

**DYNAMICS OF MICRONUTRIENTS IN
CALCARIOUS VERTIC USTOCHREPTS SOILS
UNDER AICRP-LTFE**

A
THESIS SUBMITTED TO THE
JUNAGADH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE

OF

DOCTOR OF PHILOSOPHY
(AGRICULTURE)

IN

AGRICULTURAL CHEMISTRY AND SOIL SCIENCE

BY

VEKARIA LALITKUMAR CHANDULAL
M.Sc. (Agri.)

**DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOIL
SCIENCE**

**COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH CAMPUS, JUNAGADH - 362 001.**

JANUARY, 2009

(Registration No. J4 - 00226 - 2006)

**DYNAMICS OF MICRONUTRIENTS IN
CALCARIOUS VERTIC USTOCHREPTS SOILS
UNDER AICRP-LTFE**

BY

VEKARIA LALITKUMAR CHANDULAL
M.Sc. (Agri.)

**DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOIL
SCIENCE
COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH CAMPUS, JUNAGADH - 362 001.**

JANUARY, 2009

(Registration No. J4 - 00226 - 2006)

**DYNAMICS OF MICRONUTRIENTS IN CALCARIOUS
VERTIC USTOCHREPTS SOILS UNDER AICRP-LTFE**

Name of Student

Mr. L. C. Vekaria

Major Advisor

Dr. B.A. Golakiya

**DEPARTMENT OF AGRIL. CHEMISTRY AND SOIL SCIENCE
COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH CAMPUS, JUNAGADH**

ABSTRACT

Micronutrients play a vital role in enhancing crop productivity and improving quality of crops. Intensification of agriculture with high yielding crop varieties, continuous use of highly analysed fertilizer restricting supply of organic matter, negligible use of crop residuals and increasing cropping intensity, all together exhausted micronutrients from soils. The deficiencies of micronutrients in Indian soils as well as Gujarat soils were very well recognized with special reference to Cu, Mn, Zn and Fe. Further, different pools were recognized and a number of sequential fractionation procedures were developed to study the relative abundance and importance of different fractions in the soil. Junagadh is one of the centers representing medium black calcareous soil (*Vertic ustocrepts*). These sub soils are difficult to manage from fertility point of view. Further most of our research information is largely emanated from short term study and unable to answer critical questions about how the

intrinsic properties of soils being changed by anthropogenic activities affect the micronutrient resource. In view of above following broad objectives were set :

- ❖ To study the status of micronutrient (Fe, Zn, Mn, Cu) fractions in calcareous *Vertic ustrochrepts* soils under AICRP-LTFE.
- ❖ To investigate the depletion of micronutrients fractions in the soils under investigation.
- ❖ Modeling the dynamics of micronutrient fractions in the AICRP-LTFE soils.

To achieve the forgoing objectives, this investigation initiated which comprised of samples derived from long term fertilizer experiment started 8 years back on *Vertic ustocrept* calcareous medium black clayey soils of Junagadh. The samples were subjected to fractionation of micronutrients viz., Cu, Mn, Zn and Fe. The micronutrients, their fractions and soil properties were related to various yields and NPKS content from plants. In this part also the data were subjected to correlation analysis, stepwise regression, multiple correlation and path analysis. The LTFE experiment involved twelve treatments including untreated control which was subjected to analysis of variance in order to find out the effect of various treatments on yield, NPKS content and micronutrient fractions and also depletion in a long term cycle of 4 and 8 years.

In a long run, treatment differences in groundnut yield diminished while wheat yield showed significantly higher values in T₈ after long spell of 8th year. The treatment T₃ registered the highest N concentration and T₈ the lowest in groundnut pod while T₂ recorded highest concentration and T₉ the lowest in groundnut haulm. The T₈ registered

the highest concentration while control the lowest both in wheat grain and straw. In groundnut pod phosphorus concentration decreased while in haulm increased like wise in wheat grain phosphorus concentration was increased but in straw decreased after a period of 8 years. The concentration of potash after 4th year of cycles showed increase while after 8th year cycle it was declined in groundnut and wheat. In groundnut sulphur concentration increased after 4th year while declined after 8th year. In wheat, sulphur concentration decline after 4th and 8th year.

From the overall picture with respect to various forms of Cu it can be deduced that there was a decline in the soil Cu levels where a significant decline in most of all important forms. There was a decline in the soil Mn status in the LTFE soils in different form and these was a significant decline in the important forms such as exchangeable Mn, total Mn and residual Mn. Overall mean DTPA available Mn recorded medium values (6.297 ppm) as compared to the critical values. The DTPA available Zn was maintained high quite above critical values (0.5 to 1.0 ppm) and did not indicate any need to supplement Zn nutrient in near future. Particularly DTPA available ferrous showed considerable depletion over time and chemical fertilizers triggered utilization thereby the levels reaching below critical values. Although iron is the most abundant element, its availability needs suitable management practices.

The DTPA available nutrients were the predominant form in copper, manganese, zinc and iron. Chemical fertilizers supplemented and enhanced utilization of DTPA available Mn and Cu along with a shift in inter-conversion among forms, over the 4 and 8 years cycles.

Correlations

Groundnut pod yield and haulm yield exhibited significant positive relationship with DTPA available Cu, exchangeable Mn, per cent available Mn, residual Mn, residual Zn, per cent available Zn, water soluble Fe, residual Fe and per cent available Fe. Obviously wheat grain yield showed significant negative relationship with available Cu, while significant positive relationship with all forms of Mn and Zn and exchangeable Fe, DTPA available Fe, total Fe and available total Fe. Available form of Cu showed positive relationships with nitrogen concentration particularly in wheat grain (cereals), P concentration in groundnut pod and K concentration in groundnut haulm and S concentration in wheat grain and straw. Available Mn facilitated the partitioning of nitrogen towards wheat grain and groundnut pods. Available Mn favored accumulation of K in wheat gain and groundnut pod over the vegetative parts in both the crops. Phosphorus accumulation was promoted in legumes while it diminished in cereals by Zn. The Fe was found to indirectly regulate partitioning between vegetative and reproductive parts via regulating P concentration which was known to influence the osmotic relations.

The total Cu was predominantly reflected by DTPA available Cu followed by residual, per cent available and residual. The DTPA available copper showed significant positive correlation with soil pH. The data from correlation studies indicated strong association between DTPA-Mn and its reducible, total, residual, and available total. The DTPA available Mn showed significant positive relationship with many soil properties viz., soil pH, O.C. and available K_2O . The DTPA available Zn showed highly significant positive relationship with available total and percent available Zn. The DTPA available Zn also showed significant

positive relationship with various soil properties viz., soil pH, EC, O.C., available N, available P and available K₂O. The DTPA available Fe displayed a highly significant positive relationship with available total, total and exchangeable forms. The DTPA available Fe recorded significant positive relationship with most of the soil properties viz., Soil pH, EC, O.C., available N and available P. The interactions viz., zinc x iron, manganese x zinc and copper x zinc showed more conspicuous relationships.

Regressions

The DTPA available micronutrients as influenced by other forms were subjected to stepwise regression and multiple correlation and regression analysis. The prediction models were based on multiple and correlation analysis over a cycle of 1, 4 and 8 years. The stepwise regression analysis indicated that total form in copper, manganese, zinc and ferrous had the maximum impact on DTPA available micronutrients. The stepwise regression analysis of DTPA available micronutrient as the dependent variable and soil properties as the independent variables indicating a low degree of influence. Nevertheless, Properties utilized for analysis soil pH influenced DTPA available Cu, soil O.C. to DTPA Mn and Zn, soil EC and O.C. to DTPA Fe, to the maximum extent.

Path Co-efficients

The residual Cu form exhibited significant positive correlation with DTPA available Cu. Total and per cent available form of Mn had a direct positive effect on DTPA Mn. The residual Zn and total Zn had a high direct effect on DTPA available Zn. The total ferrous showed a direct positive effect, while reducible ferrous showed a direct negative effect on DTPA available ferrous.


spatiotemporal variations according to soil type, land use, agronomic package, cropping patterns and agro-ecological situations. Most of all micronutrients with their forms exhibited in general a negative trend in the long term fertilizer experiment after 8 years.


COLLEGE OF AGRICULTURE
JUNAGADH AGRICULTURAL UNIVERSITY
JUNAGADH


CERTIFICATE-III

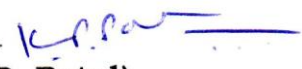
Date : 29-06-09


This is to certify that the thesis entitled "**DYNAMICS OF MICRONUTRIENTS IN CALCARIOUS VERTIC USTOCHREPTS SOILS UNDER AICRP-LTFE**" submitted by **Mr. VEKARIA LALITKUMAR CHANDULAL** to Junagadh Agricultural University, Junagadh in partial fulfillment to the requirements for the degree of **Ph.D.** in the subject of **AGRICULTURAL CHEMISTRY AND SOIL SCIENCE** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination was satisfactory; we therefore, recommended that the thesis be approved.

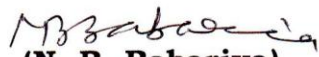

(B. A. Golakiya)
Major Advisor &
Professor & Head
Deptt. of Biochemistry
J.A.U., Junagadh


(B. K. Sagarka)
Minor Advisor &
Professor(P)
Deptt. of Agronomy
J.A.U., Junagadh


(B. S. Yadav)
External Examiner &
Zonal Director of Research
Agricultural Research Station
Rajasthan Agricultural University
Shriganganagar (Rajasthan)


(K. P. Patel)
External Examiner &
Research Scientist
Micronutrient Project
Anand Agricultural University
Anand


(P. G. Butani)
Principal & Dean
College of Agriculture
J.A.U., Junagadh


(N. B. Babariya)
Professor & Head
Deptt. of Agril. Chem. & Soil Science
College of Agriculture
J.A.U., Junagadh

Approved



(D. B. Kuchhadia)
Director of Research & Dean, P.G.
J.A.U., Junagadh

Dr. B. A. Golakiya
Professor and Head
Department of Biochemistry,
College of Agriculture,
Junagadh Agricultural University,
JUNAGADH - 362 001

CERTIFICATE

This is to certify that the thesis entitled "DYNAMICS OF MICRONUTRIENTS IN CALCARIOUS VERTIC USTOCHREPTS SOILS UNDER AICRP-LTFF" submitted by Mr. VEKARIA LALITKUMAR CHANDULAL in partial fulfillment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY (Agriculture) in DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOIL SCIENCE, of the JUNAGADH AGRICULTURAL UNIVERSITY is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously been formed the basis for the award of any degree, diploma or other similar title.

Place : Junagadh
Date : 27-01-2009


(B. A. Golakiya)
Major Guide

ACKNOWLEDGEMENT

After successful completing my education journey, I look back and find that through mine has been a fair sail it has been memoring extravaganza of memorable experience.

I feel great pleasure in expressing my sincere and deep sense of gratitude to Dr. B. A. Golakiya, Professor and Head, Department of Biochemistry, College of Agricultural, Junagadh Agricultural University, Junagadh for his valuable scholarly guidance, talented and enlivening advice, imperative and worthy suggestion, useful and constructive criticism and whole hearted support throughout the course of investigation and preparation of this dissertation.

It is my pleasant duty to express sincere thanks to minor advisor Dr. B. K. Sagaraka, Associate Professor, Department of Agronomy, my committee member Dr. K. B. Palara, Professor, Department of Agricultural Chemistry and Soil Science, Dr. S. M. Upadhyay, Professor and Head, Department of agricultural Statistics, Junagadh agricultural University, Junagadh for their constant attention, valuable suggestion and help through the period of investigation. Shri D.V. Patel, are helping in statistical analysis of the experimental data.

I express my deepest sense of regard to Dr. N. B. Babaria Professor and Head, Department of Agricultural Chemistry and Soil Science, JAU, Junagadh for his suggestion and providing necessary facilities during this study.

I heartily express my thanks to Dr. K. B. Paramar for his inspiring and thought provoking suggestion, valuable guidance throughout the course of the investigation.

I acknowledge with lots of thank to Dr. B. K. Kikani, the Vice-Chancellor and to Dr. D. B. Kuchhadia, the Director of Research and Dean, P.G. Studies, Junagadh Agricultural University for giving me an opportunity to improve my career by granting admission in in-service Ph.D. study. I am also grateful to Dr. P. G. Butani, the Principal, College of Agriculture, Junagadh for providing necessary facilities for conducting the research work and library staff for necessary help and cooperation to me during the period of study.

My sincere thanks are also due to Shri H. L. Sakarvadia, Shri A. V. Rajani, Dr. S. G. Savaliya, Dr. N. M. Zalawadia, Dr. P. J.

Marsonia, Dr.J. V .Polara, Dr. B. B. Kunjadia, Shri H. K. Sobhana, Dr. G. J. Hadwani, Shri R.G.Koria, Dr. M. S. Solanki, Shri N. K. Timbadia, Shri T. M. Hadiyal, Shri P. B. Bunsal, , J. D. Ardensana, and Shri S. R. Odedara Department of Agricultural Chemistry and Soil Science, J.A.U., Junagadh for their valuable assistance and help during work and partnerships in enjoyment of pleasure time.

No one should escape from the work just by excusing the facilities and infrastructure of the institute. In my mother institute "College of Agriculture- Junagadh" which is still growing under many constraints: I got full support from all the sides, utilized the available facilities to its maxima and could work as much as desired.

I will fail in my duty if I do not take opportunity to record my love affection and gratitude to my beloved and honorable parents Mr. C. H. Vekaria, Mrs. V. C. Vekaria, and my family whose kind blessing, moral support and scarifies could lead this task to see this day of reality and achievements.

Last but not least, a million thanks to GOD, the almighty that made me do this task and made every job a success for me.

Now as I carry this in my hand I carry with me a lots of memories that will enrich my breath, heart and mind.

Place : Junagadh

Date : 27-1-2009

(L. C. Vekaria)

CONTENT

CHAPTER	TITLE	PAGE
I	INTRODUCTION	1 - 5
II	REVIEW OF LITERATURE	6 - 46
III	MATERIALS AND METHOD.....	47 - 56
IV	RESULTS AND DISCUSSION	57 -160
V	GENERAL DISCUSSION.....	161 - 173
VI	SUMMARY AND CONCLUSION.....	174 - 182
	REFERENCES.....	183 - 203
	APPENDIX	i-xx

LIST OF TABLES

TABLE	TITLE	PAGE
1.1	Major natural sources of Cu, Mn, Zn and Fe, their chemical forms and range of content in the surface soils	2
3.1	Normal range of weather data at Junagadh	49
3.2	Physico-chemical characteristics of the long-term fertilizers experimental soil before the commencement of the experiment and proposed analytical method used	51
3.3	Ratings (low, medium, high) of micronutrients used for categorizing the soil status	56
4.0.1	Groundnut pod yield in 1 st , 4 th and 8 th year of LTFE experiment.	58
4.0.2	Groundnut haulm yield in 1 st , 4 th and 8 th year of LTFE experiment	58
4.0.3	Wheat grain yield in 1 st , 4 th and 8 th year of LTFE experiment	59
4.0.4	Wheat straw yield in 1 st , 4 th and 8 th year of LTFE experiment	59
4.0.5	Nitrogen concentration of groundnut pod in 1 st , 4 th and 8 th year of LTFE experiment	62
4.0.6	Nitrogen concentration of groundnut haulm in 1 st , 4 th and 8 th year of LTFE experiment	62
4.0.7	Nitrogen concentration of wheat grain in 1 st , 4 th and 8 th year of LTFE experiment	63
4.0.8	Nitrogen concentration of wheat straw in 1 st , 4 th and 8 th year of LTFE experiment	63
4.0.9	Phosphorus concentration of groundnut pod in 1 st , 4 th and 8 th year of LTFE experiment	66
4.0.10	Phosphorus concentration of groundnut haulm in 1 st , 4 th and 8 th year of LTFE experiment	66
4.0.11	Phosphorus concentration of wheat grain in 1 st , 4 th and 8 th year of LTFE experiment	67

TABLE	TITLE	PAGE
4.0.12	Phosphorus concentration of wheat straw in 1 st , 4 th and 8 th year of LTFE experiment	67
4.0.13	Potash concentration of groundnut pod in 1 st , 4 th and 8 th year of LTFE experiment	69
4.0.14	Potash concentration of groundnut haulm in 1 st , 4 th and 8 th year of LTFE experiment	69
4.0.15	Potash concentration of wheat grain in 1 st , 4 th and 8 th year of LTFE experiment	70
4.0.16	Potash concentration of wheat straw in 1 st , 4 th and 8 th year of LTFE experiment	70
4.0.17	Sulphur concentration of groundnut pod in 1 st , 4 th and 8 th year of LTFE experiment	73
4.0.18	Sulphur concentration of groundnut haulm in 1 st , 4 th and 8 th year of LTFE experiment	73
4.0.19	Sulphur concentration of wheat grain in 1 st , 4 th and 8 th year of LTFE experiment	74
4.0.20	Sulphur concentration of wheat straw in 1 st , 4 th and 8 th year of LTFE experiment	74
4.1.1	Status of water soluble form of copper in soils of LTFE experiment in 1 st , 4 th and 8 th year	77
4.1.2	Status of exchangeable form of copper in soils of LTFE experiment in 1 st , 4 th and 8 th year	77
4.1.3	Status of DTPA available form of copper in soils of LTFE experiment in 1 st , 4 th and 8 th year	78
4.1.4	Status of reducible form of copper in soils of LTFE experiment in 1 st , 4 th and 8 th year	78
4.1.5	Status of total form of copper in soils of LTFE experiment in 1 st , 4 th and 8 th year	81
4.1.6	Status of residual form of copper in soils of LTFE experiment in 1 st , 4 th and 8 th year	81
4.1.7	Status of percentage available form of copper in soils of LTFE experiment in 1 st , 4 th and 8 th year	82
4.1.8	Status of total available form of copper in soils of LTFE experiment in 1 st , 4 th and 8 th year	82

TABLE	TITLE	PAGE
4.2.1	Status of water soluble form of manganese in soils of LTFE experiment in 1 st , 4 th and 8 th year	89
4.2.2	Status of exchangeable form of manganese in soils of LTFE experiment in 1 st , 4 th and 8 th year	89
4.2.3	Status of DTPA available form of manganese in soils of LTFE experiment in 1 st , 4 th and 8 th year	90
4.2.4	Status of reducible form of manganese in soils of LTFE experiment in 1 st , 4 th and 8 th year	90
4.2.5	Status of total form of manganese in soils of LTFE experiment in 1 st , 4 th and 8 th year	93
4.2.6	Status of residual form of manganese in soils of LTFE experiment in 1 st , 4 th and 8 th year	93
4.2.7	Status of percentage available form of manganese in soils of LTFE experiment in 1 st , 4 th and 8 th year	94
4.2.8	Status of total available form of manganese in soils of LTFE experiment in 1 st , 4 th and 8 th year	94
4.3.1	Status of water soluble form of zinc in soils of LTFE experiment in 1 st , 4 th and 8 th year	99
4.3.2	Status of exchangeable form of zinc in soils of LTFE experiment in 1 st , 4 th and 8 th year	99
4.3.3	Status of DTPA available form of zinc in soils of LTFE experiment in 1 st , 4 th and 8 th year	100
4.3.4	Status of reducible form of zinc in soils of LTFE experiment in 1 st , 4 th and 8 th year	100
4.3.5	Status of total form of zinc in soils of LTFE experiment in 1 st , 4 th and 8 th year	104
4.3.6	Status of residual form of zinc in soils of LTFE experiment in 1 st , 4 th and 8 th year	104
4.3.7	Status of percentage available form of zinc in soils of LTFE experiment in 1 st , 4 th and 8 th year	105
4.3.8	Status of total available form of zinc in soils of LTFE experiment in 1 st , 4 th and 8 th year	105
4.4.1	Status of water soluble form of iron in soils of LTFE experiment in 1 st , 4 th and 8 th year	111

TABLE	TITLE	PAGE
4.4.2	Status of exchangeable form of iron in soils of LTFE experiment in 1 st , 4 th and 8 th year	111
4.4.3	Status of DTPA available form of iron in soils of LTFE experiment in 1 st , 4 th and 8 th year	112
4.4.4	Status of reducible form of iron in soils of LTFE experiment in 1 st , 4 th and 8 th year	112
4.4.5	Status of total form of iron in soils of LTFE experiment in 1 st , 4 th and 8 th year	115
4.4.6	Status of residual form of iron in soils of LTFE experiment in 1 st , 4 th and 8 th year	115
4.4.7	Status of percentage available form of iron in soils of LTFE experiment in 1 st , 4 th and 8 th year	116
4.4.8	Status of total available form of iron in soils of LTFE experiment in 1 st , 4 th and 8 th year	116
4.5.1	Correlation coefficient between different forms of Cu and MN to among forms of LTFE soils in the 1 st , 4 th and 8 th year	124
4.5.2	Correlation coefficient between different forms of Cu and MN to yield of LTFE soils in the 1 st , 4 th and 8 th year	127
4.5.3	Correlation coefficient between different forms of Cu and MN to Soil Properties of LTFE soils in the 1 st , 4 th and 8 th year	128
4.5.4	Correlation coefficient between different forms of Cu to NPKS Concentration of LTFE soils in the 1 st , 4 th and 8 th year	129
4.5.5	Correlation coefficient between different forms of Mn to NPKS Concentration of LTFE soils in the 1 st , 4 th and 8 th year	131
4.5.6	Correlation coefficient between different forms of Zn and Fe to among forms of LTFE soils in the 1 st , 4 th and 8 th year	133
4.5.7	Correlation coefficient between different forms of Zn and Fe to yield of LTFE soils in the 1 st , 4 th and 8 th year	134
4.5.8	Correlation coefficient between different forms of Zn and Fe to Soil Properties of LTFE soils in the 1 st , 4 th and 8 th year	135

TABLE	TITLE	PAGE
4.5.9	Correlation coefficient between different forms of Zn to NPKS Concentration of LTFE soils in the 1 st , 4 th and 8 th year	136
4.5.10	Correlation coefficient between different forms of Zn to NPKS Concentration of LTFE soils in the 1 st , 4 th and 8 th year	139
4.5.11	Correlation coefficient between interaction of different forms of two elements in LTFE soils in the 1 st	144
4.5.12	Correlation coefficient between interaction of different forms of two elements in LTFE soils in the 1 st , 4 th and 8 th year	146
4.5.13	Correlation coefficient between interaction of different forms of two elements in LTFE soils in the 1 st , 4 th and 8 th year	148
4.6.1	Regression equation between DTPA available form to forms and DTPA available form to properties for Cu, Mn, Zn and Fe in LTFE	150

LIST OF FIGURES

FIGURE	TITLE	PAGE
4.0.1	Yield of groundnut and wheat crop sequence in 1 st , 4 th and 8 th year of LTFE experiment	60
4.0.2	Nitrogen concentration (%) in groundnut and wheat in 1 st , 4 th and 8 th year of LTFE experiment	64
4.0.3	Phosphorus concentration (%) in groundnut and wheat in 1 st , 4 th and 8 th year of LTFE experiment	68
4.0.4	Potash concentration (%) in groundnut and wheat in 1 st , 4 th and 8 th year of LTFE experiment	71
4.0.5	Sulphur concentration (%) in groundnut and wheat in 1 st , 4 th and 8 th year of LTFE experiment	75
4.1.1	Status (ppm) of form of Cu in the LTFE soils in 1 st , 4 th and 8 th years	79
4.1.2	Status (ppm) of form of Cu in the LTFE soils in 1 st , 4 th and 8 th years	83
4.1.3.1	Percent distribution in different forms of available total Cu (Avt) in 1 st , 4 th and 8 th years in the LTFE soils	84
4.1.3.2	Percent distribution in different forms of available total Cu (Avt) in 1 st , 4 th and 8 th years in the LTFE soils	85
4.2.1	Status (ppm) of form of Mn in the LTFE soils in 1 st , 4 th and 8 th years	91
4.2.2	Status (ppm) of form of Mn in the LTFE soils in 1 st , 4 th and 8 th years	95
4.2.3.1	Percent distribution in different forms of available total Mn (Avt) in 1 st , 4 th and 8 th years in the LTFE soils	96
4.2.3.2	Percent distribution in different forms of available total Mn (Avt) in 1 st , 4 th and 8 th years in the LTFE soils	97
4.3.1	Status (ppm) of form of Zn in the LTFE soils in 1 st , 4 th and 8 th years	101
4.3.2	Status (ppm) of form of Zn in the LTFE soils in 1 st , 4 th and 8 th years	106
4.3.3.1	Percent distribution in different forms of available total Zn (Avt) in 1 st , 4 th and 8 th years in the LTFE soils	107

FIGURE	TITLE	PAGE
4.3.3.2	Percent distribution in different forms of available total Zn (Avt) in 1 st , 4 th and 8 th years in the LTFE soils	108
4.4.1	Status (ppm) of form of Fe in the LTFE soils in 1 st , 4 th and 8 th years	113
4.4.2	Status (ppm) of form of Fe in the LTFE soils in 1 st , 4 th and 8 th years	117
4.4.3.1	Percent distribution in different forms of available total Fe (Avt) in 1 st , 4 th and 8 th years in the LTFE soils	118
4.4.3.2	Percent distribution in different forms of available total Fe (Avt) in 1 st , 4 th and 8 th years in the LTFE soils	119
4.5.1	Percent depletion in DTPA available form of micronutrients in soils of LTFE experiment of 1 st and 8 th year cycles	121
4.6.1	Path diagram of the effect of different forms of Cu on DTPA-Cu in the LTFE soils	153
4.6.2	Path diagram of the effect of different forms of Mn on DTPA-Mn in the LTFE soils	154
4.6.3	Path diagram of the effect of different forms of Zn on DTPA-Zn in the LTFE soils	155
4.6.4	Path diagram of the effect of different forms of Fe on DTPA-Fe in the LTFE soils	156
4.6.5	Path diagram of the effect of different soil physico-chemical properties on DTPA-Cu in the LTFE soils	157
4.6.6	Path diagram of the effect of different soil physico-chemical properties on DTPA-Mn in the LTFE soils	158
4.6.7	Path diagram of the effect of different soil physico-chemical properties on DTPA-Zn in the LTFE soils	159
4.6.8	Path diagram of the effect of different soil physico-chemical properties on DTPA-Fe in the LTFE soils	160

ABBREVIATION

%	Per cent
*	Significant at 5% level
**	Significant at 1% level
Anon.	Anonymous
Av.	DTPA Available Form
AvT.	Available Total viz., WS+EF+Av+RED
C.D.	Critical Difference
CaCO ₃	Calcium Carbonate
CEC	Carbon Exchangeable Capacity
CKFS	Potash Concentration (%) in Fodder Sorghum
CKGH	Potash Concentration (%) in Groundnut Haulm
CKGP	Potash Concentration (%) in Groundnut Pod
CKWG	Potash Concentration (%) in Wheat Grain
CKWS	Potash Concentration (%) in Wheat Straw
Cm	Centimeter
Cmol	Centimol
CNFS	Nitrogen Concentration(%) in Fodder Sorghum
CNGP	Nitrogen Concentration(%) in Groundnut Pod
CNJH	Nitrogen Concentration(%) in Groundnut Haulm
CNWG	Nitrogen Concentration(%) in Wheat Grain
CNWS	Nitrogen Concentration(%) in Wheat Straw
CPFS	Phosphorus Concentration (%) in Fodder Sorghum
CPGH	Phosphorus Concentration (%) in Groundnut Haulm
CPGP	Phosphorus Concentration (%) in Groundnut Pod
CPWG	Phosphorus Concentration (%) in Wheat Grain
CPWS	Phosphorus Concentration (%) in Wheat Straw

Cu	Copper
dS/m	Deci Siemon per meter
EC	Electrical Conductivity
EF	Exchangeable Form
ESP	Exchangeable Sodium Percent
Fe	Iron
Fig.	Figure
FYM	Farm Yard Manure
Kg ha ⁻¹	Kilogram per hectare
Kuf	Potash uptake in sorghum fodder
Kugh	Potash uptake in g'nut haulm
Kugp	Potash uptake in groundnut pod
Kuwg	Potash uptake in wheat grain
Kuws	Potash uptake in wheat straw
LTFE	Long Term Fertilizer Experiment
Mn	Manganese
N	Normal
Nuf	Nitrogen uptake in sorghum fodder
Nuh	Nitrogen uptake in g'nut haulm
Nup	Nitrogen uptake in g'nut pod
Nuwg	Nitrogen uptake in wheat grain
Nuws	Nitrogen uptake in wheat straw
OC	Organic Carbon
P.A.	Percent Availability
ppm	Parts per million
Pug	Phosphorus uptake from wheat grain
Puh	Phosphorus uptake from g'nut haulm
Pus	Phosphorus uptake from sorghum fodder

Pup	Phosphorus uptake from groundnut pod
Pus	Phosphorus uptake from wheat straw
r	Correlation coefficient
R	Regression
r ²	Regression square
RED	Reducible Form
RES	Residual Form
S.Em.	Stand Error of Mean
SOC	Soil Organic Carbon
Sol.	Soluble
T	Total
WS	Water Soluble
Zn	Zinc

CHAPTER - I

INTRODUCTION

Soil is a finite resource both in term of area and its capacity to produce the biomass i.e. productivity. Soil productivity is declining with advent of modern agro-technologies. This is because of declining or disturbed soil fertility under anthropogenic activities. We are continuously mining soil nutrients since decades and centuries while faring the soil. What ever we are adding as a fertilizer or manure may not be sufficient or suitable for propelling the dynamics of nutrients in the soil. This is particularly so in case of dynamics of micronutrients because they are in minute quantity and are indispensable for the crop plants. They are being made available to plant through their various fractions like water soluble, exchangeable, available, reducible, soluble and residual. What is the status of these micronutrients fractions in the soils of an entire landscape? Are they changing over a period of time? Are they being replenished or diminishing in a give set of agronomic package being followed collectively by the farmers of a particular region? These are the questions to be answered first before doing any thing to sustain the quality of soil resource which supports the life of all kind on this earth.

The availability of the micronutrients in soil is also influenced by the soil properties like soil pH, soil EC, content of organic matter, free lime, soil, moisture, proportion of clay and silt fractions, type of clay, concentrations of interacting ions, etc.

The micronutrients are present in soils mainly as their oxides, sulphides and silicates and are inherited from the soil-forming rocks and

mineral through transformation during various stages of soil development. The micronutrient content of soil is determined by the chemical composition of its parent material. The distribution of micronutrient minerals is not uniform in a soil and the spatial variation is very high. The natural sources of micronutrients in soil vary considerably from soil to soil and generalized picture is given in Table 1.1 for Indian soils. The total and available content of Cu, Mn, Zn and Fe vary considerably in different soils. Besides inorganic minerals, organic matter also contributes substantially to the total content of micronutrients in surface soils. Soil amendments and fertilizers add frequently to micronutrient pools in soil.

The micronutrients cations such as Cu, Mn, Zn and Fe, released during these transformation reactions are either adsorbed on soil colloids or may become a part of the secondary silicate minerals by the isomorphous substitution. Micronutrients are held tightly both in various inorganic and organic combinations and become very slowly available to crops. (Table 1.1)

Table 1.1. Major natural sources of Cu, Mn, Zn and Fe, their chemical forms and range of content in the surface soils.

Sr. No.	Micro nutrients	Minerals	Major forms in nature	Total content in surface soil (ppm)	Available content in surface oil (ppm)
1	Copper	Chalcocite (Cu ₂ S) Covellite (CuS) Cuprite (Cu ₂ O) Malachite [Cu ₂ (OH) ₂ CO ₃] Chrysocolla (CuSiO ₃ .2H ₂ O) Azurite [Cu ₃ (OH) ₂ C(O ₃) ₂]	Sulphides, oxides, hydroxy carbonates & silicates	1.8 to 960	Tr-32.0

2	Manganese	Pyrolusite (MnO ₂) Manganite (MnOOH) Rhodochrosite (MnCO ₃) Rhodonite (MnSiO ₃)	Oxides, carbonates and silicates	37 to 11,5000	0.60-164
3	Zinc	Sphalerite (ZnS) Smithsonite (ZnCO ₃) Hemimorphite [Zn ₄ (OH) ₂ Si ₂ O ₇ H ₂ O]	Sulphite, oxides, carbonates & silicates	7 to 1000	0.8-20.5
4	Iron	Hematite (Fe ₂ O ₃) Goethite (FeOOH) Magnetite (Fe ₃ O ₄) Pyrite (FeS ₂) Olivine [(My,Fe) ₂ SiO ₄]	Oxides, sulphides & silicates	4000 to 2,73,000	0.36-174

(Narayanasamy, 2002)

The physiological and bio-chemical functions of micronutrients are described below :

- Zinc, copper and manganese are involved in carbohydrates and protein metabolism through several enzymes systems. Zinc is also involved in the synthesis of some growth promoting hormones and in the reproductive process of many plants which are very vital for grain formation. The most important metalloenzymes in which Zn is associated are carbonic anhydrase, dehydrogenase, proteinases and peptidases.
- Iron - containing enzymes include cytochrome oxidase, catalase and peroxidase.
- Copper - containing enzymes include cyto-chrome oxidase, ascorbic acid oxidase and polyphenol oxidase.

- Manganese is a part of all decarboxylases and dehydrogenases of TCA cycle. Manganese is an essential element in photo system II where it participates in photolysis of water.

Micronutrient cations are usually held very strongly by the organic legends. Micronutrient cations exist in the soils in different pools. Viet (1962) postulated existence of five distinct pools of micronutrient cations in soil viz., (i) soil solution or water soluble, (ii) exchangeable, (iii) adsorbed, complexed and chelated, (iv) associated with secondary minerals and as insoluble metal oxides and hydroxides, and (v) associated with primary minerals. First three pools exist in a state of dynamic equilibrium and constitute the labile pool from which the plants draw micronutrients. Consequently, a number of sequential fraction procedures have been developed for studying the relative abundance of different fractions in the soils and their relative importance in supplying micronutrients to the growing crops.

The long term experiments are of immense value in assessing the sustainability of agricultural systems and practices. Our aim is to study the trend of the pools of micronutrients in long run. Considering future strategy of soil fertility and its management only achieved with scientific information generated via different pools of soil micronutrients like Cu, Mn, Zn and Fe over a periods of time. The study of these eminent pools of soil micronutrients is only possible with the inclusion of long term fertilizer experiment. The first of its kind in the world was started in the year 1843 at Rothamsted, England and in India establishment of long term manurial experiments dates back to 1885. In 1908 one more study was started at Pusa and in 1909 at Coimbatore. These and other long term experiments initiated during 1930's and 1940's in India revealed that for sustained crop production adequate P and K fertilization was

necessary along with nitrogen. In a long term experiment on intensive cropping (groundnut-wheat-sorghum fodder) under medium and high fertility levels in calcareous soils of Junagadh, the status of available Cu, Mn and Zn decreased to nearly half of the initial value after 12 years (Anon., 1992).

During three decades of research on micronutrients in Junagadh zone it has been recognized that there is a considerable variation in research information related to soil fertility evaluation and management practices of micronutrients. Most of our research information has largely emanated from short-term studies and is unable to answer critical questions about how the intrinsic properties of micronutrients resource in our soil are being changed by anthropogenic activities. Losses in the intrinsic value of micronutrient are, in fact, gradual and sometimes hidden. It is therefore not easy to recognize and understand the physical, chemical and biological processes leading to such micronutrient constraints in sustaining high productivity in major soil-cropping systems at sub-agro-ecological level. In view of the growing concern for sustainable management of micronutrient fertility of soils, research work on the following areas has become our priority.

- ❖ To study the status of micronutrient (Fe, Zn, Mn, Cu) fractions in calcareous Vertic Ustochrepts soils under AICRP-LTFE.
- ❖ To investigate the depletion of micronutrients fractions in the soils under investigation.
- ❖ Modeling the dynamics of micronutrient fractions in the AICRP-LTFE soils.

CHAPTER - II

REVIEW OF LITERATURE

A voluminous work has been reported about the fractionations of micronutrients (Viet, 1962). Our purpose here is to look for reports of the periodic monitoring of same soils on long term basis. This is particularly important when we want to appraise the changes in nutrient dynamics over a period of time. Scarce literature is available because it requires a long tradition of research project being handed over to the descendent coming in the same stream of work. The relevant available literature pertinent to the objectives of present investigation is reviewed and dealt suitably under the following heads.

- 2.1 Chemistry (adsorption and desorption) of copper, manganese, zinc and iron in soils.
- 2.2 Factor affecting the availability of copper, manganese, zinc and iron in soils.
- 2.3 Status of copper, manganese, zinc and iron.
- 2.4 Interactions of different micronutrient in soils.
- 2.5 Forms of copper, manganese, zinc and iron.
- 2.6 Depletion and increase of copper, manganese, zinc and iron under intensive cropping.
- 2.7 The micronutrient availabilities, forms and relationship with soil properties in LTFE's.

2.1 CHEMISTRY (ADSORPTION AND DESORPTION) OF COPPER, MANGANESE, ZINC AND IRON

COPPER: The total content of copper in soils is generally lower (20 mg kg⁻¹) than that in the material from which the soils are formed (Hodgson, 1963). This cation is held in soils principally on organic or inorganic surfaces or substituted as accessory constituents in common soil minerals. They are strongly held by the soil surface. But when this cation is present in divalent states in highly insoluble oxides and phosphates, they become much less amenable to leaching. This explains their low concentration during the formation of soils from rocks of the earth's crust.

ZINC: Hodgson (1963) presented a detailed review of the adsorption of micronutrients in soils. Since the hydrolysis constant of Zn²⁺ for the reaction $Zn^{2+} + H_2O \rightleftharpoons ZnOH + H$ is 10^{-9.7}, zinc showed to exist as an ionic species.

Available Zn decreases as soil pH increases. This decrease is due to increased adsorption by soil constituents. As soil pH is increased above approximately 5.5, Zn is adsorbed by hydrous oxides of Al, Fe and Mn. Udo *et al.* (1970) stated that when the added Zn²⁺ exceeded the adsorption maxima, the value of the Zn(OH)₂ ion concentration product in solution corresponded to the solubility of zinc hydroxide or carbonate, so long as soil carbonates were present. At lower amounts of adsorbed Zn²⁺ the Zn(OH)₂ product was about the hundred fold less indicating that the soils then retained Zn²⁺ about as strongly as zinc silicate and more strongly than zinc hydroxide or carbonate.

Shuman (1986) reported that soils high in clay or organic matter have a higher adsorption capacity and bonding energy for Zn than sandy

soils with low in organic matter. Thus Zn is held with lower bonding energy in light textured soils and hence is more mobile than in heavy texture soils. Similarly the data on desorption of the sorbed Zn indicated that weakly adsorbed or electrostatically bonded Zn was high in coarse textured soils, as observed by Prasad and Agarwal (1991).

IRON: The solubility of inorganic Fe in well coarse soils is controlled by the dissolution and precipitation of Fe³⁺ oxides. The concentration of Fe³⁺ is related to pH, declining from 10⁻⁸ to 10⁻²⁰ M as pH increased from 4 to 8 (Romheld and Marschner, 1986). High HCO₃ concentration decreased the availability of Fe in calcareous soils (Bloom and Inskeep, 1986).

The formation of soluble Fe complexes by naturally occurring chelating ligands may enhance the solubility of Fe. Humic and fulvic ligands form the most stable complexes with Fe of all the transition metals and their effectiveness increased with increasing pH, due to enhanced dispersion and ionization of the surface ligands (Stevenson and Ardakani, 1972).

Redox potential strongly influences the activity of Fe II in equilibrium with a solid Fe III oxide depending on the thermodynamic stability of the latter (Schwertmann, 1991).

MANGANESE: The activity of Mn in solution is largely dominated by pH and redox potential (Leeper, 1947). High soil pH and Eh favour the insoluble oxide forms of Mn, whereas low pH levels and redox potentials favour the divalent water soluble species (Sparrow and Uren, 1987). Some forms of organic matter such as humic acid, may fix Mn in unavailable forms (Pavanasasivam, 1973). Mc Bride (1982) reported that

exchangeability Mn^{2+} from organic solids was strongly pH dependent. It was induced by increasing pH.

Under reducing conditions both Fe^{2+} and Mn^{2+} are known to increase in solubility to the point where they become adsorbed as exchangeable ions (Mandal, 1961).

Curtin *et al.* (1980) reported that Mn adsorption maxima established from the linear parts of the conventional Langmuir isotherms, were correlated with the cation exchange capacity of the soils but not with values of organic matter content, $CaCO_3$ equivalent as free Fe. A desorption study confirm that part of the adsorbed Mn was held tightly.

Campbell and Nable (1988) reported that when Mn is in Mn (II) oxidation state, there is one unpaired electron in each of the five orbitals i.e. the stable, energetically favoured d^5 configuration is attained. Two consequences of this configuration are (i) Mn is relatively weak ligand and (ii) Mn has the potential to form compounds in several oxidation states.

2.2 FACTORS AFFECTING ON THE AVAILABILITY OF COPPER, MANGANESE, ZINC AND IRON

Total content of nutrient in soil is not only the criterion of its availability to plants, but also other factors like pH of the soils, the content of organic matter, the nature and amount of clay, content of calcium carbonate, soil moisture, presence of heavy metallic ions, cropping pattern and fertilizer application, etc. govern the nutrient supplying capacity of the soil.

COPPER

Soil Reaction : Several workers have shown that copper availability increases with increase in soil acidity (Thuo *et al.*, 1994; Saha *et al.*, 1999 and Gopichand *et al.*, 1985), while few reports indicate the non-existence of any relationship (Rai *et al.*, 1972). They observed a significant negative relationship between pH and amount of available copper in soils of Gujarat, Madhya Pradesh and Punjab, respectively. Gupta *et al.* (1980) also observed the same relationship between Cu and pH of the soil.

Soil pH is major determinant of the fractions in which a particular micronutrient ion is likely to exist. Solubility of these ions is depicted by the following relationships (Lindsay, 1979).

$$(\text{Zn}^{2+}) = 10^{5.8} (\text{H}^+)^2$$

$$(\text{Cu}^{2+}) = 10^{2.8} (\text{H}^+)^2$$

$$(\text{Mn}^{2+}) = 10^{\times} (\text{H}^+)^2$$

$$(\text{Fe}^{2+}) = 10^{2.7} (\text{H}^+)^2$$

The relationship implies that the solubility of divalent and trivalent cations decreases 100 and 1000 fold with a unit increase in pH. Similarly, the solubility of divalent and trivalent anions increases 100 and 1000 fold with a unit decrease in pH.

A large body of literature indicates that micronutrient metals become less plant available at higher pH values (Gupta *et al.*, 1980; Patel and Dangarwala, 1984; Sakal *et al.*, 1985 and Prasad and Sakal, 1991). Micronutrient distribution as a bio-available fraction is mobilized by drop in pH. Addition of CaCO_3 to acid soils decreases the reactivity or extractability of added heavy metals through the increase in pH (Ma and Uren, 1998).

Organic Matter : Kanwar (1976) found that fixation of copper in soils was associated with the formation of organo-metallic complexes. Mandal and Jha (1970) observed decrease in the exchangeable copper content in soil with the application of organic manures. Kavimandan *et al.* (1964) reported that the available copper content was high in soils enriched with organic matter.

Calcium Carbonate : The existence of free calcium carbonate in soil would adversely affect the availability of copper (Lal, 1968). The studies of Grewal *et al.* (1969) and Mandal and Jha (1970) supported the above findings, the reason attributed to the formation of insoluble compound of copper carbonates.

Soil Texture : Copper deficiency usually occurs in sandy and gravelly soils and its availability increases with an increase in the finer fraction of the soil (Mandal and Jha, 1970). Research work has shown that there appears to be a positive but statistically non-significant relationship between available copper content on one hand and the fineness of soil texture on the other (Mehta *et al.*, 1964 and Mishra *et al.*, 1969). Sangwan and Singh (1993) reported that clay and cation exchange capacity of soil controlled and dominated the availability of Cu in soil.

MANGANESE

Soil Reaction : Increase in pH decreased the availability of Mn (Biswas, 1951 and Gupta *et al.*, 1980). Calcareous soils were high in pH and low in active Mn (Zende and Khonde, 1958; Bhumda and Dhingra, 1964). Likewise, significant negative relationships between pH and available Mn have been reported by Badhe *et al.* (1971) and Patel *et al.* (1972) in Gujarat soils.

Wang and Zhu (1990) reported that the distribution of the soils deficient in Mn is quite consistent with that of calcareous soils, which readily adsorbed Mn. They observed negative relationship with pH value of the soils. Biswas and Guwande (1964) stated that exchangeable manganese was more related to pH than clay content.

Similar results of negative relationship between available Mn and pH value of the soils were reported elsewhere (Shinde *et al.*, 1979; Gupta *et al.*, 1980; Patel and Dangarwala, 1984; Sangwan and Singh, 1993).

Organic Matter : The concentration of exchangeable manganese was more at the surface than in the lower horizons (Biswas, 1953; Randhawa *et al.*, 1961; Sharma and Shinde, 1968 and Grewal *et al.*, 1969). This is because the surface soils contain maximum organic matter. Takkar *et al.* (1989) studied different forms of manganese from calcareous surface soils of Punjab and Haryana and reported that free active forms of manganese did not depend on organic carbon content of these soils. But Badhe and Naphade (1970) reported a significant relationship between organic carbon and available manganese. Similarly, Mehta and Patel (1967) reported a positive significant correlation between water soluble plus exchangeable manganese forms and organic matter content of the soil.

Calcium Carbonate : Various authors have shown that non-calcareous soils have higher exchangeable manganese than calcareous soils indicating negative relationship with CaCO_3 (Sharma and Matirumani, 1969; Shinde *et al.*, 1979; Sakal *et al.*, 1985; Wang and Zhu, 1990; Sangwan and Singh, 1993). Likewise, Shukla *et al.* (1975) observed a negative relationship between exchangeable Mn and CaCO_3 content in soil. Takkar *et al.* (1989) noted decrease in reducible Mn with increased quantity of CaCO_3 in calcareous soils.

However, Malewar and Randhawa (1978) reported that although non-calcareous soils were higher in total Mn, the calcareous soils were higher in available Mn than non-calcareous soils. Similarly, positive relationship between CaCO₃ and available Mn was reported by Gupta *et al.* (1980).

Soil Texture : Hoon and Dhawan (1943) noted that an increase in the silt and clay fraction was accompanied by a slight increase in the manganese content. Baser and Saxena (1970) observed that as the texture of the soil changed from sandy to clayey, the average value of exchangeable manganese decreased. Yadva and Kaltra (1964) noted that exchangeable manganese increased progressively with an increase in clay content upto 40 per cent.

ZINC

Soil Reaction : Zinc deficiency occurs usually in soils of pH more than 7.5. As the pH of the soil increases the availability of zinc decreases. The deficiency markedly increased from 21 to 32 per cent as the soil pH increased from less than 8.0 to greater than 8.5 (Dangarwala *et al.*, 1983). Patel and Dangarwala (1984) and Sakal *et al.* (1985) reported negative correlation of available Zn with pH. Epstein and Stout (1951) found that zinc availability increased with increase in H⁺ concentration. Zinc deficiency was predominantly found in pH ranging from 7.5 to 8.5.

Soil EC : Due to increasing concentration of soluble salts which is the measure of EC (mmhos/cm) was increased and consequently availability of Zn was also increased, as reported by Dangarwala *et al.* (1983).

Organic Matter : The presence of organic matter may promote the availability of Zn probably by complexing the substances, which fix up zinc. While working with Gujarat soils, Nair and Mehta (1959) obtained

a positive significant relationship ($r = 0.385$) between organic matter and acid soluble zinc. Similarly, positive correlation between available Zn and organic carbon was reported by number of workers (Malewar and Randhawa, 1978; Gupta *et al.*, 1980; Dangarwala *et al.*, 1983; Sakal *et al.*, 1985 and Maji *et al.*, 1993). In most of the soils, organic matter improves zinc availability.

Calcium Carbonate : Zinc deficiencies are more common in calcareous soils. Gupta and Singh (1972) reported a negative correlation between calcium carbonate and available zinc in Indian soils. Nair and Mehta (1959) observed in a number of instances, that the availability of zinc decreased as the lime content increased, but in some instances this relationship did not hold true.

A highly significant positive correlation was observed between available zinc and CaCO_3 (Malewar and Randhawa, 1977). They reported that although non-calcareous soils were higher in total Zn, calcareous soils were higher in available Zn than non calcareous soil. The Zn deficiency is more common in calcareous soils (Hodgson *et al.*, 1966) as calcium carbonate might act as a strong absorbent of Zn (Leeper, 1952). According to Kanwar and Chopra (1976), it may be due to the presence of a large excess of Ca as compared to Zn which compete with strongly complexed Zn.

Negative relationship between available Zn and CaCO_3 was reported by Sakal *et al.* (1985). Similar results were also found by Gupta and Singh (1972) and Patel and Dangarwala (1984).

Soil Texture : Zinc availability was found to vary as per the textures of soils (Nair and Mehta, 1959). Kalyansundaram and Mehta (1970) observed that Zn fixation increased with increase in clay content. Meelu

and Randhawa (1973) reported that the Zn content of different fractions generally varied in the order of coarse sand < fine sand < silt < clay. Seshachalam and Mehta (1976) observed higher availability of applied Zn in clayey soils as compared to loamy sand.

IRON

Soil Reaction : There are abundant evidences about the negative relationship between available Fe and soil pH (Agarwal *et al.*, 1964; Bansal *et al.*, 1969; Shukla and Singh, 1973; Parakhia, 1979; Shinde *et al.*, 1979; Patel and Dangarwala, 1984 and Sakal *et al.*, 1985).

Takkar *et al.* (1969) working with calcareous soils found that free iron content did not depend on soil reaction, however, a close relationship ($r=+0.794$) was observed between exchangeable and extractable iron. Bhumbra (1965) reported that Fe^{++} content of a soil increased with decreasing pH. Available Fe in calcareous soils has significant negative correlation with pH (Prasad and Sakal, 1991). Similarly, in calcareous soils of Junagadh district, available Fe was negatively related with pH (Parakhia, 1979).

Organic Matter : The content of available and potentially available Fe forms in most soils has been found to depend on organic matter content (Kanwar and Randhawa, 1974). Takkar *et al.* (1969) reported that the exchangeable, extractable and free iron contents of soils depended largely on organic matter content in calcareous soils of Punjab.

The positive correlation between available Fe and organic carbon content was observed by Sakal *et al.* (1985); Prasad and Sakal (1991) and Maji *et al.* (1993). However, Patel and Dangarwala (1984) noted significant positive relationships in case of available Fe with organic

carbon. Available Fe was positively correlated with organic carbon and clay content (Parakhia, 1979).

Calcium Carbonate : Distribution of Fe was influenced by CaCO₃ content (Sangwan and Singh, 1993). With the increase in calcium carbonate, the available Fe content was found to decrease in shallow medium black calcareous soils of north and south Saurashtra, where the 17 to 22 per cent soils were deficient in available Fe as compared to 3 to 6 per cent in other agro-climatic zone. In calcareous soils of Junagadh district, available Fe was negatively correlated with CaCO₃ (Parakhia, 1979). Similar results were also reported by Patel and Dangarwala (1984) for soils of Gujarat and by Shinde *et al.* (1979) and Prasad and Sakal (1991).

Rai *et al.* (1972) observed a negative correlation between available iron and calcium carbonate in shallow black soils of Madhya Pradesh. But , Shukla and Gupta (1975) did not find any correlation between available Fe and CaCO₃ content in soils. However, stepwise regression analysis indicates that the availability of Fe is dominantly controlled by pH (Maji *et al.*, 1993). Takkar *et al.* (1969) observed significant positive correlations between exchangeable Fe and CaCO₃ and between extractable Fe and CaCO₃.

Soil Texture : Singh (1964) and Gangawar *et al.* (1971) reported that fine-textured soils contained more available Fe than coarse textured ones. Parakhia (1979) reported positive relationship with clay content for calcareous soils of Junagadh district of Gujarat.

Zwydak (2001) found that total iron contents correlated positively with clay fraction, soil reaction, the basic cation content of the mountain soils at Poland.

2.3 STATUS OF COPPER, MANGANESE, ZINC AND IRON

Bobrzecka (1988) studied the fertilizing effect (5-10-20 kg ha⁻¹) of copper in the cultivation of field crops and observed that Cu fertilization increased the content of available copper in soil.

Maciejewska (1987) studied for three year in pot experiment the influence of soil fertilization with superphosphate applied in combinations with and without lime on the content of available copper. It was found that phosphorus fertilization did not affect content of the available form of copper in the unlimed as well as in the limed soil.

Zn - status

Martin and Lara (1991) reported that under intensive cropping Zn content in the sand, silt and clay fractions tended to fall. They also stated that Zn levels ranged from 15.65 to 32.56 ppm, which although adequate from the standpoint of plant nutrition was insufficient to meet the nutritional requirements of ruminants.

Fe - status

Gao-Xianbiago *et al.* (1990) analysed 5088 soil samples collected from 12 regions in Shandong province for iron status of DTPA available Fe and categorized the soils. The available Fe ranged from 1.27 ppm to 162.00 ppm, with an average of 12.62 ppm, and 5.41 per cent of total samples contain lower than 5 ppm Fe. Among the 12 regions of the province, 7 get <10 ppm and 2 get > 29 ppm in mean value of available Fe. The contents of available Fe in brown earth and paddy soil were higher, with averages of 20.9 ppm and 43.9 ppm, respectively. The contents in drab and fluvio-genic soils were medium, with averages of 9.3 ppm and 11.3 ppm, and in black Shajiang soils it was lower, with an average of 7.5 ppm. The flood plains in north and west Shandong were

deficient in Fe and the hilly regions in middle south Shandong were partially deficient, and hilly region in east Shandong were sufficient in available Fe content.

Total Fe and Mn Status

Wang and Zhu (1990) determined DTPA extractable and total Fe and Mn in four type soils of the Nigerian Savanna. The DTPA extractable and total Fe in the soils ranged from 1.1 to 26.7 mg kg⁻¹ and 4.50 to 10.50 per cent with corresponding means of 9.5 mg kg⁻¹ and 7.33 per cent, while the corresponding forms of Mn ranged from 0.3 to 114.7 (mean 24.3) mg kg⁻¹ and 34 to 1010 (mean 346) mg kg⁻¹, respectively. The soils were high in total Fe and Mn and sufficient in the available forms (DTPA extractable forms). The total Fe and Mn were neither related to the available forms nor to soil properties tested. The available forms were however, related with one another and largely associated with organic matter.

Perer *et al.* (1994) studied availability of Fe and Mn of most of the agricultural zones of the island of Tenerite (Canary Islands). The mean Fe content was 110.4 mg kg⁻¹, about a third lower than that reported by FAO for other regions. About 10.64 per cent of the soils presented Fe values below the considered critical level (30 mg kg⁻¹). The mean DTPA extractable Mn content was 67.1 mg kg⁻¹, almost twice that reported at international level by FAO. Only 0.28 per cent of the soils showed values below 2 mg kg⁻¹ and 2.52 per cent of these were in the range of 2.5 mg kg⁻¹, respectively, considered as deficient and marginal levels. The study by zones (north and south) shows that the northern soils presented mean Fe and Mn contents sensibly higher than the southern ones.

Status of Cu, Mn and Fe

Tunio (2001) determined the micronutrient status of the soils block B and C at Latif Experimental Farm, Sindh Agricultural University, Tandojum. Fifty composite soil samples were collected from each block at the depth 0-15 cm during the year 1998-99. Soil samples were analysed for copper, manganese and iron along with some physico-chemical properties. Available copper, manganese and iron content of soils of both noted between organic matter and Mn and Zn ($r=0.57^{**}$ and 0.28^* , respectively). None of the micronutrients under the study found to correlate significantly with clay + silt per cent.

Bayrakli and Gezgin (1991) found out DTPA extractable Cu, Mn, Zn and Fe content of the soils in Konga-Eregli and Cumra area (Turkey), and it was found that the amount of Cu, Mn, Zn and Fe extracted with DTPA, fell between 0.20-2.20 ppm, 0.80-6.80 ppm, 0.36-0.98 ppm and 1.80-5.60 ppm, respectively.

Reddy and Reddy (1998) analysed sandy loam soils of Hyderabad for effect of organic manures and nitrogen levels on soil available nutrient status in maize-soybean cropping system. They found that soils had content of Cu-0.58, Mn-9.20, Zn-0.91 and Fe-6.96 mg kg⁻¹.

2.4 INTERACTIONS OF DIFFERENT MICRONUTRIENTS IN SOILS

Interaction of Zinc and Iron in Soils

Several studies of interaction amongst micronutrients have been made either through incubation studies or by growing plants in pots or in field conditions. In general, soil studies had indicated a negative interaction between Zn-Fe, Zn-Cu, Zn-P, Fe-Mn, Cu-P, Fe-Cu and Cu-Mo and positive between S-Fe, P-Mn and P-Mo. The interaction studies with

plants indicated a negative interaction between Zn-P, Zn-Fe, Zn-Cu, Fe-Mn, Cu-Mo and positive between S-Fe and P-Mo (Kalyansundaram and Mehta, 1970; Hulagur *et al.*, 1975; Dangarwala *et al.*, 1983; Sutaria and Patel, 1987 and Golakiya *et al.*, 1990).

Widespread zinc deficiency has been reported in alkaline calcareous soils (Takkar *et al.*, 1989). Continuous application of ZnSO₄ to combat zinc deficiency is likely to affect the absorption of iron and vice versa. Zinc-Iron interaction is also expected to occur in flooded rice where the concentration of Zn decreases (Gangwar and Mann, 1972; Sadana and Takkar, 1985) and that of Fe increases (Pathak *et al.*, 1975; Mishra and Pande, 1976) consequently affecting plant-growth.

Iron - Manganese Ratio

Sommers and Shive (1992) reported that the ratio between iron and manganese in nutrient medium should be between 1.5 to 2.5. If the ratio became higher than 2.5, iron would be toxic and cause manganese deficiency. When the ratio is less than 1.5, manganese would be toxic and iron will be deficient.

2.5 FORMS OF COPPER, MANGANESE, ZINC AND IRON

Micronutrients fraction of soil has been viewed as a means of assessing the dynamics and sustainability of its bioavailable forms. The availability of nutrients is determined by the dynamic equilibria involving these different forms rather than its total content in soil and positively or negatively correlated with different physical and chemical properties of soil. Work carried out on different micronutrients fractions is reviewed here under.

Viets (1962) suggested that micronutrient elements are found in five chemical pools : (i) water soluble, (ii) exchangeable, (iii) adsorbed,

chelated or complexed, (iv) secondary clay minerals and metal oxides, and (v) primary minerals.

Forms of Copper

McLaren and Crawford (1973) partitioned copper into (i) soil solution and exchangeable, (ii) copper weakly bound to specific sites, (iii) organically bound copper, (iv) copper occluded by oxide material, (v) residual copper mainly in clay lattice structures. They concluded that the amount of copper available to plants (soil solution + exchangeable) was controlled by equilibria involving specifically adsorbed forms (2.5% AcOH) and organically bound fraction.

Copper Fractions

Cumakov (1991 a) worked on chemical methods for fraction of micronutrients in soils of Slovakia, CSFR, specifically copper fractions. This method facilitates determination of seven fractions of copper in soil with soluble copper (WSC), exchangeable copper (EC), copper bound to inorganic (IC) and organic soil fraction (OC), occluded copper (OCCLUDED C), residual copper (RC) and total copper (TC). The method was verified on a set of soil samples from the most typical soils of Slovakia. The respective results of minimal, maximal and mean content of copper fraction recurred : WSC - 0.04, 0.22, 0.12; EC - 0.29, 0.50, 0.38; IC - 0.36, 0.89, 0.51; OC - 5.0, 24.6, 13.4; OCCLUDED C - 2.2, 17.7, 9.9; RC - 18.0, 41.0, 29.3; TC - 36.18, 69.44; 53.66.

Submergence caused a gradual decrease in all the forms of copper in wet land rice soils of North-East (Singh and Nongkynrich, 1999). On an average 1.2, 11.2, 12.9, 9.8 and 8.3 per cent of total Cu resided in exchangeable, weakly adsorbed, moderately adsorbed, strongly adsorbed and organically complexed forms, respectively. Singh and

Nongkyrih (1999) reported that applied Cu was transformed to the latter five forms following their relative order of pre-ponderance in native soils and constituted, on average 3.0, 23.0, 15.2, 11.1 and 16.6 per cent, respectively, of the in these fractions in that order.

In the soils under submergence for 45 days, organically complexed (OC) and crystalline sesquioxides (CRYOX) were formed. These Cu fractions recorded decrease with concomitant rise in water soluble plus exchangeable (WSEx), amorphous sesquioxides bound (AMOX) and residual (RESID) fractions, the mean magnitude of decrease being 36.4 and 47.1 per cent of their initial content in OC and CRYOX and that of increase being 15.0, 23.3 and 37.0 per cent in WSEx, AMOX and RESID fractions, respectively, in alfisols of West Bengal (Saha and Mandal, 1998). The increase in WSEx-Cu was dependent on initial pH of the soils, whereas the decrease in CRYOX-Cu was controlled by initial crystalline Fe-oxide content. The transformation of Cu into RESID fraction was controlled by the Cu released from CRYOX fraction and the changes in soil pH upon submergence. In another study by the same group, copper was mobilized from water soluble plus exchangeable (WSEx), organically complexed (OC), and crystalline iron (Fe) oxides (RYOX) bound fractions to amorphous iron oxides (AMOX) and residual (RESID) fractions, the rate of mobilization being maximum from CRYOX and to RESID fraction during initial 15 days period (Saha *et al.*, 2000a). More than 85 per cent of the applied Cu was distributed in water soluble plus exchangeable (WSEx), organically complexed (OC), and amorphous iron oxides bound (AMOX) fractions at the beginning of incubation (Saha *et al.*, 2000b).

Copper is associated with organic matter additions it changes a redistribution of Cu among fractions, especially the organic fraction of Cu. Elsokkary and Lag (1978) reported that the organic fraction and all

the oxide fraction Cu were related to soil organic matter content. An increase in the organic Cu and a decrease in the oxide fraction with organic matter additions, indicating a possible increase in bio-availability.

Significant interaction was observed between lime and organic C treatment on the transformation of co-fractions in field cropped soil. In presence of added lime, added organic C mobilized Cu into potentially plant available organically complexed and amorphous Fe oxides fraction from relatively inert fractions (Saha *et al.*, 1999). Organic matter, in the absence of added lime, immobilized Cu from these active fractions into inert residual fraction. Organic matter application retarded Cu transformation from OC into RESID fraction and increased its content AMOX fraction (Saha *et al.*, 2000a). It also decreased WSEx Cu markedly.

Forms of Manganese

Manganese has been found to exist in soils as water soluble, exchangeable and as higher oxides of manganese. These forms of manganese exist in equilibrium in soils.

Available manganese usually exists as water soluble, exchangeable, easily reducible and active forms of manganese. The first two represent the bivalent forms of manganese and are called readily available forms. The bivalent manganese may be present either in soil solution or as exchangeable ion or in a non-exchangeable form. Reducible manganese represents those higher oxides which can be reduced by easily oxidizable organic substances i.e. quinon or hydroquinone. Active manganese represents a sum total of water soluble, exchangeable and reducible forms of manganese. Miller *et al.*

(1986) suggested partitioning of total heavy metal content into (i) water soluble, (ii) exchangeable, (iii) specifically adsorbed, (iv) acid soluble, (v) Mn-oxide occluded, (vi) organic matter occluded, (vii) amorphous iron-oxide occluded, (viii) crystalline iron oxide occluded and (ix) residual fraction.

According to Joshi and Dhir (1982) DTPA - extractable Mn ranged 3.3 - 7.4 ppm and varied little with depth. Reducible and active Mn were correlated negatively with pH and CaCO_3 . Total Mn was correlated positively with HCl solution, reducible and active Mn, reducible with active Mn, and DTPA extractable with reducible and active Mn. Rewatkar and Dakhare (1980) noted that total Mn content ranged 300-2050 ppm in profile samples and showed positive correlation with available forms of Mn. Active Mn ranged 10-63, water soluble Mn 0.5-1.75, exchangeable Mn 1.5-28.5, and easily reducible Mn 5.5-58.8 ppm in profile samples. Total and active form of Mn did not show a definite trend of distribution within soil profile, but exchangeable Mn tended to increase and reducible form to decrease with depth.

Mehra and Baser (1982) observed that water soluble Mn ranged from traces to 3.82 ppm and exchangeable Mn averaged 2.07 ppm in saline sodic soils. Reducible Mn ranged 22-109 ppm and contributed the major part of the active Mn. The ratio of active to total Mn varied from 3 to 25 per cent. Water soluble and exchangeable Mn content showed a highly significant negative relationship with pH and total carbonate; and a positive correlation with clay content of the soil. The amount of manganese in this form increased markedly after water logging of soils for one month, and showed a strong positive correlation with reducible Mn content (Mitra and Mandal, 1983). Gill (1990) reported that water soluble, exchangeable and DTPA extractable fractions showed an

increase, whereas reducible and HNO₃ soluble fractions (trivalent oxides of Mn) showed decrease in concentration with submergence. The increase in water soluble and exchangeable fractions on submerging a soil may be due to enhanced solubility of manganese compounds with increase in ionic strength of the soil solution during submergence and also some of the easily reducible manganese in submerged soil.

