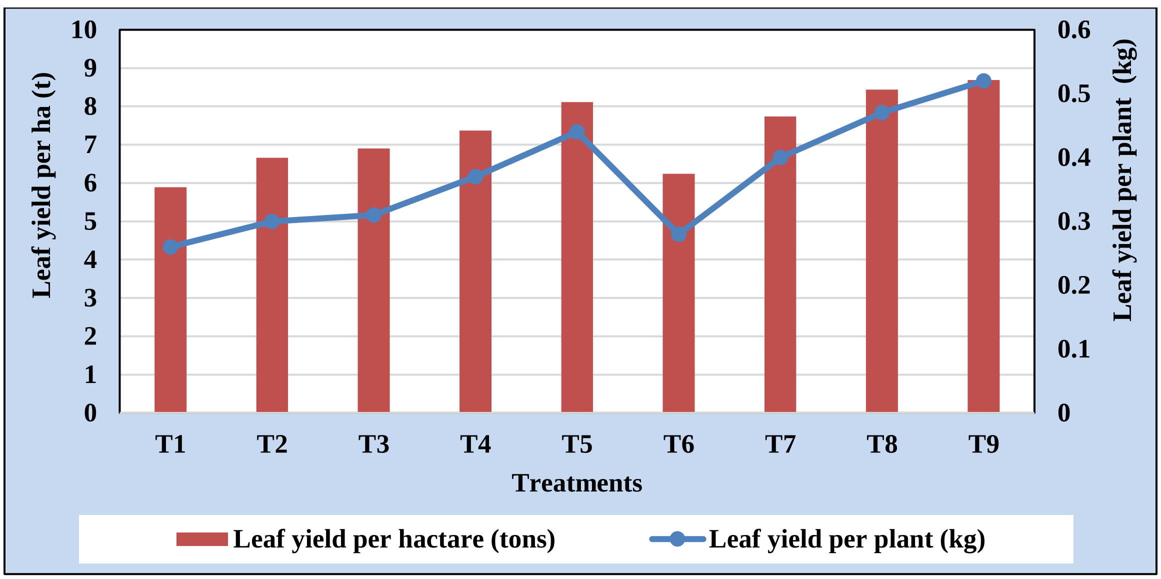

Fig. 4.6 Effect of foliar application of nano nitrogen and iron on leaf yield of mulberry

Treatment details:

T_1	:	Absolute control
T_2	:	RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha)
T_3	:	T_2 + soil application of $FeSO_4$ @ 5 kg/ha
T_4	:	T_2 + nano iron @ 500 mg/L as foliar spray
T_5	:	T_2 + nano iron @ 1000 mg/L as foliar spray
T_6	:	RDF (50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha)
T_7	:	T_6 + nano nitrogen @ 0.4% as foliar spray
T_8	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray
T_9	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray

Higher leaf yield due foliar application of nano nitrogen and iron was mainly due to better supply of nutrients to the target area where in higher concentration of nitrogen and iron in the form of nano particles would have enter through the stomata or vascular systems helping higher metabolic activitie leading to higher leaf yield. The results were in conformity with findings of Sheykhbaglou *et al*. (2010). Similar benefiary effect of nano fertilizer along with RDF was discussed by Eichert *et al*. (2008) higher uptake of nutreints might have significantly improve the efficiency of translocation of nutrients of resulting in massive growth increasing in the leaf yield.

4.3 Effect foliar application of nano nitrogen and iron on soil chemical properties and nutrient status of soil after harvest of mulberry.

The effect of foliar application of nano nitrogen and iron on soil chemical properties (pH, EC, and OC) and nutrient status after the harvest of mulberry is presented in Table 4.7, 4.8, 4.9 and 4.10.

4.3.1 pH, electrical conductivity and organic carbon content of soil after harvest of mulberry.

Data presented in Table 4.7 represents the effect of foliar application of nano Nitrogen and Iron on pH, EC and organic carbon status of the postharvest soil.

4.3.1.1 Soil reaction (pH)

The data on effect of foliar application of nano nitrogen and iron on soil pH at initial and at harvest of mulberry is presented in Table 4.7. Initial pH of the experiment was 6.9. The pH of soil decreased after the harvest, but the change was statistically non-significant. The combined action of FYM and nitrogen fertilizer reduced the pH. Similar results were reported by El-Sayed *et al*. (2020). They reported that pH of the soil was reduced by combined application of compost and nano-NPK fertilizer. Shawer and Abdalla (2019) also revealed that nano nitrogen fertilizers and organic matter had soluble anion such as sulfur and organic acid in soil which reduced soil pH as well as improved physical and chemical properties. Basumantary and Talukdar (1998) opined that continuous application chemical fertilizers alone let to decrease in soil pH.

Table 4.7 Effect of foliar application of nano nitrogen and iron on pH, EC and organic carbon status of soil after harvest of mulberry

Treatments	pH (1:2.5)	EC (dSm^{-1})	OC (%)
T_1= Absolute control	6.7	0.106	0.61
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	6.8	0. 121	0.68
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	6.6	0. 118	0.63
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	6.5	0.114	0.58
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	6.5	0.119	0.65
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	6.7	0.116	0.66
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	6.7	0.114	0.67
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	6.7	0.116	0.65
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	6.7	0.116	0.66
SEM	**0.08**	**5.22**	**0.02**
CD at 5% level of significance	**NS**	**NS**	**NS**

Note: DAP: Days After Pruning, NS: non-significant

4.3.1.2 Electrical conductivity (dSm^{-1})

Soil electrical conductivity is a indirect measurement that correlates with several physical and chemical properties. Electrical conductivity of soil did not differ significantly among treatments. The range of electrical conductivity was between 0.106 to 0.121 dS m^{-1}. Before the experimentation electrical conductivity of soil was 0.120 dS m^{-1}. El-Sayed *et al*. (2020) reported that the combined application of compost and nano-NPK fertilizer in Soyabean crop reduced the electrical conductivity. Subbramanian and Kumaraswamy (1989) observed that there was no effect on adding 100 per cent NPK +FYM on electrical conductivity of soils. Bharadwaj and Omanwar (1994) studied the effect of crop rotation and fertilization on soil properties and reported that EC of soil was not effected by any of the treatments.

4.3.1.3 Organic carbon (%)

Soil organic carbon is largely governed by the management practice and climatic condition, addition and removal of organic carbon takes place through management practices. No significant variation was recorded in organic carbon content of soil among treatments. Slight increase of organic carbon content was observed in all treatments except control plot. Higher OC (0.68 %) and lower OC (0.61 %) was noticed in treatments T_2 and T_1, respectively.

The results are in line with Shawer and Abdalla (2019) who stated that application of nano nitrogen with compost at different level increased the organic matter content of soil which lead to improving soil properties in maize cropping system.

4.3.2 Major nutrient status of soil after harvest of mulberry.

The data pertaining to available nitrogen, phosphorus and potassium (kg ha^{-1}) as influenced by foliar application of nano nitrogen and iron are presented in Table 4.8 and Fig 4.7.

4.3.2.1 Available nitrogen (kg/ha)

At the time of initiation of experiment, the available nitrogen status was 390.35 kg/ha and there was significant difference between treatments. The available N content ranged from 200.64 to 269.81 kg/ha. Treatment T_9 which received (T_6 + nano nitrogen at 0.4% + nano iron at 1000 ppm) shows higher available nitrogen (269.81 kg/ha) followed T_8 (259.88 kg/ha) which received (T_6 + nano nitrogen at 0.4% + nano iron at 500 ppm). Lower content available N (200.64 kg/ha) recorded in T_1 (control). A similar trend was observed in nitrogen uptake too. This might be due to combined effect of FYM and nano fertilizers by reducing the nitrate-nitrogen that increases the available form of nitrogen in soil.

Lower loss of nutrients due to the slow nutrient–releasing nature of manures might be responsible for increase in available nutrients in soil reported by Yadav *et al*. (2000). Muthuvel *et al.* (1985) reported that, foliar spray of 2 per cent DAP and 1 per cent urea at flowering stage, soil nutrient status was increased with the available N, P and K status of soil.

Tables 4.8 Effect of foliar application of nano nitrogen and iron on primary nutrient status in soil after harvest of mulberry

Treatments	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
T_1= Absolute control	200.64	35.25	204.15
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	210.57	60.34	215.56
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	221.54	62.25	226.7
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	233.76	63.56	235.89
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	244.63	66.78	252.35
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	205.05	58.98	209.56
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	239.88	64.25	243.23
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	259.88	68.98	263.45
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	269.81	69.34	272.87
SEM	**7.95**	**2.10**	**8.07**
CD at 5% level of significance	**23.84**	**6.32**	**24.20**

Note: DAP: Days After Pruning, NS: non-significant

4.3.2.2 Available phosphorus (kg/ha)

The results revealed that there was significant difference in available phosphorus among the different treatments. The available P_2O_5 status ranged from 35.25 to 69.34

kg/ha. Treatment T_9 which received (T_6 + nano nitrogen at 0.4% + nano iron at 1000 mg/L) shows higher available phosphorus (69.34 kg/ha) followed T_8 (68.98 kg/ha) which received (T_6 + nano nitrogen at 0.4% + nano iron at 500 ppm). Lower content available P_2O_5 (35.25 kg/ha) recorded in T_1 (control). Higher availability of P_2O_5 with application of FYM along with 100% RDF might be due to solubilizing effect of organic acids which release P from insoluble fractions, reduction of P fixation in the soil because of chelation of P fixing cations like Fe and Al and also due to enhanced microbial activities (Gupta *et al*. 1988). Alimohammadi *et al*. (2020) reported that effect of urea and nano nitrogen chelate had no significant difference in available phosphorus status of soil.

4.3.2.3 Available potassium (kg/ha)

Available potassium status of soil was 286.5 kg ha^{-1} at initial stages of the experiment. There was significant increase in available potassium content of soil due to foliar application nano nitrogen and iron. It ranged from 204.15 to 272.87 kg ha^{-1}. Treatment T_9 which received (T_6 + nano nitrogen at 0.4% + nano iron at 1000 mg/L) shows higher available potassium (272.87 kg ha^{-1}) followed T_8 (263.45ha^{-1}) which received (T_6 + nano nitrogen at 0.4% + nano iron at 500 ppm). Lower content available potassium (204.15 kg ha^{-1}) recorded in T_1 (control). There was no significant difference in available K due to the application of urea and nano nitrogen chelate. (Alimohammadi *et al*. 2020).

4.3.3 Exchangeable calcium, magnesium and available sulphur status of soil after harvest mulberry

The data on exchangeable calcium, magnesium and available sulphur status of soil after harvest of mulberry are presented in Table 4.9.

4.3.3.1 Exchangeable calcium and magnesium (C mol (p+) kg^{-1})

There was no significant difference formed with exchangeable Ca and Mg status of the soil after the harvest of mulberry. However, among different treatments, lower exchangeable calcium and magnesium contents were found in T_1 (10.36 and 6.15 C mol kg^{-1}, respectively) and higher values were recorded in T_9 (11.53 and 7.10 C mol kg^{-1}, respectively) which received T_6 + nano nitrogen at 0.4% + nano iron at 1000 ppm.

The increased calcium in plots receiving 100% NPK along with FYM @10 t ha^{-1} might be relatively higher capacity of FYM in supplying the basic cations upon mineralization (Prasad *et al*. 1996). Application of manures over the years resulted in increased Mg content in soil, while, plots receiving higher addition of N pertained to decrease it, possibly might be due to increased plant growth leading to higher uptake of Mg ions. These results are in line with Muthuvel *et al*. (1985).

Table 4.9 Effect of foliar application of nano nitrogen and iron on secondary nutrient status in soil after harvest of mulberry

Treatments	Ca (C mol(p+) kg^{-1})	Mg (C mol (p+) kg^{-1})	S (mg kg^{-1})
T_1= Absolute control	10.36	6.15	9.14
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	10.83	6.61	11.00
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	10.85	6.73	11.36
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	10.88	6.80	12.01
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	11.15	6.91	12.37
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	10.48	6.22	10.54
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	11.06	6.89	12.23
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	11.34	6.95	12.69
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	11.53	7.10	13.18
SEM	**0.24**	**0.34**	**1.12**
CD at 5% level of significance	**NS**	**NS**	**NS**

Note: DAP: Days After Pruning, NS: non-significant

4.3.3.2 Available sulphur (mg kg^{-1})

Available sulphur status of soil did not differ significantly due to the foliar nano nitrogen and iron application. Available sulphur content ranged from 9.14 to 13.18 mg kg^{-1} with no significant variation. Numerically, higher available sulphur was recorded (13.18 mg kg^{-1}) in T_9 which received (T_6 + nano nitrogen at 0.4% + nano iron at 1000 ppm). Lower available sulphur recorded 9.14 mg kg^{-1} in T_1 (control).

Eghball *et al*. (2002) reported that upon decomposition of organic manures, released active organic acids led to oxidation of sulphur from the native and added sources to sulphate form (SO_4^{-2}) thus increasing S availability in soils. But, this study was only for one season which resulted in non-significant buildup. Chikkaramappa *et al*. (2014) cited that organic matter contains abundant quantity of calcium, magnesium and sulphur and reported that FYM being a good source of calcium, magnesium and sulphur increases the secondary nutrient content of plots added with FYM.

4.3.4 Available micronutrient nutrients (Fe, Mn, Zn, Cu and B) status of soil after harvest of mulberry.

The Data on available iron, manganese, zinc, copper and boron status of soil after harvest of mulberry are presented in Table 4.10 and Fig 4.8.

The available micronutrient content before initiation of experiment was 14.05, 10.01, 2.12, 0.60 and 0.77 mg kg^{-1} of Fe, Mn, Zn, Cu and B respectively. Foliar application of nano nitrogen and iron along with FYM resulted in non-significant build-up in available micronutrients viz., Fe, Mn, Zn, Cu and B after harvest of mulberry. Available micronutrients varied from 8.56 to 12.46 mg kg^{-1} of Fe, 1.01 to 1.33 mg kg^{-1} of Zn, 0.37 to 0.51 mg kg^{-1} of Cu, 7.73 to 8.65 mg kg^{-1} of Mn and 0.40 to 0.52 mg kg^{-1} of B.

Availability of micronutrient greatly depends on pH and organic manure applied which increased availability of micronutrient through mineralization. Ali *et al*. (2017) reported that nitrogen addition significantly decreased the available copper (Cu), zinc (Zn) and total Cu concentration, but significantly decreased the available iron (Fe) concentration in the soil. A similar trend was observed in the present study but the trend was statistically non-significant. Farshid Aref (2011) reported that increased availability of micronutrient status in the soil may be due to mineralization of FYM, which is the good source of micronutrients. Decreased availability of micronutrients in the soil might due to the antagonistic interaction between zinc and those micronutrient cations in soil.

Table 4.10 Effect of foliar application of nano nitrogen and iron on micro nutrient status in soil after harvest of mulberry

Treatments	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/ kg)	Mn (mg/ kg)	B (mg/kg)
T_1= Absolute control	8.56	1.01	0.37	7.73	0.40
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	9.08	1.06	0.43	8.02	0.47
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	9.44	1.09	0.43	8.13	0.47
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	9.60	1.11	0.44	8.28	0.48
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	11.40	1.26	0.49	8.41	0.50
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	8.96	1.03	0.40	7.89	0.44
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	11.18	1.24	0.45	8.37	0.48
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	12.06	1.27	0.49	8.43	0.50
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	12.46	1.33	0.51	8.65	0.52
SEM	**1.00**	**0.08**	**0.06**	**0.20**	**0.02**
CD at 5% level of significance	**NS**	**NS**	**NS**	**NS**	**NS**

Note: DAP: Days After Pruning, NS: non-significant

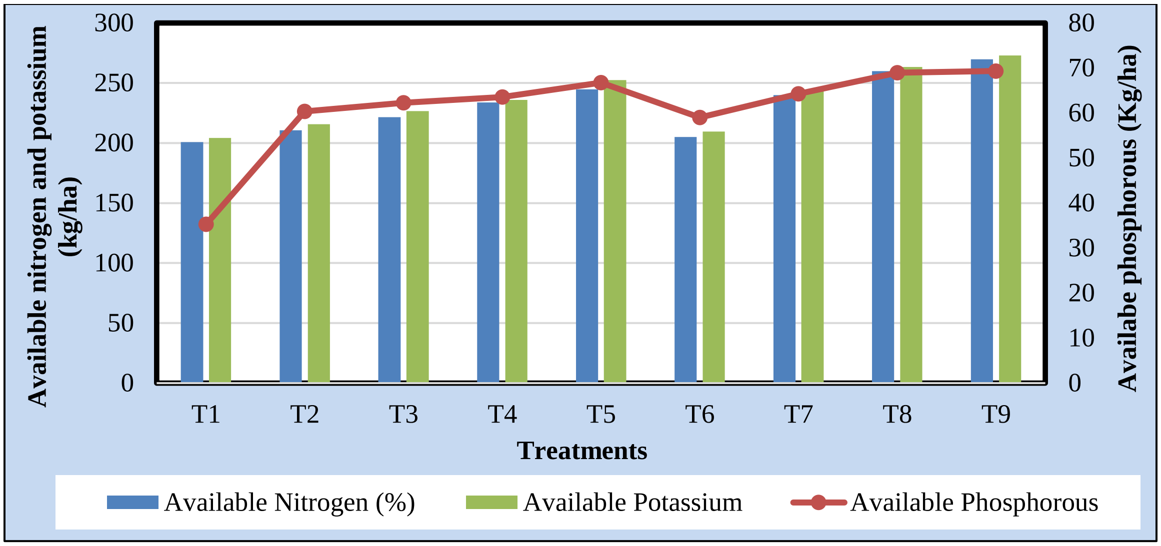

Fig. 4.7 Effect of foliar application of nano nitrogen and iron on primary nutrient status in soil after harvest of mulberry

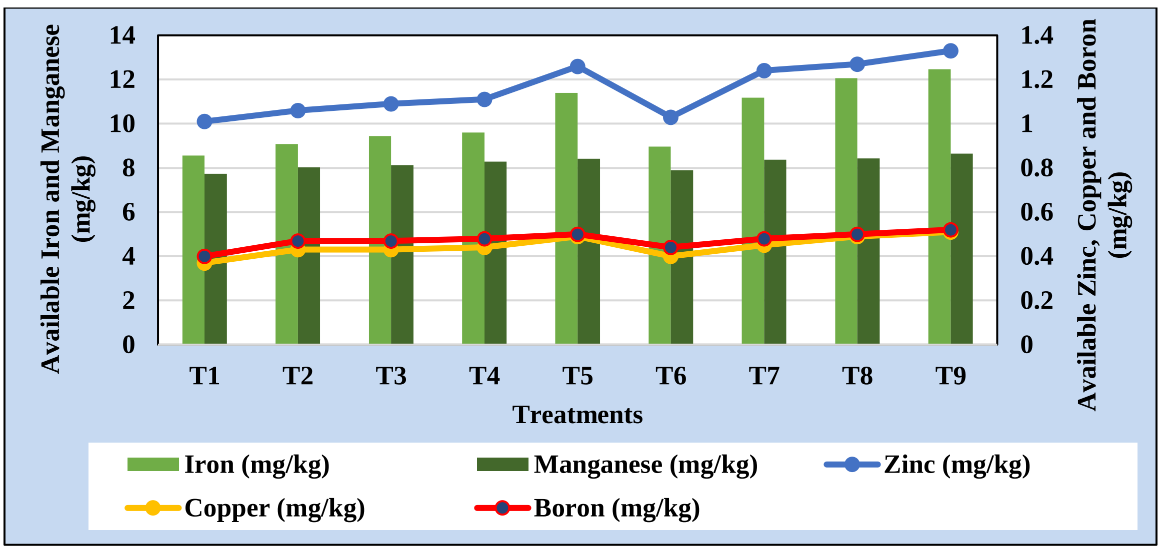

Fig. 4.8 Effect of foliar application of nano nitrogen and iron on micronutrient status in soil after harvest of mulberry

Treatment details:

T_1	:	Absolute control
T_2	:	RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha)
T_3	:	T_2 + soil application of $FeSO_4$ @ 5 kg/ha
T_4	:	T_2 + nano iron @ 500 mg/L as foliar spray
T_5	:	T_2 + nano iron @ 1000 mg/L as foliar spray
T_6	:	RDF (50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha)
T_7	:	T_6 + nano nitrogen @ 0.4% as foliar spray
T_8	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray
T_9	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray

4.4 Effect of foliar application of nano nitrogen and iron on nutrient content of mulberry leaves

4.4.1 Primary nutrients (N, P and K) (%)

Data presented in Table 4.11 and Fig 4.9 represents the effect foliar application of nano nitrogen and iron on nitrogen, phosphorus, potassium, calcium, magnesium and sulphur contents in mulberry leaves. There was no significant difference among the treatments with regard to phosphorous, potassium, except nitrogen.

Table 4.11 Effect of foliar application of nano nitrogen and iron on primary nutrient content in mulberry leaves

Treatments	Nitrogen (%)	Phosphorous (%)	Potassium (%)
T_1= Absolute control	2.90	0.22	1.05
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	3.33	0.23	1.15
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	3.49	0.24	1.19
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	3.78	0.25	1.23
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	3.93	0.27	1.29
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	3.29	0.22	1.10
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	3.84	0.25	1.25
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	3.96	0.29	1.33
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	4.10	0.31	1.36
SEM	**0.10**	**0.03**	**0.06**
CD at 5% level of significance	**0.32**	**NS**	**NS**

Note: DAP: Days After Pruning, NS: non-significant

Significantly higher nitrogen content of 4.10 per cent was recorded in leaves obtained from the treatment T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000 mg/L as foliar spray) which was on par with treatment T_8 (3.96 %). Significantly lower nitrogen content of 3.17 per cent was recorded in leaves harvested from treatment T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly higher nitrogen content in leaf (3.93 %) which received T_2 + nano iron @ 1000 mg/L as foliar spray fallowed by T_4 (3.78 %) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (3.49 %) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

Manikandan and Subramanian (2016) reported that highest N content was registered in roots of maize plants fertilized with nanozeourea (0.32 %) while urea fertilized plants had only 0.26 %. On the other hand, zeourea fertilized plants had the highest N content of 0.78 % which is significantly different from the rest of the treatments.

Phosphorus and potassium content in mulberry leaves did not differ significantly among the treatments. However, higher phosphorus and potassium content (0.31 and 1.36 %, respectively) recorded in T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000 mg/L as foliar spray) and lower P and K contents (0.22 and 1.05 %, respectively) were recorded in treatment T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly higher phosphorous and potassium content in leaf (0.27 and 1.29 %, respectively) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (0.25 and 1.23 %, respectively) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (0.24 and 1.19 %, respectively) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

4.4.2 Secondary nutrients (Ca, Mg and S) (%)

Data presented in Table 4.12 represents the effect foliar application of nano nitrogen and iron on calcium, magnesium and sulphur contents in mulberry leaves. There was no significant difference among the treatments with regard to calcium, magnesium and sulphur content.

Table 4.12 Effect of foliar application of nano nitrogen and iron on secondary nutrient content in mulberry leaves

Treatments	Calcium (%)	Magnesium (%)	Sulphur (%)
T_1= Absolute control	0.58	0.22	0.17
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	0.65	0.24	0.18
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	0.67	0.25	0.19
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	0.70	0.26	0.20
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	0.73	0.31	0.23
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	0.62	0.24	0.18
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	0.71	0.29	0.22
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	0.77	0.32	0.24
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	0.80	0.34	0.26
SEM	**0.04**	**0.02**	**0.02**
CD at 5% level of significance	**NS**	**NS**	**NS**

Note: DAP: Days After Pruning, NS: non-significant

There was no significant difference among different treatments with respect to Ca, Mg and S content in mulberry leaves. However, higher Ca (0.80 %), Mg (0.34 %) and S (0.26 %) contents in leaf were recorded in treatment T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000 mg/L as foliar spray) and lowest (0.58, 0.22 and 0.17 %) were recorded in T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly higher Ca, Mg and S content in leaf (0.73, 0.31 and 0.23 %, respectively) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (0.70, 0.26 and 0.20 %) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (0.67, 0.25 and 0.19 %, respectively) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

There was no significant difference among different treatments with respect to Ca, Mg and S content in mulberry leaves. It may be due to Mulberry requires higher secondary nutrients throughout its growth and development and FYM supplies balanced proportion of all these nutrients in addition to the chemical fertilizers, hence there was increased secondary nutrient contents in the leaves over control though not significant. The present study is in compliance with the findings of Pagaria *et al*. (1995) and Halemani *et al*. (2004).

4.4.2 Micronutrients (Fe, Zn, Mn, Cu and B) (mg/kg)

The data pertaining to the content of zinc, iron, copper, manganese and boron in mulberry leaves as influenced by foliar application of nano nitrogen and iron. Significantly higher content of Fe (199.47 mg/kg) was recorded in leaves obtained from T_9 (T_6 + nano Nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray) followed by T_8 (186.02 mg/kg) which received T_6 + nano nitrogen @0.4% + nano iron @ 500 mg/L as foliar spray and significantly lower Fe (100.18 mg/kg) content was recorded in leaves of treatment T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly higher iron content in leaf (179.84 mg/kg) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (155.88 mg/kg) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (126.91 mg/kg) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha presented in Table 4.13 and Fig 4.10.

Effect of foliar application of nano Nitrogen and Iron on mulberry leaves showed non-significant difference with respect to Zn, Cu, Mn and B content in mulberry leaves. However, higher Zn, Cu, Mn and B contents of leaf (26.74, 24.86, 69.86 and 55.89 mg/kg, respectively) were recorded in treatment T_9 (T_6 + nano Nitrogen @0.4% + nano iron @1000 mg/L as foliar spray) and lowest Zn, Cu, Mn and B contents of leaf (22.08, 18.08, 55.04 and 45.58 mg/kg, respectively) were recorded in T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly higher Zn, Cu, Mn and B content in leaf (25.90, 21.81, 65.48 and 52. mg/kg, respectively) which received T_2 + nano iron @ 1000 mg/L as foliar spray fallowed by T_4 (24.22, 19.51, 59.95 and 49.15 mg/kg, respectively) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (22.80, 18.81, 57.33 and 47.93 mg/kg, respectively) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

Table 4.13 Effect of foliar application of nano nitrogen and iron on micronutrient content in mulberry leaves

Treatments	Iron (mg/kg)	Zinc (mg/kg)	Manganese (mg/kg)	Copper (mg/kg)	Boron (mg/kg)
T_1= Absolute control	100.18	22.08	55.04	18.08	45.58
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	120.94	22.48	56.07	18.25	46.68
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	126.91	22.80	57.33	18.81	47.93
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	155.88	24.22	59.95	19.51	49.15
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	179.84	25.90	65.48	21.81	52.89
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	109.04	22.22	55.46	18.34	46.00
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	174.49	24.56	63.09	20.82	51.46
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	186.02	26.08	66.65	22.60	54.02
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	199.47	26.74	69.86	24.86	55.89
SEM	**1.04**	**1.17**	**3.69**	**1.49**	**2.35**
CD at 5% level of significance	**3.12**	**NS**	**NS**	**NS**	**NS**

Note: DAP: Days After Pruning, NS: non-significant

The results suggested that application of 2 g/L nano-iron oxide was more effective than other Fe sources and rates, because nano-iron oxide had more particles per unit of weight and specific surface area that increased contact of fertilizer with plant, leading to increase in Fe and other nutrients uptake (Liscano *et al*., 2000; Liu *et al*., 2005). In addition, nano-oxide iron particles below 100 nm perhaps made Fe more efficient and dissolved in water more effectively, thus, increased their activities (Joseph and Morrison, 2006).

4.5 Effect of foliar application of nano nitrogen and iron on uptake of major, secondary and micronutrients.

Uptake of major, secondary and micronutrients by mulberry leaves as influenced by nano nitrogen and iron on foliar application has been presented in the Table 4.14, 4.15 and 4.16.

4.5.1 Uptake of nitrogen, phosphorus and potassium (kg/ha)

There was significant influence of foliar application of nano nitrogen and iron on uptake of nitrogen, phosphorous and potassium. Significant increase in uptake of N (356.29 kg/ha), P (26.94 kg/ha) and K (118.18 kg/ha) were recorded in T_9 treatment (T_6 + nano nitrogen @ 0.4% + nano iron @1000 mg/L as foliar spray) and lower uptake of nitrogen (171.71 kg/ha), P (12.96 kg/ha) and K (61.85 kg/ha) were recorded in T_1 treatment (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly increases uptake of nitrogen, phosphorous and potassium (318.72, 21.90 and 104.62 kg/ha, respectively) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (278.59, 18.43 and 90.65 kg/ha, respectively) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (240.81, 17.26 and 82.11 kg/ha, respectively) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha are presented in Table 4.14 and Fig 4.11.