Zhang and Zhang (1984) reported that in calcareous soils > 35 days after application of MnSO₄ about 70 per cent of applied Mn was transformed into easily reducible Mn, yet little applied Mn was transformed into chelated or phosphate soluble Mn. With increasing rates of Mn application, the amount of exchangeable Mn decreased significantly. This phenomenon, perhaps, could be attributed to the strong adsorption of newly-formed Mn oxides to soil Mn of exchangeable form. Exchangeable and chelated Mn was very unstable in soils under plants. Easily reducible Mn, however, did not change very much with time and was the only form that was related with Mn uptake by plants. Thus, in calcareous soils both chelated and exchangeable Mn are of little importance in the nutrient status of soil, and easily reducible Mn markedly affects the soil Mn supply for plants.

The water soluble Mn fraction constituted a very small fraction of total Mn. The exchangeable Mn fraction of total Mn accounted for 13 per cent. Reducible Mn fraction constituted 30.4 per cent of the total Mn as reported by Sharma *et al.* (1997) for Entisols.

Mn - Fraction - Status

Cumakov, A. (1991) determined the following soil fractions of manganese, water soluble (WSM), exchangeable (EM), reducible

(REDM), active (AM), labile (LM), residual, (RESM) and total (TM) manganese and the minimal, maximal and mean content of manganese fractions : WSM -0.12, 2.55, 0.83; EM - 0.50, 18.0, 6.52; REDM - 88, 330, 210; AM - 100, 333, 210; LM - 170, 560, 384; RESM - 25.5, 5.18, 37.9; TM - 300, 858, 610.

Forms of Zinc

Soil zinc in ten soils belonging to alluvial, red and laterite soil groups of India, was fractionated and the contribution of various soil Zn fractions to plant uptake was determined using maize (*Zea mays*) and moong (*Phaseolus aureus* Roxb) as test crops (Iyengar and Deb, 1977). They reported that much of the native soil Zn was present in the residual mineral fraction which contributed very little to plant uptake. However, complexed, water soluble, exchangeable and organically bound fractions were the most important fractions contributing to plant uptake. Less than 5 per cent of soil Zn was present in these fractions. Only 12.6 to 34.6 per cent of applied Zn was found in the water soluble, exchangeable and complexed fractions and they remained available to plants. About 20 to 60 per cent of applied Zn was recoverable by complexing agents like dithizone and DTPA.

Prasad *et al.* (1991) reported that zinc in old alluvial soils of south Bihar were fractionated for different forms viz., water soluble plus exchangeable, complexed, organically bound, carbonate and amorphous oxides bound, crystalline oxides bound and residual which constituted on an average about 0.33, 0.90, 0.48, 2.47, 1.10 and 9.47 per cent, respectively, of the total zinc content of soil. Most of the Zn fractions were correlated negatively and significantly with pH and positively and significantly with organic carbon, CEC, sesquioxides and clay content of the soil. Mandal and Mandal (1986) studied that more than 90 per cent of

the total zinc occurred in the relatively inactive, clay lattice bound form and that a small fraction, viz., 0.26, 0.74, 1.58 and 0.17 per cent of the total occurred as water soluble and exchangeable, organic complexed, amorphous sesquioxide, and crystalline sesquioxide bound forms. Water logging caused an increase in the organically complexed and amorphous sesquioxide bound forms of native soil zinc with a concomitant decrease in the content of the other forms. The path co-efficient analysis revealed that organically complexed zinc played the most important role in zinc nutrition of low land rice. Edward Raja and Iyenger (1986) reported that applied Zn accumulated in the residual fraction in most of soils. The complexed Zn fraction alone contributed to as much as 99 per cent of the variations in Zn uptake of tomato.

A green house experiment was conducted by Prasad *et al.* (1995) to study transformation and availability of applied zinc in calcareous soil treated with zinc sulphate and zinc fulvate (Zn-FA). From this study, with the help of path co-efficient step down regression analysis they showed that complexed Zn is the major source of the zinc availability to maize in calcareous soils treated with Zn-FA and HCl extractable Zn and CBD-extractable Zn are important in soil treated with H₂SO₄. Simultaneously the availability of Zn from all chemical pools in soils, directly and indirectly, has been decreased through strong bonding with stable organic complexes.

Prasad and Sakal (1988) studied the distribution of different chemical pools of Zn in 25 calcareous soils of north Bihar. Water soluble, exchangeable, complexed, organically bound, occluded and residual Zn fractions constituted on an average 0.03, 0.5, 1.9, 1.3, 1.6 and 94.6 per cent, respectively, of the total Zn content of soil. In general, the pH, EC, free CaCO₃, active CaCO₃ and HCO₃⁻ showed negative correlations with

different pools of Zn in soil, whereas organic carbon, clay and Fe₂O₃ showed positive relationship. The significant and positive correlation amongst different pools of soil Zn, point to the existence of a dynamic equilibrium among the various forms of soil Zn.

Sims and Patrick (1978) found that the exchangeable and organic soil fractions contained greater amounts of Zn at low EC and pH levels than at high levels, whereas the amounts of Zn in the water soluble and Mn and Fe-oxide fractions were greater in high EC and pH levels. Murthy (1982) reported that plant available zinc is controlled by equilibria, involving zinc in soluble organic complexes, exchangeable and amorphous iron and aluminium oxides ($r^2 = 0.91$).

Iyengar *et al.* (1981) reported that soil pH and Zn fractions of total Zn viz., water soluble plus exchangeable specifically adsorbed, organically bound, Mn oxide bound, Al and Fe oxide bound and residual forms, accounted for 94 per cent of the variability in Zn uptake by corn plants. Similarly, Randhawa and Singh (1995) reported that different Zn fractions of soil were correlated amongst themselves signifying the dynamic nature of the equilibrium existing between them. The dry matter yield and maize plants increased with an increase in the DTPA-extractable Zn content of the soils. It was further confirmed by the existence of a significant positive correlation ($r=0.967^{**}$) between these two parameters. The Zn concentration ($r=0.545^{**}$) and its uptake ($r=0.524^{**}$) by maize plants were also positively and significantly correlated with DTPA extractable Zn. They further noted that exchangeable, weakly adsorbed and moderately adsorbed Zn contribute to the pool of available Zn and thus play a significant role in the nutrition of maize as these fractions were significantly and positively correlated with the dry matter yield, Zn content and its uptake by maize.

Torres – Martin and Gallardo – Lara (1991) observed that initial value of exchangeable Zn were low in both calcareous soils but rise steadily under the influence of successive cropping. Cultivation also led to significant short and medium term increase in Zn associated with the organic matter fraction, while in contrast showing a general tendency to reduce Zn associated with Fe oxides.

Zn Fraction and Ratio

Chaudhary *et al.* (1997) studied the fractionation of zinc in different types of New Zealand soils. The total soil zinc concentration ranged from 38.1 to 113.8 mg kg⁻¹. Although the proportions of zinc found in individual fractions varied between soils, on an average approximately 3 per cent occurred as exchangeable zinc, 5 per cent as organic bound zinc, 9, 18, 24 per cent was associated with manganese, amorphous iron crystalline iron oxides, respectively, and 40 per cent was in the residual fraction. The extractable zinc was inversely related to soil pH. The DTPA extractable zinc was correlated strongly with exchangeable and organically bound fractions.

Yasrebi *et al.* (1994) analysed different forms of zinc from 20 highly calcareous soils of Iran. The forms determined were exchangeable (ExZn), sorbed (SRZn), organic (ORZn), carbonate (CRZn), residual (RSZn) and sum of forms (SMZn). The native sum of forms ranged from 32.4 to 60.7 mg kg⁻¹ with a mean of 49.9 mg kg⁻¹. Order of concentration of different forms of Zn in the soils was determined to be in the following sequence : RSZn >>> CRZn > SRZn>ExZn>ORZn. The concentration of native ExZn + SRZn + ORZn forms constituted less than 5 per cent of SMZn, while concentration of CRZn alone ranged from 4.37 to 16.05 per cent with a mean of 8.36 per cent. Regression equations relating different

Zn form to soil physical and chemical properties indicated that Zn forms are significantly influenced by soil properties.

In wet land rice soils of north-east 1.12 to 2.73, 2.17 to 3.93, 3.08 to 5.31, 4.07 to 6.64, 12.30 to 19.50 and 65.5 to 76.6 per cent of total zinc remained in water soluble plus exchangeable, organically complexed, manganese oxides, amorphous sesquioxides, crystalline sesquioxides, and residual forms, respectively, under prolonged submergence. The 4.18, 23.08, 19.64, 18.83 and 19.56 per cent, respectively, of the applied zinc was traced in the exchangeable, organically complexed, manganese oxides, amorphous sesquioxides, and crystalline sesquioxides fractions. (Singh *et al.*, 1999)

Zinc Forms

Very limited information is available regarding the distribution of different forms of Zn in Indian soils. Sarkar and Deb (1985) observed that water soluble, exchangeable and organic complexed Zn which constituted hardly 5 per cent of the total Zn content in soil, accounted for variability in plant available Zn to a great extent. They further emphasized the importance of organic complex form of soil Zn in nutrition of plants.

Studies on distribution of different chemical forms of Zn in thirty soils of Assam showed a wide variation in content as reported by Biswapati *et al.* (1986). The total Zn ranged from 34.0 to 135.0 ppm with a mean of 88.4 ppm. The water soluble plus exchangeable, organic complexes, DTPA extractable, amorphous sesquioxide and crystalline sesquioxide bound forms of Zn constituted on an average about 0.7, 2.0, 3.2, 3.8 and 1.2 per cent, respectively, of the total content. The water soluble plus exchangeable, DTPA extractable and amorphous

sesquioxide bound Zn content showed significant negative correlation with pH of soil. The organically complexed and crystalline sesquioxide bound Zn showed significant positive correlation with organic carbon content of soil.

The organic materials besides supplying micronutrients in readily available forms to plants, they also help to establish equilibrium among different pools of soil Zn. The Zn exists in different fractions i.e. water soluble plus exchangeable, organically bound Zn, occluded - Zn and residual - Zn in soil as reported by Prasad *et al.* (1990).

Distribution of various fraction of soil zinc in alluvial soils of Haryana and Delhi was studied by Shinghal and Rattan (1995). Fraction of Zn in soil samples showed that zinc in water soluble and exchangeable pools was virtually non-existent. The residual zinc fraction constituted higher percentage of total zinc fraction.

Studies on distribution of various fractions of soil zinc in laterite soils of Orissa were conducted by Pal *et al.* (1997). Total zinc which ranged from 157 to 237 ppm was fractionated into water soluble plus exchangeable, organic complexed, amorphous sesquioxide, crystalline sesquioxide and residual zinc. The last fraction constituted higher percentage (94.0%) of the total zinc. Correlation study indicated that these fractions were in a state of dynamic equilibrium and were influenced by clay, organic carbon, CEC and free Fe₂O₃ content.

Gowrisankar and Murrigappan (1998) studied the distribution of different forms of Zn and its relationship with soil parameters affecting Zn availability in soils of Tamil Nadu. They reported that the mean concentration of water soluble and exchangeable Zn, which constituted the most readily available form of soil for plant nutrition was the least

(0.19 ppm). The organically bound Zn was in the range of 0.03 to 1.20 ppm. The complexed Zn with organic matter ranged between 0.2 and 1.4 ppm and the occluded Zn, which was bound to amorphous sesquioxide ranged from 0.19 to 1.92 ppm. The residual Zn which contributed the major fraction in soil and apparently associated with soil minerals, showed a higher mean value of 24.6 ppm. The water soluble and exchangeable Zn showed positive relationship with coarse sand only. The complexed Zn showed no association with soil properties.

The movement of Zn to lower layers was found negligible in cultivated soil studies on redistribution of the applied zinc to continuous cropping indicated that applied zinc gets transformed into amorphous sesquioxides bound Zn > complexed Zn > exchangeable Zn > crystalline sesquioxide bound Zn > residual mineral Zn fraction. The exchangeable and amorphous sesquioxides bound Zn fractions contributed significantly to Zn uptake by cereals compared to its other forms (Singh, 2001).

Total Cu and Zn Status

Tagwira (1994) analysed in 22 different samples of Zimbabwean soils. The copper content averaged 9.88 ppm with a range of 2.18 to 36.38 ppm. Granite derived soils generally had lower total copper content than other soils. The average total zinc status was 8 ppm and the range was 3.7 to 16.3 ppm.

Forms of Iron

Iron is one of the most common elements in the earth crust and also in soils. In calcareous soils it is generally distributed in the profiles as oxides and carbonates and as an essential part of clay. The deficiency of iron is quite common in calcareous soil because of its low availability.

The most readily available form of iron taken up by the plants from the soil is ferrous (Fe^{2+}), the availability of which is governed by the variation in soil temperature, moisture, pH, phosphate, heavy metals, calcium carbonate and organic matter. These factors influence redox potential, hydration and dehydration of iron compounds.

Gupta *et al.* (1982) observed that the moisture regimes generally enhanced the contents of all the forms of Fe and the increase was more pronounced under water logged situation.

Joshi and Dhir (1982) noted that the soils of Barmer and Jodhpur districts ranged from 3.6 - 7.8 ppm in DTPA - extractable Fe. The HCl extractable Fe ranged from 0.59 to 1.22 per cent, whereas exchangeable Fe varied widely from traces to 3.20 ppm. However, Mitra and Mandal (1983) showed that soils from rice fields of west Bengal alluvial tract under air dried conditions, the amount of water soluble and exchangeable ferrous iron was practically nil in almost all cases, whereas the content of water soluble and exchangeable manganese was fairly high.

Singh *et al.* (1990) reported that average values for available, exchangeable, water soluble, reducible and total Fe in representative arid soil profiles from Haryana were 2.9, 0.2, 1.8, 34.0 ppm and 2.1 per cent, respectively. The clay and organic matter were found to be the most effective soil parameters influencing the distribution of different forms of Fe. Kothandaraman and Chandrasekaran (1981) reported that Fe forms in the calcareous soils, as H_2O - soluble, exchangeable, available, diluted - acid soluble and total Fe were 0.1 - 0.35, 0.4 - 2.3, 0.8 - 4.4, 3.0 - 6.0 ppm and 2.2 - 4.5 per cent, respectively. The average values for all soil series of exchangeable, available, dilute acid soluble and total Fe were 1.2, 2.12, 4.33 ppm and 3.2 per cent, respectively.

Singh *et al.* (1988a) reported with a sequential fraction that about 62, 53, 82 and 52 per cent of the total soil Cu, Mn, Zn and Fe, respectively, was present in residual fraction. Shuman (1986) observed that increasing lime rates decreased exchangeable Zn and increased organic fraction of Zn and Mn. However, DTPA - extractable Fe and Zn were well correlated with plant uptake (0.842** and 0.377**). They further reported that a soil extractant for micronutrients should remove the exchangeable fraction but none of the oxide fractions and for Mn and Zn, none of the organic fraction.

Iron Fraction

Kalembara *et al.* (2001) studied sequential fraction of iron in Poland soils and showed that the highest amount of iron was determined in organo-mineral fraction and the lowest in water soluble and exchangeable fraction.

Joshi *et al.* (1988) analysed different forms of iron and manganese and their availability in the salt-affected soils of the Guhiya catchment of the Upper Luni Basin of Rajasthan. Exchangeable Fe ranged between 2-8 ppm and 2-10 ppm in salt-affected and normal soils, respectively. The DTPA - soluble Fe showed wide variation both in saline soils (2.6 - 16 ppm) and normal soils (5.2 - 12.2 ppm). The HCl - soluble and free Mn in different horizons of the salt-affected and normal soils varied widely between 128 - 460 ppm and 12.5 - 218 ppm, respectively. Reducible Mn content was also highly variable in salt affected soils (4.9 - 149.8 ppm) and normal soils (14.9 - 124.9 ppm).

Suthar and Ramakrishnayya (1983) analysed different forms of Fe in Goradu soils of Gujarat. They reported that the available, exchangeable, free Fe oxide and total Fe varied from 0.58 to 5.21 ppm,

0.28 to 3.80 ppm, 0.65 to 1.62 per cent and 1.60 to 4.95 per cent, respectively. Exchangeable iron content of the soil was less than the available Fe content. The free iron oxide in the soils varied between 16.6 to 52.2 per cent of total Fe. The available and exchangeable iron were highly significant and negatively correlated with pH, carbonate and bicarbonate content of soils. The OC, silt + clay and clay were positively correlated with available and exchangeable iron content of soil. Available Fe was found to have a very highly significant negative correlation with exchangeable Fe and positive correlation with free iron oxide and total Fe.

Forms of iron were studied in five typical Vertisol series of Karnataka. The percentage contribution of different fraction to the total Fe was in following order : Residual > amorphous Fe oxide occluded > organically bound > Mn oxide occluded > pH displaceable > exchangeable > acid soluble > water soluble iron. The amount of iron in labile pools was very low.

Randhawa and Singh (1996) studied the native iron fractions distribution in alluvium derived soils of Punjab and their relationship with important soil characteristics. Total and free oxides of Fe in soils ranged from 0.8 to 8.3 and 0.3 to 1.3 per cent with average values of 2.0 and 0.6 per cent. The DTPA extractable Fe varied from 1.0 to 21.4 ppm with a mean value of 7.2 ppm. A sequential fractionation showed that a major portion of Fe was present in the occluded fraction and it constituted about 1 per cent of the total Fe content. The exchangeable, adsorbed and organically bound Fe each constituted < 1.0 per cent of total average Fe content.

Chahal and Saini (1996) reported that all the forms of Fe increased with the increase in organic carbon and clay content. The organically

bound Fe, water soluble plus exchangeable and total Fe were positively correlated with each other.

Nirupama *et al.* (1999) showed a positive balance for all the fractions with and without organic matter addition, except for acetic acid soluble fraction of Fe, which showed a negative balance with the addition of 10t FYM ha⁻¹. The addition organic matter showed a positive balance for water soluble, exchangeable and reducible Fe fractions but their values were lower than the values without added organic matter. However, higher positive balance of organic Fe with organic matter addition indicated its build-up through the process of chelation or organometal complexation of soluble iron by the added organic matter.

Fraction of Cu, Mn, Zn and Fe

Changes in soil properties may alter the availability and forms of micronutrient in the soil. The changes that occur in various chemical pools of micronutrients under different cropping systems were studied by Singh *et al.* (1990). They observed that berseem-rice system resulted in the release of Mn, Zn and Fe from crystalline oxide surfaces to exchangeable, organic and amorphous oxide fractions.

Profile distribution was investigated for total and DTPA extractable Cu, Mn, Zn and Fe in soils of Punjab by Sharma *et al.* (1992). Based on linear co-efficient of correlation, DTPA extractable micronutrients increased with an increasing organic carbon, CEC, silt and clay and decreased with an increase in sand content. The Mn content decreased with an increase in sand and calcium carbonate content. Total content of all micronutrients increased with an increase in silt and clay, whereas Zn and Fe increased with increase in organic carbon content.

2.6 DEPLETION OF COPPER, MANGANESE, ZINC AND IRON UNDER INTENSIVE CROPPING

Introduction of high yielding varieties coupled with the use of chemical fertilizers has been responsible for creating additional stress on available micronutrients status in soils, tending to increase the incidence and extent of micronutrient deficiencies. An assessment of rate of depletion of micronutrients under conditions of use of high level of fertilizer and intensive cropping is therefore of important.

The depletion in soil available Zn was enhanced with increasing soil fertility levels (Sakal *et al.*, 1988). Kumaresean *et al.* (1985) found that the effect of continuous cropping and fertilization on the rate of depletion of micronutrient was highest for zinc followed by copper, manganese and iron in both Typic Haplustalfs and Typic Ustortherts of Tamilnadu. There was also a greater rate of depletion of these nutrients in Typic Haplustalfs indicating the need for proper micronutrient fertilization in it.

Similarly, an assessment of micronutrients balance made by Ramanathan *et al.* (1979) after ten crops indicated that the use of high levels of fertilizers tended to cause faster rate of depletion of micronutrient elements. The rate of depletion of micronutrients followed a set pattern with reference to the sequences of the rate of depletion, soil groups and crops for each one of the micronutrients elements. The per cent depletion of zinc from the total micronutrient content ranged from 0.24 to 2.45 per cent for all soils considered together but however, attained a maximum value of only 2.45 per cent for the first ten crops. The depletion of manganese showed an exactly similar trend. Increased dose of fertilizers tended to cause a higher rate of depletion of manganese from soils. But the values of per cent depletion ranged from

0.047 to 0.857 with reference to iron, the per cent depletion from the total was still of the lower order, the values ranging from 0.0009 to 0.0834. But increasing rate of depletion with increasing levels of soil fertility was once again evident. The total iron content was high in all soils and hence the percent depletion was of very low.

In long term field experiment study under continuous rice-wheat cropping, Singh *et al.* (1988b) concluded that raising high yielding crops with high fertilizer doses may create micronutrient deficiency condition which may be responsible for decline in rice yield. In control plots, Fe content changed little but with the application of 40, 80 and 120 kg N ha⁻¹, available Fe content depleted by 1.32, 1.52 and 1.66 ppm, respectively. Thus it is clear that application of nitrogen alone, which is a common practice with Indian farmers, may lead in the decline of soil available Fe content. Application of P and K fertilizer also had adverse effect on available soil Fe content, which may be due to enhanced Fe uptake from fertilizer plots. The Mn was the next nutrient affected by fertilizer application, though its content remains higher than the critical level for deficiency.

With intensive agriculture more multi-micro and secondary nutrients deficiencies are emerging and magnitude of response is increasing in various soil-crop-management situations. Fertilizer use efficiency of micronutrients presently is only 2 to 5 per cent. Balanced and integrated plant nutrient supply and management involving low doses of organic materials enhance the use efficiency of native and applied micronutrient.

Long term trials carried out at Anand by Dangarwala *et al.* (1983) under pot culture and field conditions to investigate the extent of micronutrient depletion under continuous cropping using almost all the

crops grown in Gujarat. The results indicated that after the harvest of 14 crops, available Zn (35%) and Fe (30%) contents of soil were decreased, whereas Cu contents did not show any change; but Mn showed slight improvement.

Bhardwaj and Omanwar (1994) at Pantnagar (Uttar Pradesh) observed that continuous cropping without fertilization after 9th cycle of rice-wheat cowpea cropping depleted Cu, Mn, Zn and Fe by 0.6, 12.3, 2.9 and 26.8 mg kg⁻¹ from their initial values of 1.88, 26.0, 4.46 and 34.2 mg kg⁻¹, respectively.

Dangarwala and Patel (1996) reported that use of high analysis fertilizers and adoption of high yielding varieties had resulted in greater stress on the status of micronutrients in soil. After harvesting of 26 crops reduction in the Zn availability to the extent of 49 per cent was noticed. Likewise, the Fe status had also dwindled by 52 per cent. Such reduction in case of Mn and Cu was also noticed. These findings were based on 20 years (1967-1989) of experimentation on integrated nutrient management under continuous cropping at Anand, Gujarat.

The total contents of micronutrients in soils of Gujarat varied between Fe - 0.8 to 11.3 per cent, Mn - 1344 to 1937 ppm, Zn - 20 to 95 ppm, Cu - 11 to 176 ppm. In general, the critical levels of deficiency so fixed for demarcation for each of the DTPA extractable micronutrient cations in ppm is Cu - 0.2, Mn - 5, Zn - 0.5, Fe - 50 ppm. (Dangarwala *et al.*, 1983). The delineation work revealed overall percentage deficiency of available micronutrients as Cu - 4, Mn - 4, Zn - 24 and Fe - 8, respectively, in different pockets of the Gujarat. (Patel, 2001). The maximum deficiency of 33.2 and 9.6 per cent was observed in Entisols and Inceptisols, respectively.

Continuous application of increasing levels of N, depleted DTPA extractable Cu, Mn, Zn and Fe. The addition of phosphorus also decreased Cu and Mn, whereas Fe and Zn contents of soils were increased. The available micronutrient contents were least affected by K addition (Harjit Singh *et al.*, 1995).

A long term experiment on bajra-wheat-moong cropping sequence conducted at micronutrient project, Gujarat Agricultural University, Anand (Gujarat) revealed that application of inorganic fertilizer alone depleted Zn status to one third of the initial value (1.62 ppm) in ten years of continuous cropping which decreased crop productivity to a greater extent indicating necessity for Zn addition (Dangarwala and Patel, 1996). Patel *et al.* (1999) reported that the rate of depletion of micronutrients under continuous cropping in goradu soil was in the order of Zn > Fe > Mn > Cu.

The analysis of surface soil samples collected from a fertilizer schedule and cropping sequence for nearly a decade at Bangalore, indicated an overall decline in available Cu and Mn status of soil, irrespective of the treatments and also decrease in Zn contents in all except FYM plus fertilizer treatments and reported considerable increase in Fe content. The FYM had a favourable effect on soil Cu and Fe contents, even though it failed to maintain the initial status of Cu (Sudhir *et al.*, 1997).

Golakiya and Gundaliya (1999) observed that in the agro-climatic zones, Zn deficiency ranges from 38 to 51 per cent as well as Fe deficiency were in 18 to 58 per cent of the total area.

Bhardwaj and Omanwar (1994) studied on long term effects of continuous rotational cropping and fertilization on crop yield, soil

properties and available nutrients of soil at Pantnagar (UP). As compared with the initial status (Cu, Mn, Zn and Fe), a general decrease in status of micronutrients were observed in fertilized as well as in unfertilized plots. This shows insufficient application of micronutrients through the fertilizers and utilizing micronutrients from soil resources. Average depletion of 0.171, 1.057, 0.079 and 0.889 kg ha⁻¹ for Cu, Mn, Zn and Fe, respectively, is an alarming situation for sustainable agriculture. Organic matter was found to be correlated with available Zn ($r = 0.691^{**}$).

The results of 20 years of experimentation at Coimbatore were compiled by Takkar *et al.* (1989). They observed that Fe amended organic manures had significantly enhanced the availability of applied Fe from 0.7 to 8.8 ppm. Hence, the practice of addition of organic manures with fertilizers will help augment the availability of applied as well as native Fe.

Darusman *et al.* (1991) collected soil samples after 20 years of experimentation. Samples were analysed for soil physical and chemical properties. Nitrogen fertilization caused an increase in micronutrients (Fe, Cu and Mn).

The results of field experiment conducted at Bijapur (Karnataka) on Typic Chromustorts for ten years (1984-1994) indicated that availability of micronutrients increased significantly with organic sources of nutrients either alone or in combination with fertilizers over the fertilizer alone. Increase in micronutrient contents might be due to addition of organic materials which might have enhanced the microbial activity in the soil and the consequent release of complex organic substances (Chelating agents) could have prevented micronutrients from precipitation, fixation, oxidation and leaching and also addition of these nutrients through organic source (Bellakki and Budanur, 1997).

Patel (1998) studied the effect of application of organic and inorganic fertilizers on soil fertility at Sardar Krushinagar (Gujarat) and observed that organic carbon and DTPA extractable Fe were maximum with organic manures, while available Cu, Mn and Zn contents in soil were consistently significantly higher with the application of organic plus inorganic fertilizer in comparison to only inorganic fertilizers. The results of the survey conducted to monitor the fertility status of soil revealed that application of only organic manure was more beneficial with respect to availability of Cu, Zn and Fe, while integrated nutrient supply system was found to benefit only the status of major nutrients added through inorganic fertilizer.

Patel *et al.* (1999) observed that application of FYM recorded comparatively higher DTPA extractable Fe in surface soil compared to other micronutrients in a continuous cropping experiment.

2.7 THE MICRONUTRIENTS AVAILABILITY, FORMS AND RELATIONSHIP WITH SOIL PROPERTIES IN LTFE's

Lal and Mathur (1989) studied the effect of continuous manuring and fertilization for the past 30 years on the available micronutrient status of an acid red loam soil (Paleustlt) of Kanke, Ranchi. Removal of micronutrients (Cu, Mn, Zn and Fe) for the last 28 years without supplementing through outside source did not bring their level below the critical limits as a result of constant supply through native minerals (Feldspar, Hornblend, biotite, tourmaline, etc.) and fertilizer carrying these nutrients as impurities. The additions of lime along with NPK increased the availability of the micronutrients in these soils and prevent the loss of these cations through fixation, precipitation, oxidation and reduction. This may be due to the higher organic matter of these soils supporting enhanced microbial activity and consequent release of

organic complexies (chelating agents) which would make micronutrients cations especially Cu and Zn stable. This resulted in positive significant correlation between pH and available micronutrients. Available Zn and Mn were positively correlated with Cu, while Zn was only positively and significantly correlated with Mn ($r = 0.678^*$), Fe did not show any significant relationship with other micronutrients. This may reflect that the solubility and perceptibility of Cu, Mn and Zn are similar but irons behave differently under these conditions.

Bellakki and Badunar (1997) studied long term effect of Integrated Nutrient Management on properties of Vertisol under Dry land Agriculture at Bijapur during 10 years period (1984-94). The application of $ZnSO_4$ along with RDF recorded significantly higher Zn content. Incorporation of organic sources of nutrients either alone or in combination with fertilizes recorded comparatively higher DTPA - extractable micronutrients (Cu, Mn, Zn and Fe) in surface soils (mean 1.35, 10.36, 1.44 and 4.66 mg kg^{-1}). The addition of organic materials might have enhanced the microbial activity in the soil and the consequent release of complex organic substances (chelating agents) could have promoted micronutrients from precipitation, fixation, oxidation and leaching and also addition of these nutrients through organic source.

Agarwal and Praveen Kumar (1996) reported that the continuous application of FYM increased the status of available micronutrient in the soils of Jodhpur (arid region) on pearl millet crop.

Prasad and Singh (1980) worked on changes in soil properties with long term use of fertilizer, lime and Farm Yard Manure on red loam soils of Ranchi (Bihar). They found that there was significant effect of manuring and cropping on available micronutrient states of the soil.

Available Cu, Mn, Zn and Fe (1.9, 44, 1.2 and 30.0 ppm) increased considerably with continuous use of chemical fertilizers and particularly FYM. Farm yard manure containing 3, 69, 40 and 140 ppm of Cu, Mn, Zn and Fe, respectively, seems to have contributed towards improving the micronutrient status in soil. A comparison of lime + NPK with NPK treatment showed that liming reduced the availability of micronutrients.

LTFE : Zinc - Total and Available

Zarkovic *et al.* (2000) investigated the effect of long term application of mineral and organic fertilizer (Farm Yard Manure and corn stalks) on the content of zinc in a calcareous chernozem soil. Total zinc content did not change significantly under the influence of applied fertilizers. However, the content of available zinc increased significantly where organic manures had been applied.

Distribution of different forms of micronutrient cations in cultivated profiles of Sikkim soils was studied by Gupta and Srivastava (1990). They also observed that all micronutrients cations had significant negative correlation with soil pH, while only available Cu and Fe had significant positive correlation with soil organic carbon.

The distribution of micronutrients like Cu and Mn in Pseudo-gley, hydromorphic black soil of Yugoslavia was studied by Bertic *et al.* (1984). This investigation comprised representative soil types of Slavonia and Baranja. Available trace elements content mostly decreases with profile depth, this applies less to copper and zinc and more to iron and manganese. The pH value did not affect available copper and zinc, but it exerted negative influence on available manganese. The carbonate content affected inactivation of manganese and copper. Humus content affected distribution of available copper and manganese, but it did not

affect zinc. The clay content is in positive correlation with copper content and as negative one with zinc content, while available phosphorus is in significant correlation only with zinc content in the soil.

Thuo *et al.* (1994) studied the dynamics of accumulated copper in the soils of Kenya. Samples were analysed for total and available copper, available phosphorus, organic carbon and soil pH. The level of available copper in the soil was found to depend primarily on soil pH, total copper, organic carbon and available phosphorus. Available copper in both top and sub soil were found to be negatively correlated to soil pH, organic carbon and available phosphorus.

Gopichand *et al.* (1985) studied available Cu, Mn, Zn and Fe with soil characteristics of representative soils of Andhra Pradesh. They worked out simple correlations between soil characteristics and available Cu, Mn, Zn and Fe, none of the correlations between soil properties and available Cu, Mn, Zn and Fe attained the level of significance. However, available copper exhibited more significant positive relationship with organic carbon and silt fraction of the soils.

Karajani (1998) studied the relationship between pH and Zn uptake in soil fractions of 45 soils of republic of Albania. Total Zn content of soil ranged from 42.7 to 126.5 mg kg⁻¹ while its amounts in the exchangeable + sorbed fraction were 0.8 - 4.43 mg kg⁻¹ soil, which consisted of 1.1 - 5.2 per cent of total zinc. It has very close relationship with soil pH. The decreasing pH raise exchangeable fraction of Zn. The influence of pH is especially correlated with clay content.

Organic carbon showed a positive and significant correlation with Cu, Mn and Zn due to the formation of stable complexes with natural complexing agents in soil solution.

Komisarek *et al.* (1991) stated that increasing lime rates decreased water soluble and exchangeable Cu and Mn in contaminated Poland soils. Those metals were found in specifically adsorbed and organic fractions. In limed (1 Hh) soil samples the exchangeable copper decreased 27 times and zinc 4 times but water soluble copper decreased only one time.

CHAPTER - III

MATERIALS AND METHOD

The present study, we worked on LTFE soils started some 8 years back on calcareous *Vertic ustocrepts* soils at Junagadh. There is a no gross addition of micronutrient except Zn in this particular experiment, this is the reason why the crop is exhibiting micronutrient hidden hunger of now. It's a high time to study the soils with respect to the micronutrient status and its fractions. We presume that there was a definite change in micronutrient status and its fraction according to treatments imposed so far. Moreover, soils of the selected treatments of long term fertilizer were also analysed for micronutrient fraction. It was the purpose to ventilate the dynamics of micronutrients at farm (LTFE) level through studying the interrelations among micronutrients fractions and soil properties over a period of time.

3.1 HISTORY OF LONG TERM EXPERIMENT :

The long term fertilizer experiment was started in the year 1999 at Instructional Farm, College of Agriculture, Junagadh Agricultural University at Junagadh to know effect of continuous application of fertilizers (N, P, K) and manure in a crop rotation of groundnut-wheat.

It is a high time to study the soils with respect to the micronutrients fractions. We presumed that there would be a definite change in soil micronutrient fractions according to treatments imposed so far over a period of eight years. The soils of following treatments were studied.

Tr. No.	Treatment Details
T ₁	50% N P K of recommended doses in G'nut -Wheat sequence
T ₂	100 % N P K of recommended doses in G'nut -Wheat sequence
T ₃	150 % N P K of recommended doses in G'nut -Wheat sequence
T ₄	100 % N P K of recommended doses in G'nut -Wheat sequence + ZnSO ₄ @ 50 kg/ha once in three year to G'nut only (i.e. '99, 02, 05 etc)
T ₅	N P K as per Soil Test
T ₆	100 % N P of recommended doses in G'nut -Wheat sequence
T ₇	100 % N of recommended doses in G'nut -Wheat sequence
T ₈	50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t/ha G'nut and 100 % N P K to Wheat
T ₉	Only FYM @ 25 t/ha to G'nut only
T ₁₀	50 % N P K of recommended doses in G'nut -Wheat sequence + Rhizobium + PSM to G'nut and 100 % N P K to Wheat
T ₁₁	100 % N P K of recommended doses in G'nut -Wheat sequence (P as S S P)
T ₁₂	Control

Recommended dose (kg ha⁻¹) :

Crop	N	P ₂ O ₅	K ₂ O
Groundnut (GG 20)	12.5	25	0
Wheat (GW 496)	120*	60	60*

*50 % as basal & 50 % at 21 DAS

Source of Fertilizer: Urea, DAP & MOP

Location of Experiment:

Long term fertilizer experiment was conducted at Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh. Junagadh is situated at 21.5⁰ N latitude and 70.5⁰ E longitude

with altitude of 60 meters above the mean sea level on the Western side at the foothills of mountain Girnar in South Saurashtra agro-climatic zone of Gujarat state.

Climatic and Weather Parameters :

Table 3.1. Normal range of weather data at Junagadh.

Weather parameter	Monsoon (June-September)	Winter (October-January)	Summer (February-March)
Temperature			
Max (°C)	30.6 - 37.6	29.5 - 36.8	31.6 - 39.7
Min (°C)	22.5 - 26.7	10.0 - 26.2	12.3 - 26.2
R.H. (%)	73 - 88	53 - 73	51 - 73
Wind speed (km/h)	4.9 - 13.4	4.2 - 7.2	6.5 - 12.5
B.S.S. (hr)	2.1 - 8.2	8.3 - 9.6	9.4 - 10.1
Evaporation (mm)	3.6 - 9.5	4.9 - 6.6	6.8 - 10.7
Rainfall (mm)	787.3	56	9.1
Rainy days	37.8	4.8	0.8

Soil Description :

This residual soil has basaltic trap parent material. Morphologically the profile of these soils has A-C horizon characteristics and having moderate sub angular blocky structure. They are plastic, sticky and hard in consistency. The colour of the soil varies from dark gray to light gray. Taxonomically, the soil is classified as Ustochrepts. The soil is dominated by smectite group of clay minerals, which give rise to mild cracking in dry season, due to which it is further classified as Vertic Ustochrepts at sub group level. The soil is calcareous in nature,

alkaline in reaction and clayey in texture. From fertility point of views, it is medium in available nitrogen, low in available phosphorus but high in available potassium (Kanzaria and Patel, 1985). The initial physico-chemical properties of LTFE soils are given in Table 3.2.

Initial Year and Season of Experiment :

1999 *Kharif* - groundnut

1999-2000 *Rabi* - wheat

Soil Samples of Selected Years :

Three period (0, 4th and 8th years)

(1) Initial soil (1999 – before groundnut)

(2) 2002-03 4th year (2003 – after Wheat)

(3) 2006-07 8th year (2007 – after Wheat)

Collection of Soil Samples (LTFE) :

Collected soil samples were air dried in shade, powdered with wooden mortar, passed through 2 mm sieve and analysed for physico-chemical properties and micronutrient fractions.

3.2 PREPARATION OF SOIL SAMPLES :

The soil samples, after air-drying, were ground with wooden mortar and pestle to pass through a 2 mm plastic sieve. The bulk soil samples were stored in polyethylene bags for chemical analysis.

3.3 METHOD OF ANALYSIS :

Soil Analysis : The prepared soil samples were analysed for determining physico-chemical parameters by adopting standard methods. The details regarding methods of analysis and relevant reference for each parameter are furnished in Table 3.2.

Table 3.2. Physico-chemical characteristics of the long-term fertilizers experimental soil before the commencement of the experiment and proposed analytical method used.

Physical Parameters	Properties	Methodology	Reference
Texture	Clayey	International pipette method	Piper (1950)
Depth	7.00 cm		
Field capacity (%)	41.00 %	Pressure plate apparatus	Richards (1954)
Permanent wilting point (%)	20.00%	Pressure plate apparatus	Richards (1954)
Infiltration (cm/h)	Well drained	Double cylinder infiltration test	Richards (1954)
Chemical Parameters Properties			
pH _{2.5}	8.50	Potentiometry	Jackson (1979)
EC _{2.5} (dSm ⁻¹)	0.19	Conductometry	Jackson (1979)
Organic carbon (g kg ⁻¹)	6.5	Wet oxidation	Walkley & Black (1935)
CaCO ₃ (g kg ⁻¹)	480	Rapid titration method	Puri (1963)
Total N (%)	0.083	Macro-Kjeldhal digestion	Piper (1966)
Avai. N (kg ha ⁻¹)	106.06	Alkaline permanganate method	Subbaiah and Asija (1956)
Avai. P ₂ O ₅ (kg ha ⁻¹)	28.16	Colorimetry	Olsen <i>et al.</i> (1954)
Avai. K ₂ O (kg ha ⁻¹)	272.00	Flame photometry Neutral normal ammonium acecate	Jackson (1979)
Avai. Sulphur (ppm)	22.00	CaCl ₂	Chopra and

		extractable turbidimetry	Kanwar (1976)
CEC (Cmol (P ⁺) kg ⁻¹)	27.30	Sodium saturation method	Chapman (1965)
Exch. Ca (Cmol (P ⁺) kg ⁻¹)	22.40	Versanate EDTA titration	Schewardzenbach and Biederman (1948)
Exch. Mg (Cmol (P ⁺) kg ⁻¹)	3.60	Versanate EDTA titration	- do -
Micronutrients :			
Cu	0.98	DTPA extractable	Lindsay and Norvell (1978)
Mn	4.01	Atomic	
Zn	1.22	Absorption Spectrophotometer	
Fe	1.78		
Micronutrient fraction	--	Sequential fraction	Jackson (1979) Viet (1962)

3.4 MICRONUTRIENT FRACTIONS :

Exactly 10 gram processed air-dried soil was weighted accurately into conical flask of 150 ml capacity and was kept ready for the sequential fraction of Cu, Mn, Zn and Fe as per procedure described by Jackson (1979) and Viet (1962) as follows :

- (a) **Water Soluble Form :** About 40 ml distilled water was added and the conical flask was shaken for 2 hr on horizontal (mechanical) shaker. The soil suspension was allowed to settle down for one hr and supernatant liquid was filtered for Cu, Mn, Zn and Fe determination as per the procedure mentioned earlier.

- (b) **Exchangeable Form** : Residual soil was used to determine the exchangeable Cu, Mn, Zn and Fe. Forty ml of 1 N neutral ammonium acetate was added in the same conical flask and shaken for 2 hr. The soil suspension was allowed to settle down as mentioned above and supernatant liquid was used for the estimation of above.
- (c) **DTPA available Form** : Residual soil was used for the determination of DTPA available Cu, Mn, Zn and Fe by adding 40 ml DTPA-TEA-CaCl₂ (pH 7.3) in the same conical flask and was shaken for 2 hr. The soil suspension was allowed to settle down for one hr. The supernatant liquid was used for the estimation of above nutrients.
- (d) **Reducible Form** : Residual soil was used for the determination of reducible Cu, Mn, Zn and Fe by adding 1 N neutral ammonium acetate containing 0.2 per cent hydro quinon in the same conical flask and was shaken and after settle down of suspension for one hr., the supernatant liquid was used for the estimation of above nutrients.
- (e) **Total Cu, Mn, Zn and Fe** : Total nutrients viz., Cu, Mn, Zn and Fe were determined using HF : HClO₄ (5:1). The soil (1 g) taken in a platinum crucible treated with 2 ml water and 1 ml HClO₄ before 5 ml HF was added. The contents were evaporated to dryness. The residue was heated with 1 ml HCl and 5 ml water till it dissolved (discolour). After cooling, the 100 ml volume was made before filtration and used for the estimation of total elements.

- (f) **Residual Cu, Mn, Zn and Fe :** Residual Cu, Mn, Zn and Fe were calculated by deducting water soluble + exchangeable + DTPA available + residual (i.e. available total) from total nutrients of Cu, Mn, Zn and Fe.
- (g) **Percent available of Cu, Mn, Zn and Fe :** The percent available of Cu, Mn, Zn and Fe was calculated as percent available nutrients in the form of water soluble + exchangeable + DTPA available + residual (i.e. available total) of the total nutrients content in the respective soils.
- (h) **Depletion percent :** These nutrients depleted from soil by different cycles were calculated by the formula :

$$\text{Depletion of nutrient (\%)} = \frac{\text{Nutrient status of index year} - \text{Nutrient status of final year}}{\text{Period between index \& final year}} \times 100$$

- (i) **Available total :** Available total was the sum of water soluble, exchangeable, DTPA available and reducible form.

3.5 STATISTICAL ANALYSIS :

All the observations on yield and analytical data recorded during the course of investigation were subjected to statistical analysis by using Randomized Block Design model.

- (1) **Analysis of variance :** As per the method outlined by Panse and Sukhatme (1985), the value of test at 5 and 1 per cent level of significant was determined and the values of SEm, CV per cent were also calculated. The pooled analysis of three cycles of data was carried out as per procedure suggested by Cochran and Cox (1967).

- (2) **Correlation Co-efficient** : Correlation co-efficient the relationship between two or more series of variable were also determined.
- (3) **Regression** : To quantify combine effect of several parameters over other parameters and stepwise regression analysis for individual weighted variable were also employed.
- (4) **Path co-efficient analysis** : Path co-efficient analysis, which is standardized partial regression co-efficient and measures the direct and indirect effect of one variable upon another thereby permitting the separation of the correlation co-efficient into the components of direct and indirect effects was also employed.
(Dewey and La, 1959)

Table 3.3 Ratings (low, medium, high) of micronutrients used for categorizing the soil status.

Sr. No.	Element	Low (ppm)	Medium (ppm)	High (ppm)
1	Copper	< 0.2	0.2 - 0.4	> 0.4
2	Manganese	< 5.0	5.0 - 10.0	> 10.0
3	Zinc	< 0.5	0.5 - 1.0	> 1.0
4	Iron	< 5.0	5.0 - 10.0	> 10.0

Dangarwala, *et al.*(1983), Tandon (1995), Patel, *et al.*(1999)

CHAPTER - IV

RESULTS AND DISCUSSION

The studies of the nutrient dynamics involve intricate chemistry of a substrate. It becomes even more complicated when a substrate is soil and target elements are micronutrients. We tried here to explore the dynamics of micronutrient fractions, their inter-relations among themselves and with soil properties. Interesting statistical and mathematical tools are applied to qualify and quantify these relation in mathematical models so as to draw some valid abstracts for practical utility. The soils of an AICRP-LTFE have been studied to know the effect of continuous cultivation manuring and fertilizing on the dynamics of micronutrients over 8 years period. It has been presumed that data base generated though LTFE soil will enhance the precision of this study. Our ultimate aim here is to know the turnover among micronutrient fractions over a period of time. The variables operating in both cases are varied soil treatments, crop and time span. The nutrient wise findings are narrated here under with brief discussion their of:

4.0.1.1 Groundnut Yield

The pod and haulm yields of groundnut were significantly influenced by various treatments in 8th years pooled result and maximum values of pod (1093.56 kg ha⁻¹) and haulm (2614.66 kg ha⁻¹) were recorded under application of 50 % NPK of RD in groundnut-wheat sequence + FYM @ 10 t ha⁻¹ to groundnut and 100% NPK to wheat (T₈). The pod and haulm yield of groundnut were not influenced significantly by various treatments of experiment in 1st year as well as in 4th year pooled result (Table 4.0.1 and 4.0.2).

Table 4.0.1 Groundnut pod yield in 1st, 4th and 8th year of LTFE experiment

Treat.	Groundnut pod yield (kg/ha)		
	1 st year	4 year pooled	8 year pooled
T1	962.00	972.25	929.81
T2	984.75	1042.31	1001.63
T3	916.25	1032.19	1041.53
T4	1048.00	1060.94	1012.31
T5	929.25	1050.06	993.63
T6	1101.75	988.81	890.03
T7	927.50	950.50	855.59
T8	916.25	1060.25	1093.56
T9	875.75	1006.56	995.81
T10	963.50	1028.00	981.69
T11	1017.25	1062.31	983.34
T12	968.25	902.69	782.28
S.Em.±	74.12	38.53	33.60
C.D. at 5 %	NS	NS	94.76
C.V. %	15.32	10.42	12.44
Mean	967.54	1013.07	963.43

Table 4.0.2 Groundnut haulm yield in 1st, 4th and 8th year of LTFE experiment

Treat.	Groundnut haulm yield (kg/ha)		
	1 st year	4 year pooled	8 year pooled
T1	1790.50	2104.63	2233.09
T2	2018.25	2272.94	2395.44
T3	1758.00	2366.25	2532.50
T4	1985.75	2158.94	2365.22
T5	1676.50	2088.94	2282.19
T6	1969.50	2343.00	2382.97
T7	1693.00	2048.81	2104.94
T8	1888.00	2292.81	2614.66
T9	1693.00	2154.06	2458.47
T10	2002.00	2247.88	2364.31
T11	1871.50	2272.94	2421.50
T12	1725.50	2062.88	2059.06
S.Em.±	131.39	83.39	68.93
C.D. at 5 %	NS	NS	194.39
C.V. %	14.29	9.14	12.03
Mean	1839.29	2201.17	2351.19

Table 4.0.3 Wheat grain yield in 1st, 4th and 8th year of LTFE experiment

Treat.	Wheat grain yield (kg/ha)		
	1 st year	4 year pooled	8 year pooled
T1	1589.00	1626.00	2039.69
T2	1908.50	2049.80	2467.38
T3	1878.50	2137.10	2525.81
T4	1806.50	1952.70	2343.22
T5	1856.50	2010.50	2472.78
T6	1718.75	1907.25	2343.25
T7	1111.00	1185.50	1448.66
T8	1898.25	2290.00	2887.91
T9	1289.25	1937.75	2587.16
T10	1419.00	1872.35	2307.47
T11	1608.75	1995.10	2435.66
T12	1309.25	1322.50	1677.16
S.Em.±	107.36	104.11	88.57
C.D. at 5 %	309.12	296.93	249.81
C.V. %	13.29	11.55	10.83
Mean	1616.10	1857.21	2294.68

Table 4.0.4 Wheat straw yield in 1st, 4th and 8th year of LTFE experiment

Treat.	Wheat straw yield (kg/ha)		
	1 st year	4 year pooled	8 year pooled
T1	2696.75	2234.75	2704.69
T2	3090.25	2540.69	3325.88
T3	2847.25	2672.75	3441.06
T4	2650.25	2425.31	3164.84
T5	2819.50	2472.31	3237.31
T6	2696.75	2287.94	3043.59
T7	1921.25	1461.69	2042.84
T8	2766.00	2509.50	3911.41
T9	2141.25	2185.44	3205.47
T10	2581.00	2283.69	3111.66
T11	2963.00	2559.63	3268.94
T12	2072.00	1624.31	2119.94
S.Em.±	155.89	110.57	121.74
C.D. at 5 %	448.86	318.37	343.34
C.V. %	11.97	13.20	11.50
Mean	2603.77	2271.50	3048.13

4.0.1.2 Wheat Yield

The grain and straw yields of wheat were significantly affected by various fertilization treatments of LTFE experiment in 1st year as well as 4 and 8 years pooled results. Significantly maximum values of grain (2887.91 kg ha⁻¹) and straw (3911.41 kg ha⁻¹) were obtained under treatment of 50 % NPK of RD in groundnut-wheat sequence + FYM @ 10 t ha⁻¹ in groundnut and 100 % NPK to wheat (T₈) in respect of remaining treatments in pooled results of 4 and 8 years (Table 4.0.3 and 4.0.4).

4.0.2.1 N content in Groundnut

Treatment difference were found non significant in the pooled one for both pod and haulm concentration of nitrogen (Table 4.0.5 and 4.0.6). However, interaction between year and treatment were found significant. In 1st years, in pod the concentration of N was recorded the highest value in application of 100 % N of recommended doses in G'nut -Wheat sequence (T₇) and lowest under application of 100 % N P of recommended doses in G'nut -Wheat sequence (T₆), while haulm N concentration was highest in T₃ at 4 years and lowest in T₃ at 1 year experimentation.

4.0.2.2 N content in Wheat

One thing was very distinct that, in a long terms the wheat grain N concentration decreased from 2.396 to 1.886 per cent (Table 4.0.7 and 4.0.8). Although the pooled differences among treatment were not significant but year x treatment interaction differences were significant and grain nitrogen percent was obtain highest in T₂ in initial years and lowest in T₁₂ (Control) at 8 years, while straw nitrogen concentration was highest in T₈ and lowest in T₁ at 8 years.

Table 4.0.5 Nitrogen concentration of groundnut pod in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of N % in groundnut pod			
	1 st year	4 th year	8 th year	pooled
T1	3.060	2.955	2.880	2.965
T2	2.945	2.928	2.870	2.914
T3	2.523	3.150	3.085	2.919
T4	2.168	2.885	2.913	2.655
T5	2.355	2.800	2.905	2.687
T6	1.923	3.000	3.040	2.654
T7	3.235	3.068	2.743	3.015
T8	2.445	3.113	2.578	2.712
T9	2.285	3.003	2.823	2.703
T10	3.100	3.073	2.835	3.003
T11	2.528	3.010	2.855	2.798
T12	2.638	3.458	2.813	2.969
S.Em.±	0.152	0.144	0.088	0.157
C.D. at 5 %	0.438	NS	0.252	NS
C.V. %	11.70	9.49	6.11	9.25
Mean	2.600	3.036	2.861	2.832
Y * T	S.Em.±	0.131	C.D. at 5 %	0.368

Table 4.0.6 Nitrogen concentration of groundnut haulm in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of N % in groundnut haulm			
	1 st year	4 th year	8 th year	pooled
T1	1.570	1.405	1.400	1.458
T2	1.463	1.198	1.590	1.417
T3	0.700	1.665	1.460	1.275
T4	1.168	1.490	1.498	1.385
T5	0.968	1.380	1.365	1.238
T6	1.228	1.548	1.420	1.398
T7	1.318	1.380	1.350	1.349
T8	1.135	1.470	1.363	1.323
T9	0.958	1.548	1.323	1.276
T10	1.365	1.405	1.370	1.380
T11	0.983	1.540	1.420	1.314
T12	0.845	1.358	1.343	1.182
S.Em.±	0.093	0.078	0.046	0.107
C.D. at 5 %	0.267	0.224	0.131	NS
C.V. %	16.3	10.78	6.5	11.25
Mean	1.141	1.448	1.408	1.333
Y * T	S.Em.±	0.075	C.D. at 5 %	0.211

Table 4.0.7 Nitrogen concentration of wheat grain in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of N % in wheat grain			
	1 st year	4 th year	8 th year	pooled
T1	2.543	2.040	1.668	2.083
T2	2.598	2.135	1.953	2.228
T3	2.395	2.288	2.023	2.235
T4	2.118	2.228	1.930	2.092
T5	2.473	2.245	1.933	2.217
T6	2.428	2.103	1.875	2.135
T7	2.520	2.043	1.813	2.125
T8	2.228	2.405	2.100	2.244
T9	2.423	2.038	2.030	2.163
T10	2.568	2.298	1.875	2.247
T11	2.213	2.190	1.945	2.116
T12	2.255	1.968	1.490	1.904
S.Em.±	0.092	0.061	0.032	0.083
C.D. at 5 %	0.264	0.176	0.091	NS
C.V. %	7.64	5.64	3.36	6.16
Mean	2.396	2.165	1.886	2.149
Y * T	S.Em.±	0.066	C.D. at 5 %	0.185

Table 4.0.8 Nitrogen concentration of wheat straw in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of N % in wheat straw			
	1 st year	4 th year	8 th year	pooled
T1	0.544	0.568	0.405	0.506
T2	0.574	0.575	0.615	0.588
T3	0.588	0.585	0.715	0.629
T4	0.630	0.580	0.638	0.616
T5	0.609	0.630	0.575	0.605
T6	0.658	0.593	0.518	0.589
T7	0.637	0.663	0.505	0.602
T8	0.511	0.573	0.763	0.615
T9	0.518	0.513	0.715	0.582
T10	0.595	0.568	0.510	0.558
T11	0.628	0.625	0.658	0.637
T12	0.546	0.638	0.420	0.535
S.Em.±	0.045	0.041	0.023	0.047
C.D. at 5 %	NS	NS	0.0656	NS
C.V. %	15.35	14	7.77	12.81
Mean	0.586	0.592	0.586	0.588
Y * T	S.Em.±	0.037	C.D. at 5 %	0.106

4.0.3.1 P content in Groundnut

Overall phosphorus concentration in groundnut pod showed declining trend from 0.580 to 0.438 per cent overtime. The Y x T interactions was significant in both pod and haulm yield of groundnut. The concentration of P in groundnut pod was recorded the highest value in application of 50% N P K of recommended doses in G'nut -Wheat sequence at 1st year, lowest value in T₁₂ and T₁₀ at 8th year. The concentration of P in groundnut haulm was highest in T₁₁ at 4th year while it was lowest in T₃ in the initial year (Table 4.0.9 and 4.0.10, Fig. 4.0.3).

4.0.3.2 P content in Wheat

Phosphorus concentration in wheat grain increase in a span of 4 years and was stable after 8 year and in wheat straw increase in span of 4 and 8 years. Although in pooled result, the concentration of P in wheat grain was found significant under various treatments but it was found non significant in wheat straw, while interaction between the treatment and year were observed significant in both grain and straw. The highest value recorded under application of FYM @ 25 t/ha to G'nut at 4th year, while lowest value was recorded in T₁₂ (Control) in the initial year in wheat grain. In wheat straw the highest value was recorded in T₉ of 8th year, while lowest value was recorded in T₁₁ of initial year (table 4.0.11 and 4.0.12, Fig. 4.0.3).

4.0.4.1 K content in Groundnut

The pooled differences as well as interactions were significant (Table 4.0.13 and 4.0.14). In pooled highest significant value of K content was observed under application of FYM @ 25 t/ha to G'nut (T₉) followed by T₃ and T₅ in groundnut pod and highest significant in application of

Table 4.0.9 Phosphorus concentration of groundnut pod in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of P % in groundnut pod			
	1 st year	4 th year	8 th year	pooled
T1	0.628	0.483	0.420	0.510
T2	0.613	0.528	0.433	0.524
T3	0.572	0.513	0.445	0.510
T4	0.502	0.530	0.463	0.498
T5	0.546	0.503	0.453	0.500
T6	0.557	0.500	0.455	0.504
T7	0.607	0.450	0.420	0.492
T8	0.543	0.540	0.453	0.512
T9	0.578	0.518	0.473	0.523
T10	0.601	0.490	0.405	0.499
T11	0.606	0.513	0.440	0.520
T12	0.612	0.478	0.405	0.498
S.Em.±	0.021	0.016	0.012	0.019
C.D. at 5 %	0.0596	0.0452	0.0334	NS
C.V. %	7.14	6.25	5.31	6.48
Mean	0.580	0.503	0.438	0.507
Y * T	S.Em.±	0.016452	C.D. at 5 %	0.04623

Table 4.0.10 Phosphorus concentration of groundnut haulm in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of P % in groundnut haulm			
	1 st year	4 th year	8 th year	pooled
T1	0.103	0.228	0.173	0.168
T2	0.109	0.208	0.188	0.168
T3	0.082	0.240	0.180	0.167
T4	0.118	0.218	0.158	0.164
T5	0.099	0.245	0.175	0.173
T6	0.093	0.245	0.205	0.181
T7	0.095	0.168	0.158	0.140
T8	0.102	0.238	0.155	0.165
T9	0.095	0.215	0.175	0.162
T10	0.101	0.215	0.178	0.165
T11	0.095	0.263	0.165	0.174
T12	0.096	0.160	0.155	0.137
S.Em.±	0.004	0.015	0.010	0.011
C.D. at 5 %	0.0124	0.0418	0.0274	NS
C.V. %	8.7	13.14	11	12.57
Mean	0.099	0.22	0.171	0.163
Y * T	S.Em.±	0.0103	C.D. at 5 %	0.029

Table 4.0.11 Phosphorus concentration of wheat grain in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of P % in wheat grain			
	1 st year	4 th year	8 th year	Pooled
T1	0.209	0.375	0.340	0.308
T2	0.181	0.398	0.378	0.319
T3	0.214	0.413	0.358	0.328
T4	0.223	0.363	0.353	0.313
T5	0.195	0.400	0.345	0.313
T6	0.199	0.413	0.390	0.334
T7	0.198	0.338	0.323	0.286
T8	0.227	0.428	0.295	0.316
T9	0.214	0.443	0.415	0.357
T10	0.214	0.393	0.383	0.330
T11	0.209	0.390	0.338	0.312
T12	0.193	0.358	0.320	0.290
S.Em.±	0.009	0.015	0.011	0.014
C.D. at 5 %	NS	0.043	0.032	0.040
C.V. %	9.06	7.56	6.37	7.58
Mean	0.206	0.392	0.352	0.317
Y * T	S.Em.±	0.012	C.D. at 5 %	0.034

Table 4.0.12 Phosphorus concentration of wheat straw in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of P % in wheat straw			
	1 st year	4 th year	8 th year	pooled
T1	0.025	0.046	0.043	0.038
T2	0.031	0.054	0.058	0.047
T3	0.041	0.050	0.165	0.085
T4	0.048	0.048	0.115	0.070
T5	0.051	0.048	0.138	0.079
T6	0.048	0.059	0.065	0.057
T7	0.048	0.039	0.060	0.049
T8	0.033	0.059	0.183	0.091
T9	0.040	0.060	0.188	0.096
T10	0.025	0.050	0.053	0.042
T11	0.015	0.062	0.148	0.075
T12	0.023	0.047	0.063	0.044
S.Em.±	0.003	0.005	0.006	0.018
C.D. at 5 %	0.0072	NS	0.0179	NS
C.V. %	14.03	19	11.73	14.89
Mean	0.035	0.052	0.106	0.064
Y * T	S.Em.±	0.0047	C.D. at 5 %	0.0134

Table 4.0.13 Potash concentration of groundnut pod in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of K % in groundnut pod			
	1 st year	4 th year	8 th year	pooled
T1	0.718	0.728	0.653	0.699
T2	0.688	0.740	0.655	0.694
T3	0.709	0.828	0.668	0.735
T4	0.723	0.805	0.660	0.729
T5	0.840	0.743	0.650	0.744
T6	0.684	0.730	0.630	0.681
T7	0.615	0.700	0.613	0.642
T8	0.693	0.763	0.748	0.734
T9	0.699	0.800	0.813	0.771
T10	0.655	0.740	0.623	0.672
T11	0.637	0.755	0.648	0.680
T12	0.704	0.655	0.663	0.674
S.Em.±	0.035	0.032	0.024	0.027
C.D. at 5 %	0.1016	0.0933	0.0677	0.0785
C.V. %	10.14	8.67	7.03	8.75
Mean	0.6970	0.7487	0.6683	0.7047
Y * T	S.Em.±	0.0308	C.D. at 5 %	0.0866

Table 4.0.14 Potash concentration of groundnut haulm in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of K % in groundnut haulm			
	1 st year	4 th year	8 th year	pooled
T1	0.501	0.568	0.408	0.492
T2	0.606	0.575	0.478	0.553
T3	0.692	0.640	0.508	0.613
T4	0.659	0.643	0.438	0.580
T5	0.541	0.538	0.413	0.497
T6	0.600	0.495	0.395	0.497
T7	0.602	0.428	0.400	0.476
T8	0.722	0.833	1.158	0.904
T9	0.482	0.820	1.043	0.781
T10	0.667	0.600	0.428	0.565
T11	0.555	0.705	0.443	0.567
T12	0.432	0.525	0.403	0.453
S.Em.±	0.028	0.034	0.033	0.081
C.D. at 5 %	0.089	0.097	0.094	0.237
C.V. %	9.65	10.96	12.08	10.9
Mean	0.5881	0.6139	0.5425	0.5815
Y * T	S.Em.±	0.0317	C.D. at 5 %	0.0890

Table 4.0.15 Potash concentration of wheat grain in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of K % in wheat grain			
	1 st year	4 th year	8 th year	pooled
T1	0.285	0.443	0.308	0.345
T2	0.261	0.475	0.315	0.350
T3	0.269	0.470	0.335	0.358
T4	0.300	0.440	0.333	0.357
T5	0.288	0.473	0.328	0.363
T6	0.277	0.478	0.333	0.362
T7	0.296	0.448	0.323	0.355
T8	0.269	0.455	0.355	0.360
T9	0.277	0.463	0.375	0.371
T10	0.300	0.453	0.330	0.361
T11	0.265	0.488	0.320	0.358
T12	0.250	0.438	0.303	0.330
S.Em.±	0.008	0.016	0.007	0.010
C.D. at 5 %	0.023	NS	0.020	NS
C.V. %	5.82	6.92	4.32	6.23
Mean	0.2779	0.46	0.3295	0.3558
Y * T	S.Em.±	0.011091	C.D. at 5 %	0.031167

Table 4.0.16 Potash concentration of wheat straw in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of K % in wheat straw			
	1 st year	4 th year	8 th year	pooled
T1	1.061	1.155	0.820	1.012
T2	0.945	1.175	0.940	1.020
T3	1.011	1.120	1.043	1.058
T4	1.015	1.188	1.165	1.123
T5	1.256	1.565	0.990	1.270
T6	0.925	1.750	0.500	1.058
T7	1.002	1.358	0.628	0.996
T8	1.124	1.388	1.785	1.432
T9	0.960	1.405	1.778	1.381
T10	1.216	1.390	1.013	1.206
T11	0.869	1.478	0.945	1.097
T12	0.820	1.530	0.910	1.087
S.Em.±	0.070	0.062	0.041	0.153
C.D. at 5 %	0.201	0.177	0.119	NS
C.V. %	13.79	8.98	7.93	10.31
Mean	1.017	1.375	1.043	1.145
Y * T	S.Em.±	0.0590	C.D. at 5 %	0.1657

50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t/ha G'nut and 100 % N P K to Wheat (T₈) followed by T₉ in groundnut haulm. Highest value was observed in T₅ of initial year and lowest value was observed in T₇ of initial and 8 year in groundnut pod while highest value was observed in T₈ of 8 year and lowest value was observed in T₇ of 8 year in groundnut haulm.

4.0.4.2 K content in Wheat

The pooled differences were not significant while interaction was significant (Table 4.0.15 and 4.0.16. Fig. 4.0.4). However potassium concentration in 4th year, in general, recorded highest value while in the initial year recorded lowest value.

4.0.5.1 S content in Groundnut

The sulphur concentration in groundnut pod and haulm was highest after 4th year while at 8th year it declined again as also in the pooled results the difference was not significant but interaction was significant and the highest value was recorded under application of 100 % N P K of recommended doses in G'nut -Wheat sequence + ZnSO₄ @ 50 kg/ha once in three year to G'nut only (T₄) of 4th year in pod and under application of 100 % N P of recommended doses in G'nut -Wheat sequence of 4th year in haulm while lowest value was recorded in T₄ of initial year in pod and T₂ and T₃ of 8th year in haulm (Table 4.0.17 and 4.0.18).

4.0.5.2 S Content in Wheat

Overall sulphur concentration in wheat grain and straw showed declined overtime (Table 4.1.1 and 4.1.2). Although the pooled differences among treatments were not significant but Y x T interaction were significant. The highest values recorded under application of 100 %

Table 4.0.17 Sulphur concentration of groundnut pod in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of S % in groundnut pod			
	1 st year	4 th year	8 th year	pooled
T1	0.120	0.300	0.154	0.191
T2	0.132	0.298	0.163	0.198
T3	0.145	0.293	0.171	0.203
T4	0.091	0.328	0.168	0.196
T5	0.108	0.295	0.149	0.184
T6	0.108	0.268	0.151	0.175
T7	0.207	0.290	0.149	0.215
T8	0.079	0.295	0.188	0.187
T9	0.075	0.300	0.181	0.185
T10	0.149	0.290	0.136	0.192
T11	0.103	0.303	0.173	0.193
T12	0.112	0.265	0.137	0.171
S.Em.±	0.013	0.018	0.008	0.015
C.D. at 5 %	0.037	NS	0.024	NS
C.V. %	21.76	12.07	10.4	14.2
Mean	0.118813	0.2935	0.1598	0.1907
Y * T	S.Em.±	0.0135	C.D. at 5 %	0.0380

Table 4.0.18 Sulphur concentration of groundnut haulm in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of S % in groundnut haulm			
	1 st year	4 th year	8 th year	pooled
T1	0.124	0.275	0.102	0.167
T2	0.120	0.293	0.094	0.169
T3	0.124	0.283	0.094	0.167
T4	0.132	0.283	0.119	0.178
T5	0.108	0.390	0.134	0.210
T6	0.124	0.425	0.122	0.224
T7	0.128	0.273	0.129	0.177
T8	0.153	0.315	0.119	0.196
T9	0.116	0.240	0.112	0.156
T10	0.124	0.353	0.119	0.198
T11	0.103	0.298	0.139	0.180
T12	0.116	0.260	0.132	0.169
S.Em.±	0.011	0.028	0.007	0.019
C.D. at 5 %	NS	0.0806	0.0207	NS
C.V. %	18.3	18.2	12.27	19.6
Mean	0.1225	0.3070	0.1177	0.1824
Y * T	S.Em.±	0.0178	C.D. at 5 %	0.0502

Table 4.0.19 Sulphur concentration of wheat grain in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of S % in wheat grain			
	1 st year	4 th year	8 th year	pooled
T1	0.227	0.183	0.097	0.169
T2	0.252	0.208	0.084	0.181
T3	0.269	0.210	0.112	0.197
T4	0.198	0.215	0.077	0.163
T5	0.256	0.215	0.082	0.184
T6	0.260	0.203	0.102	0.188
T7	0.293	0.185	0.109	0.196
T8	0.269	0.173	0.104	0.182
T9	0.207	0.160	0.094	0.154
T10	0.260	0.188	0.104	0.184
T11	0.256	0.220	0.079	0.185
T12	0.227	0.190	0.119	0.179
S.Em.±	0.017	0.014	0.004	0.012
C.D. at 5 %	0.049	NS	0.011	NS
C.V. %	13.64	14.73	7.95	14.46
Mean	0.2478	0.1956	0.0967	0.1800
Y * T	S.Em.±	0.0130	C.D. at 5 %	0.0365

Table 4.0.20 Sulphur concentration of wheat straw in 1st, 4th and 8th year of LTFE experiment

Treat.	Concentration of S % in wheat straw			
	1 st year	4 th year	8 th year	pooled
T1	0.240	0.230	0.122	0.197
T2	0.269	0.225	0.129	0.208
T3	0.269	0.220	0.089	0.193
T4	0.239	0.210	0.117	0.189
T5	0.248	0.200	0.104	0.184
T6	0.248	0.190	0.136	0.191
T7	0.273	0.215	0.124	0.204
T8	0.269	0.183	0.055	0.169
T9	0.244	0.175	0.064	0.161
T10	0.252	0.210	0.137	0.200
T11	0.252	0.260	0.141	0.218
T12	0.252	0.185	0.137	0.191
S.Em.±	0.016	0.018	0.007	0.012
C.D. at 5 %	NS	NS	0.0187	NS
C.V. %	12.93	17.48	11.61	15.29
Mean	0.2542	0.2085	0.1127	0.1918
Y * T	S.Em.±	0.0146	C.D. at 5 %	0.0412

N of recommended doses in G'nut -Wheat sequence of initial year in both grain and straw, while lowest value was recorded in under application of 100 % N P K of recommended doses in G'nut -Wheat sequence + ZnSO₄ @ 50 kg/ha once in three year to G'nut only (T₄) of 8th year in grain while T₈ of 8th year in wheat straw.

COPPER

4.1.1 Cu - Water Soluble

The water soluble copper showed non significant difference among treatment when pooled over years and only significant result were observed in 8th year (Table 4.1.1). Overall water soluble copper declined overtime. In pooled, the highest value of Cu-water soluble was observed under application of 100 % NPK in groundnut-wheat sequence(T₂). Komisarek *et al.* (1991) stated that increasing lime rates decreased water soluble Cu.

4.1.2 Cu - Exchangeable

The exchangeable copper showed significant difference in pooled result and it was recorded higher under application of 100 % NPK in groundnut-wheat sequence (T₂) followed by T₇, T₁₀, T₃, T₁₁, T₁₂ and T₂ (Table 4.1.2). In long term, there seems to be a slight increase in 4th year but it was declined again at 8th year of experimentation. Komisarek *et al.* (1991) stated that increasing lime rates decreased exchangeable Cu.

4.1.3 Cu - DTPA Available

The DTPA available Cu showed significant difference due to treatments when pooled over year and also in Y x T interactions. Highest value was recorded by application of FYM @ 25 t ha⁻¹ to groundnut (T₉) followed by T₈, T₂ and T₁₁. In long run, there was a slight decrease in overall DTPA copper (Table 4.1.3). The results are supported by earlier

Table 4.1.1 Status of water soluble form of copper in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Copper water soluble from in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.185	0.207	0.075	0.155
T2	0.215	0.176	0.086	0.159
T3	0.161	0.158	0.069	0.129
T4	0.211	0.177	0.063	0.150
T5	0.183	0.144	0.075	0.134
T6	0.211	0.153	0.071	0.145
T7	0.184	0.149	0.068	0.134
T8	0.214	0.170	0.069	0.151
T9	0.209	0.179	0.082	0.157
T10	0.179	0.203	0.084	0.155
T11	0.188	0.167	0.082	0.146
T12	0.170	0.155	0.075	0.134
SEm±	0.018	0.021	0.005	0.009
CD at 5%	NS	NS	0.014	NS
C.V. %	18.3	25.06	13.26	22.24
Mean	0.192	0.170	0.075	0.146
Y * T	S.Em.±	0.016205	C.D. at 5 %	NS

Table 4.1.2 Status of exchangeable form of copper in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Copper exchangeable form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.251	0.254	0.179	0.228
T2	0.227	0.285	0.229	0.247
T3	0.283	0.297	0.246	0.275
T4	0.233	0.258	0.216	0.235
T5	0.255	0.300	0.195	0.250
T6	0.285	0.335	0.242	0.287
T7	0.252	0.346	0.238	0.278
T8	0.236	0.271	0.188	0.232
T9	0.212	0.245	0.158	0.205
T10	0.288	0.332	0.210	0.277
T11	0.235	0.329	0.253	0.272
T12	0.247	0.322	0.209	0.259
SEm±	0.018	0.034	0.026	0.015
CD at 5%	NS	NS	NS	0.043
C.V. %	14.19	22.55	24.22	20.89
Mean	0.250	0.298	0.213	0.254
Y * T	S.Em.±	0.027	C.D. at 5 %	NS

Table 4.1.3 Status of DTPA available form of copper in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Copper DTPA available form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	1.410	1.231	1.006	1.216
T2	1.471	1.356	1.298	1.375
T3	1.334	1.133	1.038	1.168
T4	1.418	1.283	1.024	1.242
T5	1.224	1.171	1.214	1.203
T6	1.471	1.205	0.998	1.224
T7	1.327	1.243	1.224	1.264
T8	1.412	1.650	1.298	1.453
T9	1.471	1.786	1.451	1.569
T10	1.275	1.126	1.340	1.247
T11	1.417	1.372	1.293	1.360
T12	1.413	0.913	0.950	1.092
SEm±	0.069	0.097	0.090	0.078
CD at 5%	NS	0.278	0.258	0.229
C.V. %	9.89	14.98	15.23	13.35
Mean	1.387	1.289	1.178	1.285
Y * T	S.Em.±	0.086	C.D. at 5 %	0.241

Table 4.1.4 Status of reducible form of copper in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Copper reducible form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.207	0.190	0.174	0.190
T2	0.173	0.232	0.151	0.185
T3	0.185	0.177	0.169	0.177
T4	0.203	0.197	0.181	0.194
T5	0.175	0.241	0.124	0.180
T6	0.174	0.155	0.185	0.171
T7	0.178	0.232	0.147	0.186
T8	0.192	0.263	0.231	0.229
T9	0.198	0.248	0.236	0.227
T10	0.206	0.202	0.155	0.187
T11	0.215	0.221	0.183	0.206
T12	0.189	0.123	0.124	0.145
SEm±	0.013	0.020	0.022	0.016
CD at 5%	NS	0.056	0.064	0.048
C.V. %	14.04	18.86	25.76	19.7
Mean	0.191	0.207	0.172	0.190
Y * T	S.Em.±	0.019	C.D. at 5 %	0.053

works of Prasad and Singh (1980) and Patel (1998) who also showed the increase in available Cu in a long run by application of either organic or inorganic fertilizers in LTFE soils. However Lal and Mathur (1989) reported an increase in available Cu even without application of any type of nutrients in different crops.

4.1.4 Cu - Reducible

Pooled over the year and interactions were significant in reducible copper. Highest value was recorded by application of 50 % NPK in groundnut-wheat sequence + FYM @ 10 t ha⁻¹ to groundnut (T₈) followed by T₉, T₁₁, T₄, T₁, T₁₀, T₇ and T₂. In long run term, there seems to be slight decline in overall reducible of copper form (Table 4.1.4). Organic matter application retarded Cu transformation from OC into residual fraction (Saha *et al.*, 2000a).

4.1.5 Cu - Total

The total copper showed significant difference among treatment, when pooled over the years. The highest value was recorded by application of FYM @ 25 t ha⁻¹ to groundnut (T₉) followed by application of 50 % NPK in groundnut-wheat sequence + FYM @ 10 t ha⁻¹ to groundnut and 100 % N P K to wheat (T₈) (Table 4.1.5). In long term, was decline in overall total copper due to long term changes in the soil chemistry. Nevertheless there was distinct numerical reduction in total content over the years and the possibilities of mobilization from total to some of the available forms such as DTPA available and reducible copper can not be denied. The total copper content averaged 9.88 ppm with a range of 2.18 to 36.38 ppm (Tagwira, 1994).

Table 4.1.5 Status of total form of copper in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Copper total form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	13.17	12.32	10.56	12.02
T2	14.08	13.34	12.98	13.47
T3	13.74	12.16	9.83	11.91
T4	14.66	12.41	8.48	11.85
T5	13.81	12.25	9.78	11.95
T6	14.66	12.74	10.31	12.57
T7	14.01	12.35	9.41	11.92
T8	14.83	15.99	11.66	14.16
T9	14.44	17.94	15.56	15.98
T10	15.39	10.51	10.93	12.28
T11	14.66	12.01	12.86	13.18
T12	14.14	9.68	9.76	11.19
SEm±	0.47	0.84	0.93	0.81
CD at 5%	NS	2.41	2.68	2.36
C.V. %	6.52	13.09	16.93	12.15
Mean	14.30	12.81	11.01	12.71
Y * T	S.Em.±	0.77	C.D. at 5 %	2.17

Table 4.1.6 Status of residual form of copper in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Copper residual form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	11.122	10.436	9.626	10.395
T2	11.994	11.296	11.218	11.503
T3	11.778	10.392	8.307	10.159
T4	12.591	10.494	6.994	10.026
T5	11.974	10.394	8.176	10.182
T6	12.520	10.897	8.811	10.743
T7	12.073	10.383	7.729	10.062
T8	12.779	13.633	10.421	12.278
T9	12.347	15.480	13.636	13.821
T10	13.445	14.503	9.919	12.622
T11	12.608	9.922	11.050	11.193
T12	12.124	8.165	8.398	9.562
SEm±	0.486	0.884	0.799	0.737
CD at 5%	NS	2.545	2.299	2.161
C.V. %	7.92	15.6	16.77	13.45
Mean	12.27948	11.33308	9.5237938	11.04545
Y * T	S.Em.±	0.742862	C.D. at 5 %	2.087474

Table 4.1.7 Status of percentage available form of copper in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Percentage available of copper in soil			
	1 st year	4 th year	8 th year	pooled
T1	15.59	15.31	13.01	14.64
T2	14.81	15.64	13.65	14.70
T3	14.32	14.66	15.68	14.89
T4	14.11	15.55	17.83	15.83
T5	13.40	15.78	16.39	15.19
T6	14.62	14.46	15.07	14.72
T7	13.85	16.00	18.36	16.07
T8	13.88	14.83	14.73	14.48
T9	14.75	13.77	12.51	13.68
T10	12.68	11.52	15.42	13.21
T11	14.06	17.46	14.08	15.20
T12	14.32	15.64	13.89	14.62
SEm±	0.77	1.09	1.15	0.82
CD at 5%	NS	NS	3.32	NS
C.V.%	10.88	14.43	15.33	13.78
Mean	14.20	15.05	15.05	14.77
Y * T	S.Em.±	1.02	C.D. at 5 %	2.86

Table 4.1.8 Status of total available form of copper in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Total available forms of copper in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	2.05	1.88	1.43	1.79
T2	2.09	2.05	1.76	1.97
T3	1.96	1.76	1.52	1.75
T4	2.06	1.91	1.48	1.82
T5	1.84	1.86	1.61	1.77
T6	2.14	1.85	1.50	1.83
T7	1.94	1.97	1.68	1.86
T8	2.05	2.35	1.79	2.06
T9	2.09	2.46	1.93	2.16
T10	1.95	1.86	1.79	1.87
T11	2.05	2.09	1.81	1.98
T12	2.02	1.51	1.36	1.63
SEm±	0.07	0.10	0.09	0.08
CD at 5%	NS	0.28	0.27	0.24
C.V.%	7.40	10.07	11.50	9.59
Mean	2.02	1.96	1.64	1.87
Y * T	S.Em.±	0.09	C.D. at 5 %	0.25

4.1.6 Cu Residual

This form also showed significant differences due to treatment as well as due to long term changes (Table 4.1.6). Highest value was recorded in application of FYM @ 25 t ha⁻¹ to groundnut (T₉) followed by T₁₀ and T₈. Most of the treatments recorded numerical reduction after 4 and 8 year as compared to initial year which also gave indication that the total form was mobilized not as the residual form but as the available form.

4.1.7 Cu - Percentage Availability

In the 8th year, highest value recorded in T₇ followed by T₄, T₅, T₃, T₁₀ and T₆, while in initial year and 4th year the differences among treatments were not significant (Table 4.1.7). Though overall pooled differences were not significant but Y × T interaction was significant.

4.1.8 Cu Available Total

The available total copper showed significant differences among treatments when pooled over year and also Y × T interaction were significant. Highest value was recorded in application of FYM @ 25 t ha⁻¹ to groundnut (T₉) followed by application of 100 % N P K of recommended doses in Groundnut -Wheat sequence (P as S S P) and 100 % N P K of recommended doses in G'nut -Wheat sequence. In long term, there seems to be a slight decrease after 8th year in available total content of copper (Table 4.1.8).

4.1.9 Cu- percent Distribution of Different forms of Avt. in LTFE soils

All the forms of represent some proportion in available total with DTPA available copper having the highest proportion followed by exchangeable, reducible and water soluble (Fig. 4.1.3.1).

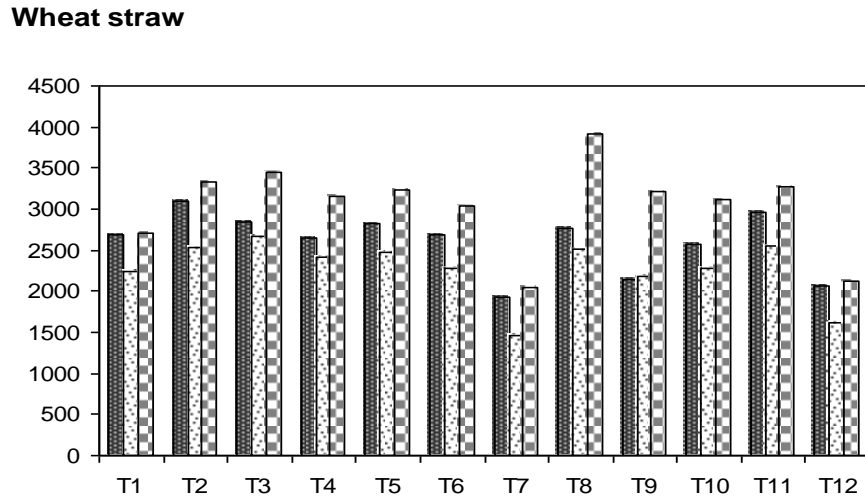
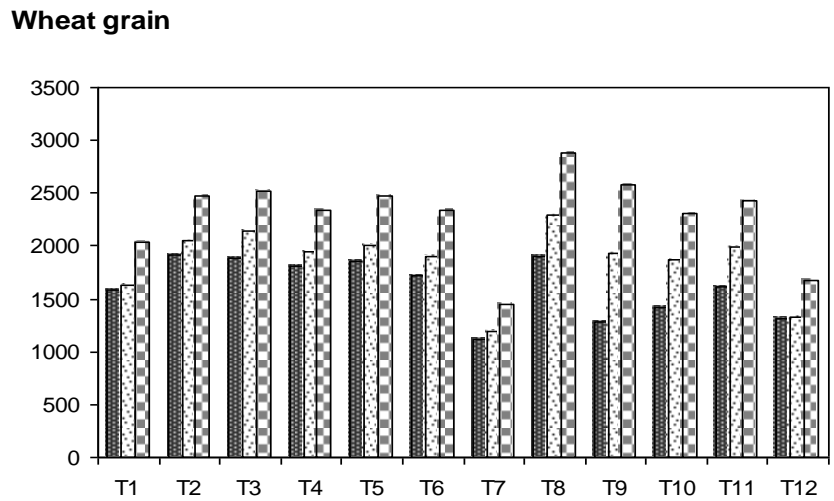
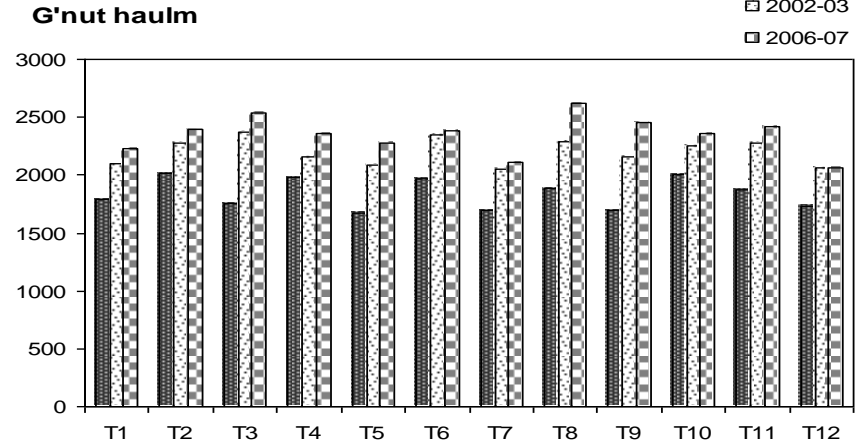
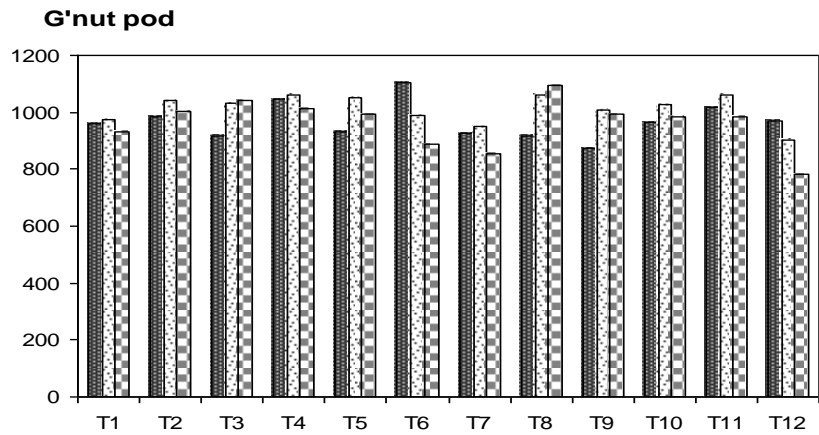


Fig. 4.0.1 yield of groundnut and wheat crop sequence in 1st, 4th and 8th year of LTFE experiment

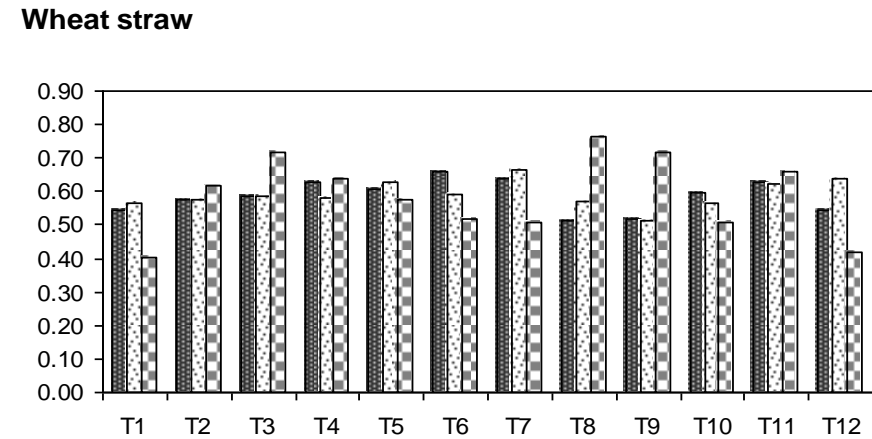
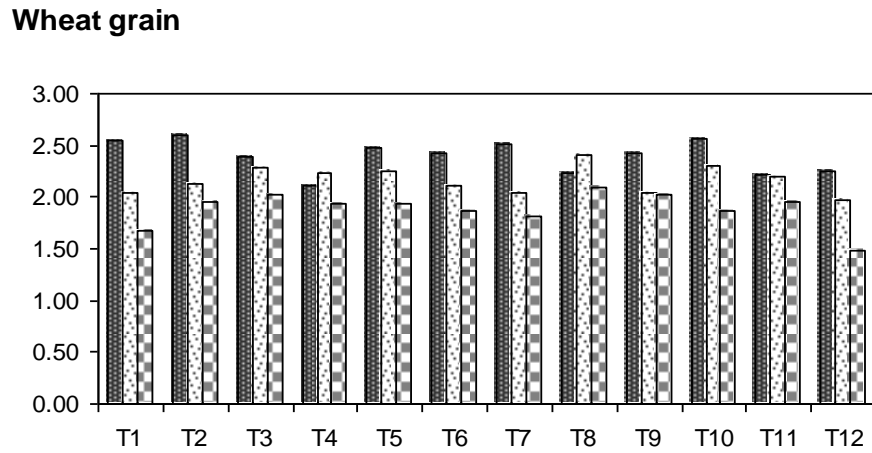
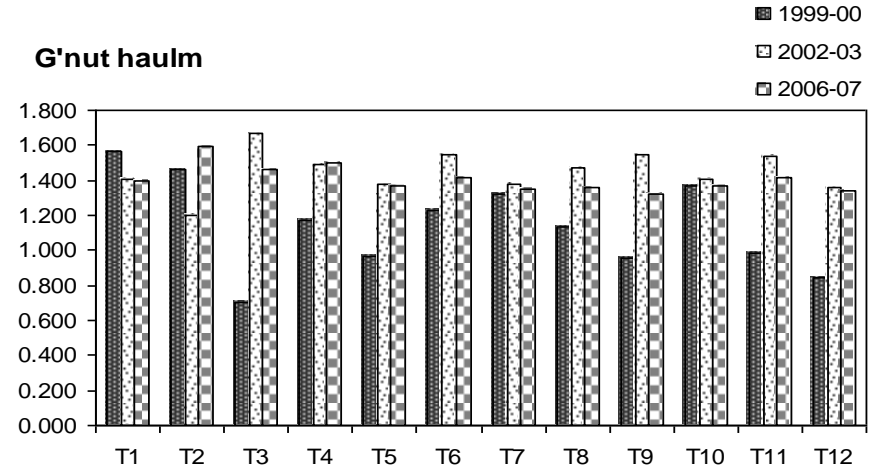
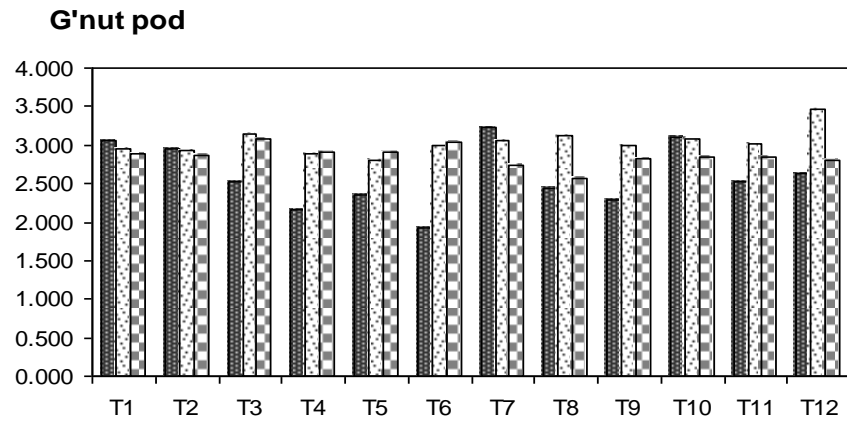


Fig. 4.0.2 Nitrogen concentration (%) in groundnut and wheat in 1st, 4th and 8th year of LTFE experiment

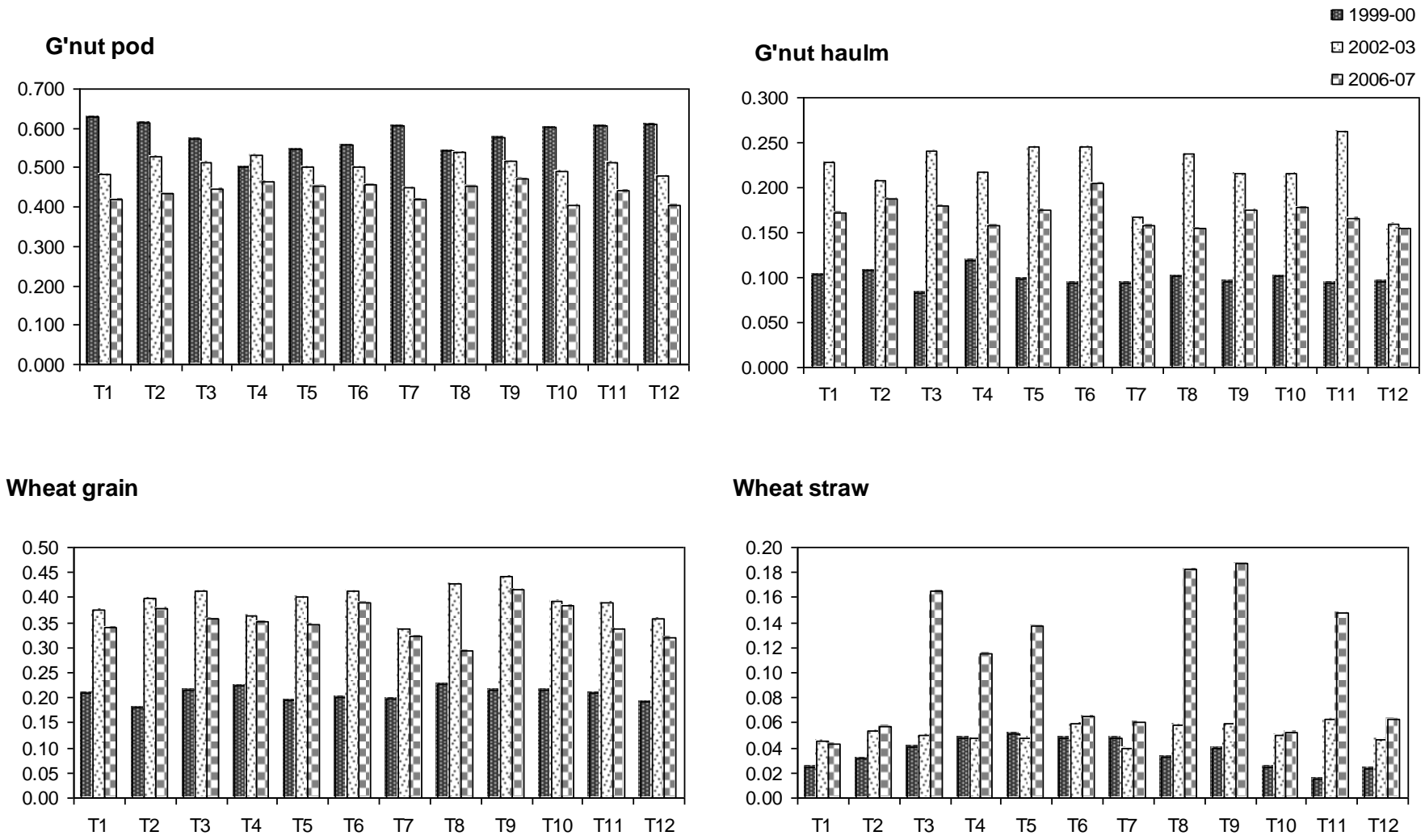


Fig. 4.0.3 Phosphorus concentration (%) in groundnut and wheat in 1st, 4th and 8th year of LTFE experiment

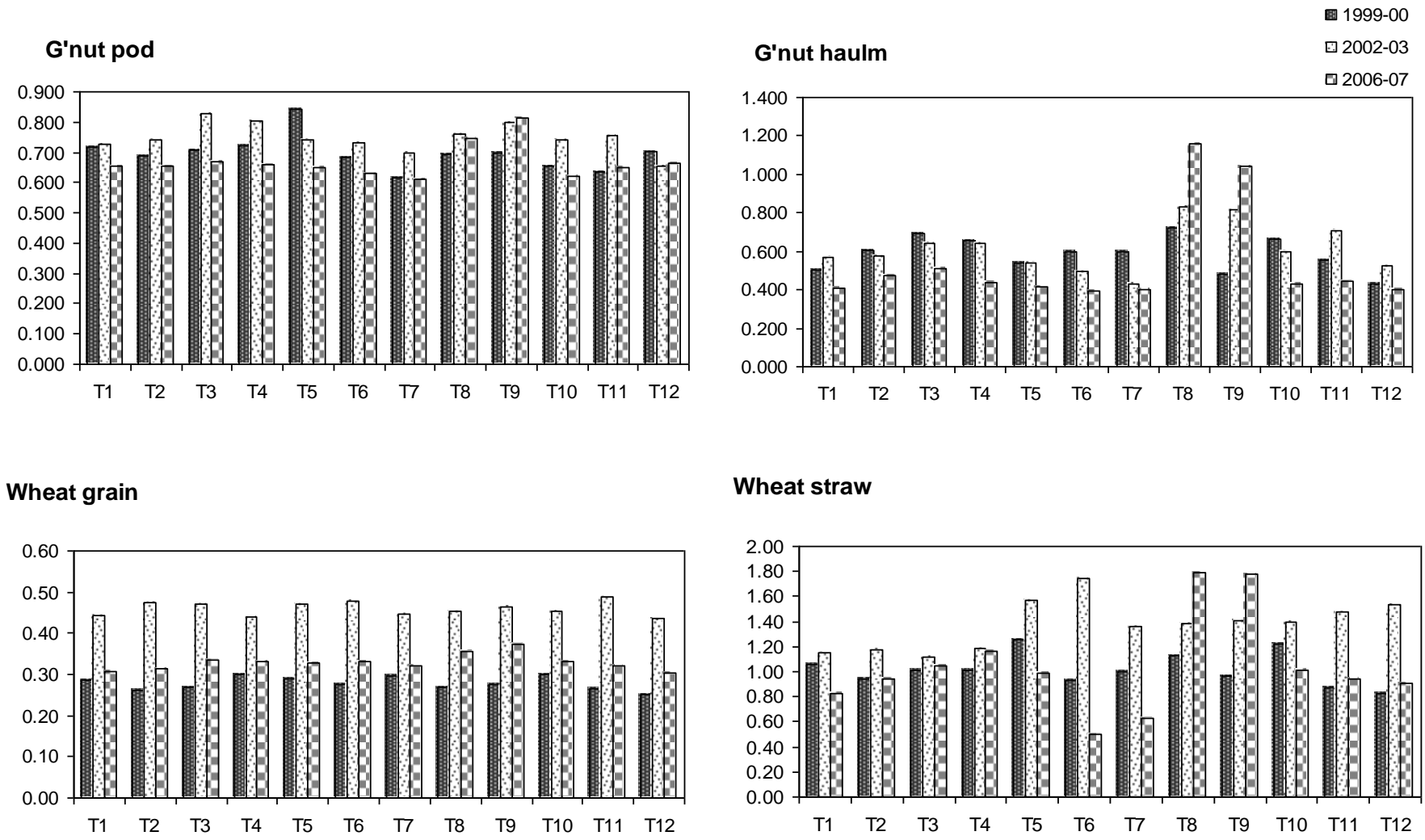


Fig. 4.0.4 Potash concentration (%) in groundnut and wheat in 1st, 4th and 8th year of LTFE experiment

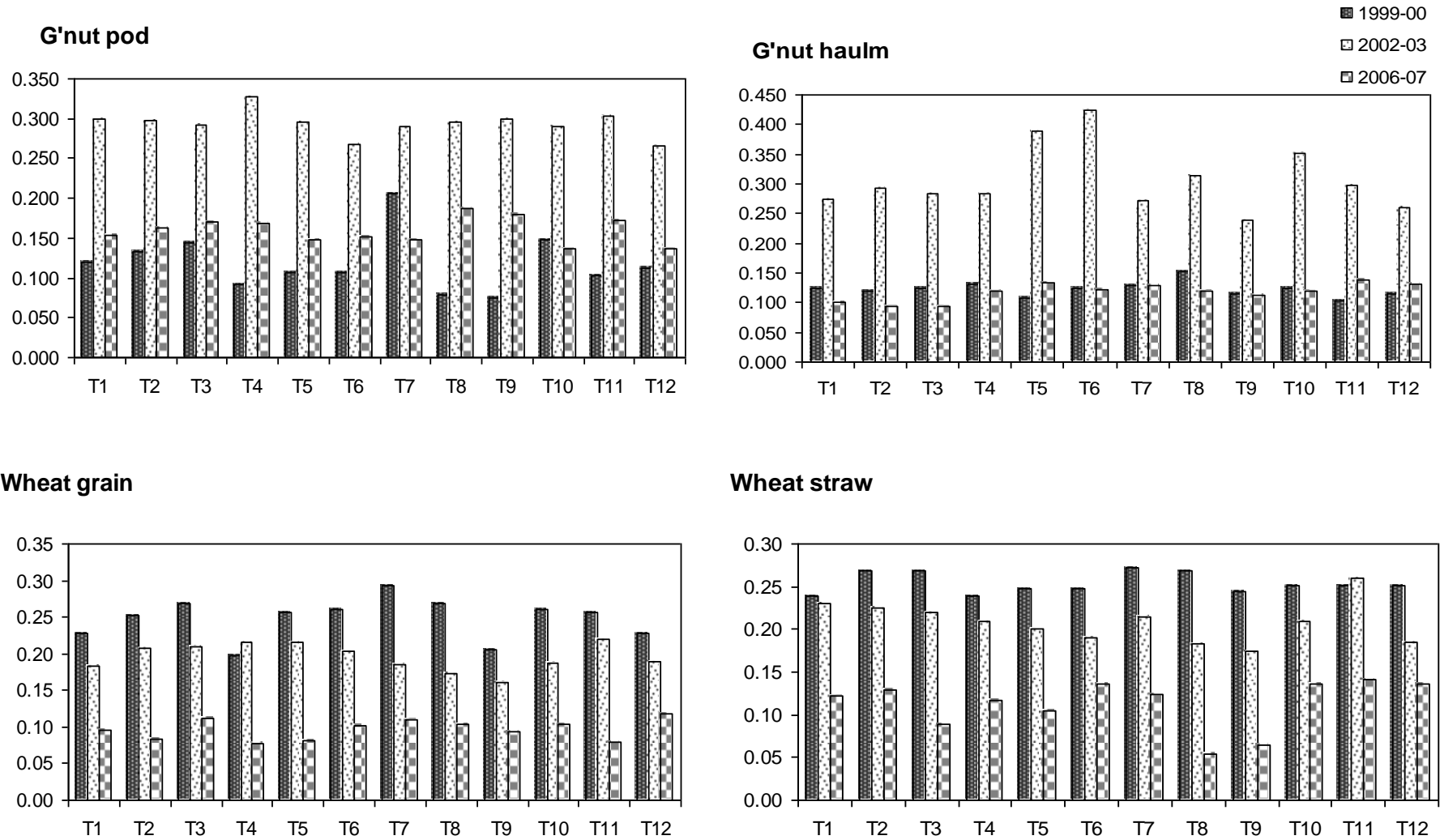


Fig. 4.0.5 Sulphur concentration (%) in groundnut and wheat in 1st, 4th and 8th year of LTFE experiment

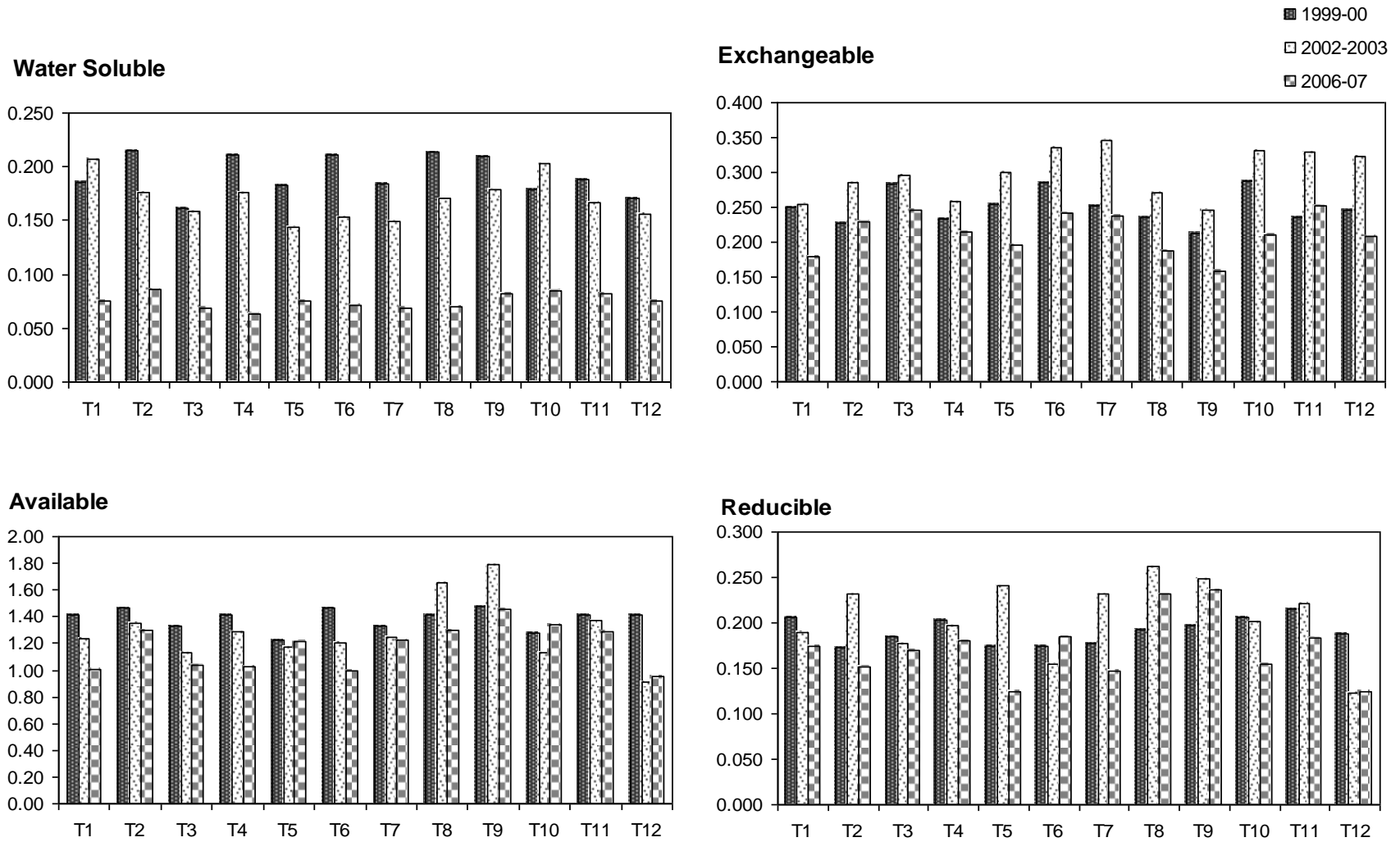


Fig. 4.1.1 Status (ppm) of form of Cu in the LTFE soils in 1st, 4th and 8th years

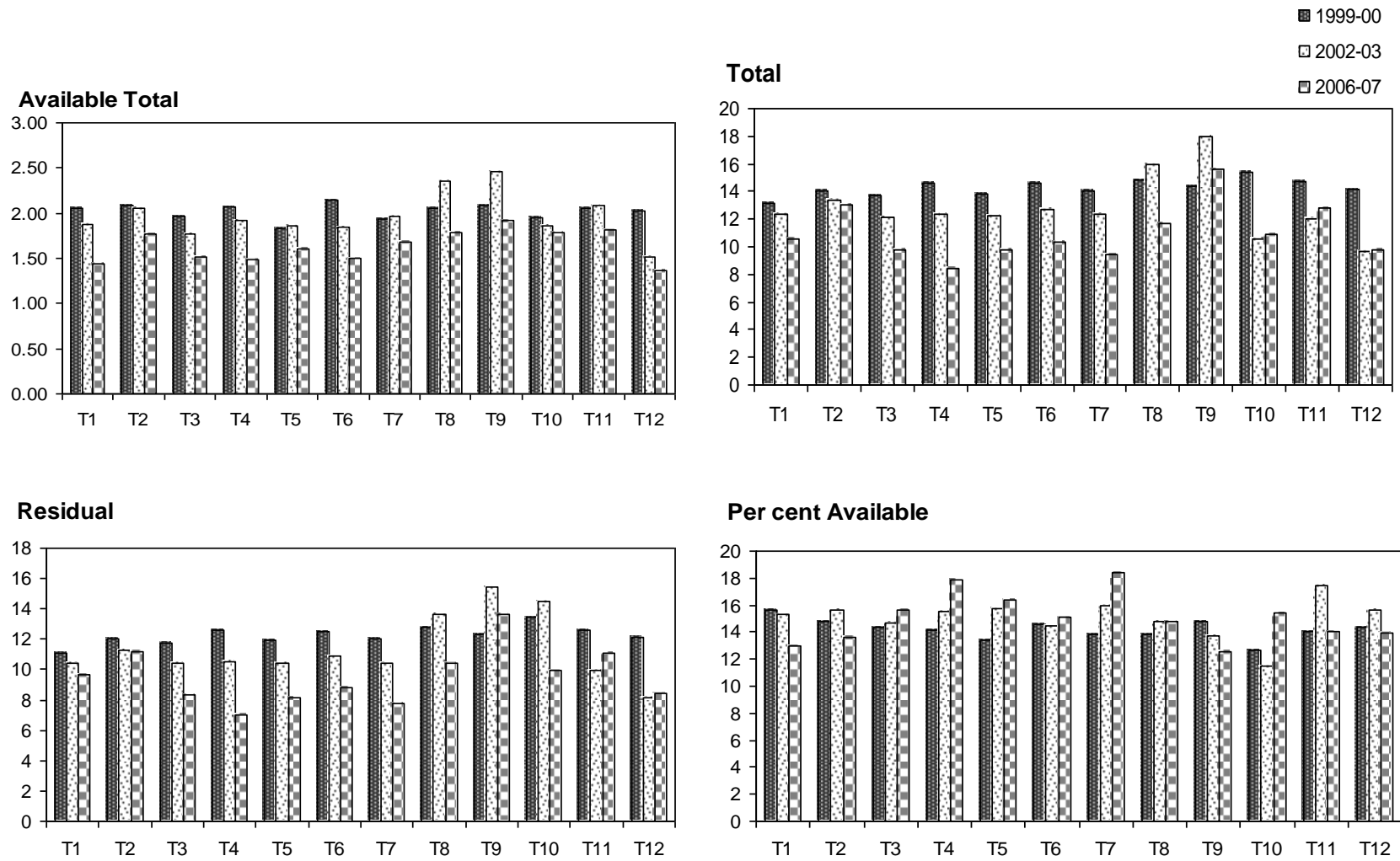


Fig. 4.1.2 Status (ppm) of form of Cu in the LTFE soils in 1st, 4th and 8th years

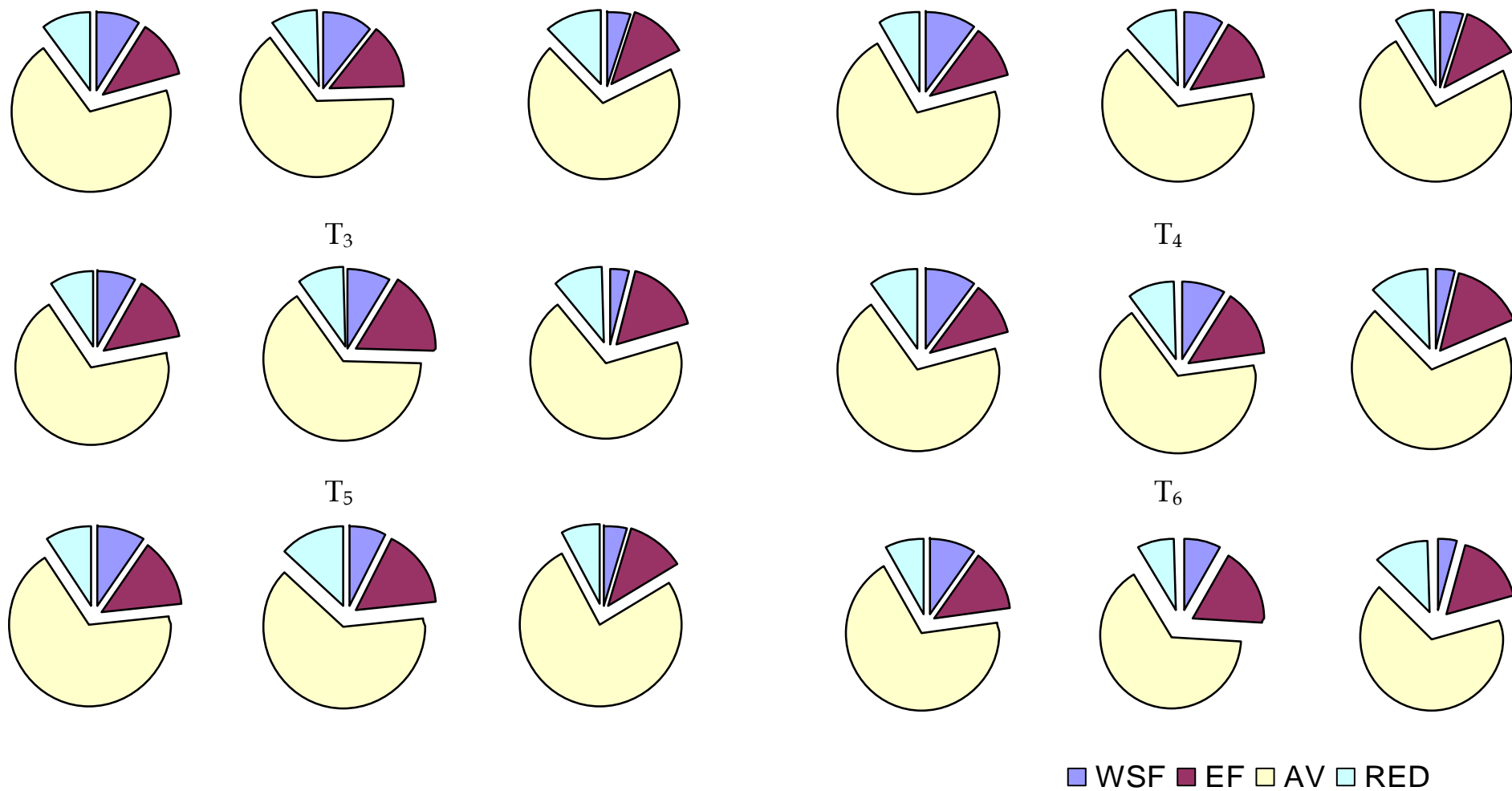


Fig. 4.1.3.1 Percent distribution in different forms of available total Cu (Avt) in 1st, 4th and 8th years in the LTFE soils

T₇

T₈

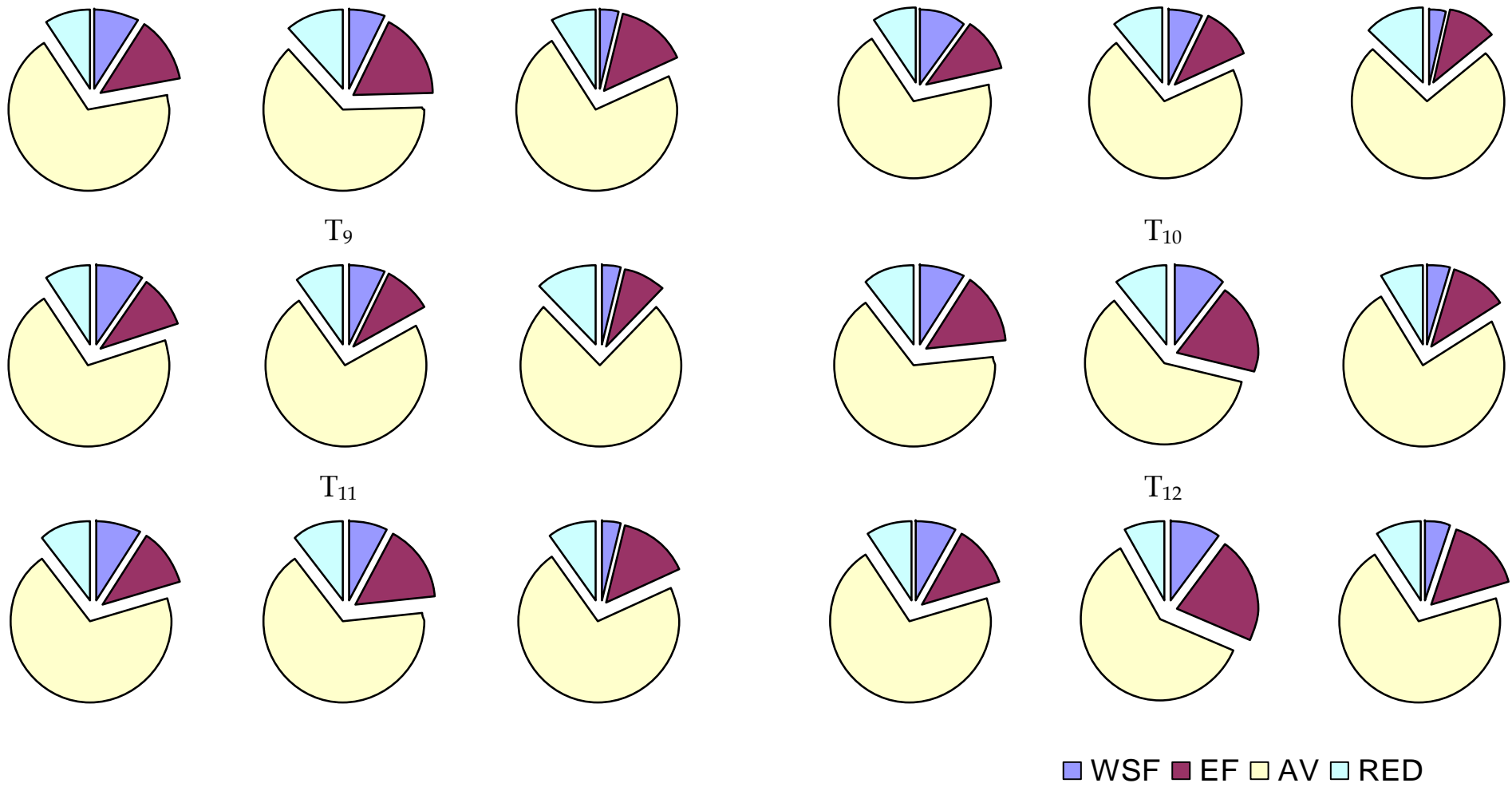


Fig. 4.1.3.2 Percent distribution in different forms of available total Cu (Avt) in 1st, 4th and 8th years in the LTFE soils

T₁

T₂

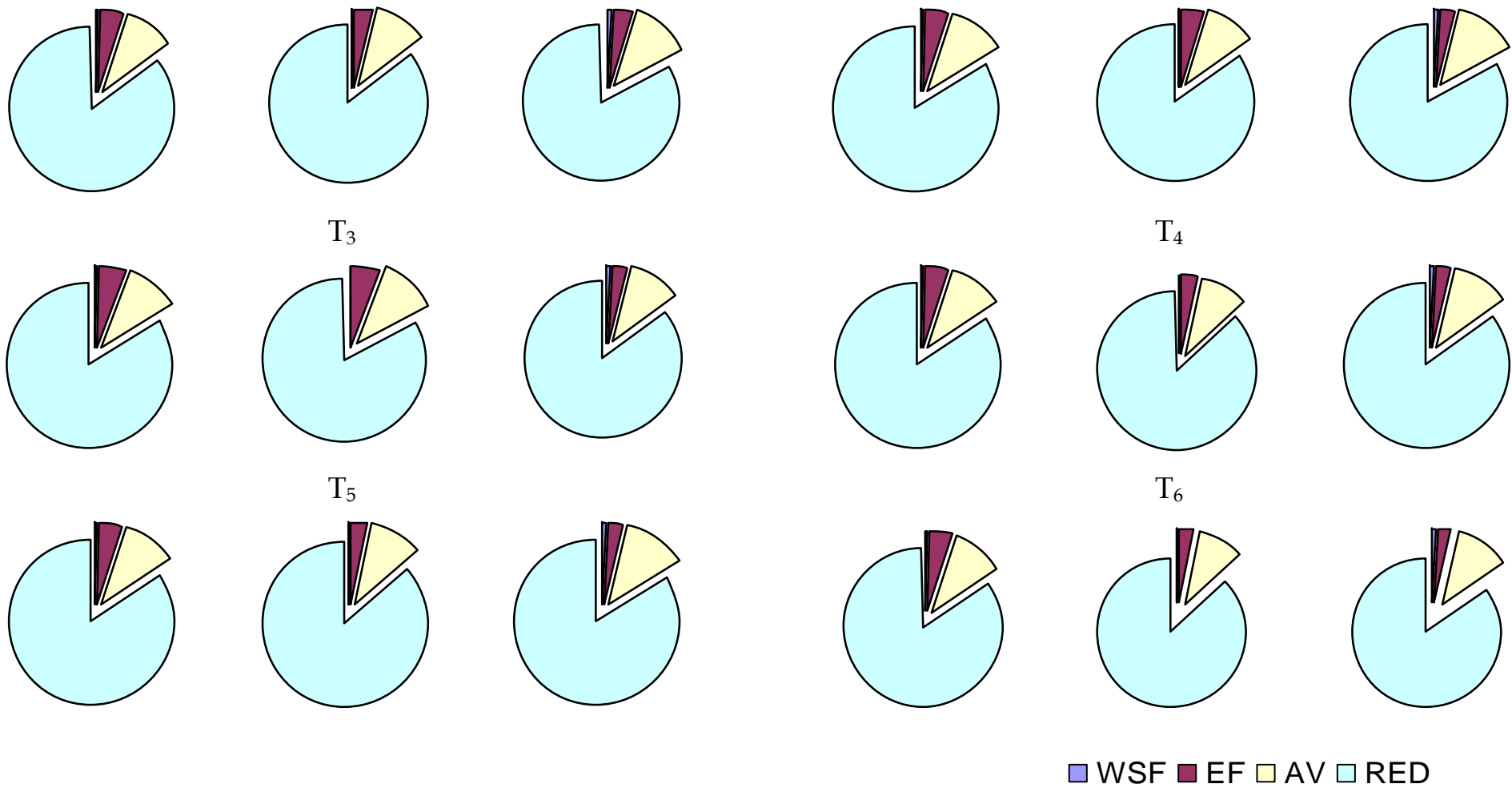


Fig. 4.2.3.1 Percent distribution in different forms of available total Mn (Avt) in 1st, 4th and 8th years in the LTFE soils

T₇

T₈

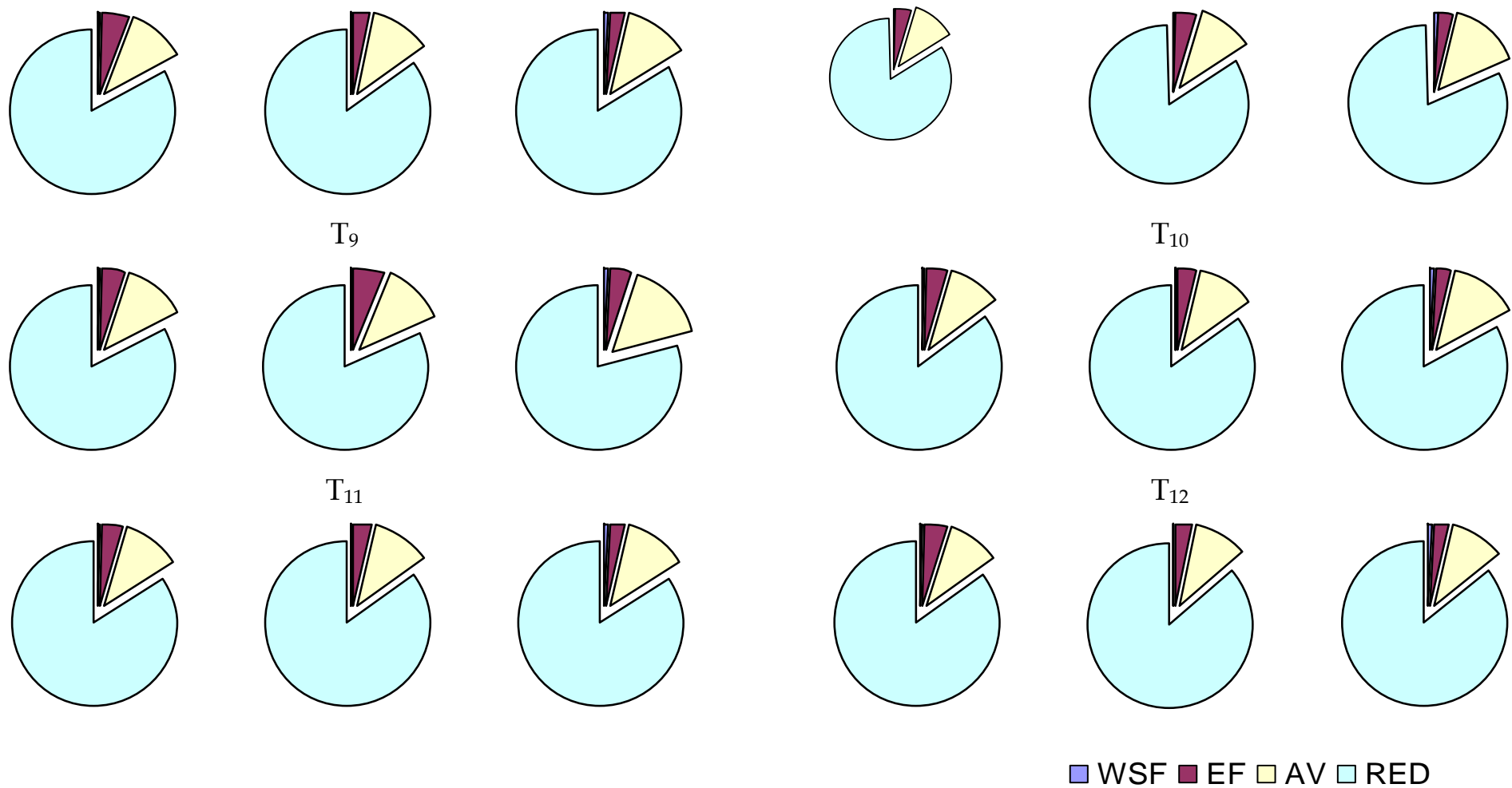


Fig. 4.2.3.2 Percent distribution in different forms of available total Mn (Avt) in 1st, 4th and 8th years in the LTFE soils

MANGANESE

4.2.1 0Mn - Water Soluble

The water soluble Mn showed significant difference among treatment, when pooled over years and also in 4th year (Table 4.2.1). Highest value was observed in T₈ followed by T₇, T₅, T₁₁, T₈, T₁, T₃ and T₄. Interaction between treatment and year was found non significant. Komisarek *et al.* (1991) stated that increasing lime rates decreased water soluble Mn. Mehra and Baser (1982) observed that water soluble Mn ranged from traces to 3.82 ppm. The water soluble Mn fraction constituted a very small fraction of total Mn (Sharma *et al.*, 1997).

4.2.2 Mn - Exchangeable

The exchangeable Mn showed significant difference among treatment when pooled over years. The highest value was recorded under application of FYM @ 25 t/ha to G'nut only (T₉) followed by application of 150 % N P K of recommended doses in G'nut -Wheat sequence (T₃) and 100 % N P K of recommended doses in G'nut -Wheat sequence (T₂). Interaction between treatment and year was also significant. In long term, there seems to be decrease over the year. The level of exchangeable Mn in first year was highest as compared to 4 and 8 year, that signified that application of chemical fertilizer in particular enhanced utilization of this form of Mn by the plants vis-à-vis in a long term changing mobilization of Mn to this particular form from other forms (Table 4.2.2). Looking to the spectrum of DTPA available Mn there seems to be conversion of this form into exchangeable form, particularly under chemical fertilizers treatments. Komisarek *et al.* (1991) stated that increasing lime rates

decreased exchangeable Mn. Mehra and Baser (1982) observed that exchangeable Mn averaged 2.07 ppm. The exchangeable Mn fraction of total Mn accounted for 13 per cent (Sharma *et al.*, 1997).

4.2.3 Mn - DTPA Available

The DTPA available form of Mn differed significant, when pooled over years and highest value was observed under application of FYM @ 25 t ha⁻¹ to G'nut, while Y x T interaction were non significant (Table 4.2.3). Mean values did not showed any significant changes after 4th year but after 8th year slight increase was in mean value. The chemical fertilizer appeared to maintain the high utilization of DTPA available Mn by the plants through out as well as conversion of DTPA available form into the exchangeable form (Fig. 4.2.3.1 and 4.2.3.2). Zhang and Zhang (1984 b) reported that in calcareous soils chelated and exchangeable Mn were of little importance in the nutrient status of soil and easily reducible Mn markedly affects the soil Mn supply for plants. Sharma *et al.* (1997) reported that reducible and exchangeable Mn fraction constituted 30.4 and 13 per cent of the total Mn, respectively.