The results are in accordance with Wen *et al*. (2014), who studied the effects of combined application of conventional urea with controlled-release nano urea on nutrient uptake, by winter wheat. The results showed that combined applications of conventional urea with controlled-release nano urea increased nitrogen uptake by wheat. Ha et al. (2019)

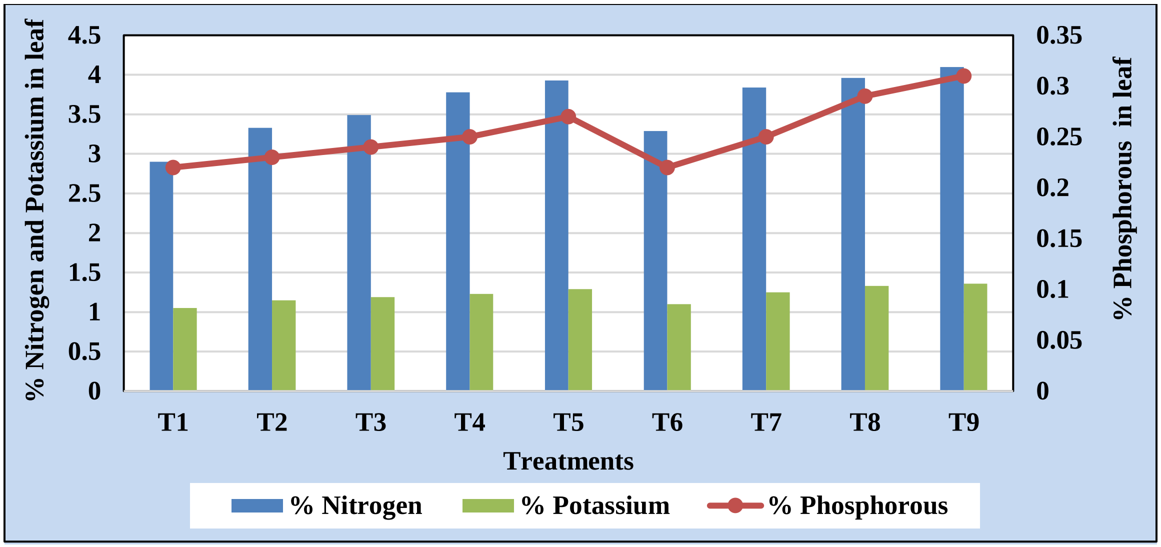

Fig. 4.9 Effect of foliar application of nano nitrogen and iron on primary nutrient content in mulberry leaves

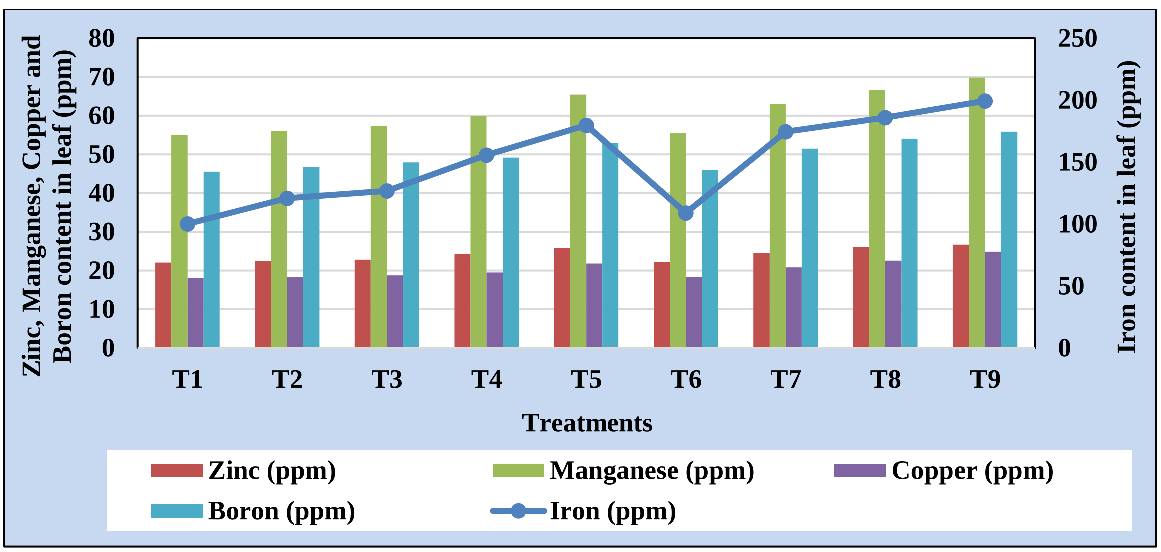

Fig. 4.10 Effect of foliar application of nano nitrogen and iron on micronutrient content in mulberry leaves

Treatment details:

T_1	:	Absolute control
T_2	:	RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha)
T_3	:	T_2 + soil application of $FeSO_4$ @ 5 kg/ha
T_4	:	T_2 + nano iron @ 500 mg/L as foliar spray
T_5	:	T_2 + nano iron @ 1000 mg/L as foliar spray
T_6	:	RDF (50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha)
T_7	:	T_6 + nano nitrogen @ 0.4% as foliar spray
T_8	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray
T_9	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray

reported that coffee crop which showed that the nano fertilizer enhanced uptake of other nutrients, application of nano fertilizer improved 17.04 per cent nitrogen, 16.31 per cent phosphorous and 67.50 per cent potassium content in the leaves of treated plots compared to the control. Azizah *et al*. (2017) reported that application of N fertilizer uptake was recorded for UF-MWCNTs treatment which recorded which was higher than that of control.

Table 4.14 Effect of foliar application of nano nitrogen and iron on primary nutrient uptake by mulberry

Treatments	Nitrogen (kg/ha)	Phosphorous (kg/ha)	Potassium (kg/ha)
T_1= Absolute control	171.71	12.96	61.85
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	221.78	15.18	75.90
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	240.81	17.26	82.11
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	278.59	18.43	90.65
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	318.72	21.90	104.62
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	205.30	13.73	68.64
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	297.22	19.35	96.75
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	334.22	24.48	112.25
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	356.29	26.94	118.18
SEM	**9.46**	**0.77**	**3.18**
CD at 5% level of significance	**28.37**	**2.31**	**9.54**

Note: DAP: Days After Pruning

FYM which is a reservoir of nutrients would have contributed to slow release of nutrients over longer period resulting in higher uptake of nutrients in applied plots (Thippeswamy, 1995). Treatments that received 7.5 t/ha of FYM had higher nutrient content and uptake compared to treatments with applied of FYM @ 5 t/ha. Therefore, it accords that integrated nutrient management directly or indirectly influence the concentration and uptake of nutrients. These results are in accordance with Subehia and Swapna (2012), Srinivasrao *et al*. (2012) and Meshram *et al*. (2019).

4.5.2 Uptake of secondary nutrients (kg/ha)

There was significant influence of foliar application of nano nitrogen and iron on uptake of secondary nutrients are presented in table 4.15. Significant increase in uptake of Ca (69.52 kg/ha), Mg (29.55 kg/ha) and S (22.59 kg/ha) was recorded in T_9 treatment (T_6 + nano nitrogen @0.4% + nano iron @1000 mg/L as foliar spray) and lower uptake of calcium (34.16 kg/ha), magnesium (12.96 kg/ha) and sulphur (10.01 kg/ha) was recorded in T_1 treatment (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly increases uptake of calcium, magnesium and sulphur (59.20, 25.14 and 18.65 kg/ha, respectively) which received T_2 + nano iron @ 1000 mg/L as foliar spray fallowed by T_4 (51.59, 19.16 and 14.74 kg/ha, respectively) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (46.23, 17.25 and 13.11 kg/ha, respectively) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha are presented in Table 4.15.

There was positive correlation observed with FYM application and secondary nutrients concentration. Organic manures are an excellent source of secondary nutrients like calcium, magnesium and sulphur which increases their respective uptake by the crop on decomposition, mineralization and solubilization. Synergistic effect of nitrogen on calcium and magnesium uptake was observed by Thirunavukkarsu and Balaji (2015) and were in close conformity which findings of Dadhwal and Katiyar (1989) who also reported enhanced uptake of calcium through organic and inorganic sources.

Table 4.15 Effect of foliar application of nano nitrogen and iron on secondary nutrient uptake by mulberry

Treatments	Calcium (kg/ha)	Magnesium (kg/ha)	Sulphur (kg/ha)
T_1= Absolute control	34.16	12.96	10.01
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	43.29	15.98	11.99
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	46.23	17.25	13.11
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	51.59	19.16	14.74
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	59.20	25.14	18.65
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	38.69	14.98	11.23
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	54.95	22.45	17.03
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	64.99	27.01	20.26
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	69.52	29.55	22.59
SEM	**1.82**	**0.73**	**0.55**
CD at 5% level of significance	**5.48**	**2.20**	**1.67**

Note: DAP: Days After Pruning

4.5.3 Uptake of Iron, Zinc, Manganese, Copper and Boron (g/ha)

There was a significant influence of foliar application of nano nitrogen and iron on uptake of iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and boron (B) are presented in Table 4.16 and Fig. 4.12. Significant increase in uptake of Fe (1733.39 g/ha), Mn (607.08 g/ha), Zn (232.37 g/ha), Cu (216.03 g/ha) and B (485.68 g/ha) was recorded in T_9 treatment (T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray) and lower uptake of Fe (590.06 g/ha), Mn (324.19 g/ha), Zn (130.05 g/ha), Cu (106.49 g/ha) and B (268.47

g/ha) were recorded in T_1 treatment (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly increases uptake of Fe, Zn, Mn, Cu and B (1458.50, 210.05, 531.04, 176.88 and 428.94 g/ha, respectively) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (1148.84, 178.50, 441.83, 143.79 and 362.24 g/ha, respectively) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (875.68, 157.32, 395.58, 129.79 and 330.72 g/ha, respectively) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

Table 4.16 Effect of foliar application of nano nitrogen and iron on micronutrient uptake by mulberry

Treatments	Fe (g/ha)	Zn (g/ha)	Mn (g/ha)	Cu (g/ha)	B (g/ha)
T_1= Absolute control	590.06	130.05	324.19	106.49	268.47
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	805.46	149.72	373.43	121.55	310.89
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	875.68	157.32	395.58	129.79	330.72
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	1148.84	178.50	441.83	143.79	362.24
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	1458.50	210.05	531.04	176.88	428.94
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	680.41	138.65	346.07	114.44	287.04
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	1350.55	190.09	488.32	161.15	398.30
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	1570.01	220.12	562.53	190.74	455.93
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	1733.39	232.37	607.08	216.03	485.68
SEM	**42.24**	**6.271**	**15.94**	**5.38**	**12.98**
CD at 5% level of significance	**126.66**	**18.80**	**47.81**	**16.14**	**38.93**

Note: DAP: Days After Pruning

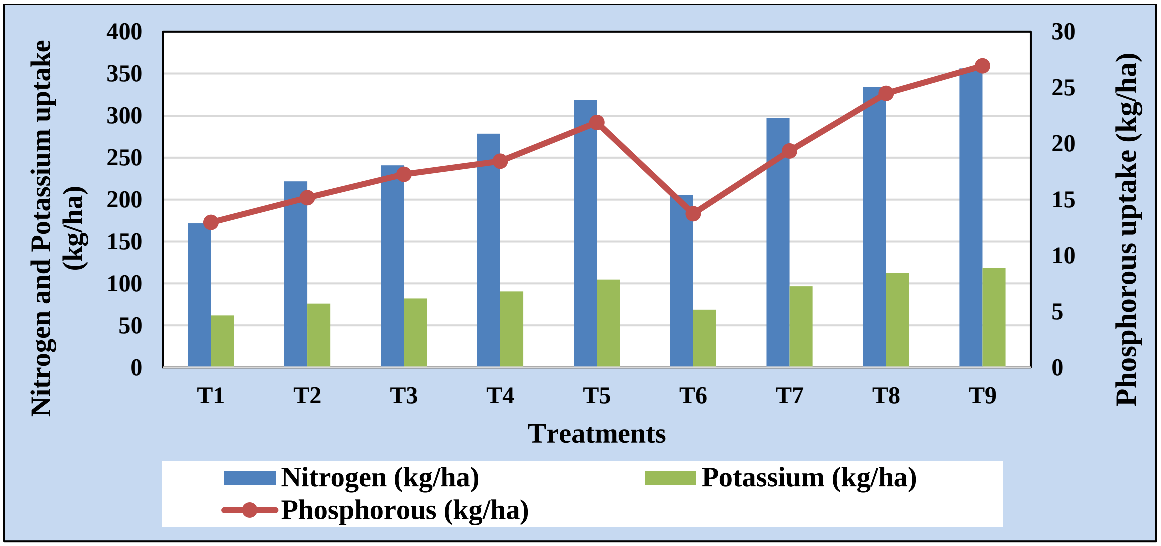

Fig. 4.11 Effect of foliar application of nano nitrogen and iron on primary nutrient uptake by mulberry

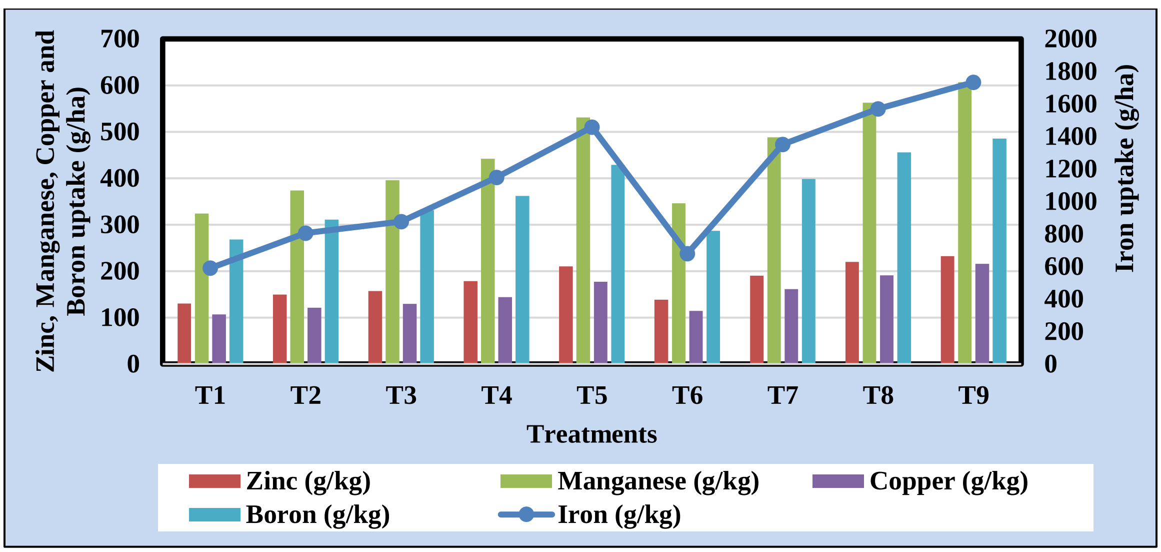

Fig. 4.12 Effect of foliar application of nano nitrogen and iron on micronutrient uptake by mulberry

Treatment details:

T_1	:	Absolute control
T_2	:	RDF (360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha)
T_3	:	T_2 + soil application of $FeSO_4$ @ 5 kg/ha
T_4	:	T_2 + nano iron @ 500 mg/L as foliar spray
T_5	:	T_2 + nano iron @ 1000 mg/L as foliar spray
T_6	:	RDF (50 % N + 100% P_2O_5+100% K_2O + 25 t FYM/ha)
T_7	:	T_6 + nano nitrogen @ 0.4% as foliar spray
T_8	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray
T_9	:	T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray

Treatments applied with higher FYM, resulted in increased uptake of micronutrients. Application of FYM increased micronutrient uptake due to higher organic matter which is a potential source of micronutrients and phsico-chemical properties of soil. On mineralization of FYM micronutrients are brought into soluble and available form, which might ultimately improve the nutrient status of the plants. These results are in conformity with the findings of Tarafdar and Rao (2001) and in most of studies indicated that N addition results in significant increases in the availabilities of micronutrients, such as the available concentrations of Cu, Mn and Fe in soils (Malhi *et al*. 1998, Tian *et al*. 2015 and Wang *et al*. 2017).