4.2.4 Mn - Reducible

Reducible form of Mn was significant, when pooled over years and highest value was observed under application of 100 % NP of recommended doses in G'nut -Wheat sequence, while Y x T interaction were non significant (Table 4.2.4). Overall mean value did not show any significant changes over time but chemical fertilizers, in general increased the reducible Mn after 8th year compared to control and FYM. This supported the contention that chemical fertilizer enhanced utilization of reducible Mn also. Mehra and Baser (1982) observed that reducible Mn ranged 22-109 ppm. Reducible Mn fraction constituted 30.4 per cent of the total Mn as reported by Sharma *et al.* (1997).

Table 4.2.1 Status of water soluble form of manganese in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Manganese water soluble from in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.480	0.312	0.794	0.529
T2	0.460	0.273	0.769	0.501
T3	0.499	0.291	0.785	0.525
T4	0.459	0.275	0.834	0.522
T5	0.496	0.365	0.798	0.553
T6	0.466	0.258	0.782	0.502
T7	0.494	0.353	0.817	0.555
T8	0.482	0.425	0.767	0.558
T9	0.446	0.345	0.805	0.532
T10	0.456	0.260	0.791	0.502
T11	0.452	0.373	0.777	0.534
T12	0.458	0.242	0.771	0.490
SEm±	0.025	0.033	0.026	0.016
CD at 5%	NS	0.095	NS	0.045
C.V.%	10.490	21.000	6.480	10.670
Mean	0.471	0.314	0.791	0.525
Y * T	S.Em.±	0.028	C.D. at 5 %	NS

Table 4.2.2 Status of exchangeable form of manganese in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Manganese exchangeable form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	2.312	1.667	1.734	1.904
T2	2.529	2.226	1.641	2.132
T3	2.643	3.214	1.448	2.435
T4	2.418	1.566	1.423	1.802
T5	2.403	1.360	1.535	1.766
T6	2.346	1.481	1.280	1.702
T7	2.712	1.365	1.239	1.772
T8	2.016	2.129	1.622	1.922
T9	2.510	3.234	2.249	2.664
T10	2.025	2.061	1.449	1.845
T11	2.130	1.538	1.388	1.685
T12	2.148	1.490	1.236	1.625
SEm±	0.229	0.258	0.175	0.213
CD at 5%	NS	0.742	0.505	0.624
C.V.%	19.460	26.500	23.070	23.030
Mean	2.349	1.944	1.520	1.938
Y * T	S.Em.±	0.223	C.D. at 5 %	0.627

Table 4.2.3 Status of DTPA available form of manganese in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Manganese DTPA available form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	5.168	5.895	6.856	5.973
T2	5.977	5.805	6.919	6.233
T3	5.821	6.145	6.059	6.008
T4	5.804	5.187	6.324	5.772
T5	5.512	5.659	6.891	6.021
T6	5.713	5.162	6.965	5.947
T7	6.328	6.610	7.043	6.660
T8	6.400	5.964	8.342	6.902
T9	6.797	7.373	8.793	7.655
T10	5.566	5.979	7.536	6.360
T11	6.161	6.398	6.709	6.423
T12	5.663	5.558	5.626	5.616
S _{Em} ±	0.394	0.376	0.427	0.231
CD at 5%	NS	1.082	1.230	0.648
C.V.%	13.350	12.570	12.200	12.690
Mean	5.909	5.978	7.005	6.297
Y * T	S _{Em} .±	0.400	C.D. at 5 %	NS

Table 4.2.4 Status of reducible form of manganese in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Manganese reducible form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	44.95	44.37	45.51	44.94
T2	44.77	44.76	44.68	44.74
T3	44.85	45.44	45.51	45.27
T4	45.38	45.41	46.15	45.64
T5	44.92	45.76	45.77	45.48
T6	46.55	45.26	48.43	46.75
T7	45.36	44.95	45.93	45.42
T8	45.42	44.60	47.02	45.68
T9	45.29	46.95	44.63	45.62
T10	45.50	45.94	45.80	45.75
T11	45.01	46.14	45.50	45.55
T12	44.52	44.67	45.21	44.80
S _{Em} ±	0.61	0.51	0.64	0.34
CD at 5%	NS	1.46	1.84	0.95
C.V.%	2.70	2.23	2.79	2.59
Mean	45.21	45.36	45.85	45.47
Y * T	S _{Em} .±	0.59	C.D. at 5 %	NS

4.2.5 Mn- Total

The pooled differences were significant, however Y x T interaction was non significant. The highest value observed with application of FYM @ 25 t ha⁻¹ to G'nut (T₉) followed by under application of 50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t/ha G'nut and 100 % N P K to Wheat (T₈). Overall mean values registered a decrease in the total Mn content on the long run basis. There is a possibility of replenishing Mn in the soil by fertilizer application. The utilization of Mn by the plants also appears to increase by the fertilizer application which was quite evident from the significant treatment differences over the years (Table 4.2.5).

4.2.6 Mn - Residual

The pooled differences were significant, but Y x T interaction was non significant, highest significant value was observed under application of FYM @ 25 t ha⁻¹ to G'nut (T₉) followed by under application of 50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t/ha G'nut and 100 % N P K to Wheat (T₈). Maximum depletion was observed in control treatment after 8th year. Overall mean registered a decrease in the residual Mn content on long run basis (Table 4.2.6).

4.2.7 Mn - Percentage Availability

The percentage available Mn in soil is largely reflected by DTPA available and reducible form of Mn. Although pooled difference differed significantly, the Y x T interaction was not significant. The untreated control recorded the highest values compare to fertilized treatment after 4th and 8th years. Thus chemical fertilizer not only favoured conversion to available form but also enhanced utilization of Mn content (Table 4.2.7).

Table 4.2.5 Status of total form of manganese in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Manganese total form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	242.76	232.64	225.99	233.80
T2	241.99	233.58	225.93	233.83
T3	241.18	228.89	224.03	231.37
T4	249.98	228.59	240.73	239.77
T5	246.31	233.79	229.80	236.64
T6	248.20	231.19	228.75	236.05
T7	256.89	229.19	243.10	243.06
T8	259.98	236.66	245.34	247.32
T9	258.81	248.37	256.09	254.42
T10	250.61	232.42	230.46	237.83
T11	247.82	231.18	219.54	232.84
T12	243.59	229.23	203.30	225.37
SEm±	4.46	3.10	6.74	2.88
CD at 5%	12.84	8.93	19.40	8.10
C.V.%	3.58	2.66	5.83	4.20
Mean	249.01	232.98	231.09	237.69
Y * T	S.Em.±	5.00	C.D. at 5 %	NS

Table 4.2.6 Status of residual form of manganese in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Manganese residual form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	189.86	180.40	171.09	180.45
T2	188.25	180.51	171.91	180.23
T3	187.36	173.80	170.23	177.13
T4	195.92	176.15	186.00	186.03
T5	192.99	180.65	174.81	182.82
T6	193.13	179.03	171.29	181.15
T7	201.99	175.91	188.07	188.66
T8	205.66	183.53	187.59	192.26
T9	203.77	190.47	199.61	197.95
T10	197.06	178.18	174.88	183.37
T11	194.06	176.72	165.16	178.65
T12	190.80	177.26	150.46	172.84
SEm±	4.52	3.29	6.65	2.90
CD at 5%	NS	NS	19.14	8.14
C.V.%	4.64	3.66	7.56	5.47
Mean	195.07	179.39	175.93	183.46
Y * T	S.Em.±	5.01	C.D. at 5 %	NS

Table 4.2.7 Status of percentage available form of manganese in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Percentage available of Manganese in soil			
	1 st year	4 th year	8 th year	pooled
T1	21.84	24.31	24.45	23.53
T2	22.22	23.95	23.95	23.37
T3	22.32	24.17	24.21	23.57
T4	21.64	22.77	22.77	22.40
T5	21.67	23.96	23.96	23.20
T6	22.22	25.16	25.16	24.18
T7	21.39	22.66	22.82	22.29
T8	20.90	23.70	23.70	22.77
T9	21.27	22.09	22.09	21.81
T10	21.38	24.17	24.17	23.24
T11	21.70	24.79	24.79	23.76
T12	21.62	26.00	26.00	24.54
S _{Em} ±	0.49	0.72	0.72	0.38
CD at 5%	NS	2.07	2.08	1.06
C.V.%	4.50	5.99	6.02	5.62
Mean	21.68	23.98	24.00	23.22
Y * T	S _{Em} .±	0.65	C.D. at 5 %	NS

Table 4.2.8 Status of total available form of manganese in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Total available forms of Manganese in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	52.91	52.24	54.89	53.35
T2	53.74	53.07	54.01	53.61
T3	53.81	55.09	53.80	54.23
T4	54.06	52.44	54.73	53.74
T5	53.33	53.14	54.99	53.82
T6	55.08	52.16	57.45	54.90
T7	54.90	53.28	55.03	54.40
T8	54.32	53.12	57.75	55.07
T9	55.04	57.90	56.48	56.47
T10	53.55	54.24	55.58	54.46
T11	53.75	54.45	54.37	54.19
T12	52.79	51.96	52.85	52.53
S _{Em} ±	0.76	0.77	0.74	0.66
CD at 5%	NS	2.21	2.13	1.92
C.V.%	2.83	2.86	2.69	2.79
Mean	53.94	53.59	55.16	54.23
Y * T	S _{Em} .±	0.76	C.D. at 5 %	2.13

4.2.8 Mn Available Total

The total available Mn also differed significantly when years pooled and also in Y x T interaction. Like wise other forms highest value was observed by T₉ followed by T₈ and T₆. Overall mean value slight decline after 4th year but after 8th year it was the higher values numerically as compared to other year, suggesting the faster replenishment from total Mn content (Table 4.2.8).

4.2.9 Mn - Percent Distribution of Different Forms of Avt. In LTFE soils

Manganese on the other hand showed reducing forms as the predominant component followed by DTPA available and exchangeable form of Mn. Water soluble form recorded negligible to almost Zero proportion. There were inter-conversions from DTPA available as well as exchangeable form to the reducible form in a long run. i.e. after 4 and 8 years in almost all the treatments including control (Fig. 4.2.3.1 and 4.2.3.2

)

ZINC

4.3.1 Zn - Water Soluble

Water soluble Zn did not showed any significant difference due to treatments over time (Table 4.3.1). Fraction of Zn in soil samples showed that zinc in water soluble pools were virtually non-existent (Shinghal and Rattan, 1995).

4.3.2 Zn Exchangeable

Exchangeable form of Zn differed significantly at 4th, 8th year and also when pooled over years (Table 4.3.2). The highest value was recorded in T₉ followed by T₄, T₈ and T₁. The Y x T interaction was also

Table 4.3.1 Status of water soluble form of zinc in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Zinc water soluble from in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.120	0.149	0.127	0.132
T2	0.125	0.112	0.118	0.118
T3	0.131	0.122	0.148	0.133
T4	0.136	0.128	0.112	0.125
T5	0.130	0.137	0.111	0.126
T6	0.113	0.115	0.139	0.122
T7	0.115	0.128	0.138	0.127
T8	0.118	0.123	0.116	0.119
T9	0.130	0.159	0.126	0.138
T10	0.131	0.115	0.147	0.131
T11	0.127	0.098	0.127	0.117
T12	0.126	0.114	0.134	0.125
SEm±	0.009	0.014	0.015	0.008
CD at 5%	NS	NS	NS	NS
C.V.%	14.920	22.850	23.640	20.900
Mean	0.125	0.125	0.129	0.126
Y * T	S.Em.±	0.013	C.D. at 5 %	NS

Table 4.3.2 Status of exchangeable form of zinc in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Zinc exchangeable form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.166	0.126	0.165	0.152
T2	0.139	0.114	0.163	0.139
T3	0.153	0.102	0.134	0.130
T4	0.147	0.223	0.186	0.185
T5	0.137	0.109	0.136	0.127
T6	0.147	0.112	0.178	0.146
T7	0.155	0.131	0.158	0.148
T8	0.159	0.142	0.173	0.158
T9	0.158	0.155	0.266	0.193
T10	0.133	0.104	0.157	0.131
T11	0.146	0.146	0.137	0.143
T12	0.155	0.107	0.125	0.129
SEm±	0.013	0.014	0.019	0.014
CD at 5%	NS	0.042	0.054	0.042
C.V.%	17.500	21.980	22.650	20.970
Mean	0.149	0.131	0.165	0.148
Y * T	S.Em.±	0.016	C.D. at 5 %	0.044

Table 4.3.3 Status of DTPA available form of zinc in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Zinc DTPA available form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.903	1.496	1.082	1.161
T2	0.819	1.083	1.461	1.121
T3	0.826	0.737	1.286	0.950
T4	0.913	1.257	2.176	1.449
T5	0.757	0.975	1.412	1.048
T6	0.731	1.091	2.148	1.323
T7	0.751	1.141	1.680	1.191
T8	0.675	1.078	2.121	1.291
T9	0.834	1.451	2.662	1.649
T10	0.820	0.862	1.383	1.022
T11	0.912	0.761	1.502	1.058
T12	0.860	0.747	1.214	0.941
SEm±	0.054	0.126	0.198	0.169
CD at 5%	NS	0.364	0.570	NS
C.V.%	13.300	23.910	23.610	23.520
Mean	0.817	1.057	1.677	1.184
Y * T	S.Em.±	0.139	C.D. at 5 %	0.391

Table 4.3.4 Status of reducible form of zinc in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Zinc reducible form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.475	0.213	1.547	0.745
T2	0.458	0.368	1.439	0.755
T3	0.482	0.345	1.262	0.696
T4	0.360	0.528	2.222	1.036
T5	0.429	0.328	1.340	0.699
T6	0.397	0.450	1.684	0.844
T7	0.422	0.346	1.176	0.648
T8	0.345	0.282	1.339	0.655
T9	0.447	0.489	1.568	0.835
T10	0.361	0.329	1.205	0.632
T11	0.434	0.252	1.257	0.648
T12	0.357	0.212	1.189	0.586
SEm±	0.036	0.028	0.152	0.095
CD at 5%	NS	0.080	0.438	NS
C.V.%	17.410	16.030	21.170	25.040
Mean	0.414	0.345	1.436	0.732
Y * T	S.Em.±	0.092	C.D. at 5 %	0.257

significant. Mean values declined after 4th year but it increased after 8th year (Fig 4.3.1).

4.3.3 Zn -DTPA Available

This forms did not differed significantly when pooled over years but Y x T interaction was found significant and the highest values was recorded in application of FYM @ 25 t/ha to G'nut only (T₉) followed by T₄, T₆ and T₈ after 8th year and also higher value observed under application of 50% N P K of recommended doses in G'nut -Wheat sequence (T₁) followed by application of FYM @ 25 t/ha to G'nut (T₉), T₄ and T₇ after 4th year. Thus, the FYM recorded the highest value as compare to other treatments at the 4th year and 8th year. Overall mean value increased with time span (Table 4.3.3) .

4.3.4 Zn - Reducible

Although the pooled differences were not significant due to treatment but Y x T was significant (Table 4.3.4). The highest values were recorded under application of 100 % N P K of recommended doses in G'nut -Wheat sequence + ZnSO₄ @ 50 kg/ha once in three year to G'nut only (T₄) followed by T₉ after 8th year and T₆ after 4th year. The mean value was declined after 4th year but it increased again after 8th year (Fig. 4.3.1). Thus, the complete recommended doses of fertilizer with ZnSO₄ recorded the highest value compare to other treatment. The residual Zn which contributed the major fraction in soil and apparently associated with soil minerals, showed a higher mean value of 24.6 ppm (Gowrisankar and Murrigappan, 1998).

4.3.5 Zn - Total

Total forms of Zn differed significantly when pooled over years and also Y x T interaction was significant (Table 4.3.5). The highest value was recorded under application of FYM @ 25 t/ha to G'nut (T₉) in mostly all the years and pooled result except 1st year. In a long run only slightly decline was observed in

the mean value. In general, total Zn converted into available Zn under its depletion status of soil, which might be utilized by crop. The total soil zinc concentration ranged from 38.1 to 113.8 ppm (Chaudhary *et al.*, 1997).

4.3.6 Zn - Residual

Like wise total, the residual form of Zn also differed significantly when pooled over years and also in Y x T interaction was significant (Table 4.3.6). The highest value was recorded under application of FYM @ 25 t/ha to G'nut (T₉). In a long run depletion was observed in all the treatments. The residual zinc fraction constituted higher percentage of total zinc fraction observed by Shinghal and Rattan (1995).

4.3.7 Zn - Percentage Availability

Pooled differences were not significant but Y x T interaction was significant. In long term in 8th year the percent available Zn increased to the highest level under application of 100 % N P K of recommended doses in G'nut - Wheat sequence + ZnSO₄ @ 50 kg/ha once in three years to G'nut only (T₄), 100 % N P of recommended doses in G'nut -Wheat sequence (T₆) and of FYM @ 25 t/ha to G'nut (T₉). The application of chemical fertilizers appeared to trigger the utilization of available Zn. In T₄, T₆ and T₉ the utilization was not triggered but in a long run because of soil reaction there is a possibility of conversion to available Zn from total, hence, the values are higher in 8th year as compared to initial year (Fig 4.3.2).

Table 4.3.5 Status of total form of zinc in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Zinc total form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	34.90	32.31	30.56	32.59
T2	34.25	32.55	32.92	33.24
T3	34.55	32.31	29.85	32.24
T4	32.82	32.63	30.05	31.83
T5	33.23	31.91	31.37	32.17
T6	35.85	33.22	31.28	33.45
T7	32.91	32.71	31.60	32.41
T8	34.73	35.64	31.69	34.02
T9	35.36	38.20	35.09	36.22
T10	34.50	32.90	33.35	33.58
T11	34.46	32.40	31.44	32.76
T12	32.81	30.32	29.62	30.92
S _{Em} ±	0.75	0.73	0.86	0.61
CD at 5%	NS	2.11	2.47	1.80
C.V. %	4.36	4.42	5.43	4.74
Mean	34.20	33.09	31.57	32.95
Y * T	S _{Em} ±	0.78	C.D. at 5 %	2.19

Table 4.3.6 Status of residual form of zinc in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Zinc residual form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	30.57	30.33	27.64	29.51
T2	32.71	30.87	29.74	31.11
T3	32.96	31.01	27.02	30.33
T4	31.26	30.50	25.35	29.04
T5	31.78	30.36	28.37	30.17
T6	34.96	31.45	27.13	31.18
T7	31.46	30.96	28.45	30.29
T8	35.19	34.02	27.94	32.38
T9	37.20	35.94	30.47	34.54
T10	33.55	31.49	30.46	31.83
T11	32.84	31.14	28.41	30.80
T12	30.07	29.14	26.96	28.72
S _{Em} ±	0.90	0.72	0.90	0.63
CD at 5%	2.58	2.08	2.60	1.85
C.V. %	5.46	4.60	6.42	5.49
Mean	32.88	31.43	28.16	30.82
Y * T	S _{Em} ±	0.85	C.D. at 5 %	2.38

Table 4.3.7 Status of percentage available form of zinc in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Percentage available of Zinc in soil			
	1 st year	4 th year	8 th year	pooled
T1	4.77	6.14	9.58	6.83
T2	4.50	5.17	9.70	6.46
T3	4.62	4.04	9.45	6.04
T4	4.78	6.56	15.62	8.99
T5	4.39	4.88	9.58	6.28
T6	3.82	5.32	13.39	7.51
T7	4.39	5.33	10.02	6.58
T8	3.55	4.55	11.90	6.67
T9	4.06	5.89	13.25	7.73
T10	4.14	4.28	8.63	5.68
T11	4.70	3.89	9.67	6.09
T12	4.74	3.90	9.04	5.89
SEm±	0.22	0.43	0.90	0.72
CD at 5%	0.62	1.23	2.58	NS
C.V.%	9.88	17.10	16.58	17.44
Mean	4.37	5.00	10.82	6.73
Y * T	S.Em.±	0.59	C.D. at 5 %	1.65

Table 4.3.8 Status of total available form of zinc in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Total available forms of Zinc in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	1.66	1.98	2.92	2.19
T2	1.54	1.68	3.18	2.13
T3	1.59	1.31	2.83	1.91
T4	1.56	2.14	4.70	2.80
T5	1.45	1.55	3.00	2.00
T6	1.39	1.77	4.15	2.44
T7	1.44	1.75	3.15	2.11
T8	1.30	1.63	3.75	2.22
T9	1.57	2.26	4.62	2.81
T10	1.44	1.41	2.89	1.92
T11	1.62	1.26	3.02	1.97
T12	1.50	1.18	2.66	1.78
SEm±	0.07	0.14	0.26	0.22
CD at 5%	0.19	0.41	0.75	0.66
C.V.%	8.77	17.03	15.29	16.01
Mean	1.51	1.66	3.41	2.19
Y * T	S.Em.±	0.18	C.D. at 5 %	0.49

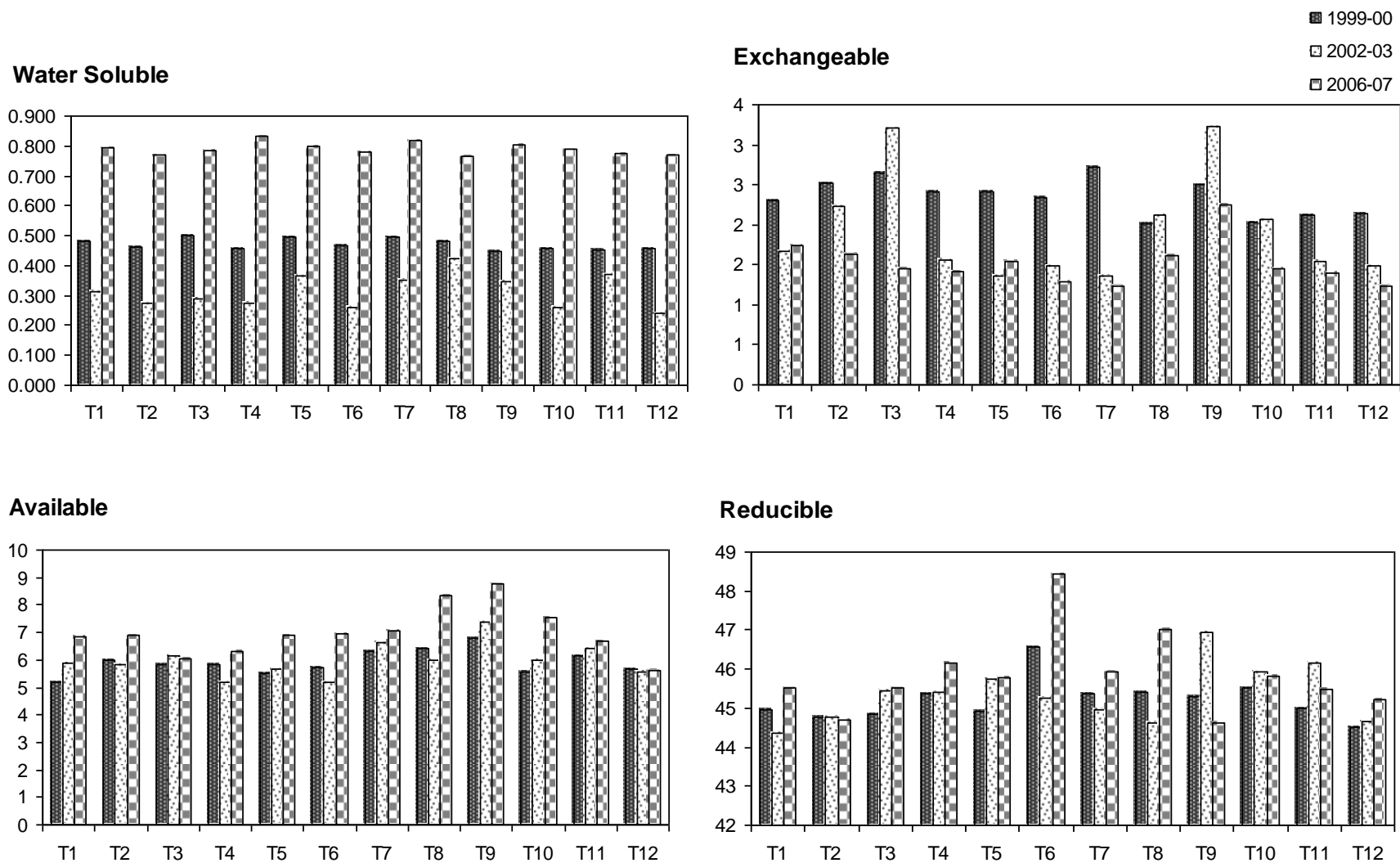


Fig. 4.2.1 Status (ppm) of form of Mn in the LTFE soils in 1st, 4th and 8th years

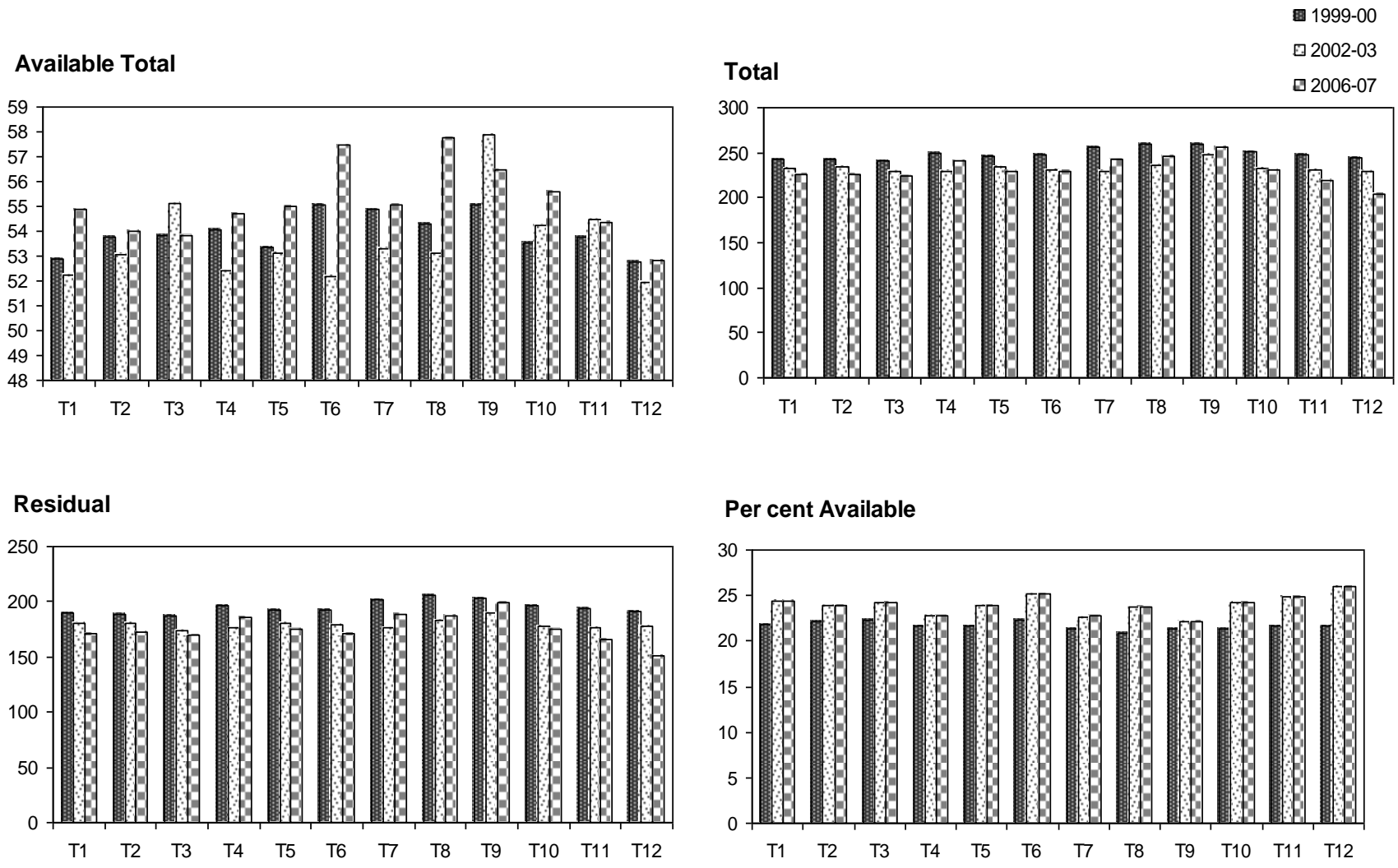


Fig. 4.2.2 Status (ppm) of form of Mn in the LTFE soils in 1st, 4th and 8th years

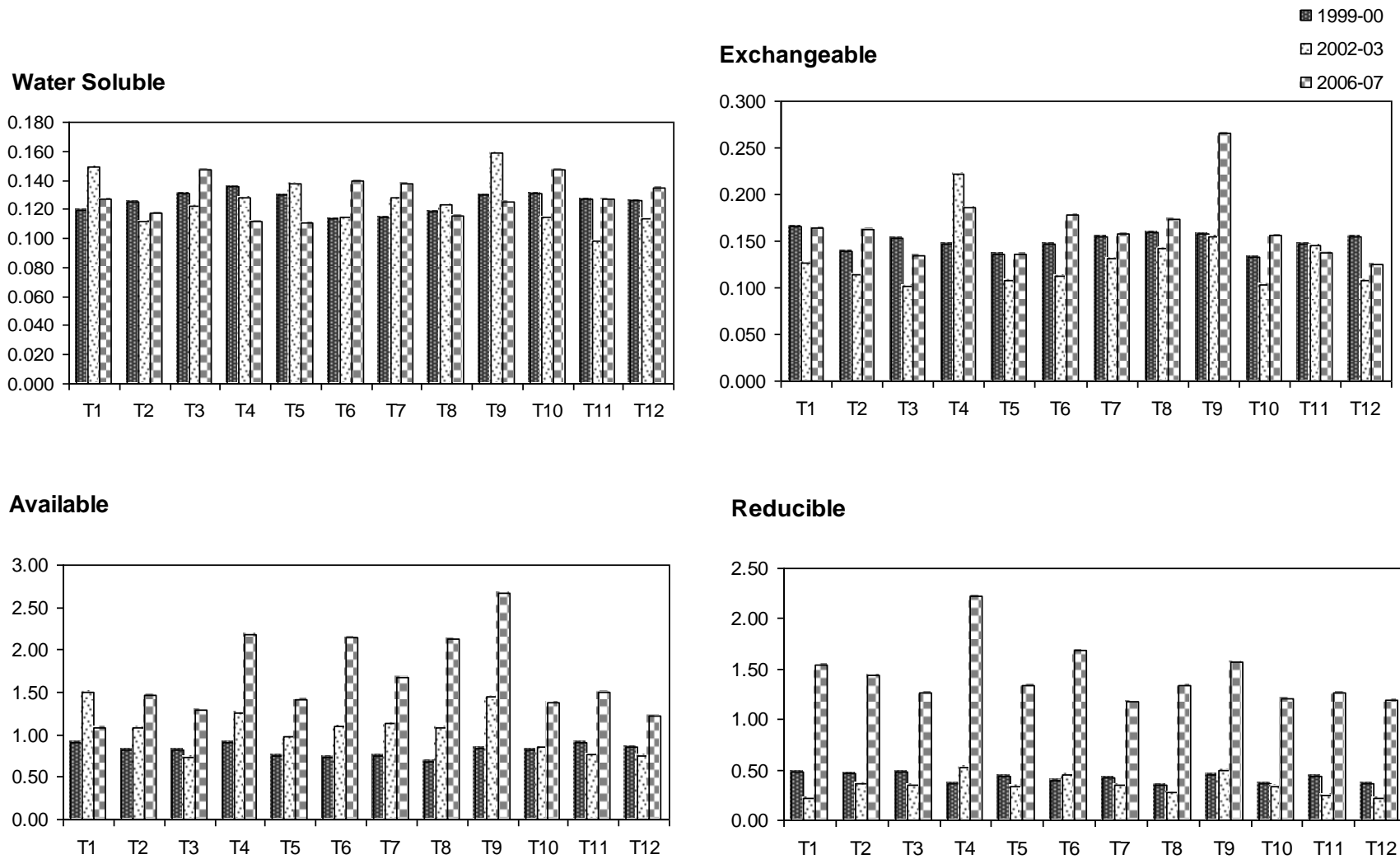


Fig. 4.3.1 Status (ppm) of form of Zn in the LTFE soils in 1st, 4th and 8th years

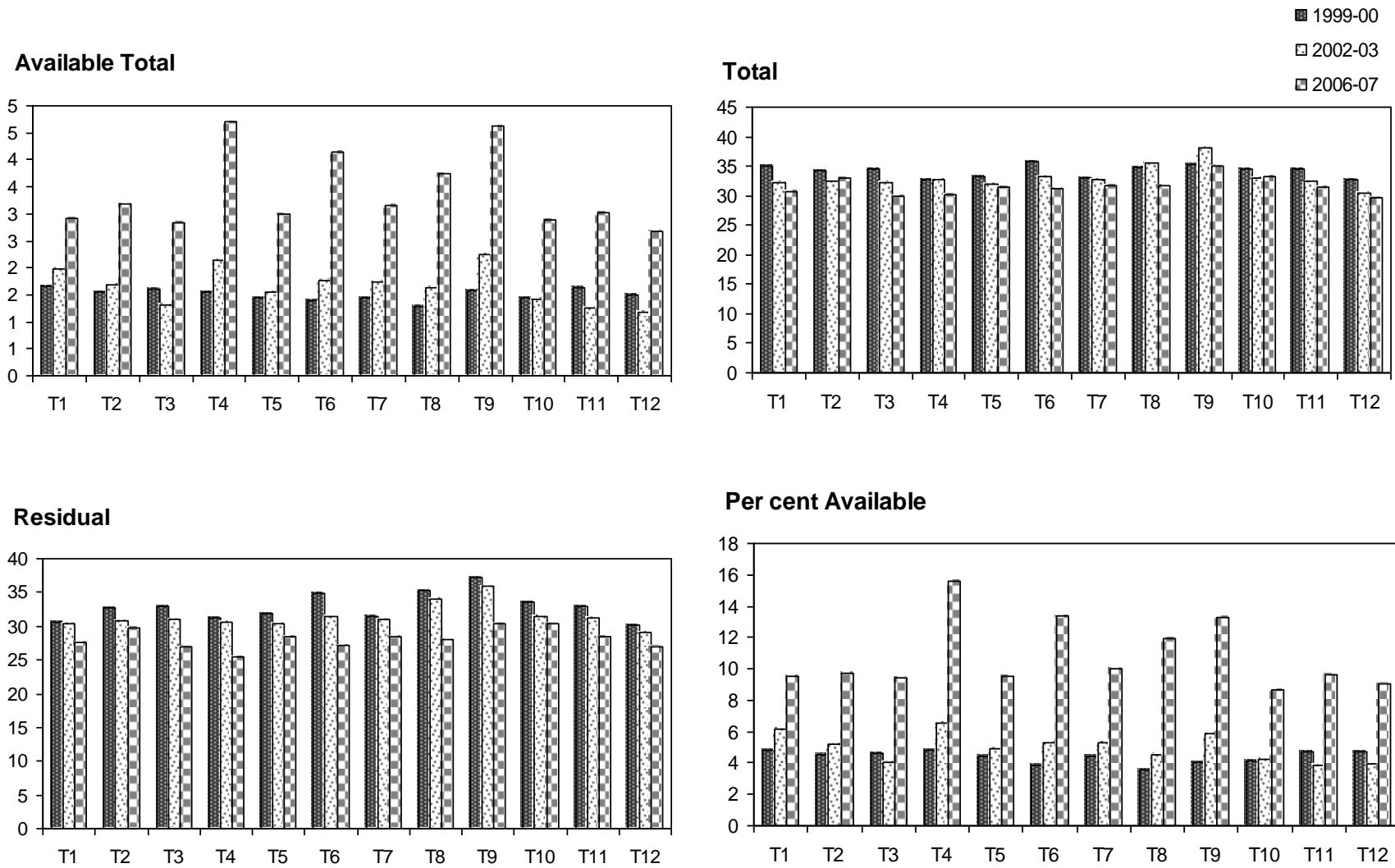


Fig. 4.3.2 Status (ppm) of form of Zn in the LTFE soils in 1st, 4th and 8th years

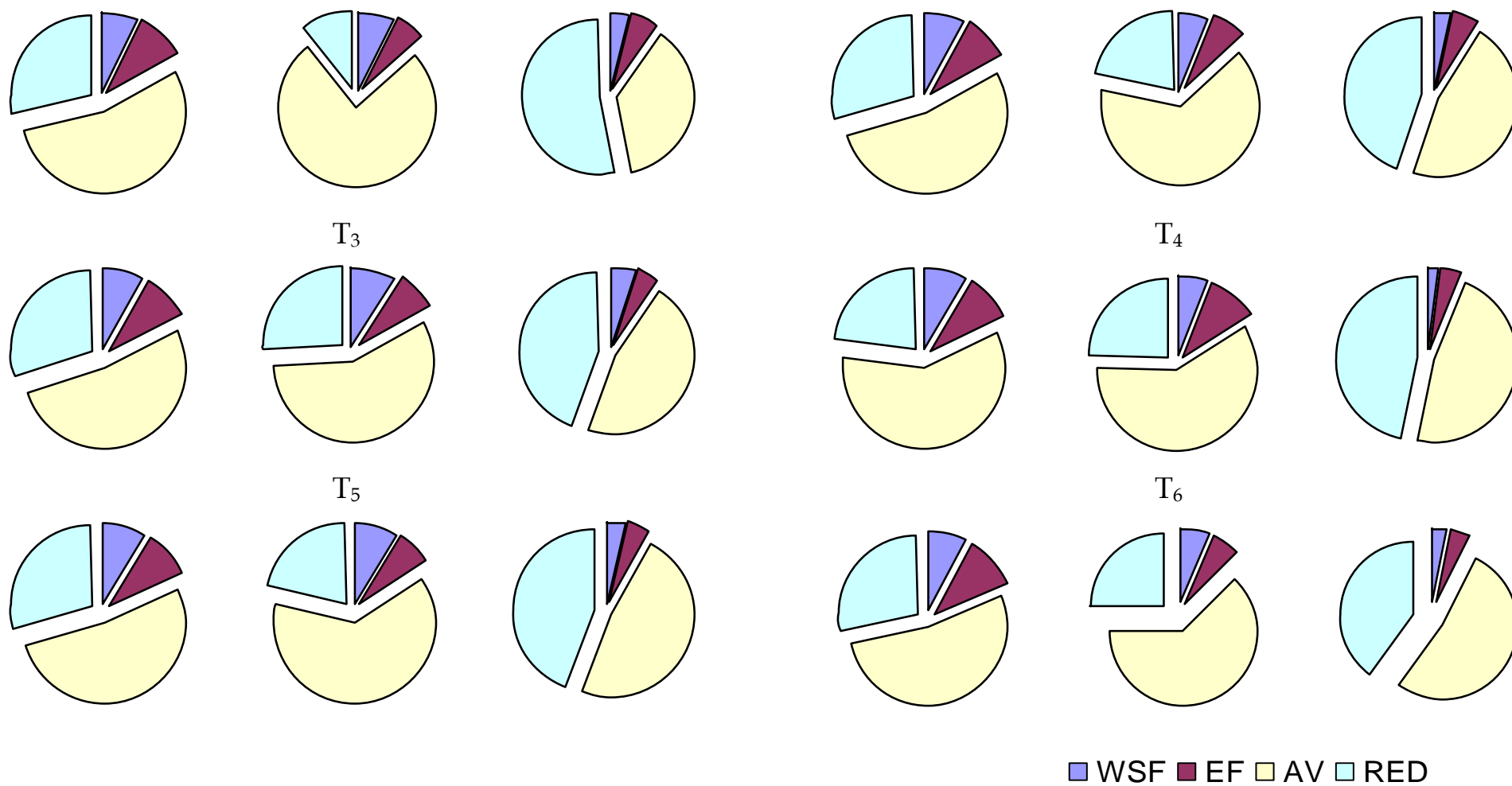


Fig. 4.3.3.1 Percent distribution in different forms of available total Zn (Avt) in 1st, 4th and 8th years in the LTFE soils

T₇

T₈

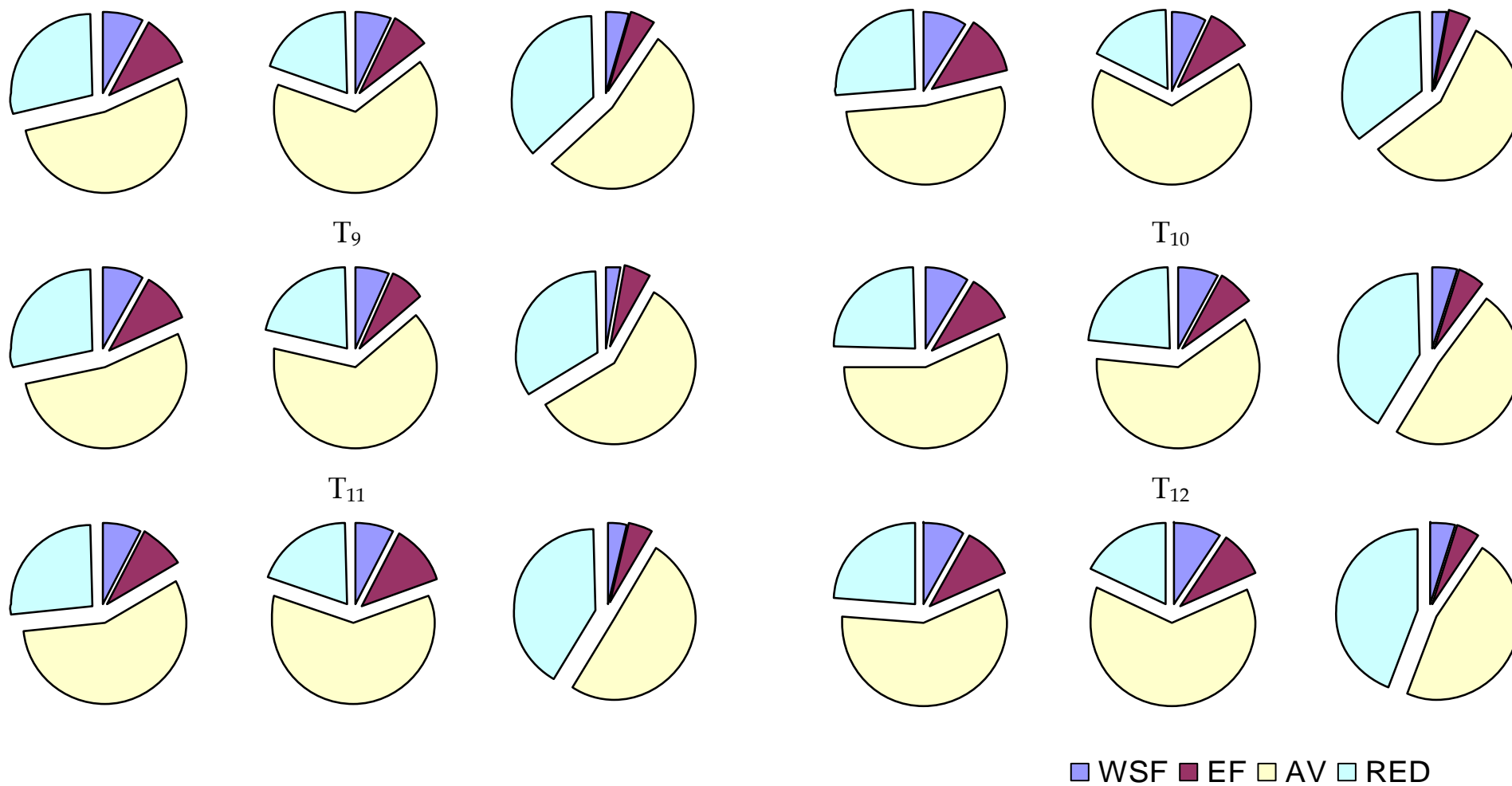


Fig. 4.3.3.2 Percent distribution in different forms of available total Zn (Avt) in 1st, 4th and 8th years in the LTFE soils

4.3.8 Zn - Available Total

Total available Zn showed significant differences when pooled over year and also Y x T interaction was significant (Table 4.3.8). The highest value observed in T₉ followed by T₄, T₆, T₈ and T₁. Overall mean value was increasing over the years. This gives an indication of supplementation and faster utilization of available Zn by the application of chemical fertilizers. Thus in a long run after 8th year in T₉ and T₄ the values remained higher by virtue of conversion of total to available form by the soil reaction.

4.3.9 Zn - Per cent Distribution of Different Forms of Avt. In LTFE Soils

As in case of water soluble form of Zn assumed negligible proportion in available total. However, DTPA available Zn had the highest proportion followed by reducible and exchangeable form. The exchangeable form and reducible form declined after 4th year but increased over a cycle of 8th years. On the contrary chemical fertilizer promoted the inter-conversion between DTPA available Zn and reducible Zn there by resulting in an increase in DTPA available Zn (Fig. 4.3.3.1 and 4.3.3.2). Sarkar and Deb (1985) observed that water soluble, exchangeable and organic complexed Zn which constituted hardly 5 per cent of the total Zn content in soil, accounted for variability in plant available Zn to a great extent.

IRON

4.4.1 Fe - Water Soluble

Pooled differences were not significant but Y x T interaction was significant. In a long run after 8th year the significant values were recorded in T₉ followed by T₄, T₁₀ and T₁₁. The results are indicative of enhancing water soluble iron utilization by the application of fertilizers in a long run. Overall there was a numerical decrease in the water soluble iron content over a period of time (Table 4.4.1). The amount of water soluble ferrous iron was practically nil in almost all cases (Joshi and Dhir, 1982)

4.4.2 Fe - Exchangeable

Exchangeable iron content did not showed any significant differences either through treatments or through years (Table 4.4.2). Exchangeable Fe ranged between 2 -8 ppm observed by Joshi *et al.* (1988).

4.4.3 Fe - DTPA Available

The DTPA available iron was significant when pooled over year and also Y x T interaction was significant (Table 4.4.3). Most of the treatments have higher significant value as compared to control in pooled results. Overall mean value was increased over a long period. The DTPA extractable Fe varied from 1.0 to 21.4 ppm with a mean value of 7.2 ppm (Randhawa and Singh, 1996).

4.4.4 Fe - Reducible

Although reducible iron was significant when pooled over year and also Y x T interaction was significant. The highest value was recorded under application of 100 % N P K of recommended doses in G'nut -Wheat sequence (T₂) followed by T₁, T₁₁, T₃ and T₁₀ (Table 4.4.4) with the least value in all chemical fertilizer treatments. In the chemical fertilizer application resulted in unutilization of reducible iron. Overall mean value is depleted on long term basis. The addition organic matter showed a positive balance reducible Fe fractions but their values were lower than the values without added organic matter observed by Nirupama *et al.* (1999).

Table 4.4.1 Status of water soluble form of iron in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Iron water soluble from in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.035	0.036	0.024	0.032
T2	0.035	0.032	0.018	0.028
T3	0.035	0.031	0.015	0.027
T4	0.035	0.033	0.029	0.032
T5	0.030	0.022	0.025	0.025
T6	0.029	0.026	0.031	0.029
T7	0.035	0.031	0.026	0.030
T8	0.032	0.033	0.020	0.028
T9	0.034	0.030	0.034	0.033
T10	0.030	0.038	0.027	0.032
T11	0.035	0.036	0.027	0.032
T12	0.035	0.037	0.021	0.031
S _{Em} ±	0.002	0.003	0.003	0.003
CD at 5%	NS	0.009	0.007	NS
C.V.%	11.300	18.480	20.160	16.560
Mean	0.033	0.032	0.025	0.030
Y * T	S _{Em} .±	0.002	C.D. at 5 %	0.007

Table 4.4.2 Status of exchangeable form of iron in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Iron exchangeable form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	0.030	0.031	0.035	0.032
T2	0.032	0.028	0.027	0.029
T3	0.035	0.033	0.027	0.032
T4	0.031	0.030	0.032	0.031
T5	0.031	0.027	0.034	0.031
T6	0.031	0.027	0.040	0.032
T7	0.030	0.023	0.032	0.028
T8	0.032	0.027	0.040	0.033
T9	0.029	0.024	0.038	0.031
T10	0.032	0.028	0.032	0.031
T11	0.033	0.030	0.034	0.032
T12	0.028	0.022	0.031	0.027
S _{Em} ±	0.002	0.003	0.003	0.002
CD at 5%	NS	NS	NS	NS
C.V.%	10.780	24.930	17.600	18.130
Mean	0.031	0.027	0.034	0.031
Y * T	S _{Em} .±	0.003	C.D. at 5 %	NS

Table 4.4.3 Status of DTPA available form of iron in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Iron DTPA available form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	4.086	5.234	9.135	6.152
T2	4.418	5.477	8.257	6.051
T3	4.312	4.466	7.964	5.581
T4	4.944	4.873	8.619	6.145
T5	4.466	5.232	8.638	6.112
T6	4.764	5.365	8.757	6.295
T7	4.114	4.864	8.156	5.711
T8	4.612	6.176	9.853	6.880
T9	4.628	6.320	7.849	6.265
T10	4.954	5.439	9.052	6.481
T11	4.735	5.463	10.492	6.897
T12	4.483	5.018	8.577	6.026
S _{Em} ±	0.228	0.316	0.483	0.284
CD at 5%	NS	0.910	1.391	0.833
C.V.%	10.040	11.860	11.000	11.530
Mean	4.543	5.327	8.779	6.216
Y * T	S _{Em} .±	0.358	C.D. at 5 %	1.007

Table 4.4.4 Status of reducible form of iron in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Iron reducible form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	8.51	9.24	7.72	8.49
T2	9.13	10.47	7.31	8.97
T3	9.16	8.11	6.59	7.95
T4	8.01	6.49	6.74	7.08
T5	7.18	5.40	6.48	6.36
T6	7.20	5.57	7.93	6.90
T7	7.44	6.24	6.42	6.70
T8	7.93	6.84	6.50	7.09
T9	7.20	4.90	5.41	5.84
T10	8.46	7.90	7.19	7.85
T11	8.22	7.88	8.28	8.12
T12	7.81	5.59	6.18	6.53
S _{Em} ±	0.62	0.71	0.54	0.48
CD at 5%	NS	2.05	1.55	1.39
C.V.%	15.44	20.23	15.65	17.16
Mean	8.02	7.05	6.90	7.32
Y * T	S _{Em} .±	0.63	C.D. at 5 %	1.77

4.4.5 Fe - Total

Total iron content showed significant change, when pooled over the year and Y x T interaction was also significant. Highest value was recorded under application of FYM @ 25 t/ha to G'nut. Overall mean value was depleted on long term basis (Table 4.4.5). The chemical fertilizer application resulted in enhancement of the utilization of total iron or conversion of total to available form by the soil reaction and under utilization by the plants.

4.4.6 Fe - Residual

Like wise total form, residual iron also showed significant differences when pooled over the year and Y x T interaction was also significant. Highest value was recorded under application of FYM @ 25 t/ha to G'nut (Table 4.4.6).

4.4.7 Fe - Percentage Availability

It was significant when pooled over the year and interaction was also significant (Table 4.4.7). The application of 50 % NPK (T₁) and 100 % NPK as P in SSP (T₁₁) of recommended doses in G'nut-Wheat sequence showed the significantly higher values as compared to Control.

4.4.8 Fe - Available Total

Total available form of iron also exhibited more or less same trend. Pooled effect was significant but Y x T interaction was not significant (Fig. 4.3.2). Highest value was recorded in T₂ followed by T₁ and T₁₀. Overall mean value was same over the time. After 8th year chemical fertilizers in general showed declining trend of Fe available total. While in FYM and control treatment it was maintain. Accumulation in soil was observed by virtue of conversion to available form (Table 4.4.8).

Table 4.4.5 Status of total form of iron in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Iron total form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	28056.75	27310.25	25556.50	26974.50
T2	29254.75	27549.50	27920.50	28241.58
T3	29548.00	27312.75	24851.50	27237.42
T4	29389.50	27634.25	25049.50	27357.75
T5	28229.25	26907.75	26368.50	27168.50
T6	30598.00	28216.75	26282.00	28365.58
T7	28655.00	27710.75	26603.75	27656.50
T8	30237.50	30643.75	26693.25	29191.50
T9	30503.75	33200.00	30091.00	31264.92
T10	29495.00	27899.75	28352.00	28582.25
T11	29457.25	27399.25	26437.50	27764.67
T12	29647.00	25318.75	24619.25	26528.33
S _{Em} ±	566.12	731.98	857.43	626.58
CD at 5%	NS	2107.63	2468.84	1837.80
C.V.%	3.85	5.21	6.45	5.20
Mean	29422.65	28091.96	26568.77	28027.79
Y * T	S.Em.±	728.35	C.D. at 5 %	2046.69

Table 4.4.6 Status of residual form of iron in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Iron residual form in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	28044.09	27295.71	25539.59	26959.80
T2	29241.13	27533.49	27904.89	28226.50
T3	29534.46	27300.11	24836.90	27223.83
T4	29376.48	27622.82	25034.08	27344.46
T5	28217.54	26897.07	26353.32	27155.98
T6	30585.97	28205.76	26265.25	28352.33
T7	28643.38	27699.60	26589.12	27644.03
T8	30224.90	30630.67	26676.83	29177.47
T9	30491.86	33188.72	30077.67	31252.75
T10	29481.53	27886.34	28335.70	28567.86
T11	29444.23	27385.85	26418.66	27749.58
T12	29634.64	25308.08	24604.44	26515.72
S _{Em} ±	566.14	731.78	857.34	626.58
CD at 5%	NS	2107.04	2468.58	1837.80
C.V.%	3.85	5.21	6.46	5.20
Mean	29410.02	28079.52	26553.04	28014.19
Y * T	S.Em.±	728.25	C.D. at 5 %	2046.42

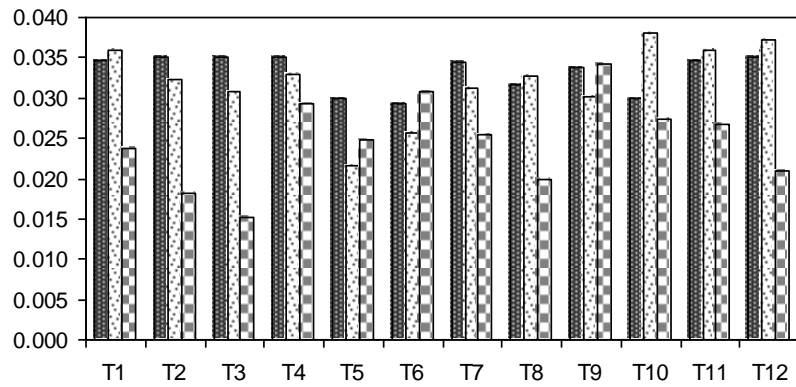
Table 4.4.7 Status of percentage available form of iron in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Percentage available of Iron in soil			
	1 st year	4 th year	8 th year	pooled
T1	0.045	0.053	0.066	0.055
T2	0.046	0.058	0.056	0.054
T3	0.046	0.046	0.059	0.050
T4	0.044	0.041	0.062	0.049
T5	0.042	0.040	0.058	0.046
T6	0.039	0.039	0.064	0.048
T7	0.041	0.040	0.055	0.045
T8	0.042	0.043	0.062	0.049
T9	0.039	0.034	0.044	0.039
T10	0.046	0.048	0.058	0.051
T11	0.044	0.049	0.071	0.055
T12	0.042	0.042	0.060	0.048
S _{Em} ±	0.002	0.003	0.003	0.003
CD at 5%	NS	0.008	0.009	0.007
C.V.%	11.220	11.950	10.890	11.400
Mean	0.043	0.044	0.060	0.049
Y * T	S _{Em} .±	0.003	C.D. at 5 %	0.008

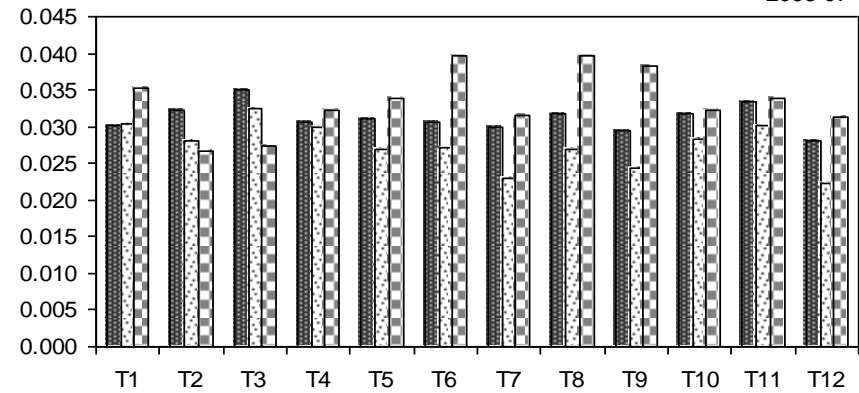
Table 4.4.8 Status of total available form of iron in soils of LTFE experiment in 1st, 4th and 8th year

Treat.	Total available forms of Iron in soil (ppm)			
	1 st year	4 th year	8 th year	pooled
T1	13.91	14.54	12.66	13.71
T2	14.38	16.01	13.62	14.67
T3	13.55	12.64	13.54	13.24
T4	13.75	11.43	13.02	12.73
T5	10.70	10.68	11.71	11.03
T6	12.27	10.99	12.03	11.76
T7	11.11	11.15	11.62	11.29
T8	12.85	13.08	12.60	12.84
T9	12.15	11.28	11.89	11.77
T10	13.90	13.41	13.47	13.59
T11	13.01	13.40	13.02	13.14
T12	11.86	10.67	12.36	11.63
S _{Em} ±	0.79	0.78	0.65	0.43
CD at 5%	2.29	2.23	NS	1.21
C.V.%	12.43	12.47	10.32	11.78
Mean	12.79	12.44	12.63	12.62
Y * T	S _{Em} .±	0.74	C.D. at 5 %	NS

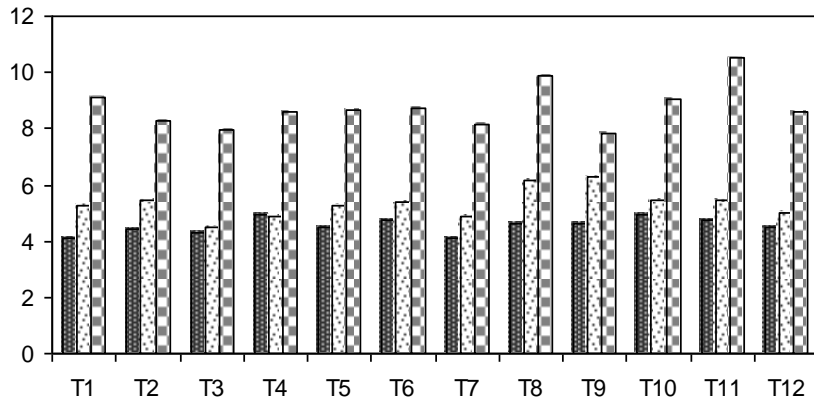
Water Soluble



Exchangeable



Available



Reducible

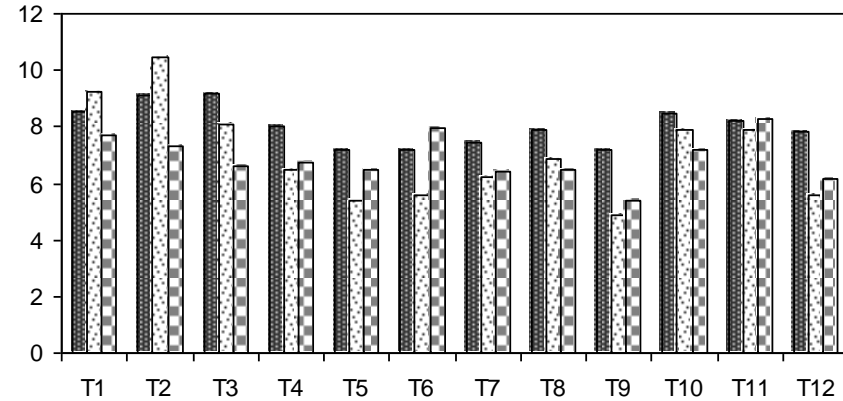
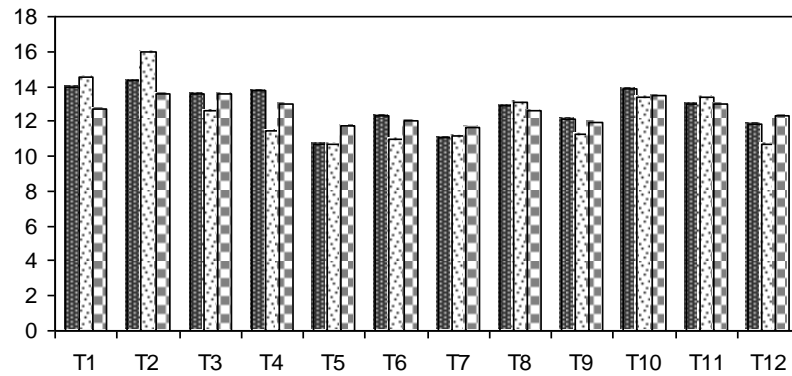
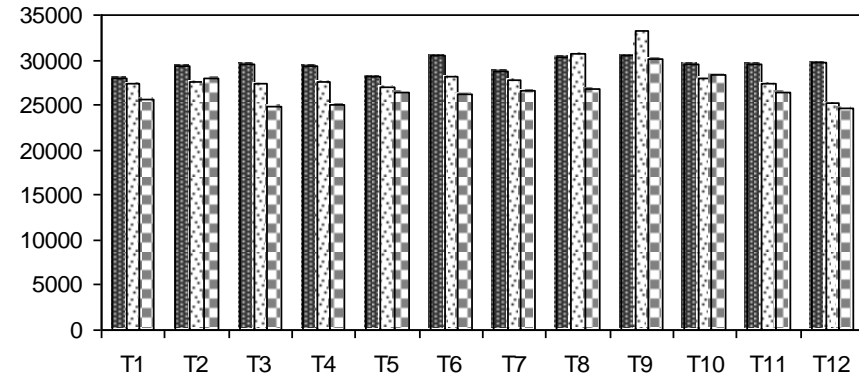


Fig. 4.4.1 Status (ppm) of form of Fe in the LTFE soils in 1st, 4th and 8th years

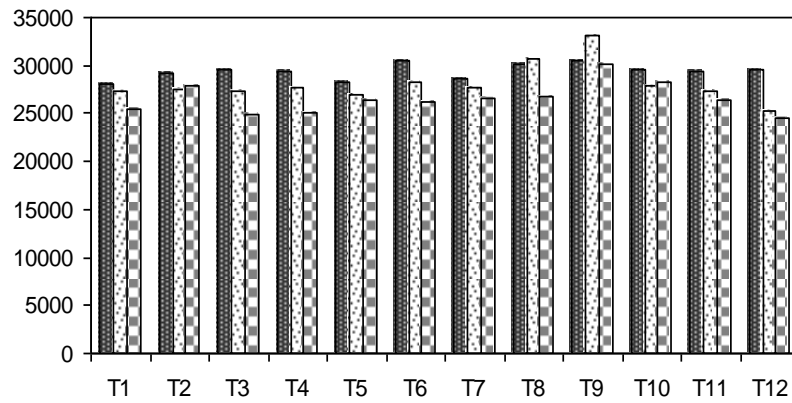
Available Total



Total



Residual



Per cent Available

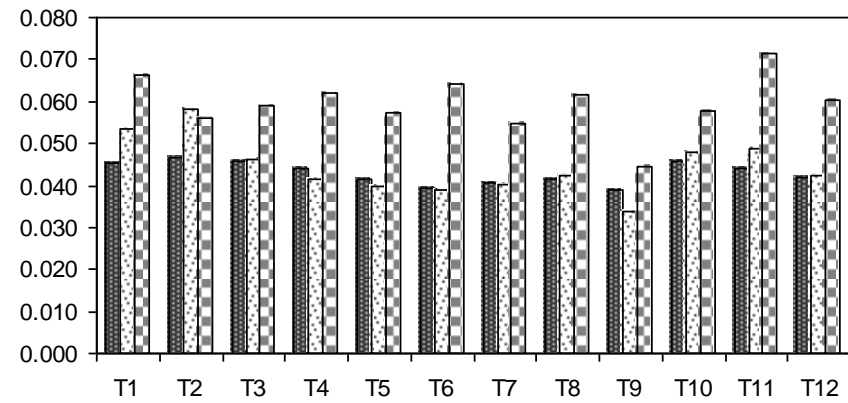


Fig. 4.4.2 Status (ppm) of form of Fe in the LTFE soils in 1st, 4th and 8th years

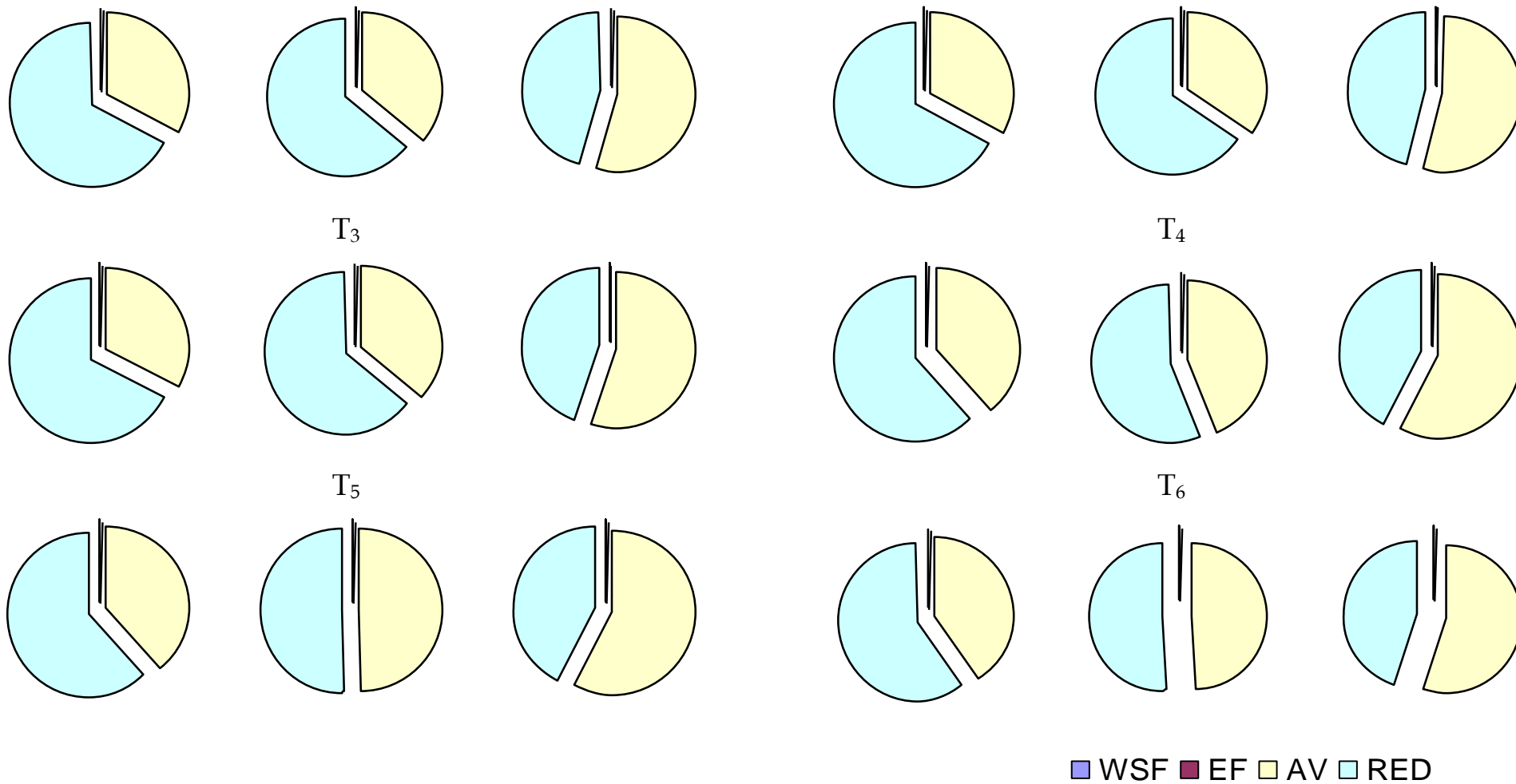


Fig. 4.4.3.1 Percent distribution in different forms of available total Fe (Avt) in 1st, 4th and 8th years in the LTFE soil

T₇

T₈

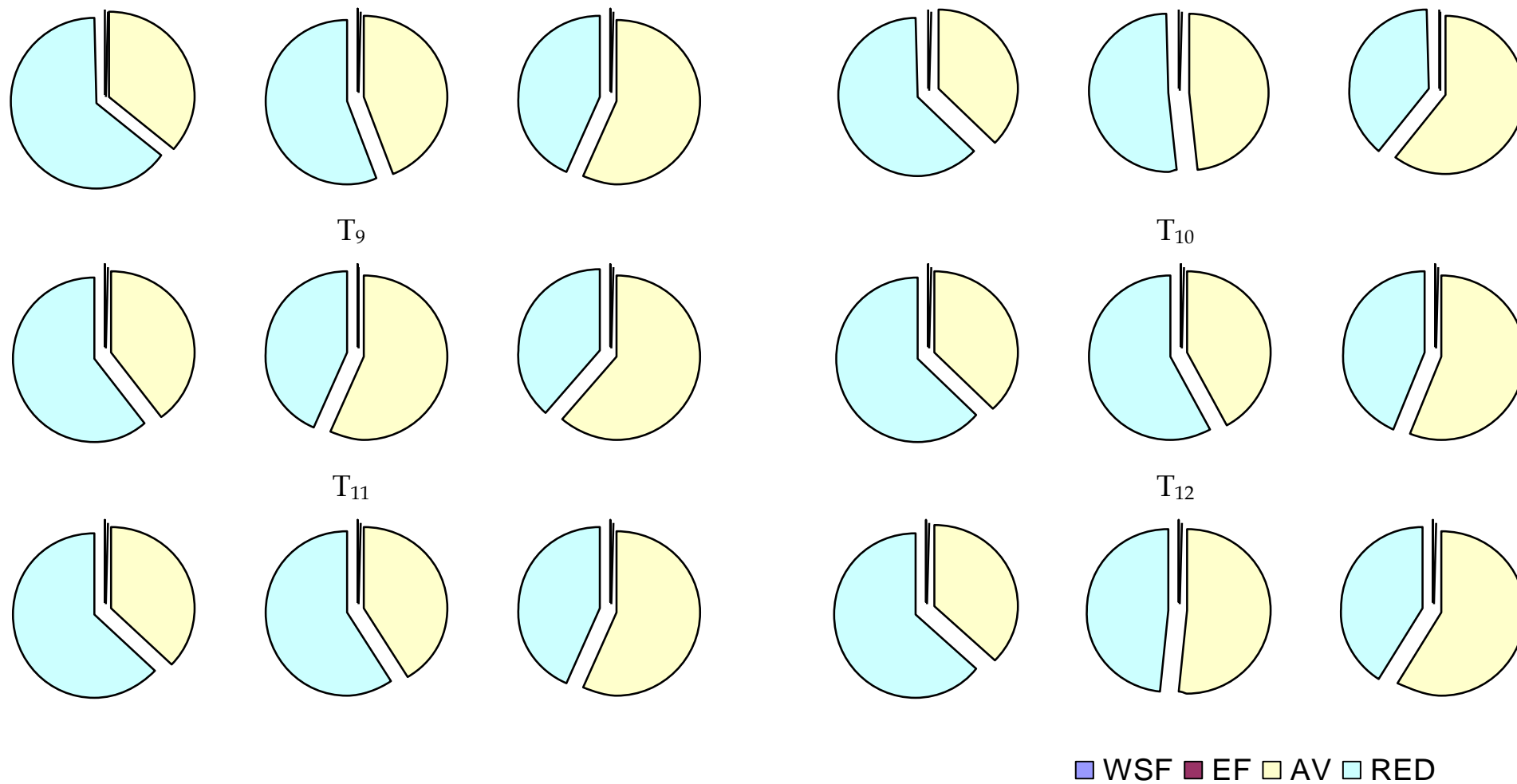


Fig. 4.4.3.2 Percent distribution in different forms of available total Fe (Avt) in 1st, 4th and 8th years in the LTFE soils

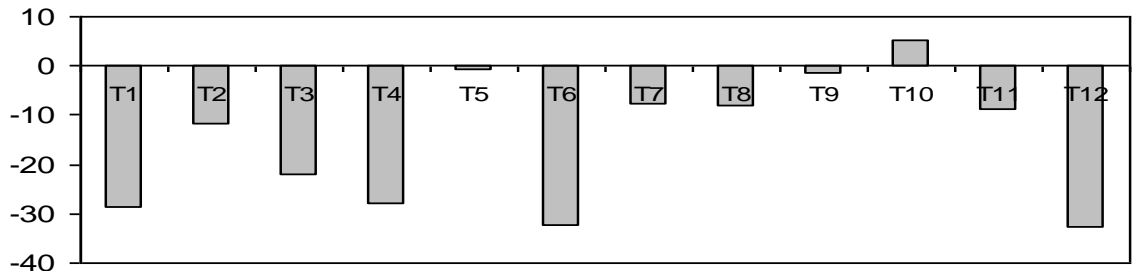
4.4.9 Fe – Percent Distribution of Different Forms of Avt. in LTFE soils

In iron the predominant component was DTPA available form followed by reducible, exchangeable and water soluble form. Although the trend was not so clear mostly there was inter-conversion between exchangeable and reducible form. In water soluble form almost maintained their proportion over time but exchangeable, and DTPA available increase over a cycle of long term while reducible form was decrease overall on long term basis. Among the various treatments, available total forms of Fe observed higher proportion under application of FYM @ 25 t/ha to G'nut after 8th year of experimentation.