4.6 Effect of foliar application of nano nitrogen and iron on nutrient use efficiency of mulberry

The data regarding nutrient use efficiency in mulberry as foliar application of nano nitrogen and iron is presented in Table 4.17

4.6.1 Nutrient use efficiency of nitrogen, phosphorous and potassium

Considering leaf yield and the total amount of nitrogen, phosphorous and potassium applied, nutrient use efficiency of N, P_2O_5 and K_2O ranged from 111 kg kg^{-1}, 95 kg kg^{-1} and 95 kg kg^{-1} respectively in treatment T_1 (combined application of 100 % RDF and 25 t FYM/ha) to 289 kg kg^{-1}, 124 kg kg^{-1} and 124 kg kg^{-1} respectively in treatment T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray).

Nutrient use efficiency was higher with combined application of nano nitrogen @ 0.4 % and iron @ 1000 mg/L treatment compared to treatments without nano nitrogen and iron. Due to foliar application of nano nitrogen and iron, the NUE of nitrogen increased 22-65 % over treatment with only nitrogenous fertilizer. Higher NUE was recorded in treatments applied with 0.4 % nano nitrogen and 1000 mg/L nano iron. This is due to the increased leaf yield with a higher dose of nano nitrogen and iron.

The results are in line with Al-Juthery *et al*. (2019) who reported that nano nitrogen fertilizer (25 % N) in superior treatment with NUE (97.43%) compare to traditional with NPK (52.27 %). Similarly, Jhanzab *et al*. (2015) experiment to determine the role of silver nano particles for improving NUE in wheat, reported that the highest nitrogen use efficiency (74.3 %) was observed with 25 ppm of SNPs. This may be due to direct contact of nano particles by foliar application which improve the nutrient uptake by plants, Thus increase the nutrient use efficiency and control the losses.

Table 4.17 Effect of foliar application of nano nitrogen and iron on nutrient use efficiency of mulberry

Treatments	yield (kg/ha)	Nutrient applied (kg ha^{-1})			Nutrient use efficiency (kg kg^{-1})		
		N	P_2O_5	K_2O	N use efficiency	P_2O_5 use efficiency	K_2O use efficiency
T_1	5891	0	0	0	0	0	0
T_2	6656	60	70	70	111	95	95
T_3	6898	60	70	70	115	99	99
T_4	7373	60	70	70	123	105	105
T_5	8113	60	70	70	135	116	116
T_6	6241	30	70	70	208	89	89
T_7	7739	30.1	70	70	257	111	111
T_8	8441	30.1	70	70	280	121	121
T_9	8691	30.1	70	70	289	124	124

Treatment details:

T_1 = Absolute control

T_2 = RDF (360:140:140: N, P_2O_5, K_2O + 25 T FYM/ha)

T_3 = T_2 + soil application of $FeSO_4$ @ 5 kg/ha

T_4 = T_2 + nano iron @ 500 mg/L as foliar spray

T_5 = T_2 + nano iron @ 1000 mg/L as foliar spray

T_6 = RDF (50 % N+100% P_2O_5+100% K_2O+25 T FYM/ha)

T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray

T_8 = T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray

T_9 = T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray

4.7 Effect of foliar application of nano nitrogen and iron on quality parameters of mulberry leaves

Data on effect of foliar application of nano nitrogen and iron on quality parameter of mulberry leaf such as relative water content (%), protein (%), crude fibre (%) and chlorophyll contents are presented in Table 4.18 and 4.19 and Fig 4.13.

4.7.1 Relative water content (RWC) (%)

There was no significant difference among the treatments with respect to relative water content due to foliar application of nano Nitrogen and Iron on mulberry crop. However, higher (71.70 %) relative water content was recorded in treatment T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @1000 mg/L as foliar spray) followed by T_8 (70.59 %) and T_5 (69.47 %). Lower relative water content (63.88 %) was recorded in treatment T_1 (control).

Increase in the relative water content with increase in concentration of nano nitrogen and iron may be due to enhanced biochemical constituent of leaves hence thereby increase in relative water content per cent. The present results are in close conformity with the findings of Ramesh Reddy (2014).

4.7.2 Protein (%)

Protein content in mulberry leaves differed significantly due to foliar application of nano nitrogen and iron. Significantly higher protein content of leaves (37.55 %) was recorded in treatment T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray) followed by T_8 (36.81 %) and T_5 (35.60 %) which were on par with each other. Significantly lower content of protein (28.49 %) was recorded in the leaves of treatment T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly higher content of protein (35.60 %) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (32.72 %) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (31.81 %) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

Kisan *et al*. (2015) reported that the increase in protein content in spinach leaves may be due to the availability of sufficient quantity of nitrogen to the plants. Hazra *et al.* (1987) Iron acts as a cofactor for approximately more than hundred enzymes and being a component of ferrodoxin, an electron transport protein associated with chloroplast. Similar trends followed in Ghafari and Razmjoog (2015) stated that grain protein, carbohydrates and iron contents effective by the rate of application of iron including the source of iron.

Table 4.18 Effect of foliar application of nano nitrogen and iron on quality of mulberry leaf

Treatment	Relative water content (%)	Protein (%)	Crude fibre (%)
T_1= Absolute control	63.88	28.49	11.28
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	66.65	31.42	12.74
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	67.93	31.81	13.62
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	68.70	32.72	13.86
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	69.47	35.60	14.06
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	65.89	30.13	12.18
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	69.07	34.19	13.97
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	70.59	36.81	14.14
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	71.70	37.55	14.22
SEM	**2.00**	**1.48**	**0.45**
CD at 5% level of significance	**NS**	**4.45**	**1.36**

Note: DAP: Days After Pruning, NS: non-significant

4.7.3 Crude fiber (%)

Crude fiber content in mulberry leaves differed significantly due to foliar application of nano nitrogen and iron. Significantly higher crude fiber content (14.22 %) was recorded in leaves of treatment T_9 (T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray) followed by 14.14 per cent T_8 (T_6 + nano nitrogen @0.4% + nano iron @ 500 mg/L as foliar spray) and 14.06 per cent in treatment T_5 (nano iron at 1000 ppm as foliar spray) which were on par with each other. Significantly lower content of crude fiber (11.28 %) in leaf was recorded in treatment T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly higher content of crude fibre (14.06 %) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (13.86 %) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (13.62 %) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

4.7.4 Chlorophyll content of leaves

Chlorophyll content (SPAD meter readings) of mulberry leaves at 30, 45 DAP and at harvest as influenced by foliar application of nitrogen and iron are presented in Tables 4.19.

At 30 days after pruning

The chlorophyll content was non-significant due to foliar application of nano nitrogen and iron at 30 Days After Pruning (DAP). However, higher (41.07) chlorophyll content was recorded in treatment T_2 (RDF-360:140:140: N, P_2O_5, K_2O + 25 t FYM/ha) followed by T_3 (40.70) and T_4 (40.37). Lower chlorophyll content (33.07) was recorded in treatment T_1 (control).

At 45 days after pruning

Chlorophyll content in mulberry leaves differed significantly due to foliar application of nano nitrogen and iron. Significantly higher chlorophyll content (46.10) was recorded in leaves of treatment T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000mg/L as foliar spray) followed by T_8 (T_6 + nano nitrogen @0.4% + nano iron @ 500 mg/L as foliar spray) (44.50) and treatment T_5 (nano iron at 1000 ppm as foliar spray) (40.83) which were on par with each other. Significantly lower content of chlorophyll (34.83) in leaf was recorded in treatment T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers treatment T_5 recorded significantly higher chlorophyll content (40.83) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (39.33) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (37.06) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha

Table 4.19 Effect of foliar application of nano nitrogen and iron on chlorophyll (SPAD) content in 30, 45 and 65 DAP of mulberry leaf.

Treatment	30 DAP	45 DAP	60 DAP
T_1= Absolute control	33.07	34.83	35.50
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	40.37	36.00	37.06
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	41.70	37.06	38.36
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	40.07	39.33	41.43
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	39.63	40.83	42.36
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	34.90	33.8	35.66
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	35.03	39.73	40.83
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	36.27	44.50	45.40
T_9= T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	35.37	46.10	47.13
SEM	**2.22**	**1.24**	**1.23**
CD at 5% level of significance	**NS**	**3.74**	**3.70**

Note: DAP: Days After Pruning, NS: non-significant

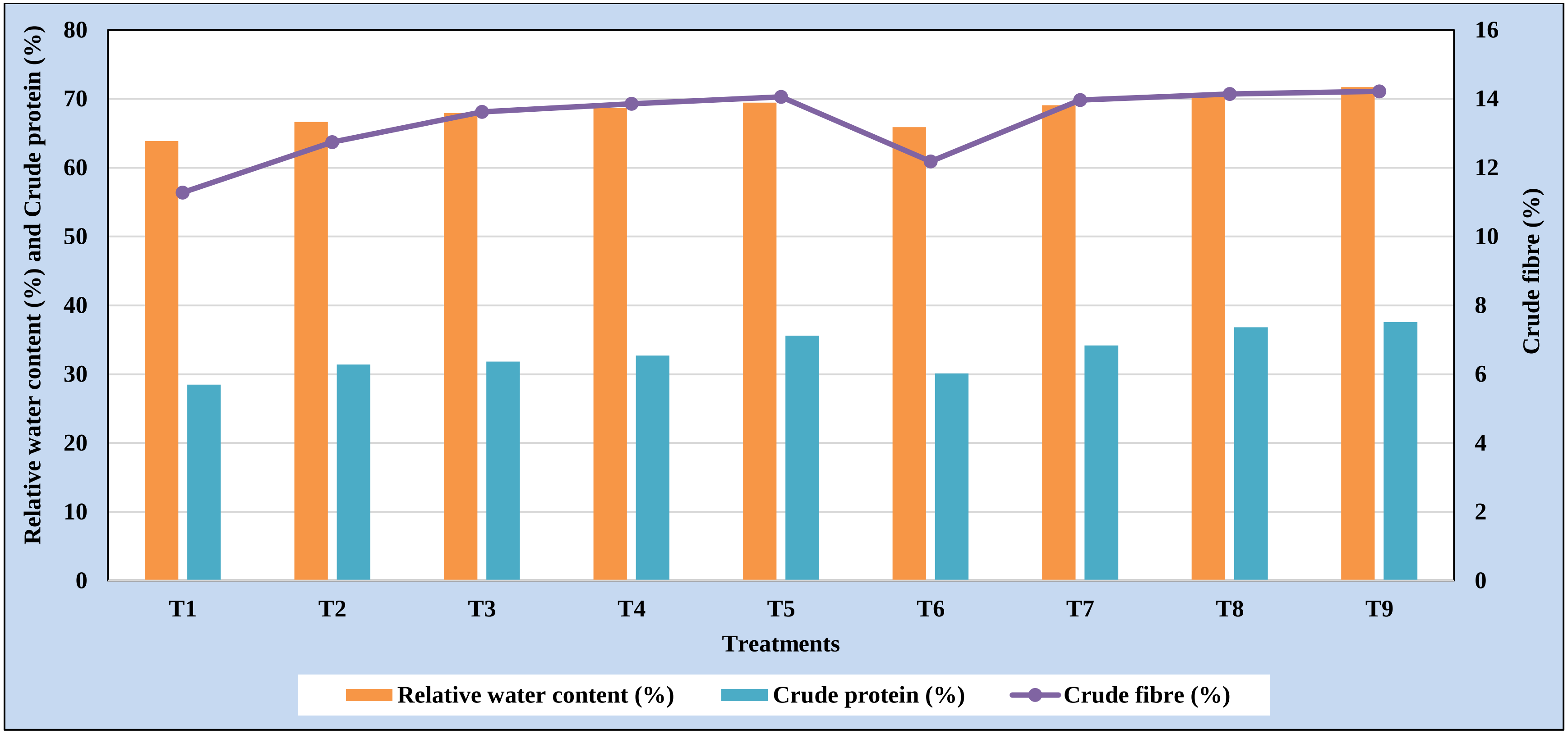

Fig. 4.13 Effect of foliar application of nano nitrogen and iron on quality of mulberry leaf

Treatment details:

T_1 = Absolute control

T_2 = RDF (360:140:140: N, P_2O_5, K_2O + 25 T FYM/ha)

T_3 = T_2 + soil application of $FeSO_4$ @ 5 kg/ha

T_4 = T_2 + nano iron @ 500 mg/L as foliar spray

T_5 = T_2 + nano iron @ 1000 mg/L as foliar spray

T_6 = RDF (50 % N+100% P_2O_5+100% K_2O+25 T FYM/ha)

T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray

T_8 = T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray

T_9 = T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray

At harvest (60 days after pruning)

Chlorophyll content in mulberry leaves differed significantly due to foliar application of nano nitrogen and iron. Significantly higher chlorophyll content (47.13) was recorded in leaves of treatment T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000mg/L as foliar spray) followed by T_8 (T_6 + nano nitrogen @0.4% + nano iron @500 mg/L as foliar spray) (45.40) and treatment T_5 (nano iron at 1000 ppm as foliar spray) (42.36) which were on par with each other. Significantly lower content of chlorophyll (35.50) in leaf was recorded in treatment T_1 (control). Comparison of foliar applied nano iron over conventional iron sulphate fertilizers, treatment T_5 recorded significantly higher chlorophyll content (42.36) which received T_2 + nano iron @ 1000 mg/L as foliar spray followed by T_4 (41.43) which received T_2 + nano iron @ 500 mg/L as foliar spray compared with treatment T_3 (38.36) which received T_2 + soil application of $FeSO_4$ @ 5 kg/ha.

Similar results Ghafari and Razmjoo (2015) reported that nano-iron oxide and iron sulfate application resulted in higher chlorophyll a and chlorophyll b contents as compared with iron chelate, while nano-iron oxide increased the total chlorophyll content the most, followed by iron sulfate and iron chelate, respectively. Iron application increased chlorophyll a, b and total contents as compared with the control and higher rates were more effective. Liu *et al*. (2005) reported that increase in chlorophyll content of wheat in our experiment could be due to promotion of the absorption and utilization of nutrients such as nitrogen by nano-Fe compound.

4.8 Effect of foliar application nano nitrogen and iron on economics of mulberry at harvest

The effect of foliar application of nano nitrogen and iron on cost of cultivation, gross return, net return and B: C ratio of mulberry are presented in Table 4.20

4.8.1 Cost of cultivation

Among different treatments cost of cultivation was found lower (Rs. 16,350) in treatment T_1 without application of any fertilizers and higher cost of cultivation

(Rs. 26,188) was observed in treatment T_9 which received (T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray).

4.8.2 Gross returns

Application of 50 % N through urea @ 0.4% + nano iron @ 1000 mg/L as foliar spray along with 25 t/ha of FYM (T_9) recorded higher gross return (Rs. 88,875) and lower (Rs. 43,585) was observed in treatment T_1 (Absolute control).

Table 4.20 Economics of mulberry as influenced by foliar application of nano nitrogen and iron

Treatments	Cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B:C Ratio
T_1	16,350	43,585	27,235	1.66
T_2	23,050	67500	44,450	1.92
T_3	23,300	70568	47,268	2.02
T_4	24,146	75375	51,229	2.12
T_5	25,238	82943	57,705	2.28
T_6	22,750	63818	41,068	1.80
T_7	24,000	79159	55,159	2.29
T_8	25,096	84318	59,222	2.35
T_9	26,188	88875	62,687	2.39

Treatment details:

T_1 = Absolute control

T_2 = RDF (360:140:140: N, P_2O_5, K_2O + 25 T FYM/ha)

T_3 = T_2 + soil application of $FeSO_4$ @ 5 kg/ha

T_4 = T_2 + nano iron @ 500 mg/L as foliar spray

T_5 = T_2 + nano iron @ 1000 mg/L as foliar spray

T_6 = RDF (50 % N+100% P_2O_5+100% K_2O+25 T FYM/ha)

T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray

T_8 = T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray

T_9 = T_6 + nano nitrogen @ 0.4% + nano iron @ 1000 mg/L as foliar spray

4.8.3 Net returns

Application of 50 % N through urea @ 0.4% + nano iron @ 1000 mg/L as foliar spray along with 25 t/ha of FYM (T_9) recorded higher net return (Rs. 62,687) and lower (Rs. 27,235) was observed in treatment T_1 (Absolute control).

4.8.4 B: C ratio

Among different treatments higher B: C ratio 2.39 was observed in treatment T_9 (T_6 + nano nitrogen @0.4% + nano iron @1000mg/L as foliar spray) followed by T_8 (2.35) and least (1.66) was observed in treatment T_1 (Absolute control).

Higher level of biomass accumulation and efficient translocation to the reproductive parts due to the supply of adequate nutrients might be responsible for increased yield, which resulted in higher monetary returns and B: C ratio (Roy *et al*. 2018). Foliar application of nano fertilizer resulted in maximum returns and benefit-cost ratio compared to conventional fertilizer application. The difference in the B: C ratio was attributed to yield differences and varying costs when different inputs were added. Combined application of nano fertilizer, reduced dose of conventional fertilizer along with FYM gave more profitable income.

V SUMMARY

An investigation entitled "Effect of foliar application of nano nitrogen and iron on growth, yield and quality of mulberry in Eastern Dry Zone of Karnataka" was conducted during *rabi* 2020 at farmer's field in Kurboor, Chintamani, Chikkaballpur. The experiment was laid out completely randomized blocks with nine treatments replicated thrice. The approaches involved in the study of foliar application of nano nitrogen and iron. The results obtained from the investigation and the conclusions drawn from the above study are summarized in the following paragraphs.

Foliar application of nano nitrogen and iron improved the growth and yield parameters studied over package of practice (RDF + FYM) and absolute control.

Growth parameters *viz*., plant height, number of shoots per plant, number of leaves per shoot, number of leaves per plant and leaf area per plant were significantly varied due foliar application of nano nitrogen and iron along with RDF + FYM at 45, 60 DAP and non-significant at 30 DAP. Growth parameters were recorded highest with foliar application of nano nitrogen (0.4 %) and iron (1000 mg/L) in treatment T_9. At harvest, the increase in plant height, number of shoots per plant, number of leaves per shoot, number of leaves per plant and leaf area by this treatment recorded was 124.18 cm, 24.80, 22.86, 441.26 and 21985.76 cm^2, respectively over package of practice (RDF + FYM) and absolute control.

Highest leaf yield were recorded with the foliar application of nano nitrogen (0.4 %) and iron (1000 mg/L) in treatment T_9 which was significantly higher than that of control. The increase in leaf yield per plant and leaf yield per hectare by this treatment were 0.52 kg and 8.69 tons/ha, respectively over control.

The soil analysis after the field experiment revealed that pH, electrical conductivity, organic carbon, available secondary nutrients (Ca, Mg and S), available micronutrients (Zn, Fe, Cu, Mn and B) in soil differed non-significantly among the different treatments.

The soil analysis after the field experiment revealed that available primary nutrients (N, P_2O_5 and K_2O) in soil differed significantly among the different treatments. Treatment T_9 which received (T_6 + nano nitrogen at 0.4% + nano iron at 1000 ppm) shows higher available nitrogen (269.81 kg/ha), available P_2O_5 (69.34 kg/ha) and K_2O (272.87 kg/ha). Lower status of available N (200.64 kg/ha), available P_2O_5 (35.25 kg/ha) and K_2O (204.15 kg/ha) recorded in T_1 (control).

Mulberry leaves showed significant differences in nitrogen content in all the treatments, highest nitrogen content of 4.10 % was recorded in T_9 treatment (T_6 + nano nitrogen @ 0.4 % + nano iron @1000 mg/L as foliar spray) and lower nitrogen content of 2.90 % was recorded in T_1 (absolute control). Among all the treatments mulberry leaves showed non-significant differences in phosphorous and potassium content. However, higher P and K content of (0.31 and 1.36 %, respectively) mulberry leaf was recorded in T_9 treatment and lower percent of P and K (0.22 and 1.05 %, respectively) was recorded in T_1 treatment (absolute control).

Among all the treatments mulberry leaves showed non-significant differences in calcium, magnesium and sulphur content. However higher Ca, Mg and S content of mulberry leaf (0.80, 0.34 and 0.26 %, respectively) was recorded in T_9 treatment and lower percent of (0.58, 0.22 and 0.17 %, respectively) was recorded in T_1 treatment (absolute control).

Significantly higher content of Fe (199.47 mg kg^{-1} in mulberry leaves) was recorded in the treatment of T_9 which received of T_6 + nano nitrogen @0.4 % + nano iron @1000 mg/L as foliar spray and lower content of Fe (100.18 mg/kg in mulberry leaves) was recorded in T1 treatment (absolute control). Among all the treatments mulberry leaves showed non-significant differences in Zinc, manganese, copper and boron content. However higher Zn, Mn, Cu and B content of mulberry leaf (26.74, 69.86, 24.86 55.89 mg/kg, respectively) was recorded in T_9 treatment and lower per cent of (22.08, 55.04, 18.08 and 45.58 mg/kg, respectively) was recorded in T_1 treatment (absolute control).

There was a significant influence of foliar application of nano nitrogen and iron on uptake of N, P, K, Ca, Mg, S, Fe, Zn, Cu, and B by mulberry. Significant increase in uptake of N (356.29 kg ha^{-1}), P (26.94 kg ha^{-1}) and K (118.18 kg ha^{-1}) was recorded in T_9 treatment (T_6 + nano nitrogen @ 0.4 % + nano iron @ 1000 mg/L as foliar spray) and lower uptake of nitrogen (171.71 kg ha^{-1}), P (12.96 kg ha^{-1}) and K (61.85 kg ha^{-1}) was recorded in T_1 treatment (absolute control). Significantly higher Fe uptake of 1733.39 g ha^{-1} was recorded in T_9 and lower uptake of Fe (590.06 g ha^{-1}) was recorded in T_1 treatment.

As far as leaf yield of mulberry is concerned, higher nitrogen (289 kg kg^{-1}), phosphorous (124 kg kg^{-1}) and potassium (124 kg kg^{-1}) use efficiency was observed with the application of FYM @ 25 t ha^{-1} + 50 % urea along with nano nitrogen @ 0.4 % and nano iron @ 1000 mg/L as foliar application. Lower was with the package of practice of mulberry (T_2: 100 % RDF +25 t/ha of FYM) without nano fertilizer application. Due to the foliar application of nano nitrogen and iron, the NUE of nitrogen increased 22-65 % over treatment with only nitrogenous fertilizer.

Significantly higher content of protein (37.55 %) and crude fiber (14.22 %) were recorded in T_9 treatment (T_6 + nano nitrogen @ 0.4 % + nano iron @ 1000 mg/L as foliar spray) whereas relative water content in leaf showed non-significant differences among the different treatments.

Significantly higher leaf chlorophyll SPAD value (46.10 and 47.13) at 45 and 60 DAP respectively, were recorded in T_9 treatment (T_6 + nano Nitrogen @0.4 % + nano iron @1000 mg/L as foliar spray), no significant difference in leaf chlorophyll SPAD value (35.37) at 30 DAP when compared treatment T_1 (absolute control).

Higher gross return (Rs. 88,875) and net return (Rs. 78,546) with B: C ratio of 2.39 was recorded with application of 50 % N through urea + 0.4 % nano nitrogen + 1000 mg/L nano iron along with 25 t/ha of FYM (T_9), while lower B: C ratio (1.66) was recorded in the treatment T_1 (absolute control).

PRACTICAL UTILITY OF WORK

- Farmers in the study area can realize higher leaf yield, relative water content, protein content of mulberry adopting foliar spray approach comprising 100 % RDF in combination with 25 t FYM + 0.4 % nano nitrogen and Iron 1000 mg/L.
- Foliar application of 0.4 % of nano nitrogen and nano iron 1000 mg/L + 50 % urea along with 25 t/ha of FYM recorded additional returns of rupees 18,237 per ha^{-1} over recommended use of fertilizers.
- Foliar application of nano nitrogen and iron improved the NUE of nitrogen by 22-65 per cent over recommended use of fertilizers.
- Application of 0.4 % of nano nitrogen and 1000 mg/L of nano iron + 50 % urea along with 25 t FYM saved application of inorganic fertilizer (urea) by 50 per cent.

FUTURE LINE OF WORK

1. Attempt should be on application of nano fertilizers to silkworm through mulberry leaves for cocoon production.
2. Synthesis and application of nano fertilizers for phosphorous and potassium as like nitrogen to improve the nutrient use efficiency of major nutrients.
3. Studies must be focused on the safety, bioavailability and toxicity of different nano fertilizers used for agricultural plants.
4. Bio-synthesized or green synthesized nano-bio fertilizers should be explored to increase mulberry yield.

VI REFERENCES

AGHAJANI, A. AND SOLEYMANI, A., 2017, Effects of nano-fertilization on growth and yield of bean (*Phaseolus vulgaris* L.) under water deficit conditions. *Curr. Nanosci.*, **13**(2): 194-201.

ALAM, M. J., SULTANA, F. AND IQBAL, M. T., 2015, Potential of iron nanoparticles to increase germination and growth of wheat seedling. *J. Nanosci. Adv. Tech.*, **1**(3): 14-20.

ALI, Z., WANG, G., LIANG, C., LIU, H., ZHANG, J., XUE, S. AND LIU, G., 2017, Effects of nitrogen addition on the uptake and allocation of macro and micronutrients in *Bothriochloa ischaemum* on loess plateau in china. *Front. Plant Sci.*, **8**: 1476.

ALIMOHAMMADI, M., PANAHPOUR, E. AND NASERI, A., 2020, Assessing the effects of urea and nano-nitrogen chelate fertilizers on sugarcane yield and dynamic of nitrate in soil. *Soil sci. Plant Nutr.*, **66**(2): 352-359.

AL-JUTHERY, H. W., HABEEB, K. H., ALTAEE, F. J. K., AL-TAEY, D. K. AND AL-TAWAHA, A. R. M., 2019, Effect of foliar application of different sources of nano-fertilizers on growth and yield of wheat. *Biosci. Res.*, **15**(4): 3988-3997.

ANONYMOUS, 1970, *Methods of Analysis*. Association of Official Agricultural Chemist. 9th ed., Washington, pp. 781-802.

AZIZ, A. H., HASANEEN, M. N. AND OMAR, A., 2018, Effect of foliar application of nano chitosan NPK fertilizer on the chemical composition of wheat grains. *Egypt. J. Bot.*, **58**(1): 87-95.

AZIZAH, S., NORAZLINA, M. Y., MOHD, F. D., FARDAH, Y. AND JEEFFERIE, A. R., 2017, Multiwalled carbon nanotubes enhancing nitrogen uptake and use efficiency of urea fertilizer by paddy. *J. Teknologi*, **79**: 105-109.