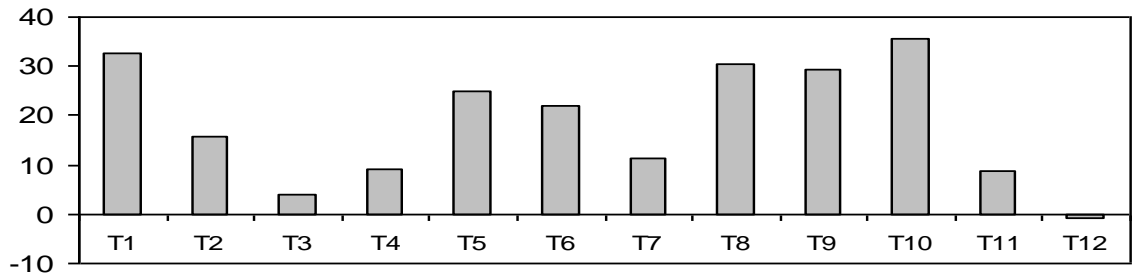
4.5.1 Depletion of Cu, Mn, Zn and Fe

Harjit Singh *et al.* (1995) reported that continuous application of increasing levels of N depleted DTPA extractable Cu, Mn, Zn and Fe. The addition of phosphorus also decreased Cu and Mn whereas Fe and Zn contents of soils were increased. The available micronutrients content were the least affected by K addition. In our LTFE investigation on medium black calcareous soils, it was observed that continuous cropping with and without fertilizer treatment after a span of 8 years (16 crops of groundnut and wheat) depleted Cu, Mn, Zn and Fe to -0.2089, +1.096, +0.8606 and +4.2361 ppm from their initial values of 1.3867, 5.9092, 0.8167 and 4.5428 ppm, respectively, whereas Bhardwaj and Omanwar (1994) at Pantnagar (Uttar Pradesh) observed that continuous cropping without fertilization after 9th cycle of rice-wheat-cowpea cropping depleted Cu, Mn, Zn and Fe to 0.6, 12.3, 2.9 and 268 ppm from their initial values of 1.88, 26.0, 4.46 and 34.2 ppm, respectively.

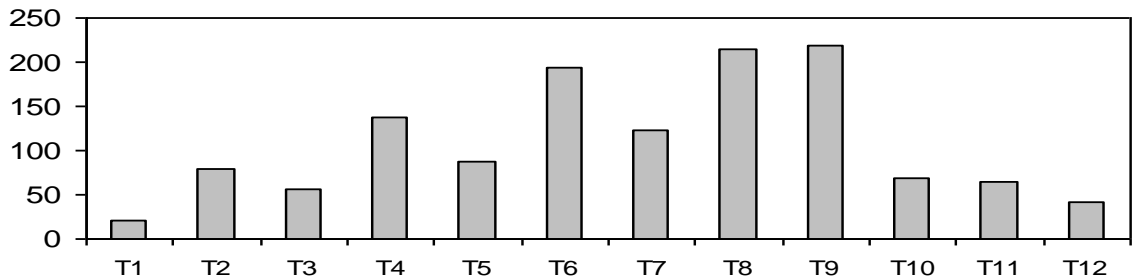
The DTPA available Cu showed maximum depletion in most of all the treatment. Highest depletion observed in chemical treatment, while



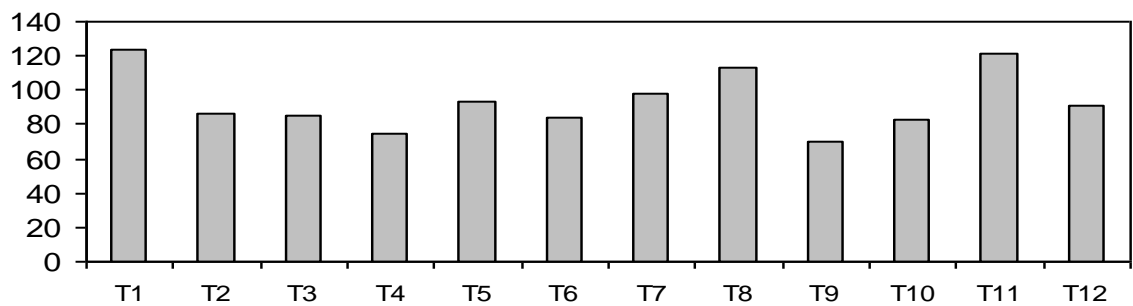
percent depletion in DTPA available form of Copper



percent depletion in DTPA available form of Manganese



percent depletion in DTPA available form of Zinc



percent depletion in DTPA available form of Iron

Fig. 4.5.1 Percent depletion in DTPA available form of micronutrients in soils of LTFE experiment of 1st and 8th year cycles

DTPA available element viz., Mn, Zn and Fe resulted in marked increase in micronutrient content after long run. With certainty the fertilizer application resulted in enhanced utilization of DTPA available elements with potash giving boost to further utilization. Even in absence of potash zinc registered an increase instead of depletion. Although in manganese and Copper untreated control showed slight depletion, but all other three elements Cu, Fe and Zn exhibited an increase in control, FYM and other treatments, thereby suggesting poor utilization as compared to NPK treatments (Fig. 4.5.1). There are reports showing depletion of micronutrients under continuous cropping (Ramanathan *et al.*, 1979; Dangarwala *et al.*, 1983; Kumaresean *et al.*, 1985; Bhardwaj and Omanwar, 1994; Dangarwala *et al.*, 1994 and Dangarwala and Patel, 1996). However, the application of organic and chemical fertilizers resulted in a varied soil status either by enhanced utilization or by supplementing the micronutrients indirectly as observed in current investigation. The FYM and chemical fertilizers (NP) have been shown to enhance utilization resulting in depletion of micronutrients at one hand (Dangarwala *et al.*, 1983; Dangarwala *et al.*, 1994 and Harjit Singh *et al.*, 1995), while at the other hand chemical fertilizers, organic manures and FYM have been shown to demote depletion and supplement the micronutrients resulting in an increase in a long run. (Sudhir *et al.*, 1997; Golakiya and Gundalia, 1999; Takker *et al.*, 1989; Darusman *et al.*, 1991; Bellakki and Budanar, 1997; Patel, 1998; Patel *et al.*, 1999; Prasad and Singh, 1980 and Zarkovic *et al.*, 2000), though these responses were micronutrient specific. In current investigation application of potash promoted utilization of micronutrients resulting in depletion in a long run but these results are in contrast with the earlier reports mentioning least effect of potassium on micronutrients (Harjit Singh *et al.*, 1995). The increases in the micronutrients in a long run may be attributed to different reasons viz., supplementing micronutrients indirectly through chemical fertilizers (Lal and Mathur, 1989), supplementing through organic manures by increased microbial activity (Prasad and Singh, 1980; Agarwal and Pravin Kumar, 1998) and or

supplementing by the parental materials due to soil reactions (Lal and Mathur, 1989). The rate of depletion of DTPA extractable micronutrients under continuous cropping in *goradu* soil has been reported in the following order: Zn > Fe > Mn > Cu (Patel *et al.*, 1998), whereas in the present investigation on an overall basis of all treatments in medium black calcareous soil under LTFE investigation with groundnut and wheat crop sequence in a span of 8 years, the rate of depletion was in the following order for micronutrients based on 1st year (1999): Cu (-14.73%) > Mn (18.58%) > Fe (+93.65%) > Zn (+108.69%).

LTFE - CORRELATION

4.1.1.1 Correlation Among Different Forms of Cu

The DTPA available copper exhibited highly significant relationship with reducible ($r = 0.2696$), Total ($r = 0.9236$), residual ($r = 0.6306$) and per cent available ($r = 0.5594$), while significant relationship with total available ($r = 0.1986$). This signified that the importance of DTPA available copper is governing the total availability as predominant form. Further water soluble copper also showed a good relationship with DTPA available ($r = 0.3887$) and exchangeable, total, residual and per cent available. Thus water soluble copper also played an important role in the availability of copper after DTPA available copper. Further exchangeable copper showed relationship with total and available total, while reducible form correlated with total, residual and per cent available. The total copper had significant relationship with residual, per cent available and available, while residual form was positive correlated with per cent available but negative correlation was with total available. Per cent available was negative correlated with available total (Table 4.5.1).

4.1.1.2 Correlation with Yield: Cu

The DTPA available Cu exhibited highly significant relationship with groundnut pod yield ($r = 0.3694$) and haulm yield ($r = 0.3478$), while negative relationship with wheat grain yield ($r = -0.1916$). Water soluble, exchangeable, reducible, total, residual and per cent available showed significant positive

relationship with groundnut pod and haulm yield, while water soluble exchangeable, total, residual and per cent available showed significant negative relationship with wheat grain and straw yield. We may not get the absolute relationship with various crop yields because complex of micro and macro environmental factors influence the ultimate yield (Table 4.5.2).

4.1.1.3 Correlation with Soil Properties : Cu

Water soluble copper showed significant positive relationship with Soil pH, while negative relationship with Soil EC, Organic C, Avail. N and Avail. P₂O₅. The exchangeable copper also showed positive relationship with Soil pH and HSS, but negative significant relationship with Soil EC, Avail. N, and Avail. P₂O₅. The DTPA available copper also had significant positive correlation with Soil pH ($r = 0.2617$) and negative correlation with Soil EC ($r = -0.2878$) and HSS ($r = -0.2874$). Reducible, total, residual and per cent available were positive significant with Soil pH and Avail. K₂O, while total, residual and per cent available showed significant negative relationship with Soil EC and HSS. This might be due to inter conversion of available total and residual form of copper (Table 4.5.3). Thu *et al.* (1994) exhibited a negative relationship between soil pH and organic carbon while Saha *et al.* (1990) and Gopichand *et al.* (1985) obtained positive relationship with available Cu and organic carbon.

4.1.1.4 Correlation Between NPK Concentration in Plant Parts : Forms of Cu

As in case of Cu, various forms of copper were significantly negative related with groundnut pod nitrogen concentration. However, groundnut haulm nitrogen concentration has negative relationship with available ($r = -0.1822$) and per cent available ($r = -0.1826$) but positive significant relationship with total copper (Table 4.5.4). Groundnut pod phosphorus concentration has significant positive relationship with most of the form and available form ($r = 0.3514$), while groundnut haulm phosphorus concentration has significant negative relationship with available ($r = -0.1820$). Groundnut pod potash concentration has significant

Table 4.5.1 Correlation coefficient between different forms of Cu and MN to among forms of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between Cu Form to among forms		Sr. no.	Correlation between Mn Form to among forms	
	1	Cu WS v/s Cu EF		0.3087**	1
2	Cu WS v/s Cu AV	0.3887**	2	Mn WS v/s Mn AV	0.3048**
3	Cu WS v/s Cu T	0.6094**	3	Mn WS v/s Mn T	0.2924**
4	Cu WS v/s Cu RES	0.4697**	4	Mn WS v/s Mn PA	-0.1833*
5	Cu WS v/s Cu PA	0.4274**	5	Mn WS v/s Mn TA	0.3295**
6	Cu EF v/s Cu T	0.1920*	6	Mn EF v/s Mn T	0.2787**
7	Cu EF v/s Cu TA	0.2156*	7	Mn EF v/s Mn RES	0.3416**
8	Cu AV v/s Cu RED	0.2696**	8	Mn EF v/s Mn PA	0.3093**
9	Cu AV v/s Cu T	0.9236**	9	Mn AV v/s Mn RED	0.1699*
10	Cu AV v/s Cu RES	0.6306**	10	Mn AV v/s Mn T	0.7277**
11	Cu AV v/s Cu PA	0.5594**	11	Mn AV v/s Mn RES	0.1749*
12	Cu AV v/s Cu TA	0.1986*	12	Mn AV v/s Mn TA	0.2756**
13	Cu RED v/s Cu T	0.3681**	13	Mn RED v/s Mn T	0.6882**
14	Cu RED v/s Cu RES	0.3456**	14	Mn RED v/s Mn TA	0.3656**
15	Cu RED v/s Cu PA	0.3254**	15	Mn T v/s Mn RES	0.2538**
16	Cu T v/s Cu RES	0.6735**	16	Mn T v/s Mn TA	0.3630**
17	Cu T v/s Cu PA	0.5956**	17	Mn RES v/s Mn PA	0.9895**
18	Cu T v/s Cu TA	0.2296**	18	Mn RES v/s Mn TA	-0.8059**
19	Cu RES v/s Cu PA	0.9949**	19	Mn PA v/s Mn TA	-0.8822**
20	Cu RES v/s Cu TA	-0.5401**	20		
21	Cu PA v/s Cu TA	-0.6181**	21		

positive relationship with water soluble, total, residual and per cent available, while haulm potash concentration has significant positive relationship with available ($r = 0.3160$), total, residual and per cent available, while negative relationship with available total. Groundnut pod sulphur concentration has significant relationship with exchangeable and reducible, however haulm sulphur concentration was having positive significant with water soluble, exchangeable and reducible.

Wheat grain nitrogen concentration has significant positive relationship with most of the form, however phosphorus concentration was negative significant relationship with water soluble and available ($r = -0.2068$), while straw concentration of phosphorus has significant negative relationship with water soluble, exchangeable, total, residual and per cent available. Wheat grain potash concentration has significant

Table 4.5.2 Correlation coefficient between different forms of Cu and Mn to yield of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between		Sr. no.	Correlation between	
	Cu Form to yield			Mn Form to yield	
1	Cu WS v/s GPY	0.7660**	1	Mn WS v/s GPY	-0.8015**
2	Cu WS v/s GHY	0.7026**	2	Mn WS v/s GHY	-0.7660**
3	Cu WS v/s WGY	-0.6807**	3	Mn WS v/s WGY	0.7874**
4	Cu WS v/s WSY	-0.5621**	4	Mn WS v/s WSY	0.6482**
5	Cu EF v/s GPY	0.3539**	5	Mn EF v/s GPY	0.4392**
6	Cu EF v/s GHY	0.3438**	6	Mn EF v/s GHY	0.4313**
7	Cu EF v/s WGY	-0.2700**	7	Mn EF v/s WGY	-0.2928**
8	Cu EF v/s WSY	-0.2150*	8	Mn EF v/s WSY	-0.2249**
9	Cu AV v/s GPY	0.3694**	9	Mn AV v/s GPY	-0.3323**
10	Cu AV v/s GHY	0.3478**	10	Mn AV v/s GHY	-0.3026**
11	Cu AV v/s WGY	-0.1916*	11	Mn AV v/s WGY	0.3679**
12	Cu RED v/s GPY	0.2158*	12	Mn AV v/s WSY	0.3404**
13	Cu RED v/s GHY	0.2229**	13	Mn RED v/s GPY	-0.1802*
14	Cu T v/s GPY	0.5803**	14	Mn RED v/s GHY	-0.1997*
15	Cu T v/s GHY	0.5490**	15	Mn RED v/s WGY	0.2130*
16	Cu T v/s WGY	-0.3827**	16	Mn RED v/s WSY	0.2131*
17	Cu T v/s WSY	-0.3047**	17	Mn T v/s GPY	-0.2203**
18	Cu RES v/s GPY	0.5098**	18	Mn T v/s GHY	-0.2144*
19	Cu RES v/s GHY	0.4902**	19	Mn T v/s WGY	0.3174**
20	Cu RES v/s WGY	-0.2937**	20	Mn T v/s WSY	0.3135**
21	Cu RES v/s WSY	-0.2418**	21	Mn RES v/s GPY	0.2994**
22	Cu PA v/s GPY	0.4750**	22	Mn RES v/s GHY	0.2701**
23	Cu PA v/s GHY	0.4579**	23	Mn PA v/s GPY	0.3405**
24	Cu PA v/s WGY	-0.2670**	24	Mn PA v/s GHY	0.3095**
25	Cu PA v/s WSY	-0.2212**	25	Mn PA v/s WGY	-0.1942*
			26	Mn TA v/s GHY	-0.4379**
			27	Mn TA v/s GPY	-0.4037**
			28	Mn TA v/s WGY	0.3377**
			29	Mn TA v/s WSY	0.2735**

Table 4.5.3 Correlation coefficient between different forms of Cu and MN to Soil Properties of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between Cu Form to Soil Properties		Sr. no.	Correlation between Mn Form to Soil Properties	
	1	Cu WS v/s Soil pH		0.6399**	1
2	Cu WS v/s Soil EC	-0.5760**	2	Mn WS v/s Soil EC	-0.7660**
3	Cu WS v/s Soil O.C. %	-0.3417**	3	Mn WS v/s Soil O.C. %	0.7874**
4	Cu WS v/s Soil Av. N	-0.5211**	4	Mn WS v/s Soil Av. N	0.6482**
5	Cu WS v/s Soil Av. P ₂ O ₅	-0.3520**	5	Mn WS v/s Soil Av. P ₂ O ₅	0.4392**
6	Cu EF v/s Soil pH	0.1783*	6	Mn WS v/s Soil HSS	0.4313**
7	Cu EF v/s Soil EC	-0.1846**	7	Mn EF v/s Soil pH	-0.2928**
8	Cu EF v/s Soil Av. N	-0.3304**	8	Mn EF v/s Soil EC	-0.2249**
9	Cu EF v/s Soil Av. P ₂ O ₅	-0.2455**	9	Mn EF v/s Soil Av. N	-0.3323**
10	Cu EF v/s Soil HSS	0.1864*	10	Mn EF v/s Soil HSS	-0.3026**
11	Cu AV v/s Soil pH	0.2617**	11	Mn AV v/s Soil pH	0.3679**
12	Cu AV v/s Soil EC	-0.2878**	12	Mn AV v/s Soil O.C. %	0.3404**
13	Cu AV v/s Soil HSS	-0.2874**	13	Mn AV v/s Soil Av. N	-0.1802*
14	Cu RED v/s Soil pH	0.1682*	14	Mn AV v/s Soil Av. P ₂ O ₅	-0.1997*
15	Cu RED v/s Soil Av. N	-0.1790*	15	Mn AV v/s Soil Av. K ₂ O	0.2130*
16	Cu RED v/s Soil Av. P ₂ O ₅	0.1878*	16	Mn T v/s Soil O.C. %	0.2131*
17	Cu RED v/s Soil Av. K ₂ O	0.3081**	17	Mn T v/s Soil Av. N	-0.2203**
18	Cu T v/s Soil pH	0.4122**	18	Mn T v/s Soil Av. P ₂ O ₅	-0.2144*
19	Cu T v/s Soil EC	-0.4040**	19	Mn T v/s Soil Av. K ₂ O	0.3174**
20	Cu T v/s Soil Av. N	-0.2840**	20	Mn RES v/s Soil pH	0.3135**
21	Cu T v/s Soil Av. K ₂ O	0.1725*	21	Mn RES v/s Soil EC	0.2994**
22	Cu T v/s Soil HSS	-0.1990*	22	Mn RES v/s Soil Av. P ₂ O ₅	0.2701**
23	Cu RES v/s Soil pH	0.3731**	23	Mn RES v/s Soil HSS	0.3405**
24	Cu RES v/s Soil EC	-0.3114**	24	Mn PA v/s Soil pH	0.3095**
25	Cu RES v/s Soil Av. N	-0.1697*	25	Mn PA v/s Soil EC	-0.1942*
26	Cu RES v/s Soil Av. K ₂ O	0.2786**	26	Mn PA v/s Soil HSS	-0.4379**
27	Cu RES v/s Soil HSS	-0.1928*	27	Mn TA v/s Soil pH	-0.4037**
28	Cu PA v/s Soil pH	0.3493**	28	Mn TA v/s Soil O.C. %	0.3377**
29	Cu PA v/s Soil EC	-0.2834**	29	Mn TA v/s Soil HSS	0.2735**
30	Cu PA v/s Soil Av. K ₂ O	0.2792**			
31	Cu PA v/s Soil HSS	-0.1824*			

Table 4.5.4 Correlation coefficient between different forms of Cu to NPKS
Concentration of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between Cu Form to NPKS		Sr. no.	Correlation between Cu Form to NPKS	
1	Cu WS v/s CNGP	-0.2305**	37	Cu T v/s CNGH	0.5178**
2	Cu WS v/s CPGP	0.6095**	38	Cu T v/s CPWG	-0.2000**
3	Cu WS v/s CKGP	0.2188*	39	Cu T v/s CSWG	0.4438**
4	Cu WS v/s CSGP	0.2153*	40	Cu T v/s CPWS	-0.2618**
5	Cu WS v/s CNWG	0.5467**	41	Cu T v/s CSWS	0.4483**
6	Cu WS v/s CPWG	-0.3313**	42	Cu RES v/s CNGP	-0.1968*
7	Cu WS v/s CSWG	0.6770**	43	Cu RES v/s CPGP	0.3417**
8	Cu WS v/s CPWS	-0.5397**	44	Cu RES v/s CKGP	0.2559**
9	Cu WS v/s CSWS	0.6341**	45	Cu RES v/s CNGH	-0.1882*
10	Cu EF v/s CPGP	0.1835*	46	Cu RES v/s CKGH	0.4312**
11	Cu EF v/s CSGP	0.2825**	47	Cu RES v/s CNWG	0.4603**
12	Cu EF v/s CSGH	0.2865**	48	Cu RES v/s CPWG	-0.1626*
13	Cu EF v/s CNWG	0.1905*	49	Cu RES v/s CSWG	0.4116**
14	Cu EF v/s CKWG	0.2360**	50	Cu RES v/s CPWS	-0.2196**
15	Cu EF v/s CSWG	0.3143**	51	Cu RES v/s CKWS	0.2228**
16	Cu EF v/s CPWS	-0.2210**	52	Cu RES v/s CSWS	0.3548**
17	Cu EF v/s CSWS	0.2213**	53	Cu PA v/s CNGP	-0.1731*
18	Cu AV v/s CNGP	-0.3457**	54	Cu PA v/s CPGP	0.3072**
19	Cu AV v/s CPGP	0.3514**	55	Cu PA v/s CKGP	0.2521**
20	Cu AV v/s CNGH	-0.1822*	56	Cu PA v/s CNGH	-0.1826*
21	Cu AV v/s CPGH	-0.1820*	57	Cu PA v/s CKGH	0.4215**
22	Cu AV v/s CKGH	0.3160**	58	Cu PA v/s CNWG	0.4296**
23	Cu AV v/s CNWG	0.3934**	59	Cu PA v/s CSWG	0.3868**
24	Cu AV v/s CPWG	-0.2068**	60	Cu PA v/s CPWS	-0.2030**
25	Cu AV v/s CSWG	0.2669**	61	Cu PA v/s CKWS	0.2212**
26	Cu AV v/s CSWS	0.3079**	62	Cu PA v/s CSWS	0.3244**
27	Cu RED v/s CSGP	0.1974*	63	Cu TA v/s CKGH	-0.1699*
28	Cu RED v/s CKGH	0.3716**			
29	Cu RED v/s CSGH	0.2279**			
30	Cu RED v/s CNWG	0.2210**			
31	Cu RED v/s CKWG	0.2896**			
32	Cu RED v/s CKWS	0.2138**			
33	Cu T v/s CNGP	-0.2992**			
34	Cu T v/s CPGP	0.4701**			
35	Cu T v/s CKGP	0.1905*			
36	Cu T v/s CKGH	0.3458**			

positive relationship with exchangeable, reducible and per cent available while straw potash concentration was significant positive relationship with reducible,

residual and per cent available. Wheat grain and straw sulphur concentration has significant positive relationship with water soluble, exchangeable, available ($r = 0.2669$ and $r = 0.3079$, respectively) and total. But wheat straw sulphur also significant with residual and per cent available.

4.2.2.1 Correlation among Different Forms of Mn

The DTPA available Manganese (Table 4.5.1) exhibited significant positive relationship with reducible ($r = 0.1669$), total ($r = 0.7277$), residual ($r = 0.1749$) and available total ($r = 0.6882$). It indicated that dominant component was DTPA available form. Nevertheless, the water soluble manganese also showed significant positive relationship with available ($r = 0.3048$), total ($r = 0.2924$) and available total and negative correlated with exchangeable ($r = -0.2083$) and per cent available ($r = -0.1833$). Exchangeable manganese showed significant positive relationship with total ($r = 0.2787$), residual ($r = 0.3416$) and per cent available ($r = 0.3093$), while reducible form has also significant positive relationship with total and available total. Total manganese was having positive relationship with residual and available total. Residual manganese has positive correlated with per cent available and negatively correlated with available total, while per cent available and negative correlated with available total, while per cent available was significant negative relation with available ($r = -0.8822$).

4.2.2.2 Correlation with Yield : Mn

Groundnut pod and haulm yield were having significant positive relationship with exchangeable, per cent available, residual form but

Table 4.5.5 Correlation coefficient between different forms of Mn to NPKS
Concentration of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between Mn Form to NPKS Conc.		Sr. no.	Correlation between Mn Form to NPKS Conc.	
	1	Mn WS v/s CPGP		-0.4860**	36
2	Mn WS v/s CKGP	-0.3602**	37	Mn PA v/s CPGP	0.4471**
3	Mn WS v/s CSGP	-0.4715**	38	Mn PA v/s CSGP	-0.2100*
4	Mn WS v/s CSGH	-0.6188**	39	Mn PA v/s CNGH	-0.2594**
5	Mn WS v/s CNWG	-0.4508**	40	Mn PA v/s CPGH	-0.3615**
6	Mn WS v/s CKWG	-0.4346**	41	Mn PA v/s CKGH	0.3499**
7	Mn WS v/s CSWG	-0.6633**	42	Mn PA v/s CNWG	0.3935**
8	Mn WS v/s CPWS	0.5502**	43	Mn PA v/s CPWG	-0.3570**
9	Mn WS v/s CKWS	-0.3346**	44	Mn PA v/s CSWG	0.3634**
10	Mn WS v/s CSWS	-0.6262**	45	Mn PA v/s CSWS	0.2857**
11	Mn EF v/s CPGP	0.3583**	46	Mn RES v/s CNGP	-0.2598**
12	Mn EF v/s CKGP	0.2931**	47	Mn RES v/s CPGP	0.4146**
13	Mn EF v/s CPGH	-0.2270**	48	Mn RES v/s CSGP	-0.2326**
14	Mn EF v/s CKGH	0.2768**	49	Mn RES v/s CNGH	-0.2424**
15	Mn EF v/s CNWG	0.3672**	50	Mn RES v/s CPGH	-0.3533**
16	Mn EF v/s CPWG	-0.2571**	51	Mn RES v/s CKGH	0.3776**
17	Mn EF v/s CSWG	0.3536**	52	Mn RES v/s CNWG	0.3658**
18	Mn EF v/s CSWS	0.3414**	53	Mn RES v/s CPWG	-0.3451**
19	Mn AV v/s CPGP	-0.1911*	54	Mn RES v/s CKWG	-0.1697*
20	Mn AV v/s CKGH	0.2465**	55	Mn RES v/s CSWG	0.3238**
21	Mn AV v/s CSGH	-0.2274**	56	Mn RES v/s CSWS	0.2442**
22	Mn AV v/s CNWG	-0.1807*	57	Mn TA v/s CPGP	-0.4901**
23	Mn AV v/s CSWG	-0.3259**	58	Mn TA v/s CNGH	0.2659**
24	Mn AV v/s CPWS	0.3351**	59	Mn TA v/s CPGH	0.3114**
25	Mn AV v/s CSWS	-0.3187**	60	Mn TA v/s CKGH	-0.2094**
26	Mn RED v/s CPGP	-0.1889*	61	Mn TA v/s CNWG	-0.4318**
27	Mn RED v/s CNGH	0.1783*	62	Mn TA v/s CPWG	0.3228**
28	Mn RED v/s CNWG	-0.1721*	63	Mn TA v/s CSWG	-0.4405**
29	Mn RED v/s CSWS	-0.1809*	67	Mn TA v/s CPWS	0.2110*
30	Mn T v/s CSGP	-0.1938*	68	Mn TA v/s CSWS	-0.3800**
31	Mn T v/s CKGH	0.2505**			
32	Mn T v/s CSGH	-0.2200**			
33	Mn T v/s CSWG	-0.2053*			
34	Mn T v/s CPWS	0.2679**			
35	Mn T v/s CSWS	-0.2328**			

significant negative relationship with water soluble, available, reducible, total and available total. Wheat grain and straw yield was significant positive relationship with water soluble, available, reducible, total and available total, while significant negative relationship with exchangeable and per cent available form. We may not get the absolute relationship with various crop yields because of complex of micro and macro environmental factors influence the ultimate yield (Table 4.5.2).

4.2.2.3 Correlation with Soil Properties : Zn

Water soluble, Exchangeable, available, total, residual, per cent available, available total of Mn were showed significant relationship with most of the soil properties. However, these relationships were reflected by virtue of pre dominance of DTPA available and Water soluble, which were evident from highly significant relationship between available Mn and various soil properties (Table 4.5.3).

4.2.2.4 Correlation Between NPKS concentration Plants Parts : Forms of Mn

Groundnut pod nitrogen concentration showed significant negative relationship with per cent available and residual. So also with the groundnut haulm nitrogen concentration. Groundnut pod phosphorus concentration showed significant positive relationship with exchangeable, per cent available and residual form, while negative relationship with most of other form. However haulm phosphorus concentration showed significant negative relationship with exchangeable, per cent available, residual and available total. These relationships indicated the regulation of partitioning of phosphorus by the Mn favoring the higher concentration in pod. Groundnut pod potash concentration was negative significant relationship with water soluble

Table 4.5.7 Correlation coefficient between different forms of Zn and Fe to yield of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between Zn Form to yield		Sr. no.	Correlation between Fe Form to yield	
1	Zn EF v/s WGY	0.2400**	1	Fe WS v/s GPY	0.4054**
2	Zn EF v/s WSY	0.2158*	2	Fe WS v/s GHY	0.3974**
3	Zn AV v/s GPY	-0.5613**	3	Fe WS v/s WGY	0.3550**
4	Zn AV v/s GHY	-0.5316**	4	Fe WS v/s WSY	0.3144**
5	Zn AV v/s WGY	0.5868**	5	Fe EF v/s GPY	0.2836**
6	Zn AV v/s WSY	0.5271**	6	Fe EF v/s GHY	0.2852**
7	Zn RED v/s GPY	-0.8287**	7	Fe EF v/s WGY	0.3356**
8	Zn RED v/s GHY	-0.8030**	8	Fe EF v/s WSY	0.3356**
9	Zn RED v/s WGY	0.8048**	9	Fe AV v/s GPY	0.8260**
10	Zn RED v/s WSY	0.6586**	10	Fe AV v/s GHY	0.7638**
11	Zn T v/s GPY	-0.7724**	11	Fe AV v/s WGY	0.7915**
12	Zn T v/s GHY	-0.7433**	12	Fe AV v/s WSY	0.6623**
13	Zn T v/s WGY	0.7766**	13	Fe T v/s GPY	0.5475**
14	Zn T v/s WSY	0.6584**	14	Fe T v/s GHY	0.5160**
15	Zn RES v/s GPY	0.4392**	15	Fe T v/s WGY	0.5422**
16	Zn RES v/s GHY	0.4072**	16	Fe T v/s WSY	0.4464**
17	Zn RES v/s WGY	-0.2555**	17	Fe RES v/s GPY	0.4392**
18	Zn RES v/s WSY	-0.2115*	18	Fe RES v/s GHY	0.4072**
19	Zn PA v/s GPY	0.6330**	19	Fe RES v/s WGY	0.2555**
20	Zn PA v/s GHY	0.5960**	20	Fe RES v/s WSY	0.2115*
21	Zn PA v/s WGY	-0.4767**	21	Fe PA v/s GPY	0.4396**
22	Zn PA v/s WSY	-0.4004**	22	Fe PA v/s GHY	0.4076**
23	Zn TA v/s GPY	-0.7949**	23	Fe PA v/s WGY	0.2560**
24	Zn TA v/s GHY	-0.7633**	24	Fe PA v/s WSY	0.2119*
25	Zn TA v/s WGY	0.7638**	25	Fe TA v/s GHY	0.6491**
26	Zn TA v/s WSY	0.6457**	26	Fe TA v/s GPY	0.6071**
			27	Fe TA v/s WGY	0.5661**
			28	Fe TA v/s WSY	0.4627**

Table 4.5.8 Correlation coefficient between different forms of Zn and Fe to Soil Properties of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between Zn Form to Soil Properties		Sr. no.	Correlation between Fe Form to Soil Properties	
1	Zn EF v/s Soil O.C. %	0.1765*	1	Fe WS v/s Soil pH	0.3668**
2	Zn EF v/s Soil Av. N	0.3134**	2	Fe WS v/s Soil EC	-0.3184**
3	Zn EF v/s Soil Av. P ₂ O ₅	0.3821**	3	Fe WS v/s Soil Av. N	-0.3467**
4	Zn EF v/s Soil Av. K ₂ O	0.2136*	4	Fe EF v/s Soil pH	-0.3261**
5	Zn EF v/s Soil HSS	-0.2070**	5	Fe EF v/s Soil EC	0.1891*
6	Zn AV v/s Soil pH	-0.3879**	6	Fe EF v/s Soil O.C. %	0.2577**
7	Zn AV v/s Soil EC	0.3914**	7	Fe EF v/s Soil Av. N	0.2927**
8	Zn AV v/s Soil O.C. %	0.5081**	8	Fe EF v/s Soil Av. P ₂ O ₅	0.2777**
9	Zn AV v/s Soil Av. N	0.4980**	9	Fe AV v/s Soil pH	-0.6706**
10	Zn AV v/s Soil Av. P ₂ O ₅	0.6149**	10	Fe AV v/s Soil EC	0.5783**
11	Zn AV v/s Soil Av. K ₂ O	0.3754**	11	Fe AV v/s Soil O.C. %	0.4494**
12	Zn RED v/s Soil pH	-0.7069**	12	Fe AV v/s Soil Av. N	0.7057**
13	Zn RED v/s Soil EC	0.5030**	13	Fe AV v/s Soil Av. P ₂ O ₅	0.3985**
14	Zn RED v/s Soil O.C. %	0.3251**	14	Fe RED v/s Soil pH	0.1880*
15	Zn RED v/s Soil Av. N	0.6808**	15	Fe RED v/s Soil O.C. %	-0.2672**
16	Zn RED v/s Soil Av. P ₂ O ₅	0.4187**	16	Fe RED v/s Soil Av. P ₂ O ₅	-0.2274**
17	Zn T v/s Soil pH	-0.6004**	17	Fe RED v/s Soil K ₂ O	-0.2793**
18	Zn T v/s Soil EC	0.4908**	18	Fe RED v/s Soil HSS	-0.1846**
19	Zn T v/s Soil O.C. %	0.4608**	19	Fe T v/s Soil pH	-0.4022**
20	Zn T v/s Soil Av. N	0.6643**	20	Fe T v/s Soil EC	0.3794**
21	Zn T v/s Soil Av. P ₂ O ₅	0.5819**	21	Fe T v/s Soil O.C. %	0.1669*
22	Zn T v/s Soil Av. K ₂ O	0.2318**	22	Fe T v/s Soil Av. N	0.4922**
23	Zn RES v/s Soil pH	0.2466**	23	Fe RES v/s Soil pH	0.2466**
24	Zn RES v/s Soil EC	-0.2989**	24	Fe RES v/s Soil EC	-0.2980**
25	Zn RES v/s Soil Av. K ₂ O	0.1884*	25	Fe RES v/s Soil K ₂ O	0.1884*
26	Zn RES v/s Soil HSS	-0.2840**	26	Fe RES v/s Soil HSS	-0.2846**
27	Zn PA v/s Soil pH	0.4111**	27	Fe PA v/s Soil pH	0.2470**
28	Zn PA v/s Soil EC	-0.4185**	28	Fe PA v/s Soil EC	-0.2983**
29	Zn PA v/s Soil O.C. %	-0.2093**	29	Fe PA v/s Soil K ₂ O	0.1884*
30	Zn PA v/s Soil Av. N	-0.3074**	30	Fe PA v/s Soil HSS	-0.2839**
31	Zn PA v/s Soil Av. P ₂ O ₅	-0.1855*	31	Fe TA v/s Soil pH	-0.4516**
32	Zn PA v/s Soil HSS	-0.2398**	32	Fe TA v/s Soil EC	0.4376**
33	Zn TA v/s Soil pH	-0.6067**	33	Fe TA v/s Soil K ₂ O	0.4661**
34	Zn TA v/s Soil EC	0.5051**	34	Fe TA v/s Soil HSS	-0.1846*
35	Zn TA v/s Soil O.C. %	0.4249**	35		
36	Zn TA v/s Soil Av. N	0.6457**			
37	Zn TA v/s Soil Av. P ₂ O ₅	0.5241**			

Table 4.5.9 Correlation coefficient between different forms of Zn to NPKS
Concentration of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between Zn Form to NPKS Conc.		Sr. no.	Correlation between Zn Form to NPKS Conc	
	1	Zn EF v/s CSGP		-0.2346**	35
2	Zn EF v/s CKGH	0.1953*	36	Zn T v/s CSWG	-0.7466**
3	Zn EF v/s CSGH	-0.3183**	37	Zn T v/s CPWS	0.6574**
4	Zn EF v/s CKWG	-0.2359**	38	Zn T v/s CSWS	-0.7383**
5	Zn EF v/s CSWG	-0.1750*	39	Zn RES v/s CNGP	-0.2505**
6	Zn EF v/s CPWS	0.2095*	40	Zn RES v/s CPGP	0.3449**
7	Zn EF v/s CSWS	-0.1856*	41	Zn RES v/s CKGP	0.1693*
8	Zn AV v/s CPGP	-0.4250**	42	Zn RES v/s CNGH	-0.2040*
9	Zn AV v/s CPGH	0.1717*	43	Zn RES v/s CPGH	-0.1923*
10	Zn AV v/s CKGH	0.1704*	44	Zn RES v/s CKGH	0.3511**
11	Zn AV v/s CSGH	-0.1965*	45	Zn RES v/s CNWG	0.4328**
12	Zn AV v/s CNWG	-0.4387**	46	Zn RES v/s CPWG	-0.1867*
13	Zn AV v/s CPWG	0.3414**	47	Zn RES v/s CSWG	0.3438**
14	Zn AV v/s CSWG	-0.5994**	48	Zn RES v/s CPWS	-0.2133*
15	Zn AV v/s CNWS	0.2097*	49	Zn RES v/s CSWS	0.2948**
16	Zn AV v/s CPWS	0.5994**	50	Zn PA v/s CNGP	-0.2294**
17	Zn AV v/s CSWS	-0.6128**	51	Zn PA v/s CPGP	0.4697**
18	Zn RED v/s CPGP	0.5304**	52	Zn PA v/s CKGP	0.1874*
19	Zn RED v/s CKGP	-0.2172**	53	Zn PA v/s CNGH	-0.2369**
20	Zn RED v/s CSGP	-0.2669**	54	Zn PA v/s CPGH	-0.1911*
21	Zn RED v/s CNGH	0.2056*	55	Zn PA v/s CKGH	0.2954**
22	Zn RED v/s CSGH	-0.4571**	56	Zn PA v/s CNWG	0.5527**
23	Zn RED v/s CNWG	-0.5488**	57	Zn PA v/s CPWG	-0.2618**
24	Zn RED v/s CPWG	0.2288**	58	Zn PA v/s CSWG	0.5429**
25	Zn RED v/s CKWG	-0.2370**	59	Zn PA v/s CPWS	-0.4016**
26	Zn RED v/s CSWG	-0.7428**	60	Zn PA v/s CSWS	0.4983**
27	Zn RED v/s CPWS	0.5845**	61	Zn TA v/s CPGP	-0.5425**
28	Zn RED v/s CKWS	-0.2219**	62	Zn TA v/s CNGH	0.2027*
29	Zn RED v/s CSWS	-0.7154**	63	Zn TA v/s CSGH	-0.3682**
30	Zn T v/s CPGP	-0.5243**	64	Zn TA v/s CNWG	-0.5793**
31	Zn T v/s CSGP	-0.1687*	65	Zn TA v/s CPWG	0.3013**
32	Zn T v/s CNGH	0.1875*	66	Zn TA v/s CSWG	-0.7535**
33	Zn T v/s CSGH	-0.3767**	67	Zn TA v/s CPWS	0.6421**
34	Zn T v/s CNWG	-0.5479**	68	Zn TA v/s CSWS	-0.7356**

but haulm was significant positive relationship with most of the form of Mn. Groundnut pod sulphur concentration was significant negative relationship with water soluble, per cent available and residual, while haulm sulphur concentration was also significant negative relationship with water soluble, available and total.

Wheat grain nitrogen concentration was significant positive relationship with exchangeable, per cent available and residual, while significant negative relationship with water soluble, available reducible and total available. Wheat grain phosphorus concentration was significant positive relationship with available total but negative relationship with exchangeable and residual, while wheat straw phosphorus concentration was significant positive relation with water soluble, available ($r = 0.3351$), total and available total. Water soluble was negative significant relationship with wheat grain and straw potash concentration. Wheat grain and straw sulphur concentration were significant relationship with most of all the form (Table 4.5.5).

4.3.3.1 Correlation Among Different Forms of Zn

The DTPA available zinc showed highly significant positive relationship with exchangeable ($r = 0.3879$), reducible ($r = 0.6008$), total ($r = 0.8949$) and available total ($r = 0.8581$). This indicated DTPA available zinc as the pre dominant component of available zinc. Other forms such as exchangeable also showed highly significant positive relationship with reducible, total and available total. These was highly significant positive relationship of reducible with total ($r = 0.8921$) and available total ($r = 0.9066$) and negative relationship with residual and per cent available. Highly significant positive relationship of total with available total and negative relationship with residual and per cent available was observed, like wise these was highly significant positive relationship of residual with per cent available and negative relationship with

available total. Per cent available Zn has significant negative relationship with available total (Table 4.5.6).

4.3.3.2 Correlation with Yield : Zn

As evident from the correlation among different forms, the predominant form of available zinc was DTPA available. So, relation between wheat grain and straw with exchangeable, available, reducible, total and available total of zinc were positive, while residual, per cent available of zinc were negative. The significant positive relationship of groundnut pod and haulm yield with residual and per cent available, while negative relationship was with available, reducible, total and available total. Nevertheless, as explained earlier, the relationship of different forms of micronutrients can not be absolutely with the yield (Table 4.5.7).

4.3.3.3 Correlation with Soil Properties : Zn

Exchangeable, available, reducible, total, residual, per cent available, available total of Zn showed significant relationship with most of the soil properties. However, these relationships were reflected by virtue of pre dominance of DTPA available and reducible Zn, which were evident from highly significant relationship between available Zn and various soil properties (Table 4.5.8). Badhe and Naphate (1970) and Mehta and Patel (1967) also reported a positive significant correlation between organic carbon and available Mn in the soils.

4.3.3.4 Correlation Between NPKS Concentration in Plant Parts : Forms of Zn

Groundnut pod nitrogen concentration showed significant negative relationship with per cent available of Zn, while haulm nitrogen

Table 4.5.10 Correlation coefficient between different forms of Zn to NPKS
Concentration of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between Fe Form to NPKS Conc.		Sr. no.	Correlation between Fe Form to NPKS Conc.	
	1	Fe WS v/s CPGP		0.3981**	38
2	Fe WS v/s CNWG	0.3753**	39	Fe T v/s CSWG	-0.4852**
3	Fe WS v/s CPWG	-0.1825*	40	Fe T v/s CPWS	0.3444**
4	Fe WS v/s CSWG	0.3540**	41	Fe T v/s CKWS	-0.3324**
5	Fe WS v/s CPWS	-0.2852**	42	Fe T v/s CSWS	-0.3918**
6	Fe WS v/s CSWS	-0.3957**	43	Fe RES v/s CPGP	0.3449**
7	Fe EF v/s CNGP	-0.1935*	44	Fe RES v/s CKGP	0.1693*
8	Fe EF v/s CSGH	-0.2131**	45	Fe RES v/s CNGH	-0.2040*
9	Fe EF v/s CNWG	-0.1704*	46	Fe RES v/s CPGH	-0.1923*
10	Fe EF v/s CSWG	-0.1685*	47	Fe RES v/s CKGH	0.3511**
11	Fe EF v/s CSWG	0.2560**	48	Fe RES v/s CNWG	0.4328**
12	Fe EF v/s CPWS	-0.1901*	49	Fe RES v/s CPWG	-0.1867*
13	Fe EF v/s CSWS	-0.6605**	50	Fe RES v/s CSWG	0.3438**
14	Fe AV v/s CPGP	-0.2705**	51	Fe RES v/s CPWS	-0.2133*
15	Fe AV v/s CKGP	0.2467**	52	Fe RES v/s CSWS	0.2948**
16	Fe AV v/s CNGH	0.2215**	53	Fe PA v/s CNGP	-0.2505**
17	Fe AV v/s CPGH	-0.2914**	54	Fe PA v/s CPGP	0.3452**
18	Fe AV v/s CSGH	-0.6259**	55	Fe PA v/s CKGP	0.1696*
19	Fe AV v/s CNWG	0.3879**	56	Fe PA v/s CNGH	-0.2040*
20	Fe AV v/s CPWG	-0.8023**	57	Fe PA v/s CPGH	-0.1923*
21	Fe AV v/s CSWG	0.6383**	58	Fe PA v/s CKGH	0.3511**
22	Fe AV v/s CPWS	-0.7679**	59	Fe PA v/s CNWG	0.4330**
23	Fe AV v/s CSWS	0.2182**	60	Fe PA v/s CPWG	-0.1868*
24	Fe RED v/s CPGP	0.2182**	61	Fe PA v/s CSWG	0.3442**
25	Fe RED v/s CPGH	-0.1829*	62	Fe PA v/s CPWS	-0.2136*
26	Fe RED v/s CNWG	0.2175*	63	Fe PA v/s CSWS	0.2951**
27	Fe RED v/s CPWG	-0.2388**	64	Fe TA v/s CPGP	-0.4581**
28	Fe RED v/s CPWG	0.2190**	65	Fe TA v/s CKGP	-0.3208**
29	Fe RED v/s CSWG	-0.2316**	66	Fe TA v/s CSGP	-0.1666*
30	Fe RED v/s CPWS	-0.3277**	67	Fe TA v/s CNGH	0.1722*
31	Fe RED v/s CKWS	-0.3077**	68	Fe TA v/s CKGH	-0.2274**
32	Fe RED v/s CSWS	0.3087**	69	Fe TA v/s CSGH	-0.2968**
33	Fe T v/s CPGP	-0.3712**	70	Fe TA v/s CNWG	-0.4763**
34	Fe T v/s CKGP	-0.2912**	71	Fe TA v/s CPWG	0.1910*
35	Fe T v/s CSGP	-0.2117*	72	Fe TA v/s CSWG	-0.5641**
36	Fe T v/s CSGH	-0.3242**	73	Fe TA v/s CPWS	0.3854**
37	Fe T v/s CNWG	-0.3441**	74	Fe TA v/s CKWS	-0.3340**

concentration has significant relationship with reducible, residual and available total. Groundnut pod phosphorus concentration was significant positive relationship with residual and per cent available. However, groundnut haulm showed significant negative relationship with residual and per cent available. These relationships indicated the regulation of partitioning of nitrogen by the Zn and favoring the higher concentration which has significant positive relationship with residual and per cent available, while negative relationship with reducible with pod. Groundnut pod sulphur concentration has significant negative relationship with exchangeable, reducible and total, while haulm sulphur content has significant negative relationship with exchangeable, available, reducible, total and available total.

In wheat, grain nitrogen concentration exhibited significant positive relationship with residual and per cent available but negative relationship with available, reducible, total and available total, while straw nitrogen concentration has significant positive relationship with available ($r = 0.2097$). Grain phosphorus concentration showed significant positive relationship with available ($r = 0.3414$), reducible, total and available total but negative correlated with residual and per cent available, however straw phosphorus concentration has significant positive relationship with exchangeable, available, reducible, total and available total, while negative relationship with residual and per cent available. Grain potash concentration formed significant negative relationship with exchangeable and reducible. Grain straw sulphur concentration was significant positive relationship with residual and per cent positive relationship was observed with residual and per cent available, while negative relationship with exchangeable, available, reducible, total and available total (Table 4.5.10).

4.4.4.1 Correlation Among Different Forms of Fe

The form of iron showed very highly significant positive relationship of available total ($r = 0.7083$), total ($r = 0.6905$) and exchangeable ($r = 0.2589$) with

DTPA available Fe. The other forms showed the highly significant positive relationship with total and available total. The water soluble with reducible, exchangeable with total and total with available total also showed highly significant positive relationship. Thus, two forms i.e. DTPA available and reducible form of iron appeared to constitute predominant part of available component of iron. The significant negative relationship of various forms of iron clearly signified their inter-conversion (Table 4.5.6)

4.4.4.2 Correlation with Yield : Fe

Groundnut pod and haulm showed significant positive relationship with water soluble, residual and per cent available, while negative relationship with exchangeable, available, total and available total. Wheat grain and straw yield exhibited significant positive relationship with exchangeable, available, total and available total, while negative relationship with water soluble, residual and per cent available forms (Table 4.5.7).

4.4.4.3 Correlation with Soil Properties : Fe

The DTPA available and exchangeable Fe recorded significant positive relationship with most of properties but reducible Fe recorded significant negative relationship with most of the soil properties, which indicated predominant forms were DTPA available and exchangeable. Water soluble Fe has significant positive relationship with soil pH but negative relation with soil EC and avail. N. Total form of Fe has positive relationship with soil EC, OC and avail. N, while negative relationship with soil pH. Residual and per cent available forms formed significant positive relationship with soil pH and Avail. K₂O, but significant negative relationship with soil EC and HSS. In available total significant positive relationship with soil EC and avail. N, while significant negative relationship with soil pH and Avail. K₂O (Table 4.5.8). Rajkumar *et al.* (1990), Bhosal *et al.* (1993) and Maji *et al.* (1993) showed adverse effect of high pH on availability of Fe.

4.4.4.4 Correlation Between NPKS Concentration in Plant Parts : Forms of Fe

In groundnut, pod nitrogen concentration showed significant negative relationship with exchangeable, while haulm nitrogen concentration significant relationship with available ($r = 0.2467$), residual and available total. Pod phosphorus concentration has significant positive relationship with water soluble, reducible, residual and per cent available, while haulm phosphorus concentration was significant positive relationship with available ($r = 0.2215$) and negative relationship with reducible, residual and per cent available. Pod potash concentration showed significant positive relationship with residual and per cent available but negative relationship with available ($r = -0.2706$), total and available total, while haulm potash concentration has significant positive relationship with residual and per cent available and available total. Pod S concentration has negative relationship with total and available total, while haulm S concentration was negative relationship with available ($r = -0.2914$), total and available total.

In wheat, grain nitrogen concentration showed significant positive relationship with water soluble, reducible, residual and per cent available but negative relationship with exchangeable, available ($r = -0.6259$), total and available total. Grain phosphorus concentration exhibited significant positive relationship with available ($r = 0.3879$) and available total but significant negative relationship with water soluble, reducible, residual and per cent available. In straw phosphorus concentration has significant positive relationship with exchangeable, available ($r = 0.6383$), total, and available total but negative relationship with water soluble, reducible, residual and per cent available. In grain potash concentration was significant negative relationship with total and available total, while straw potash concentration was significant negative relationship with reducible, total and available total. In grain sulphur concentration showed significant positive relationship with water soluble, reducible, residual and per cent available but negative relationship with

exchangeable, available ($r = -0.8023$), total and available total while straw sulphur concentration has significant positive relationship with water soluble, reducible, residual and per cent available but negative relationship with exchangeable, available ($r = -0.7679$), total and available total (Table 4.5.10).

Interaction as depicted by correlation between different forms of micronutrients

4.1.2.3 Cu x Mn Interaction

The DTPA Cu showed significant positive relationship with exchangeable Mn ($r = 0.2745$), available Mn ($r = 0.1884$), residual Mn ($r = 0.4653$) and per cent available ($r = 0.4607$). Similarly water soluble Cu ($r = -0.2197$) and exchangeable Cu ($r = -0.3020$) showed significant negative relationship with DTPA available Mn. The trend clearly indicated an association of availability of the two micronutrients. The DTPA available copper predominantly showed relationship with different form of Mn (Table 4.5.11).

Table 4.5.11 Correlation coefficient between interaction of different forms of two elements in LTFE soils in the 1st, 4th and 8th year

Sr. No.	Cu x Mn		Sr. No.	Cu x Zn	
1	Cu WS v/s Mn WS	-0.6602**	1	Cu WS v/s Zn AV	-0.4841**
2	Cu WS v/s Mn EF	0.3700**	2	Cu WS v/s Zn RED	-0.7090**
3	Cu WS v/s Mn AV	-0.2197**	3	Cu WS v/s Zn T	-0.6613**
4	Cu WS v/s Mn RES	0.2765**	4	Cu WS v/s Zn RES	0.4353**
5	Cu WS v/s Mn PA	0.3005**	5	Cu WS v/s Zn PA	0.5927**
6	Cu WS v/s Mn TA	-0.3419**	6	Cu WS v/s Zn TA	-0.6864**
7	Cu EF v/s Mn WS	-0.3763**	7	Cu EF v/s Zn WS	-0.1899*
8	Cu EF v/s Mn AV	-0.3020**	8	Cu EF v/s Zn AV	-0.2432**
9	Cu EF v/s Mn T	-0.2182**	9	Cu EF v/s Zn RED	-0.3488**
10	Cu EF v/s Mn RES	-0.1727*	10	Cu EF v/s Zn T	-0.3450**
11	Cu AV v/s Mn WS	-0.2077**	11	Cu EF v/s Zn TA	-0.3221**
12	Cu AV v/s Mn EF	0.2745**	12	Cu AV v/s Zn EF	0.1483*
13	Cu AV v/s Mn AV	0.1884*	13	Cu AV v/s Zn RED	-0.3023**
14	Cu AV v/s Mn RES	0.4653**	14	Cu AV v/s Zn T	-0.1970*
15	Cu AV v/s Mn PA	0.4607**	15	Cu AV v/s Zn RES	0.6759**
16	Cu AV v/s Mn TA	-0.3777**	16	Cu AV v/s Zn PA	0.6436**
17	Cu RED v/s Mn WS	-0.1732*	17	Cu AV v/s Zn TA	-0.2892**
18	Cu RED v/s Mn EF	0.2097*	18	Cu RED v/s Zn RED	0.2878**
19	Cu RED v/s Mn RES	0.2958**	19	Cu RED v/s Zn PA	0.2519**
20	Cu RED v/s Mn PS	0.2865**	20	Cu T v/s Zn AV	-0.1960*
21	Cu RED v/s Mn TA	-0.2190**	21	Cu T v/s Zn RED	-0.4992**
22	Cu T v/s Mn WS	-0.4215**	22	Cu T v/s Zn T	-0.3793**
23	Cu T v/s Mn EF	0.3172**	23	Cu T v/s Zn RES	0.6713**
24	Cu T v/s Mn RES	0.4440**	24	Cu T v/s Zn PA	0.7004**
25	Cu T v/s Mn PA	0.4501**	25	Cu T v/s Zn TA	0.4615**
26	Cu T v/s Mn TA	-0.4123**	26	Cu RES v/s Zn RED	-0.4577**
27	Cu RES v/s Mn WS	-0.3574**	27	Cu RES v/s Zn T	-0.3303**
28	Cu RES v/s Mn EF	0.3700**	28	Cu RES v/s Zn RES	0.7470**
29	Cu RES v/s Mn RES	0.3919**	29	Cu RES v/s Zn PA	0.7487**
30	Cu RES v/s Mn PA	0.3901**	30	Cu RES v/s Zn TA	-0.4310**
31	Cu RES v/s Mn TA	-0.3279**	31	Cu PA v/s Zn RED	-0.4292**
32	Cu PA v/s Mn WS	-0.3307**	32	Cu PA v/s Zn T	-0.3070**
33	Cu PA v/s Mn EF	0.3588**	33	Cu PA v/s Zn RES	0.7203**
34	Cu PA v/s Mn RES	0.3655**	34	Cu PA v/s Zn PA	0.7181**
35	Cu PA v/s Mn PA	0.3627**	35	Cu PA v/s Zn TA	-0.4052**
36	Cu PA v/s Mn TA	-0.3004**	36	Cu PA v/s Zn RES	-0.2203**
			37	Cu TA v/s Zn PA	-0.2051*

4.1.3.7 Cu x Zn Interaction

The DTPA available Cu showed significant positive relationship with exchangeable Zn ($r = 0.1486$), residual Zn ($r = 0.6759$) and per cent available Mn ($r = 0.6436$). Similarly water soluble Cu ($r = -0.4841$), exchangeable Cu ($r = -0.2432$) and total Cu ($r = -0.1960$) showed significant negative relationship with DTPA available Zn (Table 4.5.11). However, early reports have shown negative relationship between available zinc and available copper (Sutaria and Patel, 1981; Dangarwala *et al.*, 1983; Golakiya and Patel, 1988 and Golakiya and Patel, 1990).