BARDSLEY, C. E. AND LANCASTER, J. D., 1965, Sulphur in methods of soil analysis. Pp. 1102-16. C. A. Black (Ed,) Part 2. Chemical and Microbiological Properties.

BARUAH, T, C. AND BARTHAKUR, H. P., 1997, A text book of soil analysis, pp: 142-190.

BASUMANTARY, A. AND TALUKDAR, M. C., 1998, Long term effect of integrated nutrient supply on soil properties in an *Inceptisol* of Assam. *Oryza,* **35**: 43-46.

BEHBOUDI, F. F., SARVESTANI, Z. T., KASSAEE, M. Z., SANAVI, S. A. M., SOROOSHZADEH, A. AND AHMADI, S. B., 2018, Evaluation of chitosan nanoparticles effects on yield and yield components of barley (*Hordeum vulgare* L.) under late season drought stress. *J. Water Environ. Nanotechnol.,* **3**(1)**:** 22-39.

BENZON, H. R. L., RUBENECIA, M. R. U., ULTRAJR, V. U. AND LEE, S. C., 2015, Nano-fertilizer affects the growth, development, and chemical properties of rice. *Int. J. Adv. Acad. Res.,* **7**(1): 105-117.

BHARADWAJ, V AND OMANWAR, P. K., 1994, Long term effects of continuous rotational cropping and fertilization on crop yields and soil properties-II, effects on EC, pH, organic matter and available nutrients in soil. *J. Ind. Soc. Soil Sci*., **42**(3): 387-392.

BLACK, C. A., 1965, *Methods of soil analysis part -1. Physical and mineralogical properties.* Agronomy Monograph number 9. American Society of Agronomy, Inc, Madison, Wisconsin, USA, pp. 234-283.

BOONLERTNIRUN, S., BOONRAUNG, C. AND SUVANASARA, R., 2008, Application of chitosan in rice production. *J. Magn. Magn. Mater.*, **18**(2): 47-52.

BOOTE, K. J., GALLAHER, R. N., ROBERTSON, W. K., HINSON, K. AND HAMMOND, L. C., 1977, Effect of foliar fertilization on photosynthesis, leaf nutrition and yield of soybeans. *Agron. J*., **70**(5):787-791.

BOSE, P. C. AND BINDROO, B. B., 2009, Effect of micronutrients on yield of mulberry in sub-tropical region. *J. Crop Weed*, **5**(2): 142-143.

BOZORGI, H. R., 2012, Study effects of nitrogen fertilizer management under nano iron chelate foliar spraying on yield and yield components of eggplant (*Solanum melongena* L.). *J. Agric. Biol. Sci.*, **7**(4): 233-237.

BRADY, N. C. AND WEIL, R. R., 1999, *The nature and properties of soils.* Prentice Hall, Upper Saddle River, New Jersey, pp. 446-490.

BRANTON, D., DEAMER, D. W., MARZIALI, A., BAYLEY, H., BENNER, S. A., BUTLER, T., DI VENTRA, M., GARAJ, S., HIBBS, A., HUANG, X. AND JOVANOVICH, S. B., 2010, The potential and challenges of nano pore sequencing. *Nanoscience and technology: A collection of reviews from Nature Journals*, pp: 261-268.

BRAYS, R. H. AND KURTZ, L. T., 1945, Determination of total organic and available forms of phosphorous in soils. *Soil Sci*., **59**: 39-45.

CANALI, S., DIACONO, M., CIACCIA, C., MASETTI, O., TITTARELLI, F. AND MONTEMURRO, F., 2014, Alternative strategies for nitrogen fertilization of overwinter processing spinach (*Spinacia oleracea* L.) in Southern Italy. *Eur. J. Agron.*, **54**: 47-53.

CHEN, H., HU. Z., LI, X., ZHANG, F., CHEN, J. AND ZHANG, M., 2016, Iron fertilizers applied to calcareous soil on the growth of peanut in a pot experiment. *Arch. Agron. Soil Sci.*, **62**(12): 1753-1764.

CHIKKARAMAPPA, T., SHIVANNA, B., PRASANTH, G. M. AND PRAKASH, S. S., 2014, Effect of integrated nutrient management practices on physic-chemical properties of soil under different growth stages of finger millet. *JANM*, **1**(4): 280-284.

CHINNAMUTHU, C. R. AND BOOPATHI, P. M., 2009, Nanotechnology and agroecosystem. *Madras Agric. J*., **96**(1/6): 17-31.

CHOUDHURY, S. R., GHOSH, M., MANDAL, A., CHAKRAVORTY, D., PAL, M., PRADHAN, S. AND GOSWAMI, A., 2011, Surface-modified sulfur nanoparticles: an effective antifungal agent against *Aspergillus niger* and *Fusarium oxysporum. Appl. Microbiol. Biotechnol.*, **90**(2): 733-743.

DADHWAL, K. S. AND KATIYAR, V. S., 1989, Effect of FYM on growth yield and chemical composition of bhahar in mine soil. *J. Indian Soc. Soil Sci*., **37**: 412-415.

DANDIN, S. B., 2005, *Proceedings of 20th Conference of International Sericulture Commission*. CSB, Bangalore, pp. 62-65.

DATTA, S. C., 2011, Applications of Clay Science: Agriculture, Environment and Industry, Paper presented in: Nanoclay research in agriculture environment and industry. *NBSS & LUP, Nagpur*, pp: 71-73.

DIMKPA, C. O., HANSEN, T., STEWART, J., MCLEAN, J.,BBRITT, D. W. AND ANDERSON, A. J., 2015, ZnO nanoparticles and root colonization by a beneficial pseudomonad influence essential metal responses in bean (*Phaseolus vulgaris*), *Nanotoxicology*. **9**(3): 271-278.

DOBERMANN, A., 2007, Nutrient use efficiency measurement and management. *Fertilizer Best Manage. Practices,* **1**.

DROSTKAR, E., TALEBI, R. AND KANOUNI, H., 2016, Foliar application of Fe, Zn and NPK nano-fertilizers on seed yield and morphological traits in chickpea under rainfed condition. *Ecol. Res.,* **4**(2): 221-228.

DU, W., SUN, Y., JI, R., ZHU, J., WUB, J. AND GUO, H., 2011, TiO_2 and ZnO nanoparticles negatively affect wheat growth and soil enzyme activities in agricultural soil. *J. Environ. Monit*., **13**: 822–828.

DUHAN, J. S., KUMAR, R., KUMAR, N., KAUR, P., NEHRA, K. AND DUHAN, S., 2017, Nanotechnology: The new perspective in precision agriculture. *Biotechnol. Rep.*, **15**: 11-23.

DZUNG, N. A., KHANH, V. T. P. AND DZUNG, T. T., 2011, Research on impact of chitosan oligomers on biophysical characteristics, growth, development and drought resistance of coffee. *Carbohydr. Polym.*, **84**(2): 751-755.

EGHBALL, B. J, WIENHOLD, J. E. AND GILLEY EIGENBERG R. A., 2002, Mineralization of manures nutrients. *J. Soil Water Conserv*., **57**(6): 470-473.

EICHERT, T., KURTZ, A., STEINER, U. AND GOLDBACH, H. E., 2008, Size exclusion limits and lateral heterogeneity of the stomatal foliar uptake pathway for aqueous solutes and water suspended nanoparticles. *Physiologia Plantarum*, **134**: 151–160.

EKINCI, M., DURSUN, A., YILDIRIM, E. AND PARLAKOVA, F., 2014, Effects of nanotechnology liquid fertilizers on the plant growth and yield of cucumber (*Cucumis sativus* L.). *Acta Sci. Pol. Hortorum Cultus.*, **13**(3): 135-141.

ELAYARAJA, D. AND ANGAYARKANNI, A., 2005, Effect of foliar spray on the NPK uptake and yield of rice fallow blackgram (cv. ADT 3). *Mysore J. Agric. Sci.*, **39**(4): 480-483.

EL-SAYED, S. M., EL-SAYED, H. S., IBRAHIM, O. A. AND YOUSSEF, A. M., 2020, Rational design of chitosan/guar gum/zinc oxide bio nano composites based on *Roselle* calyx extract for *Ras cheese* coating. *Carbohydr. Polym.*, **239**: 135-139.

FARSHID AREF., 2011, Concentration of zinc and boron in corn leaf as affected by zinc sulfate and boric acid fertilizers in a deficient soil. *Life Sci. J.*, **8**(1): 26-32.

GAO, F., HONG, F., LIU, C., ZHENG, L., SU, M., WU, X., YANG, F., WU, C. AND YANG, P., 2008, Mechanism of nano anatase TiO_2 on promoting photosynthetic carbon reaction of spinach. *Biol. Trace Elem. Res.*, **111**: 239-253.

GEETHA, T. AND MURUGAN, N., 2017, Plant growth regulators in mulberry. *Annu. Res. Rev. Biol.*, **13**(3): 1-11.

GHAFARI, H. AND RAZMJOO, J., 2013, Effect of foliar application of nano-iron oxidase, iron chelate and iron sulphate rates on yield and quality of Wheat. *Int. J. Agro. Plant Prod*., **4** (11): 2997-3003,

GHAFARI, H. AND RAZMJOO, J., 2015, Response of durum wheat to foliar application of varied sources and rates of iron fertilizers. *J. Agr. Sci. Tech.,* **17**: 321-331.

GHAFARIYAN, M. H., MALAKOUTI, M. J., DADPOUR, M. R., STROEVE, P. AND MAHMOUDI, M., 2013, Effects of magnetite nanoparticles on soybean chlorophyll. *Environ. Sci. Technol.,* **47**(18): 10645-10652.

GOMEZ, K. A. AND GOMEZ, A. A., 1984, *Statistical procedures for Agric. Res. II Ed.* John Wiley & Sons, New York.

GOSWAMI, A., ROY, I., SENGUPTA, S. AND DEBNATH, N., 2010, Novel applications of solid and liquid formulations of nanoparticles against insect pests and pathogens. *Thin solid films.*, **519**(3): 1252-1257.

GUERTAL, E.A., 2009, Slow-release nitrogen fertilizers in vegetable production: a review. *Horttechnology*.**,** **19**(1): 16-19.

GUPTA, A. P., ANTIL, R. S. AND NARWAL, R. P., 1988, Preparation of NPK nano fertilizer based on chitosan nano particles and its effect on biophysical characteristics and growth of coffee in green house. *Res. Chem. Intermed*., **45**(1): 51-63.

GUPTA, U.C., 1979, Some factors affecting the determination of hot-water-soluble boron from podzol soils using azomethine-H. *Canadian J. Soil Sci.,* **59**: 241- 247.

HA, N. M. C., NGUYEN, T. H., WANG, S. L. AND NGUYEN, A. D., 2019, Preparation of NPK nanofertilizer based on chitosan nanoparticles and its effect on biophysical characteristics and growth of coffee in green house. *Res. Chem. Intermed.*, **45**(1): 51-63.

HALEMANI, H. L., HALLIKERI, S. S., NANDAGAVI, R. A. AND HARISHKUMAR, H. S., 2004, Effect of organics on cotton productivity and physico-chemical properties of soil. *Stratergies for Sustainable Cotton Production a Global Vision***,** pp.123-129.

HARSINIA, M. G., HABIBIB, H. AND TALAEI, G. H., 2014, Effect of nano iron foliar application on quantitative characteristics of new line of wheat. *Sci. J. Crop Sci*., **3**(4): 37-41.

HASANEEN, M. N. A. G., ABDEL-AZIZ, H. M. M. AND OMER, A. M., 2016, Effect of foliar application of engineered nanomaterials: carbon nanotubes NPK and chitosan nanoparticles NPK fertilizer on the growth of French bean plant. *Appl. Biochem. Biotechnol.*, **4**(4): 68-76.

HAWE, L. AND WAGENER, M. R., 1996, The effect of paper mill waste water irrigation and gypsum soil amendments on sodium accumulation by cottonwood and soil. *Agric*. *Water Mang*., **31**: 295-306.

HAZRA, P. MAITY, TK. AND MANDAL, AR., 1987, Effect of foliar application of micronutrients on growth and yield of okra (*Abelmoschus esculentus* L.). *Progressive Horticulture*, **19**: 219-222.

HERRERA, C. M. AND BAZAGA, P., 2016, Genetic and epigenetic divergence between disturbed and undisturbed subpopulations of a Mediterranean shrub: A 20-year field experiment. *Ecol. Evol.*, **6**(11): 3832-3847.

HOKMALIPOUR, S. AND MARYAM, D. H., 2011, Effects of nitrogen fertilizer on chlorophyll content and other leaf indicate in three cultivars of maize (*Zea mays* L.). *World Appl. Sci. J.*, **15**(12): 1780-1785.

HU, X. K., SU, F., JU, X. T., GAO, B., OENEMA, O., CHRISTIE, P., HUANG, B. X., JIANG, R. F. AND ZHANG, F. S., 2013, Greenhouse gas emissions from a wheat–maize double cropping system with different nitrogen fertilization regimes. *Environ. Pollut.,* **176**: 198-207.

JACKSON, M. N., 1973, *Soil Chemical Analysis*. Prentice Hall of India, New Delhi, pp. 259-260.

JHANZAB, H. M., RAZZAQ, A., JILANI, G., REHMAN, A., HAFEEZ, A. AND YASMEEN, F., 2015, Silver nano-particles enhance the growth, yield and nutrient use efficiency of wheat. *Int. J. Agron. Agric. Res*., **7**(1): 15-22.

JONES, J. B., AND CASE, V. W., 1990, Sampling, handling, and analyzing plant tissue samples. In: R.L. Westerman (ed), Soil testing and plant analysis. 3rd Ed. *Soil Sci. Soc. Am*., Inc. Madison, WI. pp. 389–447.

JOSEPH, T. AND MORRISSON, M., 2006, Nanotechnology in agriculture and Food. *nanoforum.org*.

JUNXI, L. I., CHIDO, WEE. AND BOKYOON, SOHN. 2013, Effect of ammonium and potassium loaded zeolite on Kale (*Brassica alboglabra*) growth and soil property. *Am. J. Plant Sci.,* **4**: 1976-1982.

JYOTHI, C. N., RAVICHANDRA, K. AND BABU, S. K., 2013, Effect of foliar supplementation of nitrogen and zinc on soybean (*Glycine max.* L.) yield, quality and nutrient uptake. *Indian J. Dryland Agric. Res. Dev*., **28**(2): 46-48.

JYOTHI, T. V. AND HEBSUR, N. S., 2017, Effect of nanofertilizers on growth and yield of selected cereals-A review. *Agric. Rev.,* **38**(2): 112-120.