4.1.4.8 Cu x Fe Interaction

The DTPA available Cu showed significant positive relationship with water soluble Fe ($r = 0.1764$), residual Fe ($r = 0.6759$), per cent available Fe ($r = 0.6758$). Similarly water soluble Cu ($r = -0.6801$), exchangeable Cu ($r = -0.2534$), available Cu ($r = -0.1970$), total Cu ($r = -0.3712$), residual Cu ($r = -0.3167$) and per cent available Cu ($r = -0.2934$) showed significant negative relationship with DTPA available Fe (4.5.12). These results are in contrast with the early reports where a negative relationship reported (Kalyansundaram and Mehta, 1970; Halagaur *et al.*, 1975; Dangarwala *et al.*, 1983; Sutaria and Patel, 1987; Golakiya and Patel, 1988 and 1990).

4.2.3.9 Mn x Zn interaction

The Mn and Zn presented an interesting case of interaction most of the interaction were significant and positive. DTPA available Mn showed significant positive relationship with exchangeable Zn ($r = 0.1948$), available Zn ($r = 0.3728$), reducible Zn ($r = 0.2893$), total Zn ($r = 0.3738$) and available total ($r = 0.3223$). Similarly water soluble Mn ($r = 0.4906$) and total Mn ($r = 0.3288$) showed significant positive relationship with

Table 4.5.12 Correlation coefficient between interaction of different forms of two elements in LTFE soils in the 1st, 4th and 8th year

Sr. No.	Cu x Fe		Sr. No.	Mn x Zn	
1	Cu WS v/s Fe WS	0.2798**	1	Mn WS v/s Zn EF	0.2994**
2	Cu WS v/s Fe AV	-0.6801**	2	Mn WS v/s Zn AV	0.4906**
3	Cu WS v/s Fe RED	0.1690*	3	Mn WS v/s Zn RED	0.8001**
4	Cu WS v/s Fe T	-0.4236**	4	Mn WS v/s Zn T	0.7257**
5	Cu WS v/s Fe RES	0.4353**	5	Mn WS v/s Zn RES	-0.2853**
6	Cu WS v/s Fe PA	0.4356**	6	Mn WS v/s Zn PA	-0.4858**
7	Cu WS v/s Fe TA	-0.5086**	7	Mn WS v/s Zn TA	0.7362**
8	Cu EF v/s Fe WS	0.1822*	8	Mn EF v/s Zn RED	-0.2889**
9	Cu EF v/s Fe AV	-0.2534**	9	Mn EF v/s Zn T	-0.2130*
10	Cu EF v/s Fe T	-0.2932**	10	Mn EF v/s Zn RES	0.3004**
11	Cu EF v/s Fe TA	-0.2174**	11	Mn EF v/s Zn PA	0.3278**
12	Cu AV v/s Fe WS	0.1764*	12	Mn EF v/s Zn TA	-0.2510**
13	Cu AV v/s Fe AV	-0.1970*	13	Mn AV v/s Zn EF	0.1948*
14	Cu AV v/s Fe RED	0.6759**	14	Mn AV v/s Zn AV	0.3728**
15	Cu AV v/s Fe PA	0.6758**	15	Mn AV v/s Zn RED	0.2893**
16	Cu AV v/s Fe TA	-0.2899**	16	Mn AV v/s Zn T	0.3738**
17	Cu RED v/s Fe RED	0.1762*	17	Mn AV v/s Zn TA	0.3229**
18	Cu RED v/s Fe RES	0.2880**	18	Mn RED v/s Zn RED	0.2523**
19	Cu RED v/s Fe PA	0.2879**	19	Mn RED v/s Zn T	0.2315**
20	Cu T v/s Fe WS	0.2542**	20	Mn RED v/s Zn TA	0.2408**
21	Cu T v/s Fe AV	-0.3712**	21	Mn T v/s Zn WS	0.2037*
22	Cu T v/s Fe T	-0.1929*	22	Mn T v/s Zn EF	0.1771*
23	Cu T v/s Fe RES	0.6712**	23	Mn T v/s Zn AV	0.3288**
24	Cu T v/s Fe PA	0.6713**	24	Mn T v/s Zn RED	0.2987**
25	Cu T v/s Fe TA	-0.4020**	25	Mn T v/s Zn T	0.3575**
26	Cu RES v/s Fe AV	-0.3167**	26	Mn T v/s Zn TA	0.3196**
27	Cu RES v/s Fe RES	0.7469**	27	Mn RES v/s Zn EF	0.2507**
28	Cu RES v/s Fe PA	0.7469**	28	Mn RES v/s Zn RED	0.1729*
29	Cu RES v/s Fe TA	-0.4047**	29	Mn RES v/s Zn RES	0.5160**
30	Cu PA v/s Fe AV	0.2934**	30	Mn RES v/s Zn PA	0.4603**
31	Cu PA v/s Fe RES	0.7202**	31	Mn PA v/s Zn EF	0.2311**
32	Cu PA v/s Fe PA	0.7202**	32	Mn PA v/s Zn RED	0.2221**
33	Cu PA v/s Fe TA	-0.3849**	33	Mn PA v/s Zn RES	0.5094**
34	Cu TA v/s Fe RES	-0.2202**	34	Mn PA v/s Zn PA	0.4730**
35	Cu TA v/s Fe TA	-0.2201**	35	Mn PA v/s Zn TA	-0.1862*
	Mn x Zn		36	Mn TA v/s Zn RED	0.3625**
39	Mn TA v/s Zn PA	0.4458**	37	Mn TA v/s Zn T	0.2772**
40	Mn TA v/s Zn TA	0.3306**	38	Mn TA v/s Zn RES	0.4132**

DTPA available Zn. Water soluble Mn and total also highly significant positive relationship with most of the form of Zn. The predominant forms of Mn, water soluble Mn followed by DTPA available Mn and total Mn were related with different form of zinc (Table 4.5.12)

4.2.3.10 Mn x Fe interaction

Almost all the forms of Mn and Fe were significantly and positively related with each other, ultimately showing a good relationship between water soluble Mn and DTPA available Fe (Table 4.5.13). The DTPA available Mn showed significant positive relationship with exchangeable Fe ($r = 0.2830$) and available Fe ($r = 0.3228$). Similarly DTPA available Fe showed significant positive relationship with water soluble Mn, total ($r = 0.1863$), and available total ($r = 0.3844$). The results are not comparable with those reported earlier showing a negative relationship (Kalyansundarm and Mehta, 1970; Halagaur *et al.*, 1975; Dangarwala *et al.*, 1983; Sutaria and Patel, 1987; Golakiya and Patel, 1988 and 1990).

4.2.4.10 Zn x Fe interaction

Almost all the forms of Zn and Fe were significantly and positively related with each other. Highly significant association was observed between residual Zn with residual Fe ($r = 1.000$) and per cent available ($r = 1.000$). This relationship was mainly due to highly significant and positive association of DTPA available Zn and iron followed by other forms. The residual forms showed negative relationship with available form as usual (Table 4.5.13). Thus certain groups revealed significant positive relationship between DTPA available Zn and Fe. The findings are in conformity of work of some earlier works (Gangwar and Mann, 1972; Sadana and Takkar, 1985; Pathak *et al.*, 1975; Mishra and Pande,

Table 4.5.13 Correlation coefficient between interaction of different forms of two elements in LTFE soils in the 1st, 4th and 8th year

Sr. No.	Mn x Fe		Sr. No.	Zn x Fe	
1	Mn WS v/s Fe WS	-0.3049**	1	Zn AV v/s Fe EF	0.2097*
2	Mn WS v/s Fe EF	0.2683**	2	Zn AV v/s Fe AV	0.5820**
3	Mn WS v/s Fe AV	0.7069**	3	Zn AV v/s Fe T	0.3650**
4	Mn WS v/s Fe T	0.5231**	4	Zn AV v/s Fe TA	0.3704**
5	Mn WS v/s Fe RES	-0.2854**	5	Zn RED v/s Fe WS	-0.2771**
6	Mn WS v/s Fe PA	-0.2859**	6	Zn RED v/s Fe EF	0.2427**
7	Mn WS v/s Fe TA	0.5666**	7	Zn RED v/s Fe AV	0.7583**
8	Mn EF v/s Fe WS	0.2511**	8	Zn RED v/s Fe T	0.5111**
9	Mn EF v/s Fe AV	-0.3626**	9	Zn RED v/s Fe RES	-0.3598**
10	Mn EF v/s Fe RED	0.2270**	10	Zn RED v/s Fe PA	-0.3602**
11	Mn EF v/s Fe RES	0.3003**	11	Zn RED v/s Fe TA	0.5861**
12	Mn EF v/s Fe PA	0.3004**	12	Zn T v/s Fe WS	-0.2225**
13	Mn EF v/s Fe TA	-0.2284**	13	Zn T v/s Fe EF	0.2528**
14	Mn AV v/s Fe EF	0.2830**	14	Zn T v/s Fe AV	0.7418**
15	Mn AV v/s Fe AV	0.3228**	15	Zn T v/s Fe T	0.4864**
16	Mn RED v/s Fe AV	0.2030*	16	Zn T v/s Fe RES	-0.2767**
17	Mn RED v/s Fe RED	-0.1950*	17	Zn T v/s Fe PA	-0.2771**
18	Mn T v/s Fe EF	0.1863*	18	Zn T v/s Fe TA	0.5271**
19	Mn T v/s Fe AV	0.2535**	19	Zn RES v/s Fe AV	-0.2828**
20	Mn RES v/s Fe AV	-0.2294**	20	Zn RES v/s Fe T	-0.1887**
21	Mn RES v/s Fe T	-0.1992*	21	Zn RES v/s Fe RES	1.000**
22	Mn RES v/s Fe RES	0.5161**	22	Zn RES v/s Fe PA	1.000**
23	Mn RES v/s Fe PA	0.5162**	23	Zn RES v/s Fe TA	-0.5339**
24	Mn RES v/s Fe TA	-0.3225**	24	Zn PA v/s Fe WS	0.1713**
25	Mn PA v/s Fe AV	-0.2735**	25	Zn PA v/s Fe AV	-0.4891**
26	Mn PA v/s Fe T	-0.2208**	26	Zn PA v/s Fe T	-0.3235**
27	Mn PA v/s Fe RES	0.5094**	27	Zn PA v/s Fe RES	0.9473**
28	Mn PA v/s Fe PA	0.5096**	28	Zn PA v/s Fe PA	0.9474**
29	Mn PA v/s Fe TA	-0.3376**	29	Zn PA v/s Fe TA	-0.6322**
30	Mn TA v/s Fe AV	0.3844**	30	Zn TA v/s Fe WS	-0.2316**
31	Mn TA v/s Fe T	0.2610**	31	Zn TA v/s Fe EF	0.2426**
32	Mn TA v/s Fe RES	-0.4132**	32	Zn TA v/s Fe AV	0.7444**
33	Mn TA v/s Fe PA	-0.4134**	33	Zn TA v/s Fe T	0.4939**
34	Mn TA v/s Fe TA	0.3434**	34	Zn TA v/s Fe RES	-0.4168**
			35	Zn TA v/s Fe PA	-0.4172**
			36	Zn TA v/s Fe TA	0.5898**

1976) while contradicted by some other reports where the relationships were negative (Kalyansundram and Mehta, 1970; Halagaur *et al.*, 1975; Dangarwala *et al.*, 1983; Sutaria and Patel, 1987; Golakiya and Patel, 1988 and 1990).

LTFE - Pooled Regression and Stepwise

Form to Form

4.1.1.1.1 Copper

The stepwise regression of DTPA available Cu with its various forms explained the variation in form up to 99 per cent. However, total Cu followed by residual form influenced DTPA available Cu to the maximum. (Table 4.6.1)

4.1.1.1.2 Manganese

The DTPA available Mn and its stepwise regression with various forms gave value of multiple correlations co-efficient to a reasonable extent of 1.000 (Table 4.6.1). Among the independent variable, total Mn had maximum influence on DTPA available Mn.

4.1.1.1.3 Zinc

The high values of multiple correlation co-efficient obtained in the stepwise regression of zinc with its various forms thereby explaining most of the variations in DTPA available Zn. Total Zn had the maximum influence followed residual form (Table 4.6.1).

4.1.1.1.4 Iron

As in iron the stepwise regression of DTPA available Fe with various forms also recorded a high value of R square (2.9379). The total Fe had the maximum impact on DTPA available Fe (Table 4.6.1).

Table 4.6.1 Regression equation between DTPA available form to forms and DTPA available form to properties for Cu, Mn, Zn and Fe in LTFE

LTFE soils	Dependent variables	Regression equation							R square
		(WS)	(EF)	(RED)	(T)	(RES)	(PA)	(AVT)	
1	Cu Av.	Y=0.02-0.970x ₁ -0.996x ₂ -0.997x ₃ +0.611x ₄ +0.0388x ₅ -0.389 x ₆ -0.001x ₇							0.9966
2	Mn Av.	Y=-0.84-1.005x ₁ -0.999x ₂ -1.000x ₃ +0.996x ₄ +0.0009x ₅ -0.004 x ₆ -0.009x ₇							1.0000
3	Zn Av.	Y=0.02-0.955x ₁ -0.968x ₂ -1.000x ₃ +0.640x ₄ +0.0353x ₅ -0.354 x ₆ -0.002x ₇							1.0000
4	Fe Av.	Y=82.05-0.741x ₁ -0.924x ₂ -1.001x ₃ +1.005x ₄ -0.0002x ₅ -0.001 x ₆ +0.076x ₇							0.9379
		Form to properties (pH) (EC) (OC) (Av N) (AV P) (AV K) (HSS)							
1	Cu Av.	Y=0.90-0.081x ₁ -0.242x ₂ +0.065x ₃ -0.002x ₄ +0.0000x ₅ +0.002 x ₆ -0.007x ₇							0.2635
2	Mn Av.	Y=10.97-0.565x ₁ -1.701x ₂ +0.686x ₃ -0.000x ₄ +0.0013x ₅ +0.002 x ₆ -0.005x ₇							0.2192
3	Zn Av.	Y=0.02-0.036x ₁ +1.213x ₂ +1.141x ₃ -0.002x ₄ +0.0005x ₅ +0.000 x ₆ -0.007x ₇							0.4603
4	Fe Av.	Y=0.90-1.078x ₁ -4.272x ₂ +3.090x ₃ +0.038x ₄ -0.007x ₅ +0.000 x ₆ -0.017x ₇							0.6883

4.5.5.5.2 DTPA Cu, Mn, Zn, Fe : Form to Soil Properties

So far as stepwise regression between DTPA available micronutrients with soil properties are concerned the R square value are low. Properties utilized for analysis soil pH influenced DTPA available Cu, soil OC to DTPA Mn and Zn, soil EC and Organic C to DTPA Fe, to the maximum extent. The prediction models for DTPA available micronutrient as influenced by various soil properties by employing multiple correlation regression analysis are presented Table no. 4.6.1.

Path Co-efficient Analysis of LTFE

4.1.1.1.1.1 Cu - Form to Different Forms

The residual form exhibited significant positive correlation with DTPA available Cu, which reflected as a direct positive effect of residual form on DTPA available copper (Fig. 4.6.1).

4.2.2.2.2.1 Mn : Form to Forms

Total and per cent available form had a direct positive effect on DTPA Mn along with a significant positive correlation between total and per cent available form of Mn to DTPA available Mn (Fig. 4.6.2).

4.3.3.3.3.1 Zn : Form to Forms

The residual Zn and total Zn had a high direct effect on DTPA available Zn. These relationships might be due to indirect positive effects of exchangeable form and per cent available forms through total Zn (Fig. 4.6.3).

4.4.4.4.4.1 Fe : Form to Forms

The total ferrous showed a direct positive effect, while reducible ferrous showed a direct negative effect on DTPA available ferrous. The negative effect of reducible ferrous was because of indirect negative effect through total Fe (Fig. 4.6.4).

4.5.5.5.2 DTPA Cu, Mn, Zn, Fe : Form to Soil Properties

The available N showed a direct positive effect with DTPA available Cu and DTPA available Fe. Available P_2O_5 form had a direct positive effect on DTPA Mn and DTPA Zn. These was indirect positive effect through available K_2O . (Fig. 4.6.5 to 4.6.8).

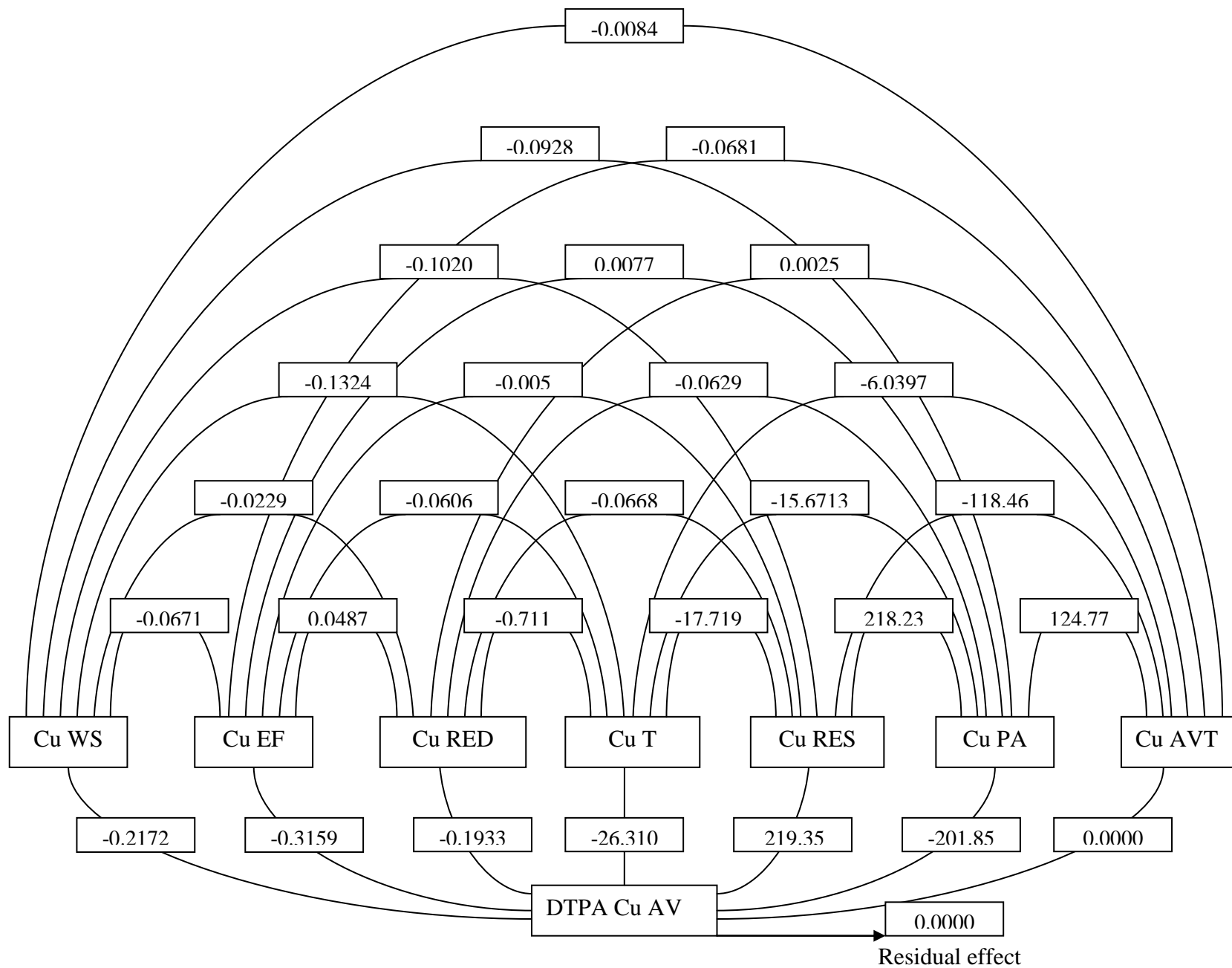


Fig. 4.6.1 Path diagram of the effect of different forms of Cu on DTPA-Cu in the LTFE soils

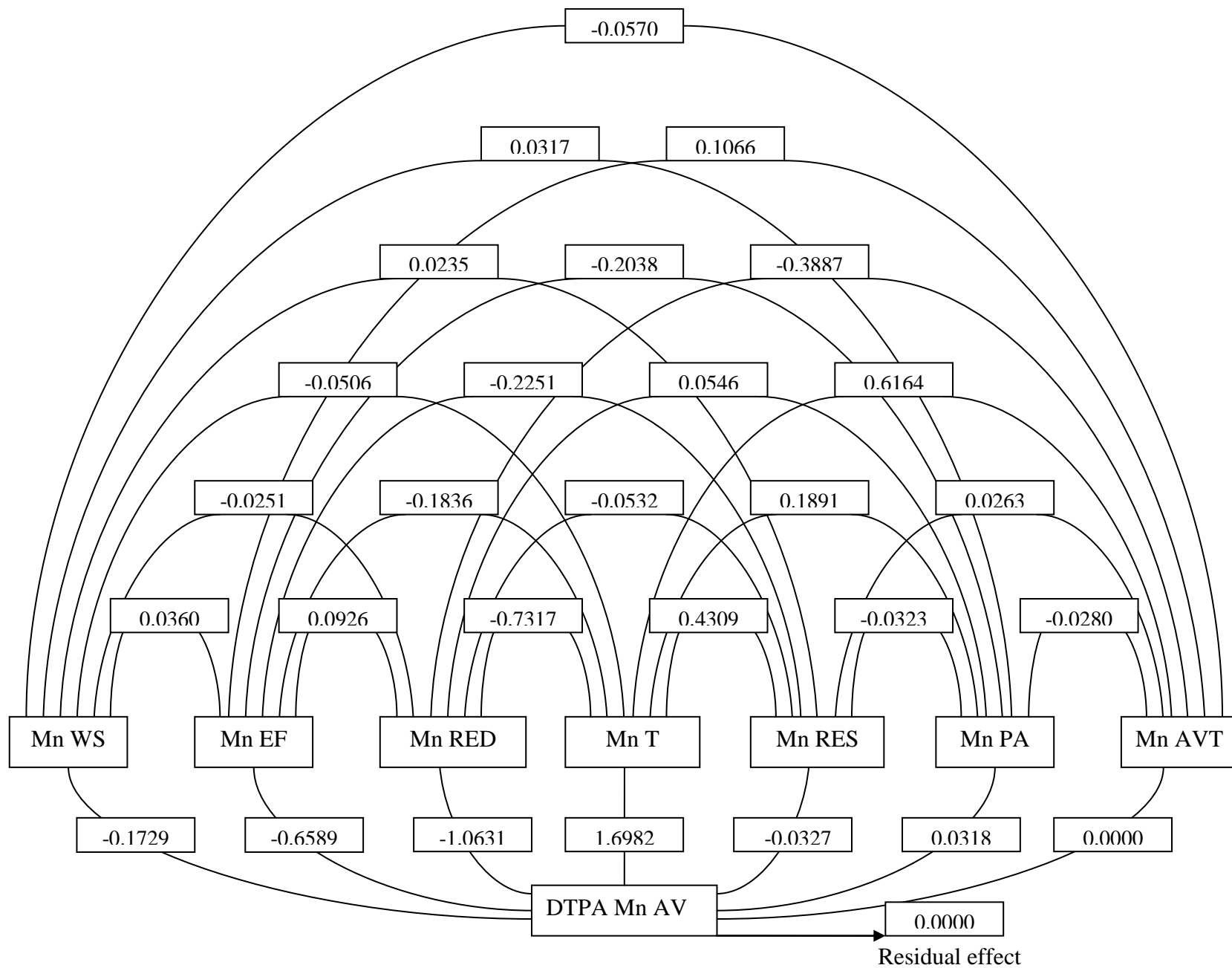


Fig. 4.6.2 Path diagram of the effect of different forms of Mn on DTPA-Mn in the LTFE soils

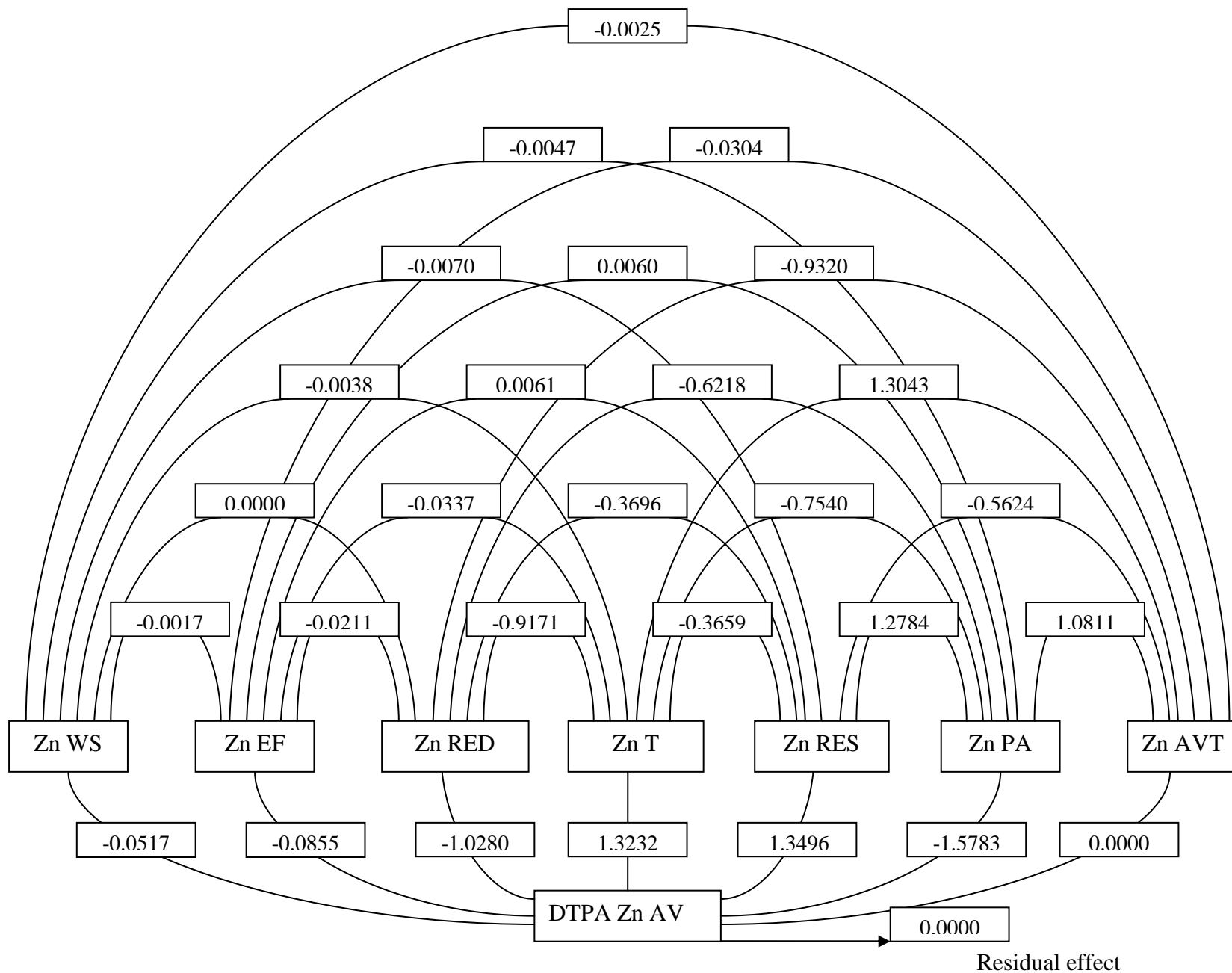


Fig. 4.6.3 Path diagram of the effect of different forms of Zn on DTPA-Zn in the LTFE soils

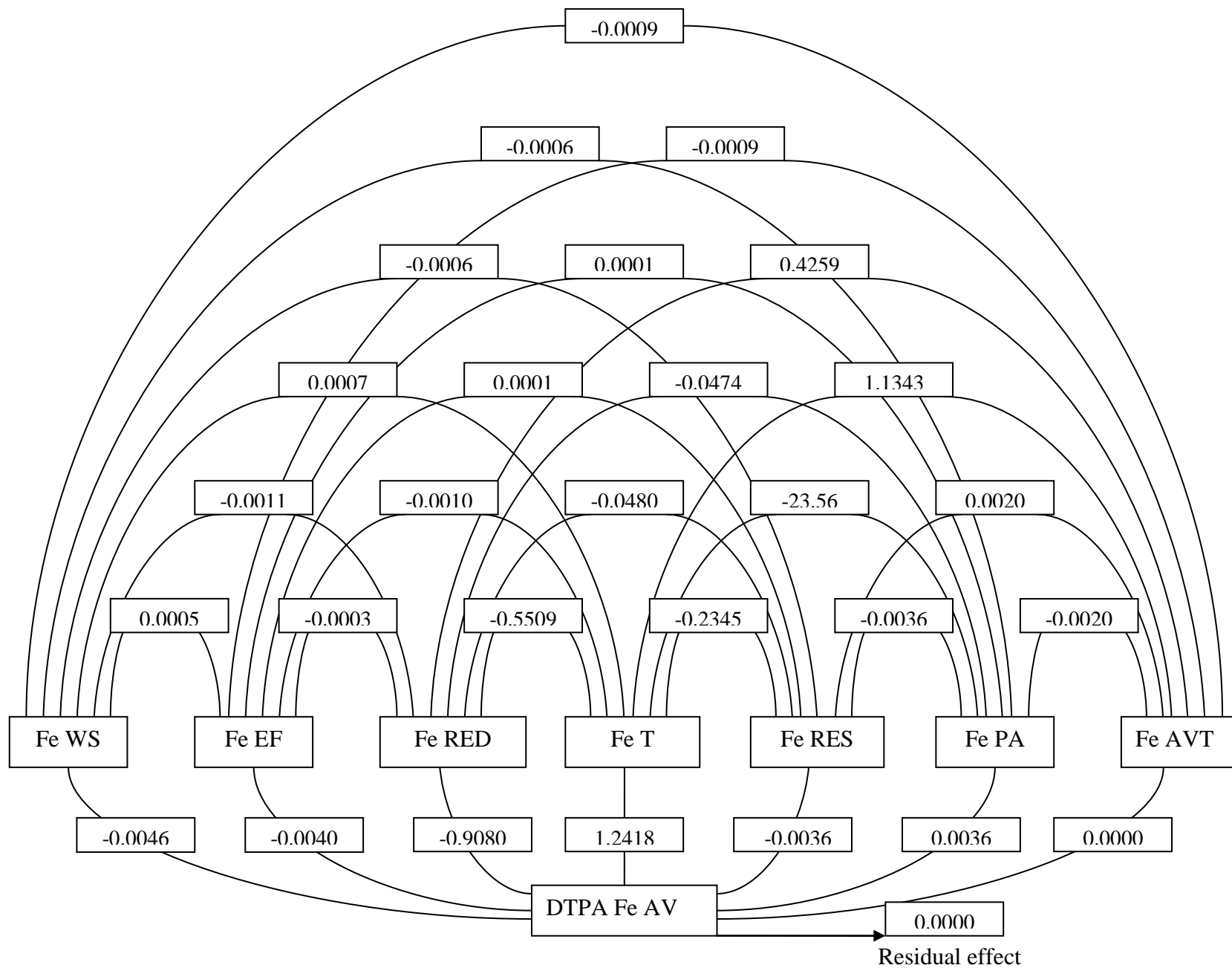


Fig. 4.6.4 Path diagram of the effect of different forms of Fe on DTPA-Fe in the LTFE soils

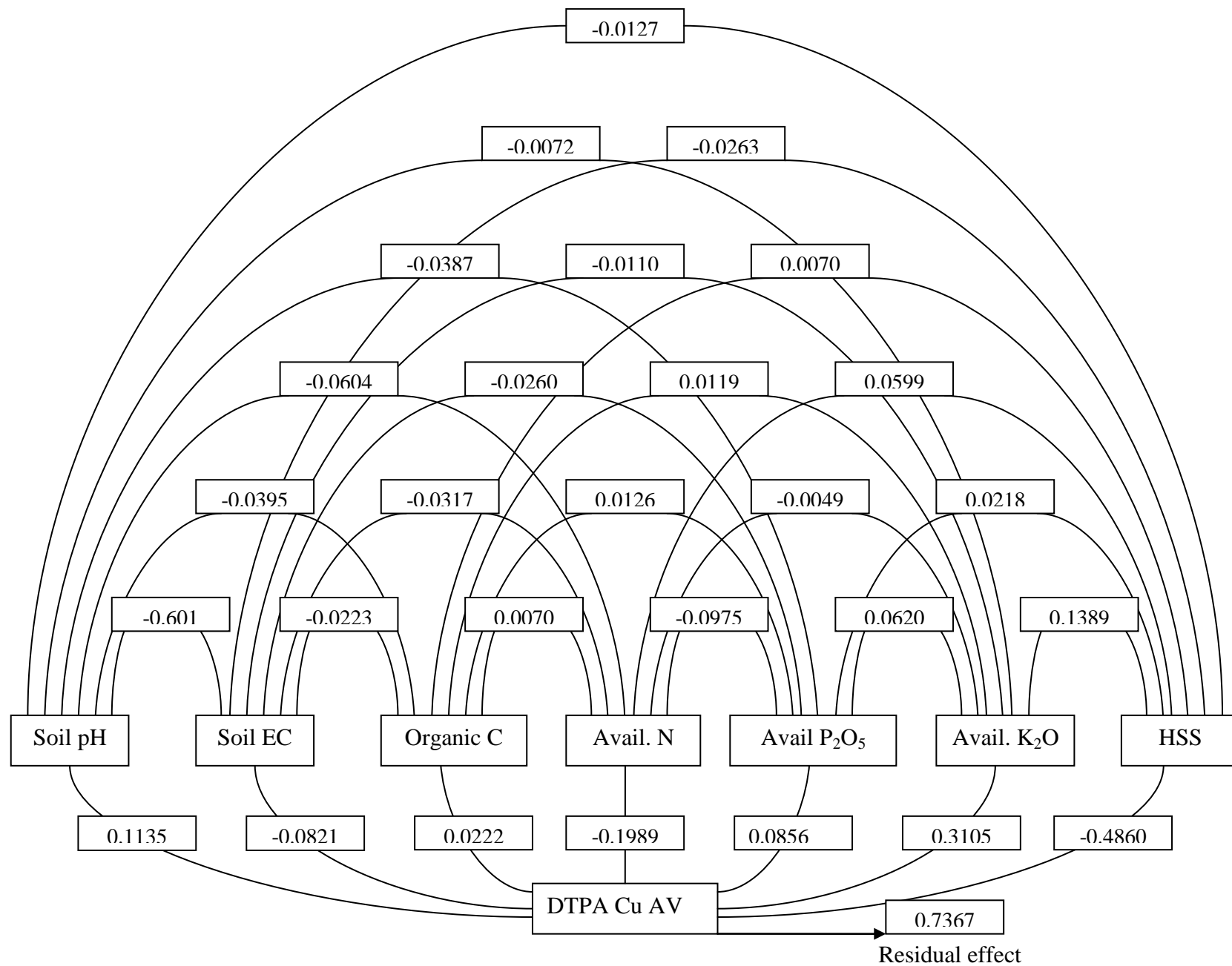


Fig. 4.6.5 Path diagram of the effect of different soil physico-chemical properties on DTPA-Cu in the LTFE soils

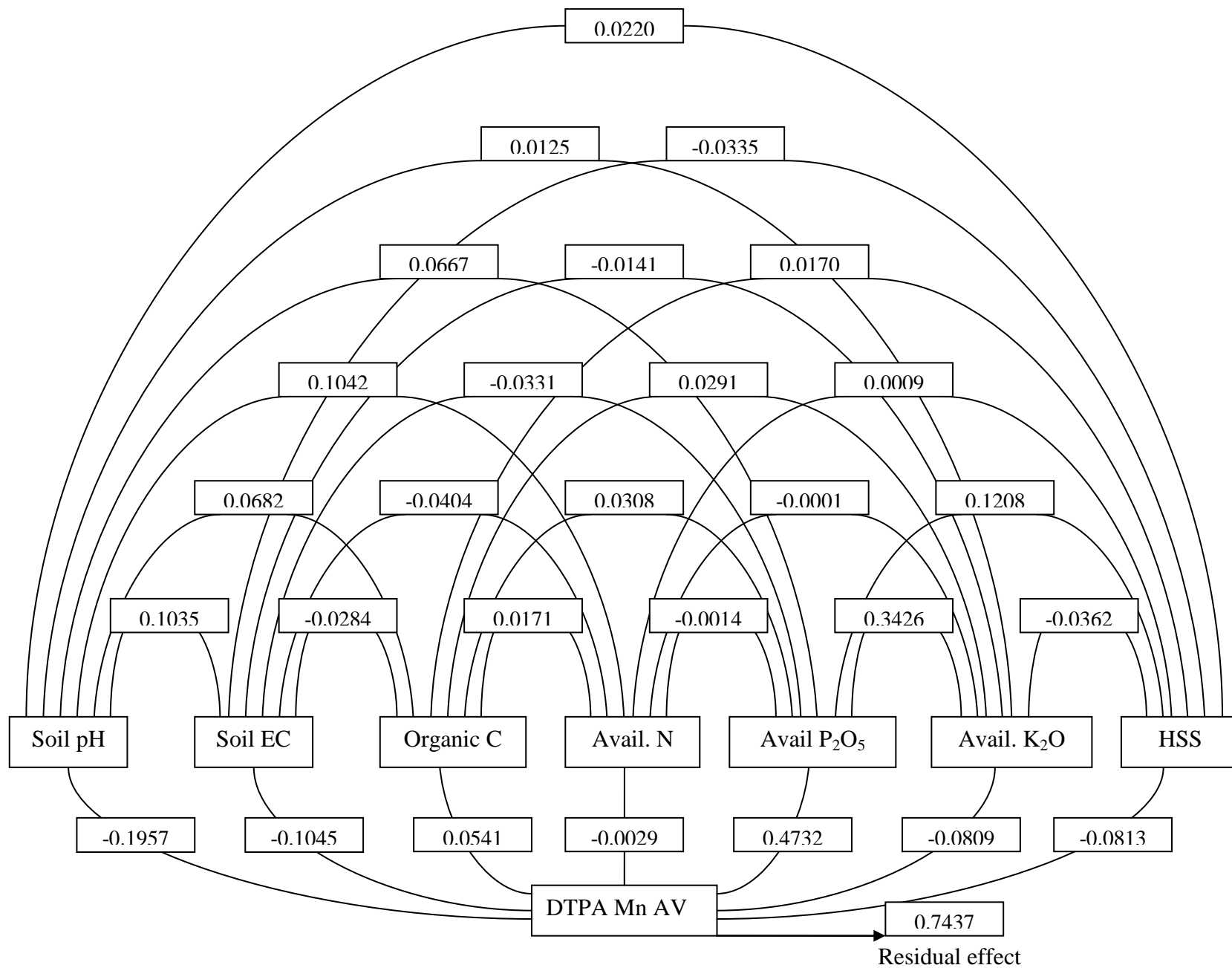


Fig. 4.6.6 Path diagram of the effect of different soil physico-chemical properties on DTPA-Mn in the LTFE soils

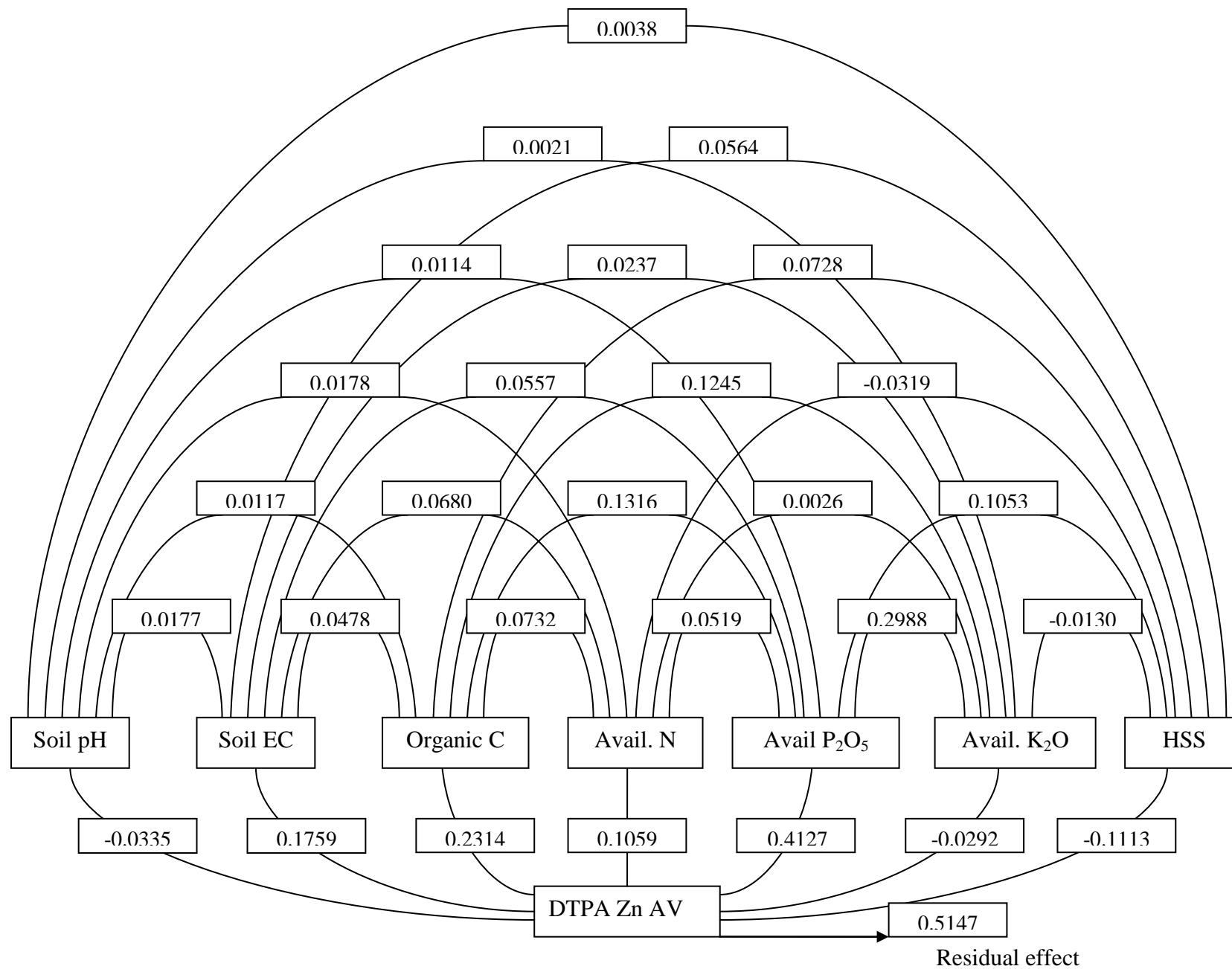


Fig. 4.6.7 Path diagram of the effect of different soil physico-chemical properties on DTPA-Zn in the LTFE soils

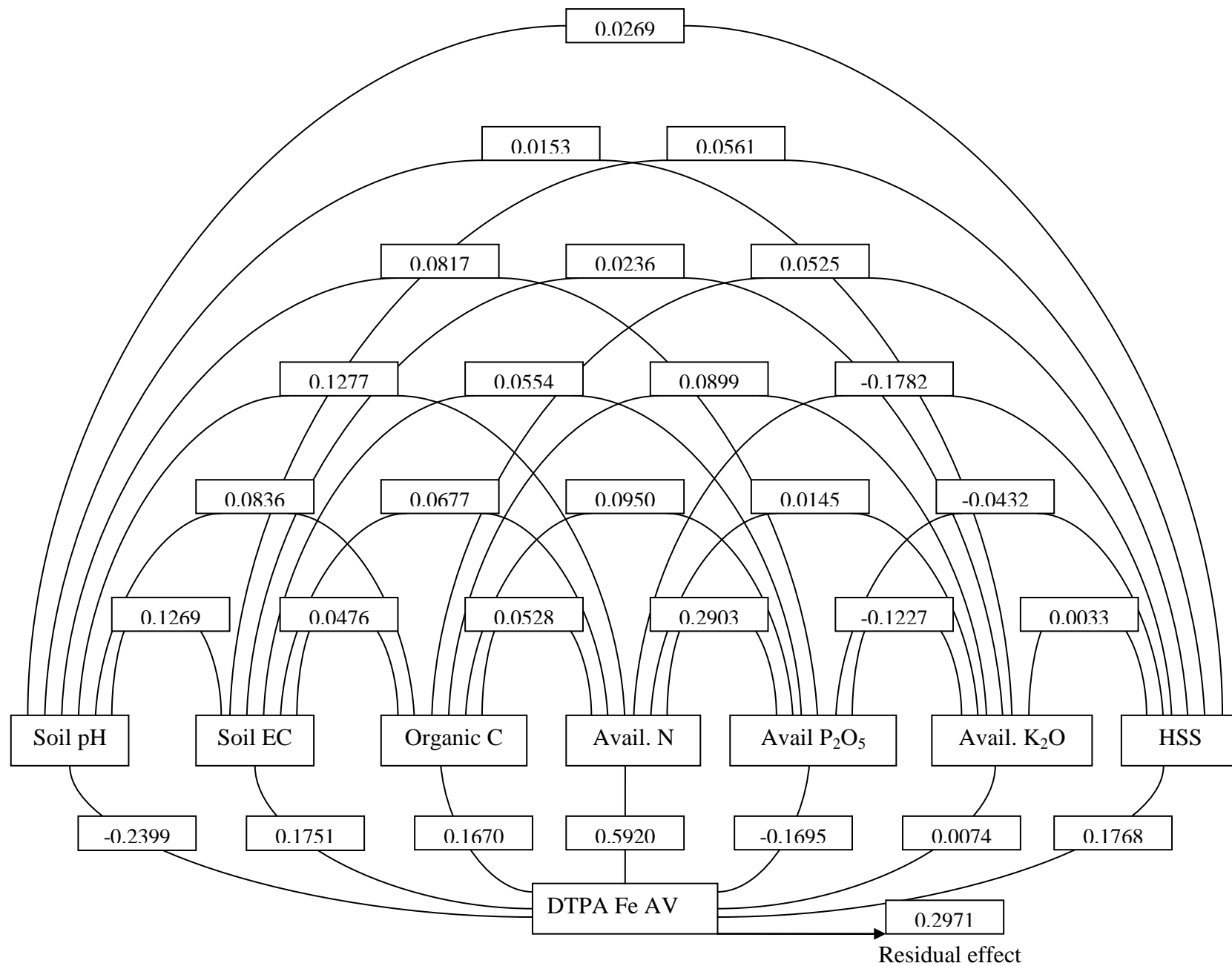


Fig. 4.6.8 Path diagram of the effect of different soil physico-chemical properties on DTPA-Fe in the LTFE soils

CHAPTER - V

GENERAL DISCUSSION

The LTFE experiment initiated 8 years back on *Vertic ustrocept* medium black clayey soil of Junagadh involved twelve treatments viz., T₁- 50 % NPK of recommended doses in G'nut-Wheat sequence, T₂ - 100 % N P K of recommended doses in G'nut -Wheat sequence, T₃-150 % N P K of recommended doses in G'nut -Wheat sequence, T₄ - 100 % N P K of recommended doses in G'nut -Wheat sequence + ZnSO₄ @ 50 kg/ha once in three year to G'nut only (i.e. '99, 02, 05 etc), T₅ - N P K as per Soil Test, T₆ - 100 % N P of recommended doses in G'nut -Wheat sequence, T₇- 100 % N of recommended doses in G'nut -Wheat sequence, T₈ - 50 % N P K of recommended doses in G'nut -Wheat sequence + FYM @ 10 t/ha G'nut and 100 % N P K to Wheat, T₉ - Only FYM @ 25 t/ha to G'nut only, T₁₀ - 50 % N P K of recommended doses in G'nut -Wheat sequence + Rhizobium + PSM to G'nut and 100 % N P K to Wheat, T₁₁ - 100 % N P K of recommended doses in G'nut -Wheat sequence (P as S S P) and T₁₂ - Control , which was subjected to analysis of variance in order to find out the effect of various treatments on yield, NPKS content in plants and micronutrient fraction also and depletion in long term cycle 4th and 8th years, except T₄, there were no gross additions of micronutrients in groundnut-wheat cropping system followed in LTFE.

5.2.1 EFFECT OF TREATMENT ON YIELD

Although the year x treatment interactions were significant, the treatment T₈ invariably recorded the highest value on long term basis both for pod and haulm yield of groundnut (Table 4.0.1 and 4.0.2). Almost similar trend was observed for grain and straw yield of wheat (Table 4.0.3 and 4.0.4). The combined application of organic and

inorganic fertilizers in continuous manner, might have sustain the crop yield.

4.2.2 EFFECT OF TREATMENTS ON NPKS CONTENT

In a long run treatment difference were not significant in pooled one for in groundnut pod and haulm. The wheat grain N concentration decreased while that of wheat straw did not follow any definite trend (Table 4.07 and 4.0.8). This indicated that a continual application of nitrogen fertilizers had a significant effect. Overall phosphorus concentration in groundnut pod showed decreasing trend over time but in groundnut haulm after 4 year it was increasing but after 8 year it was decreasing (Table 4.09 and 4.0.10), while in wheat grain and straw it showed increasing trend over time in phosphorus concentration. In groundnut, Phosphorus concentration decreased while at same level its content in wheat increased with in a period of 8 years. Potash concentration in groundnut pod and haulm decreased within the span of 8 years. In wheat also with marginal rise in 4th year and a declined there after in 8th year and same trend also observed in sulphur concentration.

5.2.3 EFFECT OF LTFE TREATMENTS ON MICRONUTREINT FRACTION AND THEIR RELATIONSHIPS

5.2.3.1 Copper

The spectrum of different forms of micronutrients revealed that they did not differ significantly only in water soluble and percentage available form of Cu. Even in along run different form differed significantly. There was slight decrease in overall DTPA available Cu content after 4 year and also after 8 year (Fig 4.1.1). however, the DTPA-Cu showed significantly higher values in T₉ followed by T₈ and T₁₁ as

compared to other chemical fertilizer treatment in long run but the later values were quite high than the critical values and therefore addition of Cu has not been prescribed. There were some inter-conversion hence the DTPA-Cu showed an increasing trend in treatment T₉ and T₈ while in rest of treatment there was an increase after 4th years and the decline after 8th years in LTFE soils. The chemical fertilizer appeared to enhance the utilization of DTPA available Cu as evidenced from the status of 4 and 8 years cycle. The results are supported by earlier works of Prasad and Singh (1980) and Patel (1998) who also showed the increase in available Cu in a long run by application of either organic or inorganic fertilizers in LTFE soils. However Lal and Mathur (1989) reported an increase in available Cu even without application of any type of nutrients in different crops.

The DTPA available Cu followed by residual and per cent available. This is signifying that the importance of DTPA available Cu is governing as predominant form. Groundnut pod yield and haulm yield had significant positive relationship with available Cu. Obviously wheat grain yield showed significant negative relationship with available Cu. The DTPA available Cu showed significant positive relationship with soil pH and significant negative relationship with soil EC and HSS. Obviously water soluble, exchangeable, total and residual Cu in particular showed significant negative relationship with almost all the soil properties. This might be due to inter conversion of available, total and residual forms of Cu (Table 4.5.3). Thuo *et al.* (1994) exhibited a negative relationship of available Cu with soil pH and organic carbon while Gopichand *et al.* (1985) and Sahu *et al.* (1990a) obtained positive relationship of available Cu with organic carbon. Available form of Cu showed positive relationships with nitrogen concentration particularly in

wheat grain (cereals), P concentration in groundnut pod (legume) and K concentration in groundnut haulm and S concentration in wheat grain and straw. The stepwise regression of DTPA available Cu and its various forms explained the variation up to 99 per cent. However total form followed by residual Cu influenced DTPA available Cu to the maximum extent. Stepwise regression analysis in case of soil properties with DTPA available Cu showed that soil pH influenced the DTPA available Cu to maximum extent (Table 4.6.1). In path analysis the residual form exhibited similar positive correlation with DTPA available Cu, which were reflected a direct positive effect of residual form on DTPA available Cu (Fig. 4.6.1).

5.2.3.2 Manganese

There was a decline in the soil Mn status of the LTFE soils. A significant decline in the important forms such as exchangeable Mn, total Mn and residual Mn was observed. Conversion of exchangeable to DTPA-Mn was evident. In light of this, overall mean DTPA available Mn recorded medium values (6.297 ppm) as compared to the critical values. Further the internal turnover of Mn along with other fertilizers could also help avoid the deficiencies of Mn even on a long run. The whole spectrum warranted a need to supply Mn nutrient through suitable sources to stabilize Mn status in the soil. However, the data from correlation studies indicated strong association between DTPA-Mn and its reducible, total, residual, and available total. It indicated that the dominant component was DTPA available form. The total form was a predominant component followed by DTPA available Mn. There were inter-conversions from DTPA available as well as total form to the reducible forms in a long run i.e. after 4 and 8 years in almost all the treatments including control. Zhang and Zhang (1984b) reported that in

calcareous soils - chelated and exchangeable Mn were of little importance in the nutrient status of soil and easily reducible Mn markedly affects the soil Mn supply for plants. Sharma *et al.* (1997) reported that reducible and exchangeable Mn fraction constituted 30.4 and 13 per cent of the total Mn, respectively.

Groundnut pod and haulm yield had significant positive relationship with exchangeable, per cent available and residual form, while wheat grain and straw yield showed significant positive relationship with water soluble, available, residual, total and available total. This was indicative of significant positive relationship of available component of Mn with crops yields. We could not observe absolute relationship of various crop yields and their nutrient status because a complex of micro and macro environmental factors influences the ultimate yield. Water soluble Mn showed significant relationship which was reflected by virtue of predominance of DTPA available Mn. Available Mn facilitated the partitioning of nitrogen towards wheat grain and groundnut pods. However, manganese behaved differentially with respect to P content in cereals and legumes and showed positive relationship in groundnut pod, while in wheat grain significant relationship with exchangeable and reducible. Available Mn favored accumulation of K in wheat gain and groundnut pod over the vegetative parts in both the crops. The relationship were predominantly due to DTPA available form of Mn. It seems that Mn in particular by DTPA available form regulated the dry matter production. Role of manganese in Photo-Phosphorylation is well documented (Anon., 1983 and Barler, 1984).

The DTPA available Mn and its stepwise regression with various forms gave value of multiple correlation co efficient to a reasonable

estimate of 1.000 (Table 4.6.1). Among the independent variables total form had maximum influence on DTPA available Mn. So far as stepwise regressions of DTPA available Mn with soil properties are concerned the R square value were very low. Nevertheless, considering the properties utilized for analysis, soil organic carbon in DTPA-Mn influence to maximum extent. Badhe and Naphate (1970) and Mehta and Patel (1967) also reported a positive significant correlation between organic carbon and available Mn in the soils. In path analysis, total and per cent available form had a direct positive effect on DTPA Mn along with a significant positive correlation between total and per cent available form of Mn to DTPA available Mn (Fig. 4.6.2).

5.2.3.3 Zinc

Overall, chemical fertilizer appeared to supplement and trigger utilization and conversion among different forms. In the long run the increase in the content of DTPA available Zn in a LTFE has also been observed by Prasad and Singh (1980), Harjit Singh *et al.* (1995) and Lal and Mathur (1989). The DTPA available form was maintained high quite above critical values of 0.5 to 1.0 ppm and did not indicate to apply Zn nutrient in near future. The water soluble Zn was represented in negligible quantity and did not recorded any significant changes among treatments. Exchangeable forms of Zn differed significantly only at 4th year, 8th year and also which pooled over years (Table 4.3.1 and 4.3.2). The FYM treatment recorded the highest values in DTPA-Zn as compared to other treatments. There might be supplementation of this form of DTPA and triggering utilization in long term there by significant in all the year. Reducible form signifying after 4th and 8th year. Total Zn content signifying after 4th and 8th year, when pooled over the year. Total form of Zn recorded significantly the highest values in T₉ (Table 4.3.5).

The application of chemical fertilizer appeared to augment the utilization of available Zn. The values were higher in 8th year as compared to first year because of soil reactions there is a possibility of conversion to available Zn from the total. In FYM treatments (T₈ and T₉), the DTPA available Zn changes highest over a span of 4 and 8 years but inter conversion between exchangeable and reducible form were quite evident. The exchangeable form was stable while reducible form increased over 8 year experimentation. On the contrary chemical fertilizer promoted the inter-conversion between DTPA available Zn and reducible Zn. There by resulting in an increase in DTPA available Zn. In agreement with our results Martin and Lara (1991) reported that under intensive cropping Zn content in sand, silt and clay fractions tended to increase. The DTPA available Zn showed highly significant positive relationship with available total and percent available Zn. This indicated DTPA available Zn as the predominant component of available zinc.

Residual and Per cent available forms of Zn were significant and positively related with groundnut pod and haulm while exchangeable, DTPA available, reducible, total and available total were significant and has positive relationship with wheat grain and straw. Most of the form exhibited significant positive relationship with almost all the soil properties viz., soil pH, EC, O.C., available N, available P and available K₂O (Table 4.5.8). The relationship of various form Zn and particularly available form with NPKS concentration suggested that Zn regulated the partitioning of nitrogen towards grain and phosphorus towards vegetative growth. Phosphorus accumulation was promoted in legumes while it diminished in cereals by Zn. The high values (1.000) of multiple correlation co-efficient obtained in the stepwise regression of Zn with its various forms there by explain of the various through DTPA available

Zn. The total Zn followed by residual form had the maximum influence. In case of stepwise regression analysis of soil properties with DTPA available Zn, the organic carbon followed by soil EC in DTPA available Zn influenced to the maximum extent. In path analysis, the residual Zn and total Zn had a high direct effect on DTPA available Zn. These relationships might be due to indirect positive effects of exchangeable form and per cent available forms through total Zn (Fig 4.6.3).

5.2.3.4 Iron

The water soluble Fe was represented in negligible quantity and recorded significant after 4th and 8th year among treatment. Treatment differences in exchangeable Fe content were non significant. There was an overall increase in the DTPA Fe content over a period of time. Although differences among different treatments found significant after 4th and 8th year and pooled over year, Y x T interaction was significant. The DTPA available form was maintained quite below critical value of 5 to 10 ppm and in spite of being most abundant micro nutrient the situation warranted a need for immediate application of available Fe nutrient on mobilization of immobile Fe already occurring in the soil. The FYM and chemical fertilizer application revealed an enhancement in utilization of reducible Fe. Thereby rendering their status to lower values. Total Fe content as well as residual Fe showed significant change after 4 and 8 year and also pooled over the year. The trend distinctly suggested the supplementation and utilization of Fe by the addition of chemical fertilizers. The conversion of the total to available form and under utilization by FYM resulted in the higher value at the 8th year compared to chemical fertilizers. Harjit Singh (1995) indicated depletion of Fe by continuous rain while increase in Fe by supply of P, thereby indirectly suggests the promotion of utilization of Fe by N supply and

supplementary Fe by supply of P. In Fe the predominant component was DTPA available form followed by reducible, exchangeable and water soluble form. Although the trend was not that clear but mostly there was an inter conversion between exchangeable and reducible form.

The DTPA available Fe displayed a highly significant positive relationship with available total, total and exchangeable. The other form showing highly significant positive relationship in total with available total, water soluble with reducible, exchangeable with total and total with available total. The significant negative relationship of various forms of iron clearly signified their inter-conversion (Table 4.5.6). Groundnut pod and haulm were significant positive relationship with water soluble, residual and per cent available form of Fe, while wheat grain and straw yield were significant positive relationship with exchangeable, available, total and available total (Table 4.5.10). However, DTPA available Fe recorded significant positive relationship with most of properties viz., Soil pH, EC, O.C., available N and available P. In almost available form of Fe regulated concentration of nitrogen towards pod in legumes and wheat grain and concentration of K in groundnut pod. Thus, Fe was found to indirectly regulate partitioning between vegetative and reproductive parts via regulating P concentration which was known to influence the osmotic relations. The relationship varied with the forms.

The stepwise regression, the DTPA available Fe with various forms also showed a high value of R square (2.9379). The total Fe had the maximum impact on DTPA available Fe (Table 4.6.1). In case of soil properties stepwise regression analysis with DTPA available Fe showed that soil EC and Organic C influenced the DTPA available Fe to the maximum extent. Rajkumar *et al.* (1990), Bhosal *et al.* (1993) and Maji *et*

al. (1993) showed adverse effect of high pH on availability of Fe. In path analysis, the total ferrous showed a direct positive effect, while reducible ferrous showed a direct negative effect on DTPA available ferrous. The negative effect of reducible ferrous because of indirect negative effect through total Fe (Fig. 4.6.4).

5.2.4 PERCENT DISTRIBUTION OF DIFFERENT FORMS OF AVAILABLE MICRONUTRIENTS IN LTFE SOILS

The DTPA available form of micronutrients was a major component of available total form followed by reducible, exchangeable and water soluble form, respectively, in Fe, Zn and Cu while in Mn the predominant component was the reducible form followed by DTPA available, exchangeable and water soluble forms. The water soluble form had negligible proportion in Mn as well as in Zn. The chemical fertilizers as evident from the changes in proportion over years i.e. in 4 and 8 years, supplemented and/or enhanced utilization of DTPA available Mn and Cu. The Mn showed uniform picture with respect to treatments and time.

5.2.5 DEPLETION OF MICRONUTRIENTS IN LTFE SOILS

In our LTFE investigation on medium black calcareous soils, it was observed that continuous cropping with and without fertilizer treatment after a span of 8 years (16 crops of groundnut and wheat) depleted Cu, Mn, Zn and Fe to -0.2089, +1.096, +0.8606 and +4.2361 ppm from their initial values of 1.3867, 5.9092, 0.8167 and 4.5428 ppm, respectively, Bhardwaj and Omanwar (1994) at Pantnagar (Uttar Pradesh) observed that continuous cropping without fertilization after 9th cycle of rice-wheat-cowpea cropping depleted Cu, Mn, Zn and Fe to 0.6, 12.3, 2.9 and

268 ppm from their initial values of 1.88, 26.0, 4.46 and 34.2 ppm, respectively.

All the four DTPA available Cu, Mn, Zn and Fe exhibited marked depletion under recommended full dose of NPK treatment. The application of recommended full dose of N and P in the absence of K also resulted in depletion though less than the full dose of NPK. It is now certain that fertilizer application resulted into enhanced utilization of DTPA available elements with K giving boost to further utilization. There are reports showing depletion of micronutrients viz., Cu, Mn, Zn and Fe under continuous cropping (Ramanathan *et al.*, 1979; Dangarwala *et al.*, 1983; Kumarsean *et al.*, 1985; Bhardwaj and Omanwar, 1994; Dangarwala *et al.*, 1994; Dangarwala and Patel, 1996). The rate of depletion of DTPA extractable micronutrients under continuous cropping in *goradu* soil has been reported in the following order: Zn > Fe > Mn > Cu (Patel *et al.*, 1998), whereas in the present investigation on an overall basis of all treatments in medium black calcareous soil under LTFE investigation with groundnut and wheat crop sequence in a span of 8 years, the rate of depletion was in the following order for four micronutrients based on 1st year (1999): Cu (-14.73%) > Mn (18.58%) > Fe (+93.65%) > Zn (+108.69%).