KANJANA, D., 2019, Foliar study on effect of iron oxide nanoparticles as an alternate source of iron fertilizer to cotton. *Int. J. Chem. Stud.,* **7**(3): 4374-4379.

KARUNAKARAN, G., JAGATHAMBAL, M., VAN MINH, N., KOLESNIKOV, E., GUSEV, A., ZAKHAROVA, O, V., SCRIPNIKOVA, E, V., VISHNYAKOVA, E, D. AND KUZNETSOV, D., 2017. Green synthesized iron oxide nanoparticles: A nano-nutrient for the growth and enhancement of Flax (*Linum usitatissimum* L.) plant. *Int. j. biotechnol. Bioeng.,* **11**: 41-48.

KASIVELU, G., SELVARAJ, T., MALAICHAMY, K., KATHICKEYAN, D., SHKOLNIK, D. AND CHATURVEDI, S., 2020, Nano-micronutrients [γ-Fe2O3 (iron) and ZnO (zinc)]: green preparation, characterization, agro-morphological characteristics and crop productivity studies in two crops (rice and maize). *New J. Chem.,* **4**(2): 151-158.

KAVIANI, B. AND NEGAHDAR, N. A. S. E. R., 2016, Effects of biological nano-fertilizer on the morphological, physiological and proliferation traits and quality of *Buxus hyrcana*. *Bangladesh J. Bot.,* **45**(5): 1135-1142.

KHALEDIAN, M., KHOSRO, M., MOHSEN, J., 2014, Grain yield and yield components of soybean affected by integrated fertilization methods. *Int. J. Agric. For,* **4**(3): 1-3.

KHOSPEYAK, S. HAGHI, R. S. AND AHMADIYAN. A. 2016, Effect of application of nano organic fertilizer and nitrogen fertilizer on yield, yield components and essential oil content of fennel. *Ira. J. of field crop res.,* **14**(4): 775-787.

KIM, S. SIN, H., LEE, S. AND LEE, I., 2013, Influence of metal oxide particles on soil enzyme activity and bioaccumulation of two plants. *J. Microbiol. Biotechnol.,* **23**(9): 1279–1286.

KIM, S., KIM, J. AND LEE, I., 2011, Effect of Zn and ZnO nanoparticle and Zn^{2+} on soil enzyme activity and bioaccumulation of Zn in *Curcumis sativus. Chem. Ecol.,* **27**: 49-55.

KISAN, B., SHRUTHI, SHARANA GOWDA, H., REVANAPPA, S. B. AND PRAMOD, N. K., 2015, Effect of nano zinc oxide on leaf physical and nutritional quality of spinach. *Agrotechnol.*, **5**(1): 2-3.

KOTTEGODA, N., MUNAWEERA, I., MADUSANKA, N. AND KARUNARATNE, V., 2011, A green slow-release fertilizer composition based on urea-modified hydroxyapatite nanoparticles encapsulated wood. *Curr. Sci.,* pp. 73-78.

KUMAR, C. V., VAIYAPURI, K., AMANULLAH, M. M. AND GOPALASWAMY, G., 2013, Influence of foliar spray of nutrients on yield and economics of soybean (*Glycine max* L. Merill). *J. Bio. Sci.,* **13**(6): 563-565.

KWAK, J., YOON, S. AND YOUN-JOO, A., 2017, Long-term effects of ZnO nanoparticles on exoenzyme activities in planted soils. *Environ. Eng. Res.,* **15**: 28-36.

LIANG, T., YIN, Q., ZHANG, Y., WANG, B., GUO, W., WANG, J. AND XIE, J., 2013, Effects of carbon nanoparticles application on the growth, physiological characteristics and nutrient accumulation in tobacco plants. *J. Food. Agric. Environ*., **11**(3/4): 954-958.

LINDSAY, W. L. AND NORVELL, W. A., 1978, Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Sci. Soc. Ame. J*., **42:** 421-428.

LISCANO, J. F., WILSON, C. E., NORMAN-JR, R. J. AND SLATON, N. A., 2000, Zinc Availability to Rice from Seven Granular Fertilizers. *Arkansas Agricultural Experiment Station Res. Bull.,* **963**: 1-31.

LIU, R. AND LAL, R., 2014, Synthetic apatite nanoparticles as a phosphorus fertilizer for soybean (*Glycine max*). *Sci. Rep.,* **4**: 5686–5691.

LIU, X. M., ZHANG, F. D., ZHANG, S. Q., HE, X. S., FANG, R., FENG, Z. AND WANG, Y., 2005, Effects of nano-ferric oxide on the Growth and Nutrients Absorption of Peanut. *Plant Nutr. Fert. Sci.,* **11**: 14-18.

LOKANATH, R. AND K. SHIVASHANKAR., 1986, Effect of foliar application of micronutrients and magnesium on the growth, yield and quality of mulberry (*Morus alba* L.). *Indian. J. Seri*., **25**(1):1-5.

LOWRY, O. H., ROSEBROUGH, N. J., LEWIS FARR, A. AND RANDALL, R. J., 1951, Protein measurement with the folin Phenol Reagent. *J. Biol. Chem*., **193**(1):256-275.

MAHAJAN, P., SHAILESH, K. D. AND KHANNA, A. S., 2013, Effect of nano-ZnO particle suspension on growth of mung (*Vigna radiata*) and gram (*Cicer arietinum*) seedlings using plant agar method. *J. Nanotechnol*., **1**: 1-7.

MAHESH, V. N., 2014, Effect of soil and foliar application of zinc and boron on quality and yield of mulberry leaves (*Morus alba* L.). *M.Sc., (Agri.) Thesis, University of Agricultural Sciences Bangalore, Karnataka.*

MALA, R., CELSIA ARUL SELVARAJ, R., BARATHI SUNDARAM, V., BLESSINA SIVA SHANMUGA RAJAN, R. AND MAHESWARI GURUSAMY, U., 2017, Evaluation of nano structured slow release fertilizer on the soil fertility, yield and nutritional profile of *vigna radiata. Recent Pat. Nanotechnol.*, **11**(1): 50-62.

MALHI, S. S., NYBORG, M. AND HARAPIAK, J. T., 1998, Effects of long-term N fertilizer induced acidification and liming on micronutrients in soil and in bromegrass hay. *Soil Tillage Res*., **48**: 91-101.

MANIKANDAN, A. AND SUBRAMANIAN, K. S., 2016, Evaluation of zeolite based nitrogen nano-fertilizers on maize growth, yield and quality on *Inceptisols* and *Alfisols*. *Int. j. plant soil sci.*, **9**(4): 1-9.

MESHRAM, N. A., ISMAIL, S., SHIRALE, S. T. AND PATIL, V. D., 2019, Impact of long-term fertilizer application on soil fertility, nutrient uptake, growth and productivity of soyabean under soyabean-safflower cropping sequence in *Vertisols*. *Legum. Res*., **42**(2): 182-189.

MILANI, N., 2011, Zinc oxide nanoparticles in the soil environment: dissolution, speciation, retention and bioavailability. *Ph. D. Thesis*, Univ. Adelaide, PMB 1, Glen Osmond (Australia).

MIRANDA-VILLAGOMEZ, E., TREJO-TELLEZ, L. I., GOMEZ-MERINO, F. C., SANDOVAL-VILLA, M., SANCHEZ-GARCIA, P. AND AGUILAR-MENDEZ, M. A., 2019, Nano phosphorus Fertilizer Stimulates Growth and Photosynthetic Activity and Improves P Status in Rice. *J. Nanomater.*, **11**: 1-11.

MIRANSARI, M., 2011, Interactions between arbuscular mycorrhizal fungi and soil bacteria. *Appl. Microbiol. Biotechnol*., **89**(4): 917-930.

MIYASHITA, Y., 1986, A report on mulberry cultivation and training methods suitable to bivoltine rearing in Karnataka. pp. 1-7.

MOGHADAM, A. L., VATTANI, H., BAGHAEI, N. AND KESHAVARZ, N., 2012, Effect of different levels of fertilizer nano iron chelates on growth and yield characteristics of two varieties of spinach (*Spinacia oleracea* L.): Varamin 88 and Viroflay. *Res. J. Appl. Sci Eng Tech*.**, 4**(22): 4813-4818.

MOSHE, T. B., FRENK, S., DROR, I. AND BERKOWITZ, B., 2012, Effects of metal oxide nanoparticles on soil properties. *Chemosphere*, **90**(2): 640-646.

MUKHOPADHYAY, R. AND DE, N., 2014, Nano clay polymer composite: synthesis, characterization, properties and application in rainfed agriculture. *Global J. Bio Sci. Biotech.*, **3**(2): 133-138.

MUTHUVEL, P., KANDASWAMY, P. AND KRISHNAMOORTHY, K. K., 1985, Potassium and calcium contents of soils under long-term fertilizer application. *J. Indian Soc. Soil Sci*., **31**(1): 128-131.

NAIR, R., VARGHESE, S. H., NAIR, B. G., MAEKAWA, T., YOSHIDA, Y. AND KUMAR, D. S., 2010, Nano particulate material delivery to plants. *Plant Science*, **179:** 154–163.

NARAYANASWAMY, T. K. AND SHANKAR, M. A., 2003, Mulberry cultivation: A tool for quality leaf and sustainable cocoon production. *Department of Sericulture and Dryland Agriculture Project, University of Agricultural Sciences, Bangalore,* p. 28.

NASEF, M. A., NADIA., BADRAN, M., AMAL. AND ABD EL-HAMIDE, F., 2006, Response of peanut to foliar spray with boron and/or rhizobium inoculation. *J. Appl. Sci. Res*. **2**(12): 1330-1337.

NELSON, K. A., MOTAVALLI, P. P. AND NATHAN, M. 2005, Response of No-till soybean to [*Glycine max* (L.) Merrill] to timing of pre-plant and foliar potassium application in a clay pan soil. *J. Agron.,* **97**(3): 832-838.

NITHYA, B. N., NAIKA, R., NAVEEN, D. V. AND KUMAR, S.T., 2018, Influence of nano zinc application on growth and yield parameters of mulberry. *Int. J. Pure App. Biosci.*, **6**(2): 317-319.

OMBODI, A. AND SAIGUSA, M., 2000, Broadcast application versus band application of polyolefin-coated fertilizer on green peppers grown on Andisol. *J. Plant Nutr.*, **23**(10): 1485-1493.

PAGARIA, T, M., RAVANKAR, H. N., KHONDE, H. W., GAWANDE, R. P. AND LABARIA, G. S., 1995, Effect of FYM with and without fertilizer on the yield and chemical composition of cotton under rainfed condition. *PKV Res. J.*, **19**(1): 87-88.

PETEU, S. F., OANCEA, F., SICUIA, O. A., CONSTANTINESCU, F. AND DINU, S., 2010, Responsive polymers for crop protection. *Polymers.*, **2**(3): 229-251.

PIPER, C. S., 1966, *Soil and Plant Analysis*. Hans Pub., Bombay, pp.152-168.

PIRVULESCU, A., SALA, F. AND BOLDEA, M., 2015, Variation of chlorophyll content in sunflower under the influence of magnetic nanofluid. *AIP Conf. Proc*, pp: 670

PRASAD, J., SRIVASTAV, N. C. AND MATHUR, B. S., 1996, Available nutrient status of a continuously fertilised and cropped acid soil. *J. Indian Soc. Soil Sci*., **44**(1): 171-173.

PRASAD, T. N., SUDHAKAR, P., SREENIVASULU, Y., LATHA, P., MUNASWAMY, V., REDDY, K. R., SREEPRASAD, T. S., SAJANLAL, P. R. AND PRADEEP, T., 2012, Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. *J. Plant Nutr*., **35**(6): 905–927.

RAI, V., ACHARYA, S. AND DEY, N., 2012, Implications of nanobiosensors in agriculture. *J. Biomater. Nanobiotechnol*., **3**: 315–324.

RAJONEE, A. A., NIGAR, F., AHMED, S. AND HUQ, S. I., 2016, Synthesis of nitrogen nano fertilizer and its efficacy. *Can. J. Appl. Sci.,* **10**: 3913-3919.

RAJU, B. B. AND PRASHANT, K. R., 2017, Studies on effect of polymer seed coating nanoparticles and hydro priming on seedling characters of Pigeonpea (*Cajanus cajan* L.). *J. Pharmacogn. Phytochem*., **6**(4):140-145.

RAMAN, R. AND VENKATARAMANA, K., 2006, Effect of foliar nutrition on N P K uptake, yield attributes and yield of green gram (*Vigna radiate* L.). *Crop Res*., **32**(1): 21-23.

RAMESH REDDY., 2014, Efficacy of nano zinc particle on growth and yield of crop plants. *M.Sc. (Agri.) Thesis,* UAS, Bangalore, p. 104.

RANI, B., ZALAWADIA, N. M., BUHA, D. AND RUSHANG, K., 2019, Effect of different levels of chemical and nano nitrogenous fertilizers on content and uptake of N, P, K by sorghum crop. *J. Pharmacogn. Phytochem.,* **8**(5): 454-458.

RAVIKUMAR, C., 1988, Western ghats as a bivoltine region- Prospects, challenge and strategies for its development. *Indian Silk,* **26**(9): 39-54.

REZAEI, M. AND ABBASI, H., 2014, Foliar application of nanochelate and non-nanochelate of zinc on plant resistance physiological processes in cotton (*Gossipium hirsutum* L.). *Iran. J. Plant Physiol.*, **4**(4): 1137-1144.

REZAEI, R., ZARGHAMY, R. AND OVEYSEE, M., 2013, Evaluate the effect of foliar application and changes sink and sources on yield and yield components of soybean (*Glysine max* (L.) Merril). *Technical J. Eng and App Sci.*, **3**(16): 1825-1828.

ROSA, DE. MONREAL, M. C., SCHNITZER, C., WALSH, M. R. AND SULTAN, Y., 2010, Nanotechnology in fertilizers. *Nat. Nanotechnol*., **5**: 91-96.

ROSTAMI, M., MOVAHEDI, Z., DAVARI, M. R. AND SIAHPOOSH, S., 2017, Effect of foliar application of biofertilizer and nano-fertilizers on morpho-physiological characteristics of peppermint (*Mentha piperita* L.). Tropentag -Future Agriculture: Socialecological Transitions and Bio-cultural shifts, Teso, Kenya.