However, application of organic and chemical fertilizers resulted in a varied trend either by enhanced utilization or by supplementing the micronutrients indirectly as observed in current investigation. The FYM and chemical fertilizers have been shown to enhance utilization resulting in depletion of micronutrients at one hand (Dangarwala *et al.*, 1983; Dangarwala *et al.*, 1994 and Harjit Singh *et al.*, 1995) while at the other hand chemical fertilizer, organic manures and FYM have been shown to denote depletion by supplementing the micronutrients resulting in an

increase in a long run (Prasad and Singh, 1980; Takkar *et al.*, 1989; Darusman *et al.*, 1991; Bellakki and Badunar, 1997; Sudhir *et al.*, 1997; Patel, 1998; Golakiya and Gundalia, 1999; Patel *et al.*, 1999 and Zarkovic *et al.*, 2000), though these trends were micronutrients specific. In current investigation application of K promoted utilization of micronutrient resulting in depletion in a long run but these results were antagonized by the earlier reports mentioning least effect of K on micronutrients (Harjit Singh *et al.*, 1995). The increases in the micronutrients in a long run may be attributed to different reasons viz., supplementing micronutrients indirectly through chemical fertilizers (Lal and Mathur, 1989; Rajeev Kumar *et al.*, 1993), supplementing through organic manures by increased microbial activity (Prasad and Singh, 1980; Agarwal and Praveen Kumar, 1998) as supplementing by the parent materials due to mineralization (Lal and Mathur, 1989).

5.2.6 CORRELATION BETWEEN FORMS OF DIFFERENT MICRONUTRIENTS

The DTPA available Cu exhibited significant positive relationship with exchangeable Mn, available Mn, residual Mn and per cent available. The DTPA available Cu was showed significant positive relationship with exchangeable Mn, residual Mn and per cent available Mn. However, early reports have shown negative relationship between available Zn and available Cu (Sutaria and Patel, 1981; Dangarwala *et al.*, 1983; Golakiya and Patel, 1988 and 1990). The DTPA available Cu was showed significant positive relationship with water soluble Fe, residual Fe and per cent available Fe. . These results are in contrast with the early reports where a negative relationship reported (Kalyansundaram and Mehta, 1970; Halagaur *et al.*, 1975; Dangarwala *et al.*, 1983; Sutaria and Patel, 1987; Golakiya and Patel, 1988 and 1990). The Mn and Zn

presented an interesting case of interaction most of the interaction was significant positive relationship. DTPA available Mn showed significant positive relationship with exchangeable Zn, available Zn, reducible Zn, total Zn and available total. Similarly water soluble Mn and total Mn showed significant positive relationship with DTPA available Zn. DTPA available Mn showed significant positive relationship with exchangeable Fe and available Fe. Similarly DTPA available Fe showed significant positive relationship with water soluble Mn, total, and available total. The results are not comparable with those reported earlier showing a negative relationship. (Kalyansundarm and Mehta, 1970; Halagaur *et al.*, 1975; Dangarwala *et al.*, 1983; Sutaria and Patel, 1987; Golakiya and Patel, 1988 and 1990). Almost all the forms of Zn and Fe were significantly and positively related with each other. Thus certain groups revealed significant positive relationship between DTPA available Zn and Fe. The findings are in conformity of work of some earlier works (Gangwar and Mann, 1972; Sadana and Takkar, 1985; Pathak *et al.*, 1975; Mishra and Pande, 1976) while contradicted by some other reports where the relationships were negative (Kalyansundram and Mehta, 1970; Halagaur *et al.*, 1975; Dangarwala *et al.*, 1983; Sutaria and Patel, 1987; Golakiya and Patel, 1988 and 1990).

CHAPTER - VI

SUMMARY AND CONCLUSION

5.0.1 Yield

The treatment T₈ invariably recorded the highest value both for pod and haulm yield of groundnut. Almost similar trend was observed for grain and straw yield of wheat. The combined application of organic and inorganic fertilizers in continuous manner, might have sustain the crop yield.

5.0.2 N Content

After a long run, T₃ registered the highest concentration and T₈ the lowest in groundnut pod while T₂ recorded highest concentration and T₉ the lowest in groundnut haulm. The nitrogen concentration of pod and haulm in groundnut did not follow any definite trend. In a long run wheat grain and straw nitrogen concentration decreased. The T₈ registered the highest concentration while control the lowest both in wheat grain and straw. Almost, treatment T₈ showed lower content of nitrogen, which might be dilution effect due to higher dry matter yield. Pooled over the year were non significant in nitrogen concentration both for groundnut and wheat.

5.0.3 P content

In groundnut pod phosphorus concentration decreased while in haulm increased like wise in wheat grain phosphorus concentration was increased but in straw decreased after a period of 8 years. There was no any specific trend in the P content of groundnut and wheat.

5.0.4 K content

The concentration of potash after 4th year increased while after 8th year it declined in groundnut and wheat. Pooled over the year was significant in groundnut but non significant in wheat.

5.0.5 S content

In groundnut sulphur concentration was increased after 4th year while it declined after 8th year. In wheat, sulphur concentration was declined over time.

5.1 Copper

The overall picture with respect to various forms of Cu suggested that there was a decline in the soil Cu levels where a significant decline in most of all important forms. However, DTPA available form of Cu showed significantly higher values in T₉ followed by T₈, T₂ and T₁₁ as compared to chemical fertilizer treatment in a long span but the latter values were quite high than the critical values and even further for a long period there is no need of copper nutrient application.

5.2 Manganese

There was a decline in the Mn status of the LTFE soils. The different form also recorded significant decline such as exchangeable Mn, total Mn and residual Mn. The Conversion of exchangeable to DTPA-Mn was evident. In light of this, overall mean DTPA available Mn recorded medium values (6.297 ppm) as compared to the critical values. Further the internal turnover of Mn along with other fertilizers could also help avoid the deficiencies of Mn even on a long run. The whole spectrum warranted a need to supply Mn nutrient through suitable sources for stable Mn nutrient in soil.

5.3 Zinc

Overall chemical fertilizers appeared to supplement and trigger utilization and conversion among different forms in a long run. The DTPA available form was maintained high quite above critical values (0.5 to 1.0 ppm) and did not indicate any need to supplement Zn nutrient in near future. Exchangeable, DTPA and reducible forms appeared to be more convertible among them and particularly under intensive agriculture.

5.4 Iron

The overall scrutiny of different forms of iron indicated that water soluble, exchangeable and DTPA available forms exhibited dominant participation by inter-conversion and utilization. In a long run application of chemical fertilizers enhanced the utilization of DTPA available form in particular, in which latter reached quite below the critical values (5.0 to 10.00 ppm) and in spite of being most abundant nutrient the situation warranted a need for immediate application of available iron or mobilization of immobile iron already lying in the soil. This was so because total iron content as well as residual iron content showed significant differences neither due to treatments nor due to time period.

5.5 Per cent Distribution of Different Forms of Available Micronutrients in LTFE Soils

The DTPA available form of micronutrients was a major component of available total form followed by reducible, exchangeable and water soluble form, in respect of iron, zinc and copper. While in manganese the predominant component was the reducible form followed by DTPA available exchangeable and water soluble form. The

chemical fertilizer as evident from the changes in proportion over years i.e. 4 and 8 years exhibited that they supplemented as well as enhanced utilization of DTPA available manganese and copper. The Mn showed uniform picture with respect to treatment and time. Chemical fertilizers brought a shift in inter-conversion between exchangeable and reducible form, and also between DTPA available Zn and reducible Zn. Iron exhibited variegated picture.

Correlation Matrix

5.5.1 Among Different Form of Individual Micronutrients

5.5.1.1 Copper

The total Cu was predominantly reflected by DTPA available Cu followed by residual, recent available and residual. This is signifying the importance of DTPA available Cu is governing the total availability as predominant form. The DTPA available copper showed significant positive correlation with soil pH.

5.5.1.2 Manganese

The data from correlation studies indicated strong association between DTPA-Mn and its reducible, total, residual, and available total. It indicated that dominant component was DTPA available form. The DTPA available Mn showed significant positive relationship with many soil properties viz., soil pH, O.C. and available K_2O .

5.5.1.3 Zinc

The DTPA available Zn showed highly significant positive relationship with available total and percent available Zn. This indicated that DTPA available Zn was the predominant component of available zinc. The DTPA available Zn also showed significant positive

relationship with various soil properties viz., soil pH, EC, O.C., available N, available P and available K₂O.

5.5.1.4 Iron

The DTPA available Fe displayed a highly significant positive relationship with available total, total and exchangeable. The other form showed highly significant positive relationship in total with available total, water soluble with reducible, exchangeable with total and total with available total. However, DTPA available Fe recorded significant positive relationship with most of properties viz., Soil pH, EC, O.C., available N and available P.

5.5.2 Correlation with Yield

Groundnut pod yield and haulm yield has significant positive relationship with available Cu. Obviously wheat grain yield showed significant negative relationship with available Cu. Groundnut pod and haulm yield has significant positive relationship with exchangeable Mn, per cent available Mn and residual Mn form, while wheat grain and straw yield has significant positive relationship with all forms of Mn. Residual Zn and Per cent available Zn forms were having significant positive relation with groundnut pod and haulm while all different forms of Zn were significant positive relationship with wheat grain and straw. Groundnut pod and haulm recorded significant positive relationship with water soluble Fe, residual Fe and per cent available Fe, while in wheat grain and straw yield exhibited significant positive relationship with exchangeable Fe, DTPA available Fe, total Fe and available total Fe.

5.5.3 Correlation between NPK Concentration in Crops and Forms

Available form of Cu showed positive relationships with nitrogen concentration particularly in wheat grain (cereals), P concentration in groundnut pod (legume) and K concentration in groundnut haulm and S concentration in wheat grain and straw.

Available Mn facilitated the partitioning of nitrogen towards wheat grain and groundnut pods. The Mn also showed positive relationship in groundnut pod, while in wheat grain significant relationship was observed with exchangeable and reducible form of Mn. The available Mn favored accumulation of K in wheat grain and groundnut pod over the vegetative parts in both the crops.

The relationship of various form Zn and particularly available form with NPKS concentration suggested that Zn regulated the partitioning of nitrogen towards grain. Phosphorus accumulation was promoted in legumes while it diminished in cereals by Zn.

Mostly available form of Fe regulated concentration of nitrogen towards pod in legumes and wheat grain and concentration of K in groundnut pod. Thus, Fe was found to indirectly regulate partitioning between vegetative and reproductive parts via regulating P concentration.

5.5.4 Correlation between Interaction of Two Micronutrients Forms

5.5.4.1 Cu x Mn

The DTPA Cu was showed significant positive relationship with exchangeable Mn, available Mn, residual and per cent available.

5.5.4.2 Cu x Zn

The DTPA available Cu showed significant positive relationship with exchangeable Mn, residual Mn and per cent available Mn.

5.5.4.3 Cu x Fe

The DTPA available Cu showed significant positive relationship with water soluble Fe, residual Fe, per cent available Fe.

5.5.4.4 Mn x Zn

DTPA available Mn showed significant positive relationship with exchangeable Zn, available Zn, reducible Zn, total Zn and available total.

5.5.4.5 Mn x Fe

DTPA available Mn showed significant positive relationship with exchangeable Fe and available Fe.

5.5.4.6 Zn x Fe

Almost all the forms of Zn and Fe were significantly and positively related with each other.

5.5.5 Pooled Regression and Stepwise Regression Analysis

The DTPA available micronutrients as influenced by other forms were subjected to stepwise regression and multiple correlation and regression analysis. The prediction models were based on multiple and correlation analysis over a cycle of 1, 4 and 8 years. The stepwise regression analysis indicated that total form in copper, manganese, zinc and ferrous had the maximum impact on DTPA available micronutrients. The stepwise regression analysis of DTPA available micronutrient as the dependent variable and soil properties as the independent variables indicating a low degree of influence. Nevertheless, Properties utilized for

analysis i.e. soil pH influenced DTPA available Cu, soil O.C. to DTPA Mn and Zn, soil EC and O.C. to DTPA Fe, to the maximum extent.

5.5.6 Path Analysis

The residual Cu form exhibited significant positive correlation with DTPA available Cu. Total and per cent available form of Mn had a direct positive effect on DTPA Mn. The residual Zn and total Zn had a high direct effect on DTPA available Zn. The total ferrous showed a direct positive effect, while reducible ferrous showed a direct negative effect on DTPA available ferrous.

CONCLUSION

It has been deduced from the experimentation on Long Term Fertilizer Experiment (LTFE) in Junagadh constituting (Medium black, Trap basalt) that the predominant form of DTPA available form, in all the micronutrients viz., copper, manganese, zinc and iron exhibited depletion over time irrespective of fertilizer treatment in long run viz., 4 and 8 years, especially available ferrous reached below critical levels. Although ferrous is the most abundant element in the earth crust its' availability requires suitable management at the earliest in the soils of LTFE. The chemical fertilizers appeared to trigger the utilization of micronutrients. The dynamics of micronutrients alongwith its forms, in general, exhibited gross negative trend with varying magnitude according to the soil.

The combined application of organic and inorganic fertilizers in continuous manner, have sustain the crop yield.

The high residual values in multiple correlation and regression analysis, the soil properties had little influence on DTPA available micronutrients. This is because the soil of the experimental block was

same and the fertilizer/manure treatment could not changed the soil propertied in the span of eight years. Based on multiple correlation and regression analysis the prediction model for DTPA available micronutrients are presented. The total form in case of all micronutrient had the maximum impact on DTPA available form of micronutrients.

The path co-efficient analysis of DTPA available micronutrients as influenced by various forms revealed that total content of micronutrients had a direct positive effect on DTPA extracted Mn and Fe. While residual forms had a direct positive effect on DTPA extracted Cu and Zn.

REFERENCES

- Agarwal, R.K. and Kumar, P. (1996). Integrated use of FYM and fertilizers, nitrogen and sustainable yield of pearl millet in an arid region. *Annals Arid Zone*, **35**(1): 29-35.
- Agarwal, S.C.; Sharma, C.P. and Kumar, A. (1964). Inter-relationship of iron and manganese supply in growth, chlorophyll and iron porphyrin enzymes in barley plants. *Plant Physiol.*, **39**: 603-609.
- Anonymous (1992). Annual Agresco Report of Agril. Chemistry and Soil Science Department, Guj. Agril. Uni., Junagadh presented at Twenty-eighth meeting.
- Badhe, N.N. and Naphade, P.S. (1970). Private communication cited by Kanwar and Randhawa (1974). Micronutrient Research in Soils and Plants in India - A review. *Tech.Bull. (Agril.)* No. 50, ICAR, New Delhi.
- Badhe, N.N.; Naphade, K.T. and Ballal, D.K. (1971). Status of available copper and manganese of soils from Bhundara district in Maharashtra. *J. Indian Soc. Soil Sci.*, **19**: 175-178.
- Bansal, K.H.; Gupta, S.K. and Verma, G.P. (1969). Distribution of micronutrients in soil profiles of Adhartal series. *J. Indian Soc. Soil Sci.*, **17**: 333-336.
- Baser, B.L. and Saxena, S.N. (1970). Manganese status of Rajasthan soils. *J. Indian Soc. Soil Sci.*, **18**: 151-155.
- Bayrakli, F. and Gezgin, S. (1991). An investigation on relationships between some soil properties and contents of available Fe, Zn, Mn and Cu in the soils of Cumra and Ergli plain, Konva. *The J. Agril. Faculty of Selcuk. Uni.*, **1**(2): 99-110.

- Bellakki, M.A. and Badanur, V.P. (1997). Long Term Effect of Integrated Nutrition Management on Properties of Vertisol Under Dryland Agriculture. *J. Indian Soc. Soil Sci.*, **45**(3): 438-442.
- Bertic, B.; Sekulic, P.; Cuijovic, M. (1984). Distribution of micronutrients in pseudo-gley, hydromorphic black soil and chernozem profiles. *Znanost-i-Praksa-v-Poljoprivredi-i-Prechramlenoj Tehnologiji*, **14**(3): 215-227.
- Bharadwaj, S. 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 of soil. *J. Indian Soc. Soil Sci.*, **42**(3): 387-392.
- Bhumbla, D.R. (1965). Annual progress report of department of soils for the year 1964-65.
- Bhumbla, D.R. and Dhingra, D.R. (1964). Micronutrient status of saline soils of Punjab. *J. Indian Soc. Soil Sci.*, **12**: 255-260.
- Biswapati, M.; Hadder, B.R. and Mandal, L.N. (1986). Distribution of different forms of zinc in some rice growing soils. *J. Indian Soc. Soil Sci.*, **34**: 488-92.
- Biswas, T.D. (1951). Manganese status of some Indian soils. *Indian J. Agric. Res.*, **21**: 97-107.
- Biswas, T.D. (1953). Distribution of manganese in profiles of some Indian soils. *J. Indian Soc. Soil Sci.*, **1**: 21-31.
- Biswas, T.D. and Gawande, S.P. (1964). Relation of manganese in genesis of catenary soils. *J. Indian Soc. Soil Sci.*, **12**: 261-268.

- Bloon, P.R. and Inskeep, W.P. (1986). Factors affecting bicarbonate chemistry and iron chlorosis in soils. *J. Plant Nutr.*, **9**(3-7): 215-228.
- Bobrzecka, D. (1988). Studies on the fertilizing effect of copper in the cultivation of some plants. *AGRIS*, **28**(1): 54.
- Campbell, L.C. and Nable, R.O. (1988). Physiological fractions of manganese in plants. *Plant and Soil Sci.*, **33**: 139-54.
- Chahal, D.S. and Saini, R.S. (1996). Surface distribution of different forms of iron in arid zone soils of Punjab. Paper presented in 61st Annual Conv. Indian Soc. Soil Sci. held at Anand. Oct-Nov.: 55.
- Chapman, H.D. (1965). Cation exchange capacity. *In: Method of Soil Analysis* (Black C.A.), pp. 891-901.
- Chaudhary, A.K.; Mc Laren, R.G.; Cameron, K.C. and Swift, R.S. (1997). Fractionation of zinc in some New Zealand soils. *Communication in Soil Science and Plant Analysis*, **28**(3/5): 301-312.
- Chopra, S.L. and Kanwar, J.S. (1976). *Analytical Agricultural Chemistry*. Kalyani Publisher, New Delhi.
- Cochran, W.G. and Cox, G.M. (1967). *Experimental design*. 2nd Edn. John Wiley and Sons Inc., New York.
- Cumakov, A. (1991a). Chemical method for fractionation of microelements in soils II: Copper. *Polnohospodarstvo*, **37**(3): 233-238.
- Cumakov, A. (1991b). Chemical methods of microelement fractionation in soils III: Manganese. *Polnohospodarstvo*, **37**(4): 323-328.

- Curtin, D.; Ryan, J. and Chaudhary, R.A. (1980). Manganese adsorption and desorption in calcareous Lebanese soils. *Soil Sci. Soc. Am. J.*, **44**(5): 945-50.
- Dangarwala, R.T. and Patel, K.P. (1996). In : Soil Research in Gujarat Agriculture, A Compendium (Bull.), G.A.U., Anand. pp.: 65-76.
- Dangarwala, R.T.; Trivedi, B.S.; Patel, M.S. and Mehta, P.M.(Ed.) (1983). Micronutrient research in Gujarat. Guj. Agril. Uni., Anand.
- Darusman, Stone, L.R.; Whitney, D.A.; Janssen, K.A. and Long, S.H. (1991). Soil properties after twenty years of fertilization with different nitrogen sources. *Soil Sci. Soc. of American J.*, **55**(4): 1097-1100.
- Dewey, D.R. and Lu, K.H. (1959). A correlation and path co-efficient analysis of components of crested wheat grass seed production. *Agron. J.*, **51**: 515-518.
- Edward Raja, M. and Iyengar, B.R.V. (1986). Chemical pools of zinc in some soils as influenced by sources of applied zinc. *J. Indian Soc. Soil Sci.*, **34**: 97-105.
- Elsokkary, I.H. and Lag, J. (1978). Distribution of different fractions of Cd, Pb, Zn and Cu in industrially polluted and non-polluted soils of Odd region, Norway. *Acta Agric. Scand.*, **28**: 262-268.
- Epstein, E. and Stont, P.R. (1951). The micronutrient cations - iron, manganese, zinc and copper : their uptake by plants from the adsorbed state. *Soil sci.*, **72**: 47-65.
- Gangwar, M.S. and Mann, J.S. (1972). Zinc nutrition of rice in relation to Fe and Mn uptake under different water regimes. *J. Indian Soc. Soil Sci.*, **42**: 1032-35.

- Gangwar, M.S.; Mann, J.S. and Sharma, A.N. (1971). Note on the distribution of total and available iron in soil profiles of Nainital food hills. *Indian J. Agric. Sci.*, **41**: 1120-1121.
- Gao-Xianbiao; Yang-Gou and Gao-Bimo. (1990). The iron state of soil and the prospect of iron fertilizers application in Shandong (China). *J. Shandong Agril. Sciences*, **5**: 12-15.
- Gill, M.P.S. (1990). Changes in soil manganese fraction of an alluvial soil under different levels of salinity, sodicity and submergence. *J. Indian Soc. Soil Sci.*, **38**: 158-160.
- Golakiya, B.A. and Gundalia, J.D. (1999). Micronutrients in Gujarat Agriculture. SSGA-9, G.A.U., Junagadh.
- Golakiya, B.A.; Patel, M.S. and Sutaria, G.S. (1990). Effect of active lime, FYM and moisture regimes on the yield and phosphorus and Zn composition of wheat cv. GW-120. *Guj. Agric. Uni. Res. J.*, **15**(2): 32-36.
- Gopichand, S.; Satyanarayana, P.H.; Subba-Rao, A. and Subbaiah, G.V. (1985). Available zinc, copper, manganese and iron status of representative soils of Andhra Pradesh. *Andhra Agril. Journal*, **32**(3): 210-211.
- Gowrisankar, D. and Murrigappan, V. (1998). Zinc fraction studies in the soils of Amarawathy River Command Area of Tamilnadu. *J. Indian Soc. Soil Sci.*, **46**(1): 140-142.
- Grewal, J.S.; Bhumba, D.R. and Randhawa, N.S. (1969). Available micronutrient of Punjab, Haryana and Himachal Soils. *J. Indian Soc. Soil Sci.*, **17**: 27-31.

- Gupta, G.P. and Singh, D. (1972). Zinc status of soils of Indore. *J. Indian Soc. Soil Sci.*, **20**: 49-51.
- Gupta, R.K. and Srivastava, P.C. (1990). Distribution of different forms of micronutrient cations in some cultivated soils of Sikkim. *J. Indian Soc. Soil Sci.*, **38**: 558-560.
- Gupta, R.K.; Singh, R.S.; Gupta, N. and Yadav, A.S. (1982). Effect of phosphorus application on the translocation of iron in soil and nutrition of rice under two moisture regime. *J. Indian Soc. Soil Sci.*, **30**: 58-62.
- Gupta, V.K.; Singh, K. and Raj, H. (1980). Available micronutrient status and its relationship with some characteristics of the arid brown soils of Haryana. *Haryana Agricultural University Journal of Research*, **10**(2): 229-234.
- Harjit Singh; Sharma, K.M. and Arora, B.S. (1995). Influence of continuous fertilization to a maize-wheat rotation on the changes in soil fertility. *Ferti. News*, **40**(1): 7-19.
- Hodgson, J.F. (1963). Chemistry of the micronutrient elements in soils. *Advances in Agronomy*. **15**: 119-159.
- Hodgson, J.F.; Lindsay, W.L. and Trierweiler, J.F. (1966). Micronutrient cation complexing in soil solution : II complexing of zinc and copper in displaced solution from calcareous soil. *Proc. Soil Sci. Soc. Am.*, **30**: 723-726.
- Hoon, R.C. and Dhawan, C.L. (1943). The occurrence and significance of trace elements in relation to soil deterioration part-I Manganese. *Indian J. Agric. Sci.*, **13**: 601-608.

- Hulagur, B.F.; Dangarwala, R.T. and Mehta, B.V. (1975). Effect of zinc, copper and phosphorus on the yield and composition of hybrid maize grown in loamy sand. *J. Indian Soc. Soil Sci.*, **32**(1): 83-90.
- Iyengar, B.R.V. and Deb, D.L. (1977). Contribution of soil zinc fractions to plant uptake and fate of zinc applied to the soil. *J. Indian Soc. Soil Sci.*, **25**(4): 426-432.
- Iyengar, S.S.; Martens, D.C. and Miller, W.P. (1981). Distribution and plant availability of soil zinc fractions. *Soil Sci. Soc. Am. J.*, **45**: 735-739.
- Jackson, M.L. (1979). Soil chemical analysis. Prentice Hall of Indian Pvt. Ltd., New Delhi.
- Joshi, D.C. and Dhir, R.P. (1982). Distribution of different forms of manganese and iron in the soil of extremely arid parts of Western Rajasthan. *Ann. Arid Zone*, **21**(1): 1-8.
- Joshi, D.C.; Singh, N. and Kolarkar, A.S. (1988). Forms of iron and manganese and their availability in the salt affected soils of the Guhiga catchment of the Upper Luni Basin of Rajasthan. *Tropical Agriculture*, **65**(1): 41-48.
- Kalembasa, D.; Pakula, K. and Becher, M. (2001). Sequential fractional of iron and manganese in soils with high iron content. *Roczniki-Gleboznawcza (Poland)*, **52**: 183-190.
- Kalyansundaram, N.K. and Mehta, B.V. (1970). Availability of zinc, phosphorus and calcium in soils treated with varying levels of zinc and phosphate - A soil incubation study. *Plant Soil*, **33**: 699-706.

- Kanwar, J.S. (1976). "Soil fertility–Theory and Practice". ICAR, New Delhi.
- Kanwar, J.S. and Chopra, S.L. (1976). Analytical Agricultural Chemistry. Kalyani Publishers, Ludhiana, New Delhi.
- Kanwar, J.S. and Randhawa, H.S. (1974). "Micronutrient Research in Soil and Plants". A review of ICAR, New Delhi.
- Kanzaria, M.V. and Patel, M.S. (1985). Soils of Gujarat and Their Management. In: Soils of Indian and Their Management, FAI, New Delhi. pp. 103.
- Karajani, M. (1998). The relationship between P and Zn uptake soil fraction. *Bulletin-i-Shkencaue-Bujquesore*, **3**: 45-50.
- Kavimandan, S.K.; Badhe, N.H. and Ballal, D.K. (1964). Available copper and molybdenum in Vidarbha soils. *J. Indian Soc. Soil Sci.*, **12**: 281-288.
- Komisarek, J.; Kocialkowski, W.Z.; Rachwal, L.; Sienkiewicz, A. (1991). Effect of CaCO₃ on the content of various forms of Cu, Zn and Pb in contaminated soils. *Panstwowe Wydawnictwo Naukowe* : 53-62.
- Kothandaraman, G.V. and Chandrasekaran, P. (1981). Studies on the different forms of iron in calcareous soils of the Coimbatore district. *Madras Agric. J.*, **68**(2): 124-8.
- Kumaresean, K.R.; Nagarajan, R.; Savithiri, P. and Manickam, T.S. (1985). Effect of continuous cropping and fertilization on depletion of micronutrients. *Madras Agric. J.*, **72**(7): 371-375.
- Lal, C. (1968). Evaluation of different methods for the determination of available copper in Punjab soils. M.Sc. Thesis, P.A.U., Hissar.

- Lal, S. and Mathur, B.S. (1989). Effect of long term fertilization mainly and liming of an Alfisol on maize, wheat and soil properties. I Maize and Wheat. *J. Indian Soc Soil Sci.*, **37**(3): 721-724.
- Leeper, G.W. (1947). The forms and reactions of manganese in the soil. *Soil Sci.*, **63**: 79-94.
- Leeper, G.W. (1952). Factors affecting the availability of inorganic nutrients in soils with special reference to micronutrients. *Ann. Rev. Pl. Physiol.*, **3**: 1-15.
- Lindsay, W.L. (1979). Chemical equilibria in soils, Wiley Inter Science, New York.
- Lindsay, W.L. and Norvell, W.A. (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.*, **42**: 421-428.
- Ma, Y.B. and Uren, N.C. (1998). Transformations of heavy metals added to soil application of a new sequential extraction procedure. *Geoderma*, **84**: 157-168.
- Maciejewski, M. (1987). Influence of phosphorus fertilizing on available Cu content in the soil. *Zeszyty-Naukowe-Akademii-Rolniczej-w-Szczecinie-Rolnictwo-Seria-Przyrodnicza*, **43**: 85-92.
- Maji, B.; Chatterji, S. and Bandyopadhyay, B.K. (1993). Available iron, manganese, zinc and copper in coastal soils of Sundarbans, West Bengal in relation to soil characteristics. *J. Indian Soc. Soil Sci.*, **41**(3): 468-471.
- Malewar, G.U. and Randhawa, N.S. (1977). Zinc and manganese status of calcareous and noncalcareous soils of Marathwada.

Research Bulletin, Marathwada Agricultural University, **1**(11): 158-159.

Malewar, G.U. and Randhawa, N.S. (1978). Distribution of zinc, iron, manganese and copper in Maharashtra soils. *J. Maharashtra Agri. Uni.*, **3**(3): 157-9.

Mandal, L.N. (1961). Transformation of iron and manganese in water-logged rice soils. *Soil Sci.*, **91**: 121-126.

Mandal, S.C. and Jha, K.K. (1970). Soils of Bihar and their fertility III. Micronutrients and Sulphur. *Fertil. News.*, **15**: 58-61.

Mandal, L.N. and Mandal, B. (1986). Zinc fractions in relation to zinc nutritional of low land rice. *Soil Sci.*, **142**: 141-148.

Martin, T. M. and Lara, G. F. (1991). Dynamics of zinc fractions in the soil plant system under condition of intensive forage cropping. *Commun. Soil Sci. Plant Anal.*, **22**(19-20): 2089-2100.

McBride, M.B. (1982). Electron spin resonance investigation of Mn²⁺ complexation in natural and synthetic organics. *Soil Sci. Soc. Am. J.*, **46**: 1137-1143.

McLaren, R.G. and Crawford, D.V. (1973). Studies on soil copper I. The fractionation of soil copper. *J. Soil Sci.*, **24**: 172-181.

Meelu, O.P. and Randhawa, N.S. (1973). Zinc content of soil and their different fraction. *J. Indian Soc. Soil Sci.*, **21**: 235-236.

Mehra, R.K. and Baser, B.L. (1982). Distribution of manganese in saline alkali soils of Bhilwara District (Rajasthan). *Trans. Indian Soc. Desert Technol., Univ. Cent. Desert Stud.*, **7**(1): 41-4.

- Mehta, B.V. and Patel, N.K. (1967). Forms of manganese and their distribution in soil profiles of Kaira district in Gujarat. *J. Indian Soc. Soil Sci.*, **15**: 41-47.
- Mehta, B.V.; Reddy, G.R.; Nair, G.G.K.; Gandhi, S.C.; Neelkantan, V. and Reddy, K.G. (1964). Micronutrient studies on Gujarat soils. *J. Indian Soc. Soil Sci.*, **12**: 329-342.
- Miller, G.W.; Pushnik, J.C. and Welkie, G.W. (1986). Iron chlorosis a world problem, the relation of chlorophyll biosynthesis to iron. *J. Plant Nutr.*, **7**: 1-22.
- Mishra, B.; Tripathi, B.R. and Din Dayal (1969). Distribution of copper in soils of Uttar Pradesh. *J. Indian Soc. Soil Sci.*, **17**: 379-383.
- Mishra, S.G. and Pande, P. (1976). Behaviour of native iron in water logged soils of Eastern Uttar Pradesh. *J. Indian Soc. Soil Sci.*, **24**: 297-302.
- Mitra, B.R. and Mandal, L.N. (1983). Distribution of forms of iron and manganese in rice soils of West Bengal in relation to soil characteristics. *J. Indian Soc. Soil Sci.*, **31**(1): 38-42.
- Murthy, A.S.P. (1982). Zinc fractions in wetland rice soils and their availability to rice. *Soil Sci.*, **133**: 150-154.
- Nair, G.G.K. and Mehta, B.V. (1959). Status of zinc in soils of western India. *Soil Sci.*, **87**: 155-159.
- Narayanasamy, G. (2002). Fundamentals of soil science. *Indian Society of Soil Science*, pp. 393, New Delhi.
- Nirupama Gogal; Das, M. and Bora, D.K. (1999). Effect of organic matter on the transformation of different fractions of iron in some

- Alfisols of Assam under submergence. *J. Indian Soc. Soil Sci.*, **47**(1): 149-151.
- Olsen, S.R; Cole, C.V.; Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *Circ. U.S. Dep. Agric.*, 939.
- Pal, A.K.; Das, P.R.; Patnaik, S.K. and Mandal, B. (1997). Zinc fractions in some rice growing soils of Orissa. *J. Indian Soc. Soil Sci.*, **45**(4): 734-738.
- Panse, V.G. and Sukhatme, P.V. (1985). Statistical methods for agricultural worker (Fourth Edition). ICAR, New Delhi.
- Parakhia, B.K. (1979). Investigation on iron supplying power of calcareous soils of Junagadh district. M.Sc. Thesis, Guj. Agril. Uni., Anand.
- Patel, G.R. and Dangarwala, R.T. (1984). Availability of iron, manganese and zinc in paddy soils of South Gujarat. *Gujarat Agril. Res. J.*, **9**(2): 29-35.
- Patel, K.P. (2001). Nutrient mining in agro-climatic zones of Gujarat. *Fertilizer News*, **46**(5): 41-48 and 51-55.
- Patel, K.P.; Patel, K.C.; Ramani, V.P. and George, V. (1999). Effect of FYM on maintenance of micronutrient status under continuous cropping. *J. Guj. Soc. Agron. Soil Sci.*, **2**(1): 18-23.
- Patel, K.P.; Valamma, G.; Patel, J.A.; Ramani, V.P. and Patel, K.C. (1999). Three decades of AICRP on Micronutrient, Anand-3.
- Patel, M.S.; Mehta, P.M. and Pandya, H.G. (1972). Study on manganese distribution and availability in South Gujarat soils. *J. Indian Soc. Soil Sci.*, **20**: 79-90.

- Patel, V.R. (1998). A comparative evaluation of organic, inorganic and integrated nutrient management system. Ph.D. Thesis submitted to G.A.U., S.K. Nagar.
- Pathak, A.N.; Tiwari, K.N. and Upadhyay, R.L. (1975). Studies on Fe and Zn nutrition of rice in saline-alkali soil at different moisture regimes. *Indian J. Agric. Sci.*, **45**: 335-339.
- Pavansasivam, V. (1973). Manganese studies in some soils with a high organic matter content. *Plant Soil*, **38**: 245-255.
- Perer, V. M.; Zorvic, B. P. and Torres, F. J. (1994). Availability of Fe and Mn of most of the agricultural zones of the island of Tenerite (Canary Islands). *Commun. Soil Sci. Pl. Anal.*, **24**: 519-526.
- Piper, C.S. (1950). Soil and plant analysis. *Inter Sci. Publication, Inc.*, New York.
- Piper, C.S. (1966). Soil and plant analysis. Hans Publishers, Bombay, India.
- Prasad, B. and Agarwal, K. (1991). Adsorption and desorption of zinc on calcareous soils. *J. Indian Soc. Soil Sci.*, **39**: 662-666.
- Prasad, B. and Singh, A.P. (1980). Changes in Soil Properties with Long Term Use of Fertilizer, Lime and Farm Yard Manure. *J. Indian Soc. Soil Sci.*, **28**(4): 465-468.
- Prasad, B.; Mehta, A.K. and Sinha, M.K. (1990). Zinc fraction and availability of applied zinc in calcareous soil treated with organic material. *J. Indian Soc. Soil Sci.*, **38**(2): 248-253.
- Prasad, B.; Sarangthem, I., and Choudhary, K.C. (1995). Transformation and availability of applied zinc to maize in calcareous soil. *J. Indian Soc. Soil Sci.*, **43**: 84-89.

- Prasad, R. and Sakal, R (1991). Availability of iron in calcareous soils in relation to soil properties. *J. Indian Soc. Soil Sci.*, **39**(4): 658-661.
- Prasad, R. and Sakal, R. (1988). Effect of soil properties on different chemical pools of zinc in calcareous soils. *J. Indian Soc. Soil Sci.*, **36**: 246-251.
- Prasad, R.; Prasad, B.L. and Sakal, R. (1991). Influence of soil properties on different forms of zinc in old alluvial rice soils of Bihar. *Ann. Agric. Res.*, **12**(2): 122-127.
- Puri, A.N. (1963). Standardization of methods of soil analysis. I Introductory and Physico-chemical Constants of Indian Soils. *Bull. Field Res. Stn.*, **2**: 14.
- Rai, M.M.; Pal, R.R.; Chimania, B.P.; Shicoley, D.B. and Vakil, P. (1972). Available micronutrients status of shallow black soils of Madhya Pradesh. *J. Indian Soc. Soil Sci.*, **20**: 129-134.
- Ramanathan, G.; Nagarajan, R.; Sheriff, M. and Krishnamoorthy, K.K (1979). Balance sheet of micronutrient and rate of depletion in four heterogeneous soils of Tamilnadu. *Madras Agric. J.*, **66**(9): 597-604.
- Randhawa, H.S. and Singh, S.P. (1995). Zinc fractions in soils and their availability to maize. *J. Indian Soc. Soil Sci.*, **43**(2): 293-294.
- Randhawa, H.S. and Singh, S.P. (1996). Distribution of zinc fractions in alluvium derived soils of Punjab. *J. Indian Soc. Soil Sci.*, **43**(1): 124.
- Randhawa, H.S.; Kanwar, J.S. and Nijhawan, S.D. (1961). Distribution of different forms of manganese in Punjan soils. *Soil Sci.*, **92**: 106-112.

- Reddy, B.G. and Reddy, M.S. (1998). Effect of organic manures and nitrogen levels on soil available nutrients status in maize-soybean cropping system. *J. Indian Soc. Soil Sci.*, **46**(3): 474-476.
- Rewatkar, S.S. and Dakhore, R.C. (1980). Distribution of different forms of manganese in Vertisol of Akola. *Punjabrao Krishi Vidyapeeth Res. J.*, **4**(2): 74-8.
- Richards, L.A. (1954). Diagnosis of improvement of saline and alkali soils. U.S.D.A. Hand Book, No. 60.
- Romheld, V. and Marschner, H. (1986). Mobilization of iron in the rhizosphere of different plant species. *Adv. Plant Nutr.*, **2**: 155-204.
- Sadana, V.S. and Takkar, P.H. (1985). Zinc equilibria in submerged sodic soils as influenced by application of amendments. *Fert. Res.*, **6**: 91-96.
- Saha, J.K. and Mandal, B. (1998). Effect of submergence on copper fractions in Alfisols. *J. Indian Soc. Soil Sci.*, **46**: 32-36.
- Saha, J.K.; Adhikar, T.; Biswapati Mandal and Mandal, B. (1999). Effect of lime and organic matter on distribution of zinc, copper, iron and manganese in acid soils. *Commun. Soil Sci. Pl. Anal.*, **30**: 1819-1829.
- Saha, J.K.; Mandal, M. and Mandal, B. (2000a). Redistribution of copper in Alfisols under submergence I. Native Copper. *Commun. Soil Sci. Pl. Anal.*, **31**: 1111-1119.
- Saha, J.K.; Mandal, M. and Mandal, B. (2000b). Redistribution of copper in Alfisols under submergence II. Applied Copper. *Commun. Soil Sci. Pl. Anal.*, **31**: 1121-1127.

- Sakal, R.; Singh, A.P. and Sinha, R.B. (1988). Effect of different soil fertility levels on the response of wheat to zinc application on calciorthent. *J Indian Soc. Soil Sci.*, **36**: 125-127.
- Sakal, R.; Singh, A.P.; Singh, B.P.; Sinha, R.B.; Jha, S.N. and Singh, S.P. (1985). Distribution of available micronutrient cations in calcareous soils as related to certain soils properties. *J. Indian Soc. Soil Sci.*, **33**(3): 672-5.
- Sangwan, B.S. and Singh, K. (1993). Vertical distribution of zinc, manganese, copper and iron in the semi-arid soils of Haryana and their relationship with soil properties. *J. Indian Soc. Soil Sci.*, **41**(3): 467.
- Sarkar, A.K. and Deb, D.L. (1985). Fate of fertilizer zinc in black soil (Vertisol). *J. Agric. Sci. Camb.*, **104**: 249-251.
- Schewardzenbach and Biederman (1948). Komplexne, X. Erdalkalik complex ven. O.G. - Dixyazo Fab. Stoffen. *Helv. Chim. Acta* **31**: 676-687. (Fide: Soil chemical analysis, Jackson, 1967)
- Schwertmann, U. (1991). Solubility and dissolution of iron oxides. *Plant and Soil*, **130**: 1-25.
- Seshachalam, H. and Mehta, B.V. (1976). Availability of zinc, nitrogen and varying levels of phosphate soil incubation study. *Madras Agric. J.*, **63**: 84-90.
- Sharma, B.D.; Sighu, D.S. and Nayyar, V.K (1992). Distribution of micronutrients in arid zone soils of Punjab and their relations with soil properties. *Arid Soil Research and Rehabilitation*, **6**(3): 233-242.

- Sharma, B.L.; Rathore, G.S. and Bapat, P.N. (1997). Status of different forms of manganese and their relationship with physico-chemical properties of Entisols. *J. Indian Soc. Soil Sci.*, **45**: 390.
- Sharma, O.P. and Sinde, D.A. (1968). Manganese status of black soils of Indore district. *J. Indian Soc. Soil Sci.*, **16**: 65-69.
- Sharma, R.B. and Matiramani, D.P. (1969). Zinc status of the soils of Madhya Pradesh. *J. Indian Soc. Soil Sci.*, **17**: 19-26.
- Shinde, P.H.; More, D.A. and Zende, G.K. (1979). Status of available iron, manganese and boron in soils from the sugarcane growing areas of Pune district (Maharashtra). *J. Maharashtra Agric. Uni.*, **4**(3): 239-42.
- Shinghal, S.K. and Rattan, R.K (1995). Soil zinc fraction and their availability in some Inceptisols and Engisols. *J. Indian Soc. Soil Sci.*, **43**(1): 80.
- Shukla, U.C. and Gupta, B.L. (1975). Response of Mn application and evaluation of chemical extractants to determine available Mn in some arid brown soils of Haryana. *J. Indian Soc. Soil Sci.*, **23**: 257-264.
- Shukla, U.C. and Singh, R. (1973). Forms and distribution of iron in some Sierozem soils of Haryana. *J. Indian Soc. Soil Sci.*, **21**: 35-40.
- Shukla, U.C.; Gupta, B.L. and Singh, R. (1975). Available and potentially available forms of iron and manganese in surface arid brown soils of Haryana. *J. Indian Soc. Soil Sci.*, **23**: 484-488.
- Shuman, L.M. (1986). Effect of liming on the distribution of manganese copper, iron and zinc among soil fractions. *Soil Sci. Am. J.*, **50**: 1236-1240.

- Sims, J.L. and Patrick, W.H. Jr. (1978). The distribution of micronutrient cations in soil under conditions of varying redox potential and pH. *Soil Sci. Soc. Am. J.*, **42**: 258-262.
- Singh, A.; Sangwan, B.S. and Singh, K. (1990). Forms and distribution of iron in some arid region soils. *Haryana Agric. Univ. J. Res.*, **20**(3): 211-216.
- Singh, A.K. and Nohgkyhrih, P. (1999). Distribution and transformation of copper in wetland soils and its availability to rice plant. *J. Indian Soc. Soil Sci.*, **47**: 452-457.
- Singh, A.K.; Khan, S.K. and Nohgkyhrih, P. (1999). Transformation of zinc in wetland rice soils in relation to nutrition of rice crop. *J. Indian Soc. Soil Sci.*, **47**: 248-253.
- Singh, H. (1964). Movement of sulphate from different fertilizers applied to tea soils of Kangra valley and determination of exchangeable Al and Fe in typical tea soils of Punjab. M.Sc. Thesis, P.A.U., Hissar.
- Singh, J.P.; Karwasra, S.P.S. and Singh, M. (1988a). Distribution and forms of copper, iron, manganese and zinc in calcareous soils of India. *Soil Sci.*, **146**: 359-366.
- Singh, M.; Singh, M.P.; Singh, Y. and Gupta, G.R. (1988b). Long range effect of continuous rice wheat cropping under varying levels of N, P and K on yield and fertility status of soil with particular reference to iron. *J. Plant Nutr.*, **11**(6-11): 1471-1478.
- Singh, M.V. (2001). Evaluation of current micronutrient stocks in different agro-ecological zones of Indian for sustainable crop production. *Ferti. News*, **46**(2): 31-38 and 41-42.

- Sommer, I.I. and Shive, J.W. (1992). The iron-manganese relation in plant metabolism. *Plant Physiol.*, **17**: 582-602.
- Sparrow, L.A. and Uren, N.C. (1987). Oxidation and reduction of Mn in acidic soils : Effect of temperature and soil pH. *Soil Biol. Biochem.*, **19**: 143-148.
- Stevenson, F.T. and Ardakani, M.S. (1972). Organic matter reactions involving micronutrients. In: J.J. Martvedt *et al.* (ed). *Micronutrients in Agriculture*, 1st Ed. SSSA, Madison, W.I.
- Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Cure Sci.*, **25**: 254-260.
- Sudhir, K.; Gowda, S.M.M.; Siddaramappa (1997). Micronutrient stats of an Alfisols under long term fertilizer application and continuous corpping. *Mysore J. of Agril. Sci.*, **31**(2): 111-116.
- Sutaria, G.S. and Patel, M.S. (1987). Effect of phosphorus, sulphur, zinc and iron on yield and nutrient uptake (P, S, Zn and Fe) by groundnut grown on highly calcareous clay soils. *Indian J. Agril. Chem.*, **20**(1): 39-48.
- Suthar, D.M. and Ramakrishnayya, B.V. (1983). Relation to various forms of iron and other relevant properties of Goradu soils of middle Gujarat. *Indian J. of Agril. Chem.*, **16**(1): 109-117.
- Tagwira, F. (1994). Some chemical and physical factors associated with copper and zinc status and availability in Zimbabwean soils. *The-Zimbabwe-Journal of Agricultural Research*, **31**(1): 43-52.
- Takkar, P.N. (1969). Effect of organic matter on soil iron and manganese. *Soil Sci.*, **108**: 108-117.

- Takkar, P.N.; Chhiba, I.M. and Metha, S.K. (1989). Twenty years of coordinated research on micronutrients in soils and plants. *Bull. IISS, Bhopal*. pp. 314.
- Tandon, H.L.S. (1995). Micronutrients Research and Agricultural Production. FDCO, New Delhi.
- Thuo, J.T.; Mburv, J.M. and Kamau, H.M (1994). Dynamics of accumulated copper in the soil and leaves of coffee arabica L. *Kenya-Coffee-Bulletin*, **59**(689): 1739-742.
- Torres-Martin, M. and Gullardo-Lara, F. (1991). Dynamics of zinc fractions in the soil plant system under condition of intensive forage cropping. *Commun. Soil Sci. Plant Anal.*, **22**(19-20): 2089-2100.
- Tunio, S.P. (2001). The micronutrient status of the soil of Latif farm : Block B and C (Pakistan). *Tandojam Cpakistan SAUT*, **28**(12): 76.
- Udo, E.J.; Bohn, H.L. and Tucker, T.C. (1970). Zinc adsorption by calcareous soils. *Proc. Soil Sci. Soc. Am.*, **54**: 405-407.
- Viet, F.G. Jr. (1962). Chemistry and availability of micronutrient in soils. *J. Agric. Food chem.*, **10**: 165-178.
- Walkley, A. and Black, I.A. (1935). An examination of methods for determining organic carbon and nitrogen in soils. *J. Agric. Sci.*, **25**: 589-609.
- Wang, X. and Zhu, K. (1990). Investigation on the distribution of soils deficient in manganese and application of manganese fertilizer. *Turang Xuebao*, **27**(2): 202-206.
- Yadav, J.S.P. and Kalra, K.K. (1964). Exchangeable manganese in certain forest soils of India. *J. Indian Soc. Soil Sci.*, **12**: 225-234.

- Yasrebi, J.; Karimiah, N.; Maffoun, M.; Abtani, A. and Sameni, A.M. (1994). Distribution of zinc forms in highly calcareous soils as influenced by soil physical and chemical properties and application of zinc sulfate. *Communications in Soil Science and Plant Analysis*, **25**(11/12): 2133-2145.
- Zarkovic, B.; Blagojevic, S. and Stevanovic, D. (2000). Content of zinc and lead in a calcareous chernozem soil after long term fertilizer. *Serbia and Mongenegro*, **49**(1): 1-8.
- Zende, G.K. and Khonde, J.S. (1958). D.S.T.A. 15th Convention, 128-137, Read from micronutrient research in soils and plants in India. A review Tech. Bull. (Agri.) No. 50, ICAR, New Delhi.
- Zhang, W. and Zhang, N. (1984). study on the manganese nutrient in calcareous soil. III Transformation of manganese II Sulfate and changes of content of manganese of different forms in soils. *Turang Xuebao*, **21**(4): 382-6.
- Zwydak, M. (2001). Selected iron forms in soils of the mountain sycamore community. *Roczniki-Gleboznawcze (Poland)*, **52**: 145-151.

APPENDIX : I

Groundnut wheat yield and NPKS content of in LTFE experimental soils of 1st, 4th and 8th cycles of groundnut and wheat crop sequence

Sr. no.	Treatment	Yield (kg/ha)				Concentration of g'nut pod (%)				Concentration of g'nut haulm (%)				Concentration of wheat grain (%)				Concentration of wheat straw (%)			
		G'nut pod	G'nut haulm	Wheat grain	Wheat straw	N	P	K	S	N	P	K	S	N	P	K	S	N	P	K	S
1	101 T1/I	957	2083	1718	2870	2.99	0.64	0.67	0.116	1.26	0.11	0.53	0.116	2.64	0.220	0.277	0.149	0.664	0.027	0.960	0.248
2	102 T1/II	944	1823	2083	2963	2.40	0.59	0.73	0.099	1.34	0.09	0.42	0.099	2.35	0.203	0.292	0.215	0.588	0.022	1.244	0.297
3	103 T1/III	970	1563	1713	2778	3.38	0.59	0.71	0.116	1.84	0.11	0.50	0.165	2.52	0.198	0.292	0.264	0.476	0.027	1.000	0.215
4	104 T1/IV	977	1563	2000	2778	3.47	0.69	0.76	0.149	1.84	0.10	0.55	0.116	2.66	0.214	0.277	0.281	0.448	0.022	1.040	0.198
5	105 T2/I	977	1823	1301	2130	2.80	0.63	0.76	0.149	1.57	0.12	0.65	0.132	2.74	0.181	0.261	0.248	0.420	0.027	0.900	0.264
6	106 T2/II	944	2083	1273	2685	3.08	0.62	0.69	0.132	1.46	0.10	0.53	0.116	2.55	0.187	0.261	0.231	0.588	0.027	0.960	0.314
7	107 T2/III	879	2344	1343	2778	2.82	0.59	0.76	0.099	1.42	0.10	0.58	0.132	2.66	0.181	0.261	0.264	0.700	0.038	0.860	0.215
8	108 T2/IV	1139	1758	1759	2731	3.08	0.62	0.53	0.149	1.40	0.11	0.65	0.099	2.44	0.176	0.261	0.264	0.588	0.033	1.060	0.281
9	109 T3/I	846	1563	1991	3287	2.99	0.56	0.58	0.165	0.81	0.08	0.69	0.132	2.24	0.220	0.277	0.248	0.588	0.044	0.763	0.281
10	110 T3/II	931	2083	2227	2685	2.10	0.58	0.65	0.132	0.68	0.09	0.69	0.116	2.52	0.203	0.261	0.281	0.476	0.033	1.000	0.281
11	111 T3/III	814	2083	1662	2083	2.15	0.53	0.80	0.132	0.64	0.08	0.71	0.149	2.72	0.214	0.277	0.248	0.672	0.049	1.040	0.248
12	112 T3/IV	1074	1823	1713	3009	2.85	0.62	0.80	0.149	0.67	0.08	0.68	0.099	2.10	0.220	0.261	0.297	0.616	0.038	1.240	0.264
13	113 T4/I	1009	1823	1181	1991	2.07	0.53	0.65	0.066	1.12	0.13	0.65	0.149	2.12	0.236	0.323	0.149	0.644	0.049	0.840	0.165
14	114 T4/II	1107	1693	1528	2315	1.96	0.46	0.64	0.116	1.23	0.12	0.65	0.083	1.90	0.187	0.261	0.132	0.588	0.049	1.100	0.264
15	115 T4/III	1230	1563	1000	1852	2.46	0.53	0.76	0.116	1.14	0.12	0.64	0.165	2.21	0.192	0.292	0.231	0.672	0.044	0.960	0.264
16	116 T4/IV	846	1823	1528	2130	2.18	0.48	0.84	0.066	1.18	0.11	0.71	0.132	2.24	0.275	0.323	0.281	0.616	0.049	1.160	0.264
17	117 T5/I	846	2474	1954	3380	2.54	0.59	0.80	0.116	1.23	0.12	0.55	0.099	2.55	0.192	0.292	0.281	0.616	0.055	1.244	0.281
18	118 T5/II	866	1693	2315	3287	2.26	0.55	0.96	0.083	1.10	0.10	0.58	0.083	2.24	0.176	0.292	0.248	0.672	0.049	1.571	0.248
19	119 T5/III	801	1823	1620	2870	2.24	0.56	0.80	0.066	0.84	0.09	0.53	0.116	2.66	0.220	0.292	0.248	0.560	0.055	0.920	0.231
20	120 T5/IV	1204	2083	1745	2824	2.38	0.49	0.80	0.165	0.70	0.09	0.50	0.132	2.44	0.192	0.277	0.248	0.588	0.044	1.288	0.231
21	121 T6/I	1074	1563	1690	2852	1.73	0.53	0.65	0.132	1.18	0.09	0.62	0.116	2.18	0.198	0.277	0.281	0.756	0.055	0.820	0.281
22	122 T6/II	957	1693	2176	2963	1.79	0.53	0.71	0.066	1.10	0.09	0.66	0.099	2.55	0.198	0.261	0.248	0.644	0.044	0.940	0.264
23	123 T6/III	1139	1367	1991	3241	2.35	0.59	0.73	0.083	1.23	0.10	0.50	0.165	2.32	0.214	0.277	0.248	0.728	0.044	0.840	0.215
24	124 T6/IV	1237	2083	1569	2222	1.82	0.57	0.65	0.149	1.40	0.09	0.62	0.116	2.66	0.187	0.292	0.264	0.504	0.049	1.100	0.231
25	125 T7/I	879	2083	1528	2778	3.38	0.58	0.57	0.198	1.23	0.10	0.57	0.116	2.74	0.203	0.292	0.297	0.616	0.044	0.820	0.248
26	126 T7/II	1074	1302	1759	3102	3.05	0.59	0.67	0.231	1.46	0.10	0.58	0.149	2.38	0.187	0.292	0.297	0.504	0.049	0.960	0.264

27	127 T7/III	1139	2018	1620	2963	3.52	0.64	0.65	0.215	1.40	0.09	0.57	0.116	2.38	0.203	0.323	0.314	0.700	0.055	0.940	0.281
28	128 T7/IV	618	2083	1528	3009	2.99	0.62	0.57	0.182	1.18	0.08	0.69	0.132	2.58	0.198	0.277	0.264	0.728	0.044	1.288	0.297
29	129 T8/I	716	1693	1208	2269	2.85	0.61	0.76	0.066	1.18	0.10	0.80	0.198	1.88	0.225	0.261	0.248	0.588	0.033	0.960	0.264
30	130 T8/II	846	1823	1343	2037	2.40	0.50	0.67	0.099	0.84	0.11	0.76	0.132	2.52	0.231	0.261	0.281	0.616	0.033	1.266	0.281
31	131 T8/III	1061	1693	1171	1852	2.24	0.49	0.68	0.083	1.57	0.10	0.67	0.165	2.16	0.203	0.261	0.264	0.448	0.027	0.840	0.248
32	132 T8/IV	1042	1563	1435	2407	2.29	0.58	0.65	0.066	0.95	0.09	0.65	0.116	2.35	0.247	0.292	0.281	0.392	0.038	1.428	0.281
33	133 T9/I	944	1693	1125	1991	2.24	0.64	0.71	0.083	1.06	0.09	0.50	0.132	2.55	0.192	0.277	0.149	0.448	0.049	0.840	0.198
34	134 T9/II	814	1693	907	1528	1.79	0.51	0.65	0.099	1.09	0.10	0.50	0.099	2.24	0.187	0.277	0.231	0.476	0.038	0.781	0.264
35	135 T9/III	840	1823	1162	1944	2.48	0.52	0.67	0.050	0.84	0.09	0.42	0.099	2.58	0.247	0.292	0.198	0.560	0.038	1.060	0.281
36	136 T9/IV	905	1563	1250	2222	2.63	0.64	0.76	0.066	0.84	0.10	0.51	0.132	2.32	0.231	0.261	0.248	0.588	0.033	1.160	0.231
37	137 T10/I	827	1693	1861	2731	3.50	0.63	0.65	0.149	1.46	0.12	0.68	0.099	2.57	0.242	0.292	0.281	0.700	0.022	0.900	0.281
38	138 T10/II	1204	1953	1569	2315	2.80	0.56	0.58	0.132	1.40	0.10	0.76	0.132	2.72	0.192	0.323	0.215	0.672	0.033	1.160	0.264
39	139 T10/III	1074	2344	1713	2407	2.66	0.64	0.65	0.149	1.20	0.09	0.58	0.132	2.63	0.225	0.323	0.297	0.588	0.022	1.377	0.281
40	140 T10/IV	749	1953	2083	3148	3.44	0.57	0.73	0.165	1.40	0.09	0.64	0.132	2.35	0.198	0.261	0.248	0.420	0.022	1.428	0.182
41	141 T11/I	944	1563	1347	2407	3.08	0.56	0.58	0.066	0.73	0.10	0.52	0.099	2.27	0.192	0.261	0.264	0.588	0.016	0.654	0.231
42	142 T11/II	977	1823	1759	2454	1.96	0.55	0.58	0.099	0.90	0.09	0.47	0.083	2.24	0.192	0.261	0.248	0.616	0.011	0.763	0.281
43	143 T11/III	944	1693	1537	2917	2.55	0.64	0.69	0.116	1.20	0.08	0.58	0.132	2.21	0.231	0.277	0.248	0.644	0.022	0.900	0.264
44	144 T11/IV	1204	2083	1713	3009	2.52	0.67	0.69	0.132	1.10	0.10	0.65	0.099	2.13	0.220	0.261	0.264	0.664	0.011	1.160	0.231
45	145 T12/I	1074	2083	1671	2685	2.91	0.65	0.65	0.083	0.89	0.08	0.45	0.116	2.24	0.198	0.261	0.248	0.504	0.022	0.716	0.215
46	146 T12/II	879	1823	1898	2778	2.46	0.59	0.64	0.132	0.84	0.09	0.37	0.099	2.18	0.165	0.231	0.165	0.476	0.027	0.745	0.248
47	147 T12/III	911	1693	1176	2315	2.94	0.56	0.76	0.099	0.95	0.11	0.48	0.099	2.30	0.210	0.246	0.248	0.588	0.022	0.920	0.297
48	148 T12/IV	1009	2279	2130	3009	2.24	0.64	0.76	0.132	0.70	0.10	0.43	0.149	2.30	0.198	0.261	0.248	0.616	0.020	0.900	0.248
49	201 T1/I	910	1639	1231	2694	2.94	0.45	0.80	0.300	1.48	0.22	0.52	0.290	1.88	0.380	0.420	0.150	0.530	0.048	1.060	0.190
50	202 T1/II	827	1727	1176	2028	3.14	0.45	0.67	0.290	1.26	0.20	0.55	0.240	2.13	0.360	0.450	0.200	0.500	0.038	1.080	0.260
51	203 T1/III	767	1791	1111	2167	2.74	0.51	0.75	0.300	1.23	0.24	0.55	0.270	1.99	0.360	0.420	0.160	0.620	0.058	1.100	0.250
52	204 T1/IV	883	1563	833	2000	3.00	0.52	0.69	0.310	1.65	0.25	0.65	0.300	2.16	0.400	0.480	0.220	0.620	0.038	1.380	0.220
53	205 T2/I	1031	1719	1852	3074	3.08	0.52	0.73	0.360	0.90	0.20	0.48	0.400	2.21	0.440	0.480	0.220	0.620	0.051	1.120	0.210
54	206 T2/II	850	2015	1370	2296	3.19	0.47	0.71	0.250	1.20	0.20	0.55	0.230	2.16	0.360	0.470	0.190	0.560	0.070	1.160	0.270
55	207 T2/III	983	1770	1519	2685	2.44	0.53	0.76	0.230	1.15	0.16	0.65	0.280	2.10	0.410	0.480	0.220	0.530	0.051	1.240	0.250
56	208 T2/IV	935	1821	1259	2389	3.00	0.59	0.76	0.350	1.54	0.27	0.62	0.260	2.07	0.380	0.470	0.200	0.590	0.042	1.180	0.170
57	209 T3/I	935	1821	1574	2630	3.56	0.53	0.73	0.360	1.34	0.22	0.60	0.340	2.35	0.390	0.430	0.170	0.620	0.051	1.120	0.200

58	210 T3/II	1045	2225	1519	2870	3.33	0.52	0.76	0.260	1.57	0.19	0.67	0.280	2.32	0.450	0.550	0.230	0.620	0.054	1.000	0.270
59	211 T3/III	1126	2243	1991	3657	2.97	0.50	0.96	0.250	2.07	0.28	0.65	0.290	2.38	0.420	0.470	0.230	0.480	0.042	1.120	0.200
60	212 T3/IV	1031	1823	1509	2602	2.74	0.50	0.86	0.300	1.68	0.27	0.64	0.220	2.10	0.390	0.430	0.210	0.620	0.051	1.240	0.210
61	213 T4/I	855	1593	1435	2583	3.44	0.54	0.76	0.330	1.15	0.18	0.73	0.330	2.30	0.360	0.430	0.220	0.530	0.054	1.040	0.230
62	214 T4/II	910	1534	1074	2222	2.86	0.50	0.80	0.310	1.43	0.18	0.53	0.200	2.13	0.370	0.480	0.230	0.530	0.042	1.290	0.170
63	215 T4/III	1124	1932	1639	3028	2.83	0.52	0.84	0.330	1.48	0.24	0.62	0.330	2.30	0.380	0.430	0.190	0.670	0.054	1.040	0.230
64	216 T4/IV	850	1806	1102	2287	2.41	0.56	0.82	0.340	1.90	0.27	0.69	0.270	2.18	0.340	0.420	0.220	0.590	0.042	1.380	0.210
65	217 T5/I	889	1766	1796	3315	3.25	0.52	0.71	0.350	1.09	0.26	0.55	0.400	2.32	0.400	0.420	0.210	0.500	0.045	1.540	0.170
66	218 T5/II	867	1580	1343	2306	2.46	0.51	0.69	0.260	1.32	0.21	0.45	0.320	2.21	0.390	0.500	0.240	0.620	0.038	1.660	0.260
67	219 T5/III	855	1593	1426	2407	2.58	0.50	0.88	0.280	1.51	0.22	0.57	0.380	2.24	0.390	0.550	0.200	0.730	0.067	1.460	0.170
68	220 T5/IV	970	1575	1574	2630	2.91	0.48	0.69	0.290	1.60	0.29	0.58	0.460	2.21	0.420	0.420	0.210	0.670	0.042	1.600	0.200
69	221 T6/I	735	1616	1111	2000	3.05	0.52	0.80	0.290	1.46	0.28	0.43	0.490	2.13	0.380	0.420	0.190	0.640	0.064	1.770	0.190
70	222 T6/II	720	1424	1148	2148	2.88	0.46	0.67	0.250	1.40	0.22	0.40	0.410	2.30	0.430	0.530	0.220	0.530	0.061	1.770	0.250
71	223 T6/III	791	1453	1296	2444	3.02	0.51	0.80	0.290	1.62	0.26	0.53	0.480	1.99	0.400	0.480	0.190	0.670	0.061	1.690	0.170
72	224 T6/IV	958	1900	1667	2815	3.05	0.51	0.65	0.240	1.71	0.22	0.62	0.320	1.99	0.440	0.480	0.210	0.530	0.051	1.770	0.150
73	225 T7/I	864	1480	778	1593	3.00	0.45	0.65	0.340	1.15	0.17	0.38	0.250	1.90	0.310	0.400	0.160	0.640	0.035	1.330	0.210
74	226 T7/II	708	1436	593	1222	3.33	0.44	0.67	0.310	1.46	0.17	0.43	0.260	1.79	0.340	0.530	0.210	0.780	0.051	1.290	0.200
75	227 T7/III	910	1847	917	1731	2.94	0.45	0.73	0.230	1.26	0.17	0.42	0.350	2.16	0.330	0.430	0.180	0.500	0.035	1.430	0.230
76	228 T7/IV	816	1635	796	1204	3.00	0.46	0.75	0.280	1.65	0.16	0.48	0.230	2.32	0.370	0.430	0.190	0.730	0.035	1.380	0.220
77	229 T8/I	1033	1925	1778	2889	3.19	0.49	0.78	0.250	1.26	0.22	0.80	0.260	2.44	0.420	0.430	0.180	0.560	0.042	1.430	0.160
78	230 T8/II	1210	2049	1426	2611	3.44	0.50	0.78	0.270	1.37	0.26	0.73	0.400	2.44	0.440	0.520	0.190	0.670	0.070	1.160	0.240
79	231 T8/III	1221	2247	2074	3685	3.16	0.56	0.76	0.300	1.46	0.22	0.88	0.290	2.30	0.480	0.450	0.210	0.500	0.058	1.360	0.180
80	232 T8/IV	1091	2280	2120	3287	2.66	0.61	0.73	0.360	1.79	0.25	0.92	0.310	2.44	0.370	0.420	0.110	0.560	0.064	1.600	0.150
81	233 T9/I	1031	2240	1667	3074	3.53	0.52	0.75	0.320	1.43	0.24	0.78	0.290	2.02	0.450	0.450	0.190	0.420	0.042	1.290	0.230
82	234 T9/II	1055	2006	1102	2287	2.63	0.48	0.90	0.290	1.51	0.20	0.90	0.210	2.16	0.410	0.480	0.170	0.700	0.077	1.540	0.170
83	235 T9/III	1126	2139	1741	3019	3.19	0.57	0.80	0.330	1.40	0.23	0.80	0.270	2.04	0.440	0.470	0.130	0.450	0.061	1.570	0.150
84	236 T9/IV	983	2395	1694	2972	2.66	0.50	0.75	0.260	1.85	0.19	0.80	0.190	1.93	0.470	0.450	0.150	0.480	0.058	1.220	0.150
85	237 T10/I	899	1547	1407	3074	2.83	0.45	0.73	0.290	1.43	0.18	0.67	0.300	2.24	0.370	0.420	0.150	0.620	0.038	1.310	0.130
86	238 T10/II	886	1559	972	2046	3.58	0.55	0.82	0.310	1.48	0.23	0.65	0.420	2.24	0.380	0.470	0.170	0.640	0.054	1.240	0.250
87	239 T10/III	1151	2008	1713	2936	2.86	0.50	0.65	0.290	1.06	0.19	0.50	0.280	2.27	0.400	0.450	0.180	0.450	0.042	1.380	0.210
88	240 T10/IV	910	1639	1250	2028	3.02	0.46	0.76	0.270	1.65	0.26	0.58	0.410	2.44	0.420	0.470	0.250	0.560	0.064	1.630	0.250