ROY, A. K. N., ALI, R. K., LAKRA, P., ALAM, P., MAHAPATRA. AND NARAYAN, R., 2018, Effect of integrated nutrient management practices on nutrient uptake, yield of finger millet (Eleusine coracana L. Gaertn.) and postharvest nutrient availability under Rainfed condition of Jharkhand. *Int. J. Curr. Microbiol. App. Sci.*, **7**(8): 339-347

RUI, M., MA, C., HAO, Y., GUO, J., RUI, Y., TANG, X., ZHAO, Q., FAN, X., ZHANG, Z., HOU, T. AND ZHU, S., 2016, Iron oxide nanoparticles as a potential iron fertilizer for peanut (*Arachis hypogaea*). *Front. Plant Sci.*, **7**: 45-52.

RYAN, J., RASHID, A., TORRENT, J., YAU, SK., IBRIKCI, H. AND SOMMER, R., 2013, Micronutrient Constraints to Crop Production in the Middle East–West Asia Region: Significance, Research, and Management. *Academic Press*, **122**: 1-84.

SADASHIVAM, S. AND MANICKAM. A., 1996, *Biochemical methods.* New age inter. (p) Ltd. Publishers. *Sed. Edn*. p. 395.

SASSON, Y., LEVY-RUSO, G., TOLEDANO, O. AND ISHAAYA, I., 2007, Nanosuspensions: emerging novel agrochemical formulations. *Insecticides design using advanced technologies, Berlin, Heidelberg*, pp: 1-39.

SCHLICH, K. AND HUND-RINKE, K., 2015, Influence of soil properties on the effect of silver nanomaterials on microbial activity in five soils. *Environ. Pollut.*, **196**: 321-330.

SHAILESH, K. D., PRAMOD, M., RAJASHRI, K. AND KHANNA, A. S., 2013, Effect of nanoparticles suspension on the growth of mung (*Vigna radiata*) seedlings by foliar spray method. *Nanotechnol. Devel*., **3**(1):1-5.

SHANKAR, M. A., 1997, *Handbook of Mulberry Nutrition.* Multiplex, Bangalore, p.121.

SHARIFI, R., MOHAMMADI, K. AND ROKHZADI, A., 2016, Effect of seed priming and foliar application with micronutrients on quality of forage corn (*Zea mays*). *Environ. Exp. Bot*., **14**(2): 51-156.

SHAVIV, A., 2000, Advances in controlled-release fertilizer. *Adv. Agron.,* **71:** 1-49.

SHAWER, S. S. AND ABDALLA, I. M., 2019, Effect of organic and nano nitrogen fertilization on soil properties, crop production and nutrients uptake by corn plant in sandy soil. *J. Biol. Chem. Environ. Sci*., **14**(1): 247-262.

SHEBL, A., HASSAN, A. A., SALAMA, Dina. M., EL-AZIZ, M. E. ABD. AND ELWAHED, M. S. A. ABD., 2019, Green synthesis of nano fertilizers and their application as a foliar for *Cucurbita pepo* L. *J. nanometer*., **2**: 11-15.

SHEFALI, GANGWAR, R., DEVI, M., CHHABRA, P. AND PRASAD, B., 2016, Role of nano science in development of India. Role of science and technology towards make in India, *Univ. Sci. and Tech., Faridabad*. March 5-7, pp. 149.

SHEN, Z., CHEN, Z., HOU, Z., LI, T. AND LU, X., 2015, Ecotoxicological effect of zinc oxide nanoparticles on soil microorganisms. *Front. Environ. Sci. Eng.,* **9**: 912-918.

SHEYKHBAGLOU, R., SEDGHI, M., SHISHEVAN, MT. AND SHARIFI, SR., 2010, Effects of nano iron oxide particles on agronomic traits of soybean. *Not. sci. biol*., **2**: 112-113.

SIDDIQUI, M. H., AL-WHAIBI, M. H., FIROZ, M. AND AL-KHAISHANY, M. Y., 2015, *Nanotechnology and Plant Sciences: Nanoparticles and Their Impact on Plants.* pp. 19-35.

SIMONIN, M., RICHAUME, A., JULIEN, P., GUYONNET, J. P., DUBOST, A., MARTINS, J. M. F. AND POMMIER, T., 2016, Titanium dioxide nanoparticles strongly impact soil microbial function by affecting archaeal nitrifiers. *Sci. Rep.,* **6**: 38-46.

SINGH, S. AND KAMATH, M. B., 1989, Phosphate utilization from full basal, split and foliar application by mustard. *J. Oilseed Res*., **6**: 133-135.

SIVA, G. V. AND BENITA, L. F. J., 2016, Iron oxide nanoparticles promotes agronomic traits of ginger (*Zingiber officinale* Rosc.). *Int. J. Adv. Res. Biol. Sci.,* **3**(3): 230-237.

SREELATA, M., 2008, India looks to nanotechnology to boost agriculture. *SciDev. Net*.

SRINIVASRAO, C. H., VENKATESWARLU, B., SINGH, A. K., VITTAL, K. P. R., KUNDU, S., GAJANAN, G. N. AND RAMACHANRAPPA, B. K., 2012, Yield sustainability and carbon sequestration potential of groundnut finger millet rotation in *Alfisols* under semi-arid tropical India. *Int. J. Agric. Sustain*., **10**: 1-15.

SUBBAIAH, V. L., 2014, Effect of nanoscale zinc oxide particles on the yield and yield attributes of maize. *M. Sc. Thesis, ANGRAU, Rajendranagar, Hyderabad (India)*.

SUBBAIYA, R., PRIYANKA, M. AND SELVAM, M. M., 2012, Formulation of green nano-fertilizer to enhance the plant growth through slow and sustained release of nitrogen. *J. Pharm. Res.,* **5**(11): 5178-5183.

SUBBIAH, B. V. AND ASIJA, C. L., 1956, A rapid procedure for method for the estimation of available nitrogen in soils. *Curr. Sci.*, **25**: 259-260.

SUBEHIA, S. K. AND SWAPNA, S., 2012, Influence of long-term nitrogen substitution through organics on yield, uptake and available nutrients in a rice-wheat system in an acidic soil. *J. Indian Soc. Soil Sci*., **25**: 259-260.

SUBRAMANIAN, K. S. AND KUMARASWAMY, K., 1989, Effect of continuous cropping and fertilization on chemical properties of soil. *J. Ind. Soc. Soil Sci*., **37**: 171.

SUBRAMANIAN, K. S. AND RAHALE, C. S., 2009, Synthesis of nanofertiliser formulations for balanced nutrition. *Proc. Indian society of Soil Science. December*, pp: 22-25.

SUBRAMANIAN, K. S. AND TARAFDAR, J. C., 2011, Prospects of nanotechnology in Indian farming. *Indian J. Agric. Sci.*, **81**(10): 887-893.

TAO, S., PANG, R., CHEN, C., REN, X. AND HU, S., 2012, Synthesis, characterization and slow release properties of O-naphthylacetyl chitosan. *Carbohydr. Polym.*, **88**(4): 1189-1194.

TARAFDAR, J. C. AND RAO, A. V., 2001, Response of cluster bean to *Glomus mosseae* and rhizobium in an arid soil fertilized with nitrogen, phosphorous and farmyard manures. *J. Indian Soc. Soil Sci*., **49**(4): 751-755.

TARAFDAR, J. C., 2012, Perspectives of nanotechnological applications for crop production. *NAAS News*, **12**: 8-11.

TARAFDAR, J. C., RALIYA, R., MAHAWAR, H. AND RATHORE, I., 2014, Development of zinc nanofertilizer to enhance crop production in pearl millet (*Pennisetum americanum*). *Agric. Res. J.*, **3**(3): 257-262.

THIPPESWAMY, H. M., 1995, Dynamics of potassium and crop response studies in selected soil series of *Alfisols* of Karnataka. *Ph.D. thesis, univ. Agric. Sci. Bangalore, Karnataka, India.*

THIRUNAVUKKARASU, M. AND BALAJI, T., 2015, Effect of integrated nutrient management (INM) on growth attributes, biomass yield, secondary nutrient uptake and quality parameters of Bhendi (*Abelmoschus esculentus* L.). *J. Nat. Appl. Sci*., **7**(1): 165-169.

TIAN, Q. Y., LIU, N. N., BAI, W. M., LI, L. H. AND ZHANG, W. H., 2015, Disruption of metal ion homeostasis in soils is associated with nitrogen deposition-induced species loss in an inner Mongolia steppe. *Biogeosciences*, **12**: 3499-3512.

TILMAN, D., CASSMAN, K. G., MATSON, P. A., NAYLOR, R. AND POLASKY, S., 2002. Agricultural sustainability and intensive production practices. *Nature*, **418**: 671-677.

TRENKEL, M. E., 1997, Controlled-release and stabilized fertilizers in agriculture. *Paris: International fertilizer industry association.* **11**: 42

VALOJAI, S. T., NIKNEJAD, Y., FALLAH-AMOLI, H. AND BARARI TARI, D., 2021, Response of rice yield and quality to nano-fertilizers in comparison with conventional fertilizers. *J. Plant Nutr.*, pp. 1-11.

WALKLEY, A. J. AND BLACK, C. A., 1934, An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration. *Soil Sci.*, **37**: 29-38.

WANG, L. J., WANG, Y. H., LI, M., FAN, M. S., ZHANG, F. S., WU, X. M., YANG, W. S. AND LI, T. J., 2002, Synthesis of ordered biosilica materials. *Chin. J. Chem.*, **20**(1): 107-110.

WANG, R., DUNGAIT, J. A. J., BUSS, H. L., YANG, S., ZHANG, Y. AND XU, Z., 2017, Base cations and micronutrients in soil aggregates as affected by enhanced nitrogen and water inputs in a semi-arid steppe grassland. *Sci. Total Environ*., **575**: 564-572.

WATANABE, F. S. AND OLSEN, S. R., 1965, Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soil. *Soil. Sci. Soc. Am. Proc.*, **29**: 677- 678.

WATSON, J. L., FANG, T., DIMKPA, C. O., BRITT, W. D., MCLEAN, J. E., JACOBSON, A. AND ANDERSON, A. J., 2015, The phytotoxicity of ZnO nanoparticles on wheat varies with soil properties. *Biometals,* **28**(1): 101–112.

WEISANY, W., SOHRABI, Y., HEIDARI, G., SIOSEMARDEH, A. AND GHASSEMI-GOLEZANI, K., 2011. Physiological responses of soybean (*Glycine max*) to zinc application under salinity stress. *Aust. J. Crop Sci.,* **5**(11): 1441.

WEN., SUN, Z., WU, L., SHI, G. L., Y. X., GU, J. L. AND XU, Q. M., 2014, Effects of coated controlled release urea combined with conventional urea on winter wheat growth and soil NO_3-N. Chin. *J. Appl. Ecol*., **22**(3):687-693.

XIAOYU, N., YUEJIN, W., ZHENGYAN, W., LIN, W., GUANNAN, Q. AND LIXIANG, Y., 2013, A novel slow-release urea fertilizer: Physical and chemical analysis of its structure and study of its release mechanism. *Biosyst. Eng.,* **115**(3): 274-282.

YADAV, R. L., DWIVEDI, B. S. AND PANDEY, P. S., 2000, Rice-wheat cropping system: Assessment of sustainability under green manuring and chemical fertilizer inputs. *Field crops res*., **65**(1): 15-30.

YOU, T., LIU, D., CHEN, J., YANG, Z. AND DOU, R., 2017, Effects of metal oxide nanoparticles on soil enzyme activities and bacterial communities in two different soil types. *J. Soil Sediments.,* **10**: 26-31.

ZAREABYANEH, H. AND BAYATVARKESHI, M., 2015, Effects of slow-release fertilizers on nitrate leaching, its distribution in soil profile, N-use efficiency, and yield in potato crop. *Environ. Earth Sci.,* **74**(4): 3385-3393.

APPENDIX– I

Particulars of different inputs used for irrigated mulberry garden (ha^{-1} crop^{-1})

Sl. No.	Particulars	Requirements	Rate (Rs. unit^{-1})	Amount (Rs.)
1	Ploughing of land (bullock pair)	3	1200/day	3600
2	FYM (T)	4	800	3200
3	Application of fertilizers (Man days)	2	450	900
4	Inter-cultivation a) Bullock pairs	3	1200	3600
	b) Labour charges (Man days) for weeding	5	350	1750
5	Pruning cum harvesting (Man days)	8	350	2800
6	Miscellaneous	-	500	500
Total				**16,350**

APPENDIX– II

Cost of fertilizers

Particulars	**Requirements**	**Rate (Rs unit^{-1})**	**Amount (Rs.)**
a) Nitrogen @ 60 kg ha^{-1} crop^{-1} (Urea, kg)	90	Rs. 300 per 50 kg bag	600
b) Phosphorus @ 70 kg ha^{-1} crop^{-1} (DAP, kg)	152	Rs. 1200 per 50 kg bag	3600
c) Potassium @ 70 kg ha^{-1} crop^{-1} (MOP, kg)	117	Rs. 1000 per 50 kg bag	2500
Total			**6,700**
Nano fertilizers			
a) Nano nitrogen (0.4%) (Litre)	2.5	Rs.250 per 500 ml *5 = 1250	1250
b) Nano Iron (500 ppm) (gram)	313	Rs.700 per 200 gram	1096
c) Nano Iron (1000 ppm) (gram)	626	Rs.700 per 200 gram	2188

APPENDICES – III

Total cost of mulberry production for different treatments

Treatments	Cost excluding treatments	Cost of fertilizers	Cost of treatments	Total cost
T_1= Absolute control	16350	-	-	16,350
T_2= RDF (360:140:140:N, P_2O_5, K_2O + 25 t FYM/ha)	16350	6700	-	23,050
T_3= T_2 + soil application of $FeSO_4$ @ 5 kg/ha	16350	6700	250	23,300
T_4= T_2 + nano iron @ 500 mg/L as foliar spray	16350	6700	1096	24,146
T_5= T_2 + nano iron @ 1000 mg/L as foliar spray	16350	6700	2188	25,238
T_6= RDF (50 % N+ 100% P_2O_5+ 100% K_2O+ 25 t FYM/ha)	16350	6400	-	22,750
T_7 = T_6 + nano nitrogen @ 0.4% as foliar spray	16350	6400	1250	24,000
T_8= T_6 + nano nitrogen @ 0.4% + nano iron @ 500 mg/L as foliar spray	16350	6400	1250+1096	25,096
T_9 = T_6 + nano nitrogen @ 0.4% + nano iron @ 1000mg/L as foliar spray	16350	6400	1250+2188	26,188