89	241 T11/I	1000	1752	1528	2676	3.14	0.50	0.80	0.270	1.40	0.26	0.60	0.290	2.07	0.330	0.520	0.230	0.560	0.054	1.220	0.240
90	242 T11/II	918	1840	1500	2519	3.05	0.50	0.64	0.290	1.51	0.24	0.75	0.270	2.18	0.410	0.480	0.200	0.590	0.054	1.600	0.290
91	243 T11/III	1043	2019	1778	3333	3.25	0.51	0.78	0.330	1.54	0.29	0.76	0.360	2.27	0.380	0.470	0.190	0.590	0.074	1.600	0.210
92	244 T11/IV	1019	1732	1843	3287	2.60	0.54	0.80	0.320	1.71	0.26	0.71	0.270	2.24	0.440	0.480	0.260	0.760	0.067	1.490	0.300
93	245 T12/I	740	1738	1120	1898	3.19	0.45	0.57	0.270	1.34	0.15	0.42	0.250	2.04	0.310	0.380	0.210	0.560	0.032	1.400	0.230
94	246 T12/II	695	1347	833	1722	3.64	0.46	0.65	0.280	1.12	0.16	0.48	0.250	1.99	0.350	0.470	0.190	0.700	0.054	1.430	0.170
95	247 T12/III	827	1623	944	2444	3.64	0.51	0.73	0.250	1.43	0.16	0.65	0.310	1.99	0.380	0.470	0.210	0.590	0.051	1.630	0.190
96	248 T12/IV	827	1623	1250	2324	3.36	0.49	0.67	0.260	1.54	0.17	0.55	0.230	1.85	0.390	0.430	0.150	0.700	0.051	1.660	0.150
97	301 T1/I	119	528	3097	3093	2.72	0.40	0.67	0.149	1.43	0.18	0.37	0.099	1.60	0.330	0.300	0.099	0.420	0.040	0.690	0.109
98	302 T1/II	210	708	2587	3018	2.94	0.39	0.67	0.149	1.37	0.15	0.36	0.109	1.82	0.360	0.310	0.099	0.450	0.040	0.730	0.139
99	303 T1/III	219	769	3352	3791	3.00	0.45	0.69	0.149	1.46	0.19	0.45	0.089	1.65	0.320	0.290	0.089	0.360	0.050	0.940	0.119
100	304 T1/IV	178	827	3005	3121	2.86	0.44	0.58	0.168	1.34	0.17	0.45	0.109	1.60	0.350	0.330	0.099	0.390	0.040	0.920	0.119
101	305 T2/I	148	783	3566	4921	2.86	0.43	0.71	0.168	1.60	0.19	0.43	0.099	1.96	0.420	0.310	0.079	0.590	0.060	0.840	0.129
102	306 T2/II	206	898	3352	3771	3.11	0.45	0.62	0.158	1.54	0.19	0.48	0.099	2.02	0.400	0.310	0.079	0.560	0.050	0.960	0.129
103	307 T2/III	189	774	3693	4729	2.74	0.43	0.65	0.168	1.57	0.17	0.48	0.089	1.90	0.360	0.310	0.089	0.670	0.060	0.940	0.119
104	308 T2/IV	226	1097	4025	4408	2.77	0.42	0.64	0.158	1.65	0.20	0.52	0.089	1.93	0.330	0.330	0.089	0.640	0.060	1.020	0.139
105	309 T3/I	243	935	3434	3987	3.08	0.43	0.65	0.168	1.51	0.18	0.55	0.099	1.99	0.360	0.340	0.119	0.730	0.170	0.980	0.099
106	310 T3/II	313	1086	3495	4516	2.94	0.41	0.62	0.188	1.37	0.18	0.53	0.099	2.04	0.370	0.330	0.099	0.700	0.150	1.020	0.089
107	311 T3/III	213	765	3943	4792	3.02	0.50	0.73	0.149	1.48	0.19	0.45	0.089	2.04	0.350	0.310	0.119	0.670	0.170	1.040	0.079
108	312 T3/IV	311	1086	3841	4581	3.30	0.44	0.67	0.178	1.48	0.17	0.50	0.089	2.02	0.350	0.360	0.109	0.760	0.170	1.130	0.089
109	313 T4/I	273	813	3791	4136	2.86	0.46	0.69	0.158	1.40	0.15	0.36	0.099	1.99	0.350	0.330	0.079	0.640	0.080	1.250	0.119
110	314 T4/II	316	973	3495	3896	3.02	0.43	0.58	0.149	1.48	0.18	0.47	0.119	1.93	0.350	0.330	0.069	0.620	0.100	1.280	0.119
111	315 T4/III	224	850	3556	4634	2.97	0.50	0.75	0.188	1.54	0.15	0.47	0.139	1.90	0.360	0.340	0.079	0.670	0.140	1.110	0.109
112	316 T4/IV	213	993	3642	4076	2.80	0.46	0.62	0.178	1.57	0.15	0.45	0.119	1.90	0.350	0.330	0.079	0.620	0.140	1.020	0.119
113	317 T5/I	143	701	3536	4034	3.05	0.44	0.67	0.139	1.48	0.14	0.40	0.119	1.93	0.360	0.330	0.079	0.560	0.150	0.840	0.119
114	318 T5/II	227	746	3331	3936	2.94	0.47	0.57	0.149	1.32	0.18	0.42	0.158	1.85	0.350	0.340	0.079	0.590	0.140	0.960	0.099
115	319 T5/III	232	859	3576	4231	3.05	0.49	0.69	0.178	1.26	0.20	0.40	0.129	1.96	0.310	0.330	0.089	0.530	0.130	1.070	0.099
116	320 T5/IV	215	1055	4211	4727	2.58	0.41	0.67	0.129	1.40	0.18	0.43	0.129	1.99	0.360	0.310	0.079	0.620	0.130	1.090	0.099
117	321 T6/I	222	783	3414	3640	2.86	0.44	0.65	0.158	1.48	0.20	0.36	0.119	1.82	0.400	0.330	0.089	0.450	0.060	0.500	0.139
118	322 T6/II	132	714	3179	4252	3.28	0.47	0.62	0.139	1.43	0.23	0.34	0.129	1.85	0.380	0.340	0.109	0.530	0.060	0.480	0.119
119	323 T6/III	149	724	3862	4804	2.88	0.45	0.67	0.139	1.34	0.20	0.40	0.099	1.93	0.400	0.330	0.099	0.500	0.080	0.500	0.129

120	324 T6/IV	142	952	3943	4688	3.14	0.46	0.58	0.168	1.43	0.19	0.48	0.139	1.90	0.380	0.330	0.109	0.590	0.060	0.520	0.158
121	325 T7/I	166	608	2537	2925	2.60	0.38	0.65	0.149	1.37	0.14	0.40	0.149	1.79	0.330	0.340	0.109	0.480	0.060	0.570	0.109
122	326 T7/II	121	746	1873	2304	3.05	0.45	0.50	0.158	1.32	0.17	0.42	0.139	1.68	0.310	0.330	0.119	0.560	0.050	0.620	0.149
123	327 T7/III	214	959	2986	3571	2.74	0.42	0.65	0.149	1.37	0.18	0.45	0.119	1.85	0.330	0.310	0.109	0.530	0.080	0.670	0.119
124	328 T7/IV	131	746	1772	2261	2.58	0.43	0.65	0.139	1.34	0.14	0.33	0.109	1.93	0.320	0.310	0.099	0.450	0.050	0.650	0.119
125	329 T8/I	297	945	4096	5378	2.66	0.44	0.78	0.168	1.37	0.14	1.00	0.109	2.04	0.290	0.330	0.089	0.780	0.170	1.880	0.050
126	330 T8/II	315	973	4147	5570	2.44	0.46	0.78	0.188	1.34	0.18	1.18	0.099	2.07	0.320	0.360	0.109	0.700	0.180	1.780	0.040
127	331 T8/III	376	1077	4442	6247	2.38	0.48	0.78	0.218	1.48	0.15	1.20	0.119	2.16	0.290	0.340	0.109	0.810	0.190	1.750	0.050
128	332 T8/IV	311	1086	4972	6064	2.83	0.43	0.65	0.178	1.26	0.15	1.25	0.149	2.13	0.280	0.390	0.109	0.760	0.190	1.730	0.079
129	333 T9/I	304	774	4046	4273	2.66	0.46	0.90	0.158	1.26	0.18	1.23	0.099	2.02	0.400	0.360	0.099	0.670	0.180	1.880	0.069
130	334 T9/II	315	825	4453	5135	3.11	0.50	0.80	0.208	1.32	0.20	1.00	0.109	1.96	0.460	0.390	0.099	0.730	0.200	1.800	0.079
131	335 T9/III	250	1011	3934	4871	2.52	0.50	0.86	0.198	1.37	0.18	0.96	0.099	2.10	0.400	0.360	0.089	0.760	0.190	1.650	0.059
132	336 T9/IV	315	973	4367	3907	3.00	0.43	0.69	0.158	1.34	0.14	0.98	0.139	2.04	0.400	0.390	0.089	0.700	0.180	1.780	0.050
133	337 T10/I	163	859	3597	3938	2.91	0.41	0.64	0.119	1.26	0.19	0.45	0.109	1.90	0.380	0.340	0.109	0.530	0.050	1.020	0.139
134	338 T10/II	227	973	3627	4369	2.88	0.41	0.58	0.158	1.51	0.15	0.48	0.119	1.85	0.400	0.340	0.109	0.560	0.050	1.070	0.149
135	339 T10/III	147	670	3729	4282	2.83	0.40	0.69	0.119	1.34	0.18	0.39	0.119	1.82	0.370	0.330	0.099	0.450	0.060	0.940	0.119
136	340 T10/IV	204	783	3617	4225	2.72	0.40	0.58	0.149	1.37	0.19	0.39	0.129	1.93	0.380	0.310	0.099	0.500	0.050	1.020	0.139
137	341 T11/I	166	1021	3464	3892	3.05	0.42	0.71	0.188	1.57	0.17	0.50	0.129	1.96	0.330	0.330	0.069	0.620	0.140	0.860	0.149
138	342 T11/II	201	859	3464	3634	2.74	0.44	0.65	0.168	1.62	0.15	0.40	0.158	1.99	0.330	0.330	0.079	0.640	0.130	0.980	0.119
139	343 T11/III	198	1097	3719	4465	2.91	0.44	0.65	0.178	1.26	0.17	0.39	0.129	1.93	0.310	0.310	0.079	0.700	0.170	0.980	0.158
140	344 T11/IV	180	1097	3893	4485	2.72	0.46	0.58	0.158	1.23	0.17	0.48	0.139	1.90	0.380	0.310	0.089	0.670	0.150	0.960	0.139
141	345 T12/I	109	608	1911	2380	2.88	0.39	0.69	0.129	1.34	0.18	0.40	0.129	1.48	0.270	0.310	0.129	0.450	0.060	0.840	0.149
142	346 T12/II	183	746	2363	2617	2.88	0.40	0.73	0.129	1.43	0.14	0.42	0.119	1.54	0.350	0.300	0.119	0.480	0.080	0.920	0.149
143	347 T12/III	149	670	2037	2214	2.80	0.40	0.65	0.139	1.34	0.13	0.39	0.149	1.43	0.310	0.300	0.119	0.390	0.050	0.860	0.119
144	348 T12/IV	170	959	2830	3291	2.69	0.43	0.58	0.149	1.26	0.17	0.40	0.129	1.51	0.350	0.300	0.109	0.360	0.060	1.020	0.129

APPENDIX : II

Different forms of Copper in LTFE experimental soils of 1st, 4th and 8th cycles of groundnut and wheat crop sequence

Sr. no.	Treatment	WSF	EF	AF	RF	AV. TOTAL	TOTAL	RESIDUAL	% AV.
1	101 T1/I	0.260	0.265	1.964	0.260	2.749	14.235	11.486	19.314
2	102 T1/II	0.153	0.136	1.354	0.160	1.803	13.560	11.757	13.295
3	103 T1/III	0.174	0.365	1.234	0.281	2.054	12.340	10.286	16.648
4	104 T1/IV	0.153	0.236	1.328	0.125	1.842	12.560	10.718	14.667
5	105 T2/I	0.219	0.173	1.762	0.197	2.350	14.256	11.906	16.484
6	106 T2/II	0.202	0.106	1.345	0.197	1.850	13.560	11.710	13.642
7	107 T2/III	0.210	0.321	1.225	0.132	1.889	14.250	12.361	13.255
8	108 T2/IV	0.227	0.325	1.553	0.165	2.270	14.250	11.980	15.933
9	109 T3/I	0.166	0.231	1.402	0.226	2.025	14.560	12.535	13.907
10	110 T3/II	0.128	0.326	1.402	0.156	2.012	12.560	10.548	16.019
11	111 T3/III	0.210	0.353	1.144	0.226	1.933	14.256	12.323	13.562
12	112 T3/IV	0.141	0.422	1.386	0.131	2.079	13.586	11.507	15.305
13	113 T4/I	0.235	0.215	1.166	0.277	1.893	11.230	9.337	16.857
14	114 T4/II	0.174	0.101	1.408	0.191	1.873	15.560	13.687	12.040
15	115 T4/III	0.194	0.290	1.473	0.175	2.132	14.580	12.449	14.619
16	116 T4/IV	0.239	0.327	1.829	0.208	2.603	19.250	16.647	13.522
17	117 T5/I	0.161	0.097	0.954	0.106	1.318	11.560	10.242	11.405
18	118 T5/II	0.215	0.138	1.200	0.106	1.660	13.560	11.900	12.239
19	119 T5/III	0.227	0.325	1.220	0.280	2.052	12.560	10.508	16.339
20	120 T5/IV	0.128	0.458	1.220	0.206	2.013	15.560	13.547	12.934
21	121 T6/I	0.215	0.236	1.607	0.159	2.217	16.250	14.033	13.641
22	122 T6/II	0.182	0.366	1.454	0.126	2.128	14.580	12.452	14.597
23	123 T6/III	0.244	0.326	1.240	0.132	1.941	15.560	13.619	12.476
24	124 T6/IV	0.280	0.524	1.581	0.159	2.545	14.250	11.705	17.857
25	125 T7/I	0.166	0.303	1.394	0.189	2.051	13.958	11.907	14.695
26	126 T7/II	0.190	0.256	1.359	0.125	1.930	13.590	11.660	14.203
27	127 T7/III	0.166	0.413	1.048	0.124	1.750	10.250	8.500	17.070
28	128 T7/IV	0.215	0.235	1.506	0.127	2.083	13.060	10.977	15.951
29	129 T8/I	0.170	0.097	1.330	0.280	1.877	15.560	13.683	12.062
30	130 T8/II	0.182	0.077	2.108	0.250	2.617	21.860	19.243	11.973
31	131 T8/III	0.239	0.235	1.720	0.125	2.319	18.250	15.931	12.708
32	132 T8/IV	0.264	0.235	1.825	0.152	2.476	15.250	12.774	16.239
33	133 T9/I	0.178	0.134	2.200	0.225	2.737	16.250	13.513	16.843
34	134 T9/II	0.223	0.068	2.097	0.225	2.613	15.250	12.637	17.134
35	135 T9/III	0.227	0.033	1.825	0.312	2.396	12.250	9.854	19.562
36	136 T9/IV	0.210	0.125	1.842	0.226	2.403	14.000	11.598	17.161
37	137 T10/I	0.104	0.321	1.124	0.259	1.808	11.256	9.448	16.063
38	138 T10/II	0.153	0.236	1.407	0.225	2.021	16.600	14.579	12.175
39	139 T10/III	0.166	0.321	1.168	0.225	1.880	18.123	16.243	10.371
40	140 T10/IV	0.293	0.326	1.243	0.225	2.086	18.223	16.137	11.448
41	141 T11/I	0.157	0.155	1.412	0.225	1.949	14.125	12.176	13.795
42	142 T11/II	0.194	0.235	1.600	0.225	2.254	16.025	13.771	14.066
43	143 T11/III	0.137	0.254	1.500	0.211	2.102	15.250	13.148	13.783
44	144 T11/IV	0.264	0.325	1.300	0.200	2.089	13.252	11.163	15.764
45	145 T12/I	0.150	0.236	1.377	0.102	1.865	13.770	11.905	13.542

46	146 T12/II	0.148	0.326	1.232	0.125	1.830	12.350	10.520	14.819
47	147 T12/III	0.178	0.413	1.298	0.141	2.030	12.890	10.860	15.748
48	148 T12/IV	0.104	0.413	1.744	0.098	2.358	11.560	9.202	20.399
49	201 T1/I	0.178	0.223	1.250	0.220	1.871	11.560	9.689	16.183
50	202 T1/II	0.166	0.137	1.240	0.221	1.764	12.580	10.816	14.024
51	203 T1/III	0.206	0.326	1.166	0.161	1.859	11.565	9.706	16.073
52	204 T1/IV	0.277	0.330	1.268	0.156	2.030	13.564	11.534	14.969
53	205 T2/I	0.151	0.153	1.677	0.252	2.233	16.798	14.565	13.294
54	206 T2/II	0.135	0.395	1.268	0.215	2.013	11.564	9.551	17.407
55	207 T2/III	0.168	0.313	1.001	0.236	1.718	10.250	8.532	16.761
56	208 T2/IV	0.248	0.276	1.476	0.226	2.227	14.765	12.538	15.084
57	209 T3/I	0.078	0.157	1.374	0.211	1.820	12.561	10.741	14.491
58	210 T3/II	0.127	0.338	0.906	0.211	1.582	11.250	9.668	14.064
59	211 T3/III	0.160	0.297	0.969	0.156	1.582	13.560	11.978	11.664
60	212 T3/IV	0.269	0.395	1.280	0.130	2.074	11.256	9.182	18.426
61	213 T4/I	0.161	0.096	1.130	0.262	1.649	13.564	11.915	12.157
62	214 T4/II	0.165	0.276	1.421	0.256	2.119	12.564	10.445	16.862
63	215 T4/III	0.165	0.288	1.351	0.135	1.939	11.251	9.312	17.236
64	216 T4/IV	0.216	0.371	1.230	0.136	1.952	12.256	10.304	15.930
65	217 T5/I	0.131	0.235	0.824	0.258	1.448	15.651	14.203	9.252
66	218 T5/II	0.143	0.309	1.250	0.224	1.926	10.560	8.634	18.242
67	219 T5/III	0.134	0.248	1.000	0.260	1.641	11.560	9.919	14.197
68	220 T5/IV	0.169	0.408	1.610	0.221	2.408	11.230	8.822	21.439
69	221 T6/I	0.145	0.256	1.000	0.124	1.525	12.250	10.725	12.446
70	222 T6/II	0.136	0.313	1.386	0.225	2.060	13.586	11.526	15.164
71	223 T6/III	0.148	0.326	1.233	0.135	1.841	12.356	10.515	14.903
72	224 T6/IV	0.182	0.444	1.200	0.135	1.962	12.784	10.822	15.346
73	225 T7/I	0.172	0.288	1.276	0.228	1.964	12.475	10.511	15.747
74	226 T7/II	0.175	0.362	1.233	0.312	2.082	12.354	10.272	16.854
75	227 T7/III	0.137	0.305	1.028	0.204	1.675	10.254	8.579	16.331
76	228 T7/IV	0.113	0.428	1.433	0.185	2.159	14.330	12.171	15.066
77	229 T8/I	0.114	0.178	1.525	0.271	2.088	15.265	13.177	13.680
78	230 T8/II	0.139	0.260	1.917	0.342	2.658	19.170	16.512	13.865
79	231 T8/III	0.187	0.260	1.530	0.225	2.202	15.265	13.063	14.424
80	232 T8/IV	0.240	0.387	1.630	0.213	2.470	14.250	11.780	17.335
81	233 T9/I	0.165	0.284	1.600	0.250	2.299	16.250	13.951	14.150
82	234 T9/II	0.109	0.085	1.991	0.260	2.445	19.985	17.540	12.233
83	235 T9/III	0.269	0.350	1.725	0.258	2.602	17.256	14.654	15.078
84	236 T9/IV	0.175	0.260	1.826	0.225	2.486	18.261	15.775	13.616
85	237 T10/I	0.232	0.334	0.985	0.125	1.676	12.560	10.884	13.342
86	238 T10/II	0.168	0.223	1.252	0.228	1.871	16.600	14.729	11.272
87	239 T10/III	0.234	0.375	1.099	0.228	1.936	18.100	16.164	10.696
88	240 T10/IV	0.177	0.395	1.166	0.225	1.963	18.200	16.237	10.787
89	241 T11/I	0.186	0.297	1.240	0.160	1.883	12.546	10.663	15.010
90	242 T11/II	0.118	0.346	1.230	0.260	1.954	12.256	10.302	15.943
91	243 T11/III	0.092	0.330	1.174	0.291	1.887	11.658	9.771	16.183
92	244 T11/IV	0.273	0.342	1.842	0.174	2.631	11.584	8.953	22.711
93	245 T12/I	0.114	0.297	0.700	0.098	1.209	8.256	7.047	14.646
94	246 T12/II	0.148	0.256	0.900	0.150	1.454	9.568	8.114	15.192
95	247 T12/III	0.131	0.371	1.123	0.120	1.745	11.564	9.819	15.088
96	248 T12/IV	0.228	0.366	0.930	0.122	1.646	9.325	7.679	17.651
97	301 T1/I	0.071	0.125	0.936	0.225	1.357	9.560	8.203	14.191

98	302 T1/II	0.071	0.112	1.005	0.120	1.308	10.560	9.252	12.390
99	303 T1/III	0.085	0.225	1.064	0.125	1.499	11.560	10.061	12.965
100	304 T1/IV	0.071	0.255	1.020	0.225	1.571	12.560	10.989	12.510
101	305 T2/I	0.071	0.154	1.125	0.210	1.561	10.250	8.689	15.225
102	306 T2/II	0.075	0.252	1.048	0.125	1.500	12.560	11.060	11.943
103	307 T2/III	0.094	0.257	1.354	0.126	1.831	13.560	11.729	13.504
104	308 T2/IV	0.102	0.255	1.665	0.143	2.165	15.560	13.395	13.914
105	309 T3/I	0.071	0.137	0.835	0.165	1.209	9.560	8.351	12.642
106	310 T3/II	0.075	0.321	0.925	0.256	1.577	10.250	8.673	15.389
107	311 T3/III	0.064	0.258	1.193	0.146	1.661	8.256	6.595	20.124
108	312 T3/IV	0.065	0.266	1.200	0.110	1.641	11.250	9.609	14.585
109	313 T4/I	0.064	0.225	1.091	0.120	1.500	10.250	8.750	14.636
110	314 T4/II	0.062	0.125	0.856	0.204	1.248	8.256	7.008	15.114
111	315 T4/III	0.064	0.266	1.125	0.142	1.597	8.250	6.653	19.358
112	316 T4/IV	0.062	0.246	1.025	0.257	1.590	7.154	5.564	22.223
113	317 T5/I	0.075	0.125	1.174	0.125	1.498	8.263	6.765	18.134
114	318 T5/II	0.074	0.215	0.914	0.124	1.328	9.256	7.928	14.345
115	319 T5/III	0.074	0.215	1.024	0.124	1.436	9.254	7.818	15.522
116	320 T5/IV	0.076	0.226	1.744	0.124	2.170	12.365	10.195	17.546
117	321 T6/I	0.064	0.250	0.777	0.124	1.215	7.147	5.932	16.997
118	322 T6/II	0.071	0.212	0.952	0.289	1.524	9.568	8.044	15.928
119	323 T6/III	0.085	0.255	1.109	0.124	1.573	14.263	12.690	11.029
120	324 T6/IV	0.062	0.251	1.154	0.204	1.672	10.250	8.578	16.310
121	325 T7/I	0.064	0.252	1.124	0.124	1.564	11.250	9.686	13.902
122	326 T7/II	0.062	0.256	1.122	0.215	1.656	8.564	6.908	19.334
123	327 T7/III	0.071	0.216	1.374	0.124	1.786	7.560	5.775	23.618
124	328 T7/IV	0.075	0.226	1.276	0.124	1.701	10.250	8.549	16.595
125	329 T8/I	0.064	0.125	1.111	0.214	1.513	12.250	10.737	12.353
126	330 T8/II	0.087	0.248	1.125	0.241	1.701	13.210	11.510	12.873
127	331 T8/III	0.062	0.154	1.532	0.256	2.004	11.250	9.246	17.813
128	332 T8/IV	0.065	0.225	1.423	0.214	1.927	12.120	10.193	15.897
129	333 T9/I	0.062	0.124	1.625	0.262	2.073	16.560	14.488	12.515
130	334 T9/II	0.086	0.125	1.429	0.244	1.883	13.564	11.681	13.885
131	335 T9/III	0.074	0.125	1.525	0.214	1.937	14.568	12.631	13.296
132	336 T9/IV	0.108	0.259	1.225	0.225	1.817	17.560	15.743	10.347
133	337 T10/I	0.064	0.236	1.370	0.165	1.836	13.745	11.909	13.355
134	338 T10/II	0.075	0.125	1.508	0.208	1.917	12.150	10.233	15.774
135	339 T10/III	0.102	0.259	1.225	0.125	1.711	10.680	8.969	16.018
136	340 T10/IV	0.095	0.222	1.255	0.122	1.694	10.256	8.562	16.517
137	341 T11/I	0.075	0.249	1.352	0.224	1.900	13.256	11.356	14.331
138	342 T11/II	0.087	0.246	1.229	0.146	1.707	12.263	10.556	13.922
139	343 T11/III	0.074	0.259	1.325	0.149	1.807	13.265	11.458	13.623
140	344 T11/IV	0.093	0.257	1.266	0.212	1.828	12.656	10.828	14.442
141	345 T12/I	0.064	0.269	1.125	0.124	1.582	11.253	9.671	14.060
142	346 T12/II	0.075	0.215	0.900	0.125	1.315	9.564	8.249	13.748
143	347 T12/III	0.075	0.126	0.700	0.123	1.024	7.562	6.538	13.540
144	348 T12/IV	0.086	0.226	1.076	0.124	1.512	10.647	9.135	14.197

APPENDIX : III
Different forms of Manganese in LTFE experimental soils of 1st, 4th and 8th cycles of groundnut and wheat crop sequence

Sr. no.	Treatment	WSF	EF	AF	RF	AV. TOTAL	TOTAL	RESIDUAL	% AV.
1	101 T1/I	0.585	3.041	5.291	44.05	52.96	230	177.19	23.012
2	102 T1/II	0.475	2.185	5.030	43.75	51.44	235	183.68	21.878
3	103 T1/III	0.574	2.397	4.939	47.28	55.19	236	180.37	23.431
4	104 T1/IV	0.487	1.747	5.414	44.70	52.35	240	187.90	21.791
5	105 T2/I	0.335	2.017	7.922	43.16	53.43	230	176.80	23.207
6	106 T2/II	0.458	1.738	4.931	44.79	51.91	245	193.54	21.151
7	107 T2/III	0.580	3.265	4.982	45.94	54.77	226	170.79	24.280
8	108 T2/IV	0.568	3.096	6.071	45.20	54.94	235	180.21	23.364
9	109 T3/I	0.568	3.403	9.440	44.40	57.81	234	176.42	24.683
10	110 T3/II	0.568	2.064	5.749	46.18	54.56	245	190.67	22.249
11	111 T3/III	0.545	3.580	3.784	44.73	52.64	215	162.59	24.458
12	112 T3/IV	0.315	3.104	5.311	44.08	52.81	240	187.31	21.995
13	113 T4/I	0.568	4.447	6.559	46.31	57.88	255	197.35	22.679
14	114 T4/II	0.568	4.073	4.380	44.50	53.52	255	201.90	20.955
15	115 T4/III	0.475	4.500	5.583	45.36	55.92	242	186.23	23.092
16	116 T4/IV	0.325	4.650	6.692	45.33	57.00	247	190.12	23.067
17	117 T5/I	0.547	3.461	4.652	44.06	52.72	248	195.51	21.237
18	118 T5/II	0.556	1.194	6.514	46.56	54.82	246	190.74	22.325
19	119 T5/III	0.584	3.806	5.782	44.18	54.35	256	201.90	21.211
20	120 T5/IV	0.448	2.152	5.100	44.87	52.57	235	182.64	22.349
21	121 T6/I	0.568	2.350	5.354	48.36	56.63	256	199.60	22.103
22	122 T6/II	0.558	1.423	5.407	45.55	52.94	245	192.18	21.598
23	123 T6/III	0.425	3.465	6.380	46.94	57.21	235	178.02	24.321
24	124 T6/IV	0.314	2.146	5.711	45.34	53.52	256	202.71	20.886
25	125 T7/I	0.585	2.366	8.745	45.70	57.39	246	188.17	23.371
26	126 T7/II	0.521	2.065	4.549	46.07	53.20	256	202.36	20.818
27	127 T7/III	0.525	3.894	5.465	44.37	54.26	261	206.30	20.823
28	128 T7/IV	0.518	2.525	7.525	45.32	55.88	266	209.98	21.020
29	129 T8/I	0.525	2.793	5.797	45.55	54.67	266	210.89	20.585
30	130 T8/II	0.514	1.560	4.786	44.19	51.05	261	210.18	19.541
31	131 T8/III	0.445	1.992	7.508	47.60	57.54	266	208.02	21.668
32	132 T8/IV	0.568	1.718	7.510	44.36	54.15	248	193.41	21.875
33	133 T9/I	0.547	2.563	8.745	43.99	55.85	269	212.71	20.796
34	134 T9/II	0.314	3.255	8.450	45.05	57.07	270	213.38	21.101
35	135 T9/III	0.348	2.082	8.091	45.74	56.26	256	199.30	22.015
36	136 T9/IV	0.354	2.140	7.902	46.38	56.78	266	208.78	21.380
37	137 T10/I	0.365	2.222	6.207	44.68	53.47	246	192.09	21.774
38	138 T10/II	0.568	2.613	4.471	44.56	52.21	256	204.02	20.377
39	139 T10/III	0.254	1.411	5.261	45.97	52.89	255	202.23	20.732
40	140 T10/IV	0.335	1.653	6.325	46.81	55.12	246	190.41	22.450
41	141 T11/I	0.548	2.192	6.340	44.61	53.69	240	186.56	22.346
42	142 T11/II	0.335	1.462	5.674	45.05	52.52	246	193.04	21.387
43	143 T11/III	0.254	1.604	8.272	43.78	53.91	245	191.32	21.984
44	144 T11/IV	0.258	1.264	8.360	46.60	56.48	230	173.75	24.533
45	145 T12/I	0.568	2.275	3.520	42.42	48.78	235	186.64	20.722
46	146 T12/II	0.325	1.585	3.741	43.82	49.48	245	195.84	20.168

47	147 T12/III	0.324	1.204	7.257	45.78	54.57	239	183.99	22.873
48	148 T12/IV	0.315	1.625	5.235	46.07	53.24	235	181.99	22.634
49	201 T1/I	0.314	1.502	6.060	44.70	52.58	226	172.98	23.311
50	202 T1/II	0.245	1.661	5.656	44.11	51.67	238	185.83	21.758
51	203 T1/III	0.345	1.800	6.610	43.75	52.50	235	182.75	22.319
52	204 T1/IV	0.345	1.706	5.256	44.91	52.22	232	180.03	22.482
53	205 T2/I	0.229	1.929	5.235	45.20	52.60	238	184.96	22.141
54	206 T2/II	0.325	1.684	6.567	45.73	54.31	230	175.81	23.600
55	207 T2/III	0.302	3.155	5.856	44.79	54.10	230	176.02	23.510
56	208 T2/IV	0.236	2.136	5.562	43.33	51.27	237	185.25	21.675
57	209 T3/I	0.252	3.253	5.650	44.08	53.24	234	180.99	22.729
58	210 T3/II	0.352	2.996	5.538	45.56	54.45	235	180.76	23.148
59	211 T3/III	0.325	3.511	8.031	46.18	58.05	226	167.51	25.735
60	212 T3/IV	0.235	3.095	5.362	45.95	54.64	221	165.92	24.773
61	213 T4/I	0.256	1.256	5.235	45.33	52.08	232	180.17	22.425
62	214 T4/II	0.354	2.560	5.125	43.98	52.02	230	177.83	22.633
63	215 T4/III	0.254	1.440	5.263	44.50	51.46	227	175.28	22.695
64	216 T4/IV	0.235	1.006	5.125	47.83	54.19	226	171.32	24.031
65	217 T5/I	0.326	1.651	5.969	44.87	52.81	230	177.33	22.948
66	218 T5/II	0.426	1.092	5.321	45.94	52.78	238	185.24	22.174
67	219 T5/III	0.354	1.564	5.861	46.56	54.34	235	180.16	23.172
68	220 T5/IV	0.352	1.132	5.484	45.66	52.63	233	179.88	22.634
69	221 T6/I	0.235	2.146	5.264	45.34	52.99	234	181.24	22.623
70	222 T6/II	0.326	1.210	4.980	46.32	52.83	230	177.04	22.984
71	223 T6/III	0.235	1.428	5.415	45.55	52.63	234	181.49	22.480
72	224 T6/IV	0.236	1.140	4.991	43.83	50.19	227	176.35	22.157
73	225 T7/I	0.568	1.278	6.641	45.32	53.80	223	169.20	24.127
74	226 T7/II	0.254	1.450	6.632	44.95	53.29	245	192.02	21.723
75	227 T7/III	0.234	1.260	7.300	46.07	54.86	234	179.35	23.424
76	228 T7/IV	0.356	1.470	5.866	43.48	51.17	214	163.08	23.882
77	229 T8/I	0.365	2.403	6.248	44.36	53.37	241	187.86	22.126
78	230 T8/II	0.425	2.569	6.412	44.66	54.07	235	181.40	22.962
79	231 T8/III	0.468	1.925	5.293	44.19	51.87	238	186.54	21.758
80	232 T8/IV	0.442	1.618	5.901	45.21	53.17	232	178.34	22.968
81	233 T9/I	0.458	3.468	7.927	46.38	58.23	246	187.33	23.714
82	234 T9/II	0.354	3.165	7.256	46.57	57.34	249	191.22	23.070
83	235 T9/III	0.335	3.036	7.054	47.57	57.99	247	189.13	23.468
84	236 T9/IV	0.231	3.265	7.256	47.27	58.02	252	194.21	23.003
85	237 T10/I	0.235	1.002	4.745	46.81	52.79	225	172.44	23.439
86	238 T10/II	0.235	3.599	8.446	46.16	58.44	235	176.68	24.856
87	239 T10/III	0.326	1.284	5.206	44.56	51.38	234	182.74	21.945
88	240 T10/IV	0.245	2.360	5.519	46.22	54.35	235	180.86	23.106
89	241 T11/I	0.389	2.016	7.474	46.60	56.48	234	177.67	24.121
90	242 T11/II	0.385	1.365	7.142	45.66	54.55	227	172.31	24.045
91	243 T11/III	0.352	1.515	5.817	45.05	52.73	235	182.74	22.394
92	244 T11/IV	0.365	1.256	5.161	47.27	54.05	228	174.18	23.684
93	245 T12/I	0.235	1.850	5.757	46.07	53.91	215	161.51	25.025
94	246 T12/II	0.254	1.525	5.696	44.87	52.34	231	179.11	22.615
95	247 T12/III	0.245	1.155	5.364	43.82	50.59	232	181.33	21.813
96	248 T12/IV	0.235	1.430	5.416	43.93	51.01	238	187.11	21.423
97	301 T1/I	0.841	2.357	5.356	45.54	54.09	220	166.14	24.562
98	302 T1/II	0.916	1.600	7.572	44.05	54.13	215	161.10	25.152

99	303 T1/III	0.702	1.426	7.378	45.17	54.68	228	173.55	23.957
100	304 T1/IV	0.715	1.551	7.120	47.28	56.67	240	183.58	23.588
101	305 T2/I	0.725	2.297	5.235	45.88	54.14	242	187.86	22.371
102	306 T2/II	0.872	1.297	7.405	43.16	52.73	214	161.27	24.639
103	307 T2/III	0.775	1.412	7.145	43.76	53.09	216	162.47	24.628
104	308 T2/IV	0.705	1.558	7.890	45.94	56.09	232	176.05	24.163
105	309 T3/I	0.814	1.374	6.713	45.18	54.08	198	144.17	27.280
106	310 T3/II	0.926	1.230	6.363	44.40	52.92	215	162.50	24.567
107	311 T3/III	0.752	1.367	5.041	47.70	54.86	240	185.35	22.839
108	312 T3/IV	0.648	1.822	6.120	44.73	53.32	242	188.93	22.011
109	313 T4/I	0.882	1.267	7.180	46.89	56.22	245	189.01	22.925
110	314 T4/II	0.899	1.752	7.449	46.31	56.41	230	173.84	24.500
111	315 T4/III	0.807	1.504	5.256	46.03	53.59	235	181.64	22.784
112	316 T4/IV	0.747	1.170	5.410	45.36	52.69	252	199.52	20.890
113	317 T5/I	0.822	1.685	7.118	46.79	56.41	247	190.84	22.816
114	318 T5/II	0.929	1.367	7.365	44.06	53.72	225	171.74	23.825
115	319 T5/III	0.732	1.362	7.066	48.06	57.22	231	174.03	24.742
116	320 T5/IV	0.708	1.725	6.016	44.18	52.63	215	162.62	24.450
117	321 T6/I	0.804	1.180	6.998	49.84	58.82	215	156.41	27.331
118	322 T6/II	0.824	0.929	5.846	48.36	55.96	230	174.29	24.304
119	323 T6/III	0.742	1.812	7.711	48.56	58.83	235	176.43	25.004
120	324 T6/IV	0.755	1.200	7.305	46.94	56.20	234	178.05	23.992
121	325 T7/I	0.840	1.031	6.560	48.64	57.07	245	188.19	23.268
122	326 T7/II	0.909	1.110	7.071	45.70	54.79	256	201.44	21.381
123	327 T7/III	0.765	1.280	7.599	45.02	54.66	235	180.60	23.235
124	328 T7/IV	0.755	1.533	6.941	44.37	53.60	236	182.05	22.747
125	329 T8/I	0.742	1.678	7.944	47.26	57.62	214	156.61	26.896
126	330 T8/II	0.834	1.225	8.373	47.00	57.43	266	208.13	21.627
127	331 T8/III	0.752	1.772	8.757	46.23	57.51	256	198.81	22.438
128	332 T8/IV	0.740	1.814	8.294	47.60	58.45	245	186.80	23.832
129	333 T9/I	0.837	2.516	8.844	44.54	56.74	270	213.51	20.995
130	334 T9/II	0.852	2.327	8.687	43.99	55.86	260	204.37	21.465
131	335 T9/III	0.844	2.658	9.441	44.25	57.19	248	191.13	23.032
132	336 T9/IV	0.688	1.494	8.202	45.74	56.12	246	189.44	22.855
133	337 T10/I	0.924	1.302	7.710	47.66	57.60	230	172.60	25.020
134	338 T10/II	0.792	1.090	7.549	44.68	54.11	235	181.10	23.003
135	339 T10/III	0.715	2.028	7.384	44.91	55.04	241	186.16	22.818
136	340 T10/IV	0.735	1.377	7.503	45.97	55.58	215	159.63	25.826
137	341 T11/I	0.862	1.297	5.757	47.64	55.56	215	159.67	25.814
138	342 T11/II	0.772	1.727	7.750	44.61	54.85	228	173.27	24.046
139	343 T11/III	0.755	1.320	7.760	45.96	55.80	214	158.43	26.045
140	344 T11/IV	0.720	1.208	5.568	43.78	51.28	221	169.28	23.249
141	345 T12/I	0.896	0.944	5.125	45.23	52.20	208	155.80	25.096
142	346 T12/II	0.767	1.725	5.012	42.42	49.93	199	148.63	25.144
143	347 T12/III	0.712	1.200	5.014	47.42	54.35	205	151.07	26.457
144	348 T12/IV	0.708	1.076	7.352	45.78	54.92	201	146.31	27.291

APPENDIX : IV

Different forms of Zinc in LTFE experimental soils of 1st, 4th and 8th cycles of groundnut and wheat crop sequence

Sr. no.	Treatment	WSF	EF	AF	RF	AV. TOTAL	TOTAL	RESIDUAL	% AV.
1	101 T1/I	0.114	0.252	1.312	0.66	2.34	30.25	27.91	7.723
2	102 T1/II	0.125	0.224	0.949	0.59	1.89	33.25	31.36	5.676
3	103 T1/III	0.115	0.197	0.967	0.65	1.93	32.86	30.92	5.878
4	104 T1/IV	0.125	0.191	0.689	0.86	1.86	32.56	30.70	5.715
5	105 T2/I	0.125	0.136	0.930	0.36	1.55	34.56	33.01	4.476
6	106 T2/II	0.114	0.169	0.634	0.57	1.49	33.56	32.08	4.426
7	107 T2/III	0.115	0.110	0.888	0.31	1.43	34.25	32.82	4.165
8	108 T2/IV	0.115	0.142	0.824	0.60	1.68	34.65	32.98	4.837
9	109 T3/I	0.115	0.125	0.937	0.52	1.70	34.26	32.56	4.965
10	110 T3/II	0.170	0.226	0.641	0.35	1.39	36.25	34.86	3.838
11	111 T3/III	0.114	0.125	0.876	0.52	1.64	34.56	32.92	4.743
12	112 T3/IV	0.124	0.108	0.850	0.53	1.61	33.13	31.52	4.851
13	113 T4/I	0.158	0.298	1.008	0.24	1.70	31.26	29.56	5.438
14	114 T4/II	0.177	0.187	1.635	0.37	2.36	35.87	33.51	6.590
15	115 T4/III	0.174	0.180	1.804	0.22	2.37	34.57	32.20	6.865
16	116 T4/IV	0.174	0.138	1.777	0.33	2.41	29.57	27.15	8.164
17	117 T5/I	0.115	0.156	0.744	0.45	1.47	31.26	29.79	4.693
18	118 T5/II	0.176	0.102	0.732	0.57	1.57	33.56	31.99	4.692
19	119 T5/III	0.115	0.092	0.864	0.55	1.62	32.85	31.22	4.940
20	120 T5/IV	0.115	0.120	0.689	0.35	1.27	35.26	33.99	3.604
21	121 T6/I	0.115	0.204	0.858	0.46	1.64	36.54	34.91	4.474
22	122 T6/II	0.114	0.113	0.696	0.45	1.37	34.58	33.21	3.955
23	123 T6/III	0.112	0.137	0.634	0.34	1.22	36.15	34.92	3.388
24	124 T6/IV	0.112	0.136	0.738	0.34	1.33	38.13	36.80	3.482
25	125 T7/I	0.109	0.176	0.832	0.46	1.57	33.56	31.99	4.691
26	126 T7/II	0.109	0.125	0.648	0.52	1.41	33.56	32.15	4.191
27	127 T7/III	0.110	0.163	0.675	0.65	1.60	30.25	28.65	5.289
28	128 T7/IV	0.110	0.155	0.849	0.25	1.37	34.25	32.88	3.995
29	129 T8/I	0.116	0.190	0.650	0.25	1.20	35.25	34.05	3.414
30	130 T8/II	0.115	0.190	0.697	0.21	1.22	38.56	37.34	3.154
31	131 T8/III	0.116	0.191	0.524	0.35	1.18	34.56	33.38	3.423
32	132 T8/IV	0.127	0.100	0.778	0.30	1.31	37.58	36.27	3.480
33	133 T9/I	0.115	0.195	0.751	0.56	1.62	40.26	38.64	4.021
34	134 T9/II	0.185	0.190	0.756	0.42	1.55	39.59	38.04	3.906
35	135 T9/III	0.155	0.146	0.890	0.56	1.75	38.56	36.81	4.536
36	136 T9/IV	0.115	0.144	0.938	0.48	1.67	36.65	34.98	4.562
37	137 T10/I	0.115	0.120	0.711	0.30	1.24	31.25	30.01	3.981
38	138 T10/II	0.111	0.114	0.580	0.24	1.04	36.23	35.19	2.871
39	139 T10/III	0.121	0.128	1.403	0.33	1.98	34.25	32.27	5.771
40	140 T10/IV	0.177	0.125	0.784	0.37	1.45	38.25	36.80	3.794
41	141 T11/I	0.127	0.176	0.948	0.55	1.80	34.22	32.41	5.271
42	142 T11/II	0.106	0.097	0.566	0.52	1.29	35.24	33.94	3.670
43	143 T11/III	0.106	0.189	0.856	0.34	1.49	35.13	33.64	4.229
44	144 T11/IV	0.170	0.108	1.237	0.33	1.84	33.25	31.41	5.534
45	145 T12/I	0.112	0.226	0.975	0.31	1.62	33.21	31.59	4.893
46	146 T12/II	0.101	0.160	0.639	0.36	1.26	29.56	28.30	4.250

47	147 T12/III	0.131	0.149	0.817	0.33	1.43	32.25	30.82	4.437
48	148 T12/IV	0.135	0.195	1.010	0.33	1.67	31.24	29.57	5.332
49	201 T1/I	0.154	0.155	1.237	0.21	1.76	31.56	29.80	5.563
50	202 T1/II	0.147	0.110	1.390	0.22	1.87	32.56	30.69	5.735
51	203 T1/III	0.121	0.125	1.746	0.21	2.20	31.56	29.36	6.973
52	204 T1/IV	0.174	0.115	1.612	0.21	2.12	33.56	31.45	6.303
53	205 T2/I	0.137	0.102	1.355	0.36	1.95	36.13	34.17	5.406
54	206 T2/II	0.092	0.120	1.200	0.36	1.77	30.26	28.48	5.855
55	207 T2/III	0.115	0.128	0.934	0.43	1.60	30.26	28.65	5.294
56	208 T2/IV	0.102	0.107	0.842	0.33	1.38	33.56	32.18	4.115
57	209 T3/I	0.147	0.081	0.853	0.38	1.46	32.56	31.10	4.476
58	210 T3/II	0.125	0.051	0.564	0.37	1.11	32.56	31.45	3.396
59	211 T3/III	0.113	0.112	0.734	0.27	1.23	32.58	31.35	3.779
60	212 T3/IV	0.103	0.165	0.796	0.36	1.43	31.55	30.12	4.529
61	213 T4/I	0.137	0.225	1.289	0.58	2.23	33.56	31.33	6.646
62	214 T4/II	0.150	0.225	1.931	0.55	2.86	31.56	28.71	9.048
63	215 T4/III	0.117	0.214	0.931	0.53	1.79	32.56	30.77	5.503
64	216 T4/IV	0.108	0.226	0.877	0.45	1.66	32.85	31.18	5.058
65	217 T5/I	0.087	0.126	0.923	0.32	1.46	35.64	34.18	4.095
66	218 T5/II	0.134	0.104	0.998	0.37	1.61	30.26	28.65	5.317
67	219 T5/III	0.151	0.163	1.098	0.37	1.78	31.48	29.70	5.664
68	220 T5/IV	0.178	0.041	0.880	0.25	1.35	30.26	28.91	4.446
69	221 T6/I	0.090	0.127	1.062	0.36	1.64	32.25	30.61	5.080
70	222 T6/II	0.180	0.116	1.228	0.51	2.03	33.55	31.51	6.063
71	223 T6/III	0.096	0.121	0.949	0.56	1.72	32.56	30.84	5.290
72	224 T6/IV	0.093	0.085	1.125	0.38	1.68	34.51	32.83	4.864
73	225 T7/I	0.182	0.110	0.878	0.24	1.41	32.46	31.04	4.353
74	226 T7/II	0.135	0.156	1.992	0.45	2.73	33.56	30.84	8.127
75	227 T7/III	0.101	0.123	0.912	0.32	1.46	30.25	28.79	4.823
76	228 T7/IV	0.093	0.135	0.782	0.37	1.38	34.57	33.18	4.004
77	229 T8/I	0.119	0.150	1.248	0.24	1.76	35.64	33.88	4.928
78	230 T8/II	0.170	0.151	1.157	0.31	1.79	37.46	35.67	4.768
79	231 T8/III	0.095	0.108	0.916	0.32	1.44	35.22	33.77	4.092
80	232 T8/IV	0.109	0.160	0.990	0.26	1.52	34.26	32.74	4.430
81	233 T9/I	0.160	0.198	1.263	0.51	2.13	37.56	35.43	5.678
82	234 T9/II	0.123	0.193	1.812	0.54	2.66	39.15	36.49	6.802
83	235 T9/III	0.180	0.131	1.218	0.48	2.01	37.54	35.53	5.349
84	236 T9/IV	0.174	0.100	1.512	0.43	2.22	38.54	36.32	5.750
85	237 T10/I	0.095	0.110	0.748	0.36	1.31	32.56	31.26	4.018
86	238 T10/II	0.159	0.095	1.133	0.47	1.86	33.26	31.40	5.584
87	239 T10/III	0.102	0.117	0.852	0.26	1.33	32.56	31.23	4.082
88	240 T10/IV	0.103	0.092	0.714	0.23	1.14	33.22	32.07	3.438
89	241 T11/I	0.095	0.156	0.862	0.27	1.38	32.56	31.18	4.238
90	242 T11/II	0.093	0.124	0.798	0.32	1.34	31.25	29.91	4.287
91	243 T11/III	0.093	0.154	0.670	0.20	1.12	32.56	31.44	3.444
92	244 T11/IV	0.112	0.148	0.714	0.21	1.19	33.22	32.03	3.575
93	245 T12/I	0.096	0.110	0.896	0.21	1.31	28.56	27.25	4.585
94	246 T12/II	0.124	0.100	0.522	0.19	0.93	30.25	29.32	3.080
95	247 T12/III	0.138	0.110	0.823	0.22	1.29	31.25	29.95	4.136
96	248 T12/IV	0.097	0.110	0.747	0.23	1.19	31.22	30.03	3.798
97	301 T1/I	0.095	0.122	0.700	2.40	3.32	29.56	26.24	11.221
98	302 T1/II	0.148	0.175	1.052	1.18	2.56	30.26	27.70	8.445

99	303 T1/III	0.178	0.205	1.225	1.14	2.74	31.55	28.80	8.699
100	304 T1/IV	0.087	0.156	1.352	1.47	3.07	30.86	27.80	9.936
101	305 T2/I	0.078	0.206	1.576	2.02	3.88	31.54	27.66	12.296
102	306 T2/II	0.135	0.175	1.549	1.19	3.05	32.55	29.50	9.365
103	307 T2/III	0.134	0.145	1.405	1.21	2.90	33.42	30.52	8.675
104	308 T2/IV	0.124	0.125	1.315	1.33	2.90	34.18	31.28	8.479
105	309 T3/I	0.176	0.156	0.642	1.45	2.42	29.56	27.14	8.196
106	310 T3/II	0.147	0.111	1.360	1.25	2.86	30.12	27.26	9.506
107	311 T3/III	0.147	0.145	1.104	1.11	2.51	28.47	25.96	8.801
108	312 T3/IV	0.121	0.125	2.037	1.24	3.53	31.25	27.73	11.280
109	313 T4/I	0.147	0.156	2.063	2.13	4.50	31.47	26.97	14.288
110	314 T4/II	0.093	0.221	1.938	1.89	4.14	27.15	23.01	15.254
111	315 T4/III	0.092	0.175	2.563	2.47	5.30	31.43	26.12	16.874
112	316 T4/IV	0.115	0.190	2.141	2.39	4.84	30.15	25.31	16.054
113	317 T5/I	0.092	0.149	1.145	1.67	3.05	31.25	28.20	9.773
114	318 T5/II	0.119	0.142	1.573	1.22	3.06	29.55	26.49	10.345
115	319 T5/III	0.145	0.146	1.250	1.29	2.83	31.46	28.62	9.009
116	320 T5/IV	0.088	0.105	1.681	1.17	3.05	33.21	30.17	9.177
117	321 T6/I	0.172	0.126	1.703	2.95	4.96	29.56	24.61	16.761
118	322 T6/II	0.178	0.256	2.547	1.33	4.31	29.56	25.26	14.566
119	323 T6/III	0.124	0.148	2.314	1.24	3.83	34.79	30.96	11.000
120	324 T6/IV	0.082	0.182	2.027	1.22	3.51	31.22	27.71	11.239
121	325 T7/I	0.172	0.123	1.856	1.21	3.37	31.46	28.09	10.697
122	326 T7/II	0.095	0.159	2.586	1.23	4.07	30.56	26.49	13.314
123	327 T7/III	0.134	0.179	1.266	1.15	2.73	31.85	29.12	8.575
124	328 T7/IV	0.151	0.169	1.014	1.11	2.44	32.55	30.10	7.504
125	329 T8/I	0.134	0.186	2.142	1.52	3.98	28.56	24.58	13.932
126	330 T8/II	0.098	0.165	2.216	1.36	3.84	31.47	27.63	12.198
127	331 T8/III	0.135	0.156	1.612	1.19	3.10	32.58	29.49	9.500
128	332 T8/IV	0.096	0.185	2.514	1.29	4.08	34.16	30.07	11.955
129	333 T9/I	0.170	0.256	2.222	1.87	4.51	36.22	31.70	12.466
130	334 T9/II	0.096	0.256	2.945	1.49	4.79	33.55	28.76	14.273
131	335 T9/III	0.135	0.326	3.127	1.52	5.11	33.46	28.35	15.269
132	336 T9/IV	0.101	0.225	2.356	1.39	4.08	37.15	33.07	10.974
133	337 T10/I	0.177	0.132	1.212	1.47	2.99	33.56	30.57	8.918
134	338 T10/II	0.147	0.136	1.593	1.21	3.09	32.55	29.46	9.494
135	339 T10/III	0.174	0.235	1.841	1.12	3.37	37.15	33.78	9.080
136	340 T10/IV	0.092	0.125	0.887	1.01	2.12	30.15	28.03	7.020
137	341 T11/I	0.175	0.056	1.018	1.10	2.35	33.15	30.79	7.100
138	342 T11/II	0.092	0.125	2.143	1.72	4.08	31.15	27.07	13.089
139	343 T11/III	0.093	0.156	1.924	1.14	3.31	30.22	26.90	10.967
140	344 T11/IV	0.147	0.212	0.922	1.07	2.35	31.25	28.90	7.517
141	345 T12/I	0.134	0.136	1.098	1.29	2.66	31.25	28.59	8.508
142	346 T12/II	0.142	0.125	1.091	1.16	2.52	29.56	27.04	8.520
143	347 T12/III	0.159	0.112	1.585	1.28	3.14	27.55	24.41	11.383
144	348 T12/IV	0.102	0.125	1.084	1.03	2.34	30.13	27.79	7.758

APPENDIX : V
Different forms of Ferrous in LTFE experimental soils of 1st, 4th and 8th cycles of groundnut and wheat crop sequence

Sr. no.	Treatment	WSF	EF	AF	RF	AV. TOTAL	TOTAL	RESIDUAL	% AV.
1	101 T1/I	0.039	0.024	4.163	13.09	17.32	25250	25232.68	0.069
2	102 T1/II	0.034	0.024	3.535	8.37	11.96	28250	28238.04	0.042
3	103 T1/III	0.045	0.033	3.143	8.27	11.49	27856	27844.51	0.041
4	104 T1/IV	0.045	0.024	5.504	9.33	14.90	27561	27546.10	0.054
5	105 T2/I	0.052	0.035	4.384	12.01	16.48	29560	29543.52	0.056
6	106 T2/II	0.045	0.028	4.442	7.03	11.54	28562	28550.46	0.040
7	107 T2/III	0.048	0.026	4.648	10.24	14.96	29245	29230.04	0.051
8	108 T2/IV	0.052	0.040	4.197	10.25	14.54	29652	29637.46	0.049
9	109 T3/I	0.036	0.049	4.298	10.02	14.40	29256	29241.60	0.049
10	110 T3/II	0.058	0.034	4.648	8.02	12.76	31250	31237.24	0.041
11	111 T3/III	0.045	0.024	4.192	8.26	12.52	29561	29548.48	0.042
12	112 T3/IV	0.045	0.033	4.111	10.33	14.51	28125	28110.49	0.052
13	113 T4/I	0.036	0.017	5.614	8.23	13.90	26256	26242.10	0.053
14	114 T4/II	0.031	0.024	5.034	10.24	15.32	30869	30853.68	0.050
15	115 T4/III	0.038	0.021	6.357	6.33	12.74	29568	29555.26	0.043
16	116 T4/IV	0.035	0.026	5.728	7.25	13.04	24568	24554.96	0.053
17	117 T5/I	0.021	0.044	4.227	7.01	11.30	26256	26244.70	0.043
18	118 T5/II	0.021	0.024	4.056	6.24	10.34	28560	28549.66	0.036
19	119 T5/III	0.034	0.031	5.321	7.25	12.64	27845	27832.36	0.045
20	120 T5/IV	0.024	0.025	4.260	4.24	8.54	30256	30247.46	0.028
21	121 T6/I	0.022	0.041	4.534	7.01	11.61	31541	31529.39	0.037
22	122 T6/II	0.024	0.024	4.934	9.24	14.22	29581	29566.78	0.048
23	123 T6/III	0.027	0.031	4.594	6.24	10.89	31145	31134.11	0.035
24	124 T6/IV	0.035	0.031	5.994	6.33	12.39	33125	33112.61	0.037
25	125 T7/I	0.034	0.026	4.134	8.02	12.22	28560	28547.78	0.043
26	126 T7/II	0.032	0.020	3.585	9.24	12.87	28560	28547.13	0.045
27	127 T7/III	0.038	0.022	4.020	6.25	10.33	25250	25239.67	0.041
28	128 T7/IV	0.034	0.022	4.719	4.25	9.02	29250	29240.98	0.031
29	129 T8/I	0.022	0.032	3.706	8.07	11.82	30250	30238.18	0.039
30	130 T8/II	0.012	0.049	5.012	8.25	13.32	33560	33546.68	0.040
31	131 T8/III	0.023	0.044	4.662	7.26	11.99	29560	29548.01	0.041
32	132 T8/IV	0.047	0.032	6.067	8.13	14.27	32580	32565.73	0.044
33	133 T9/I	0.031	0.044	4.940	8.02	13.04	35256	35242.96	0.037
34	134 T9/II	0.044	0.022	4.698	8.24	13.00	34589	34576.00	0.038
35	135 T9/III	0.034	0.032	4.262	6.32	10.65	33564	33553.35	0.032
36	136 T9/IV	0.036	0.022	5.610	6.24	11.90	31654	31642.10	0.038
37	137 T10/I	0.033	0.032	5.464	8.02	13.55	26250	26236.45	0.052
38	138 T10/II	0.022	0.012	5.033	9.24	14.30	31230	31215.70	0.046
39	139 T10/III	0.024	0.013	5.850	7.33	13.21	29250	29236.79	0.045
40	140 T10/IV	0.022	0.021	5.247	9.25	14.54	33250	33235.46	0.044
41	141 T11/I	0.021	0.031	4.820	7.02	11.89	29215	29203.11	0.041
42	142 T11/II	0.025	0.032	5.006	9.25	14.32	30235	30220.68	0.047
43	143 T11/III	0.024	0.048	4.277	8.35	12.70	30125	30112.30	0.042
44	144 T11/IV	0.015	0.033	4.837	8.24	13.12	28254	28240.88	0.046
45	145 T12/I	0.034	0.027	4.123	11.35	15.54	28210	28194.46	0.055
46	146 T12/II	0.035	0.021	4.742	5.25	10.05	24560	24549.95	0.041

47	147 T12/III	0.046	0.027	4.402	6.33	10.80	27254	27243.20	0.040
48	148 T12/IV	0.045	0.021	4.666	6.33	11.06	26235	26223.94	0.042
49	201 T1/I	0.042	0.031	6.478	10.09	16.64	26560	26543.36	0.063
50	202 T1/II	0.032	0.033	5.152	8.36	13.57	27560	27546.43	0.049
51	203 T1/III	0.030	0.029	4.537	8.50	13.10	26560	26546.90	0.049
52	204 T1/IV	0.040	0.029	4.770	10.01	14.85	28561	28546.15	0.052
53	205 T2/I	0.038	0.021	6.530	10.48	17.07	31125	31107.93	0.055
54	206 T2/II	0.031	0.023	4.889	9.32	14.27	25256	25241.73	0.056
55	207 T2/III	0.032	0.041	4.626	12.00	16.70	25256	25239.30	0.066
56	208 T2/IV	0.028	0.027	5.863	10.09	16.01	28561	28544.99	0.056
57	209 T3/I	0.040	0.031	4.222	10.02	14.32	27561	27546.69	0.052
58	210 T3/II	0.033	0.024	4.748	7.04	11.85	27560	27548.15	0.043
59	211 T3/III	0.029	0.031	4.755	7.71	12.52	27584	27571.48	0.045
60	212 T3/IV	0.022	0.044	4.139	7.65	11.86	26546	26534.14	0.045
61	213 T4/I	0.035	0.024	4.748	7.15	11.95	28564	28552.05	0.042
62	214 T4/II	0.026	0.024	4.133	7.60	11.78	26564	26552.22	0.044
63	215 T4/III	0.029	0.022	4.735	5.60	10.39	27564	27553.61	0.038
64	216 T4/IV	0.042	0.051	5.876	5.63	11.60	27845	27833.40	0.042
65	217 T5/I	0.021	0.022	5.222	6.86	12.12	30641	30628.88	0.040
66	218 T5/II	0.024	0.024	4.915	4.31	9.27	25256	25246.73	0.037
67	219 T5/III	0.024	0.031	4.722	5.75	10.53	26478	26467.47	0.040
68	220 T5/IV	0.018	0.031	6.068	4.67	10.79	25256	25245.21	0.043
69	221 T6/I	0.021	0.022	5.671	5.46	11.17	27245	27233.83	0.041
70	222 T6/II	0.021	0.033	4.844	7.72	12.61	28548	28535.39	0.044
71	223 T6/III	0.035	0.032	4.639	4.07	8.78	27564	27555.23	0.032
72	224 T6/IV	0.025	0.022	6.306	5.04	11.40	29510	29498.60	0.039
73	225 T7/I	0.034	0.024	4.479	7.85	12.39	27457	27444.61	0.045
74	226 T7/II	0.026	0.021	4.819	8.20	13.07	28564	28550.93	0.046
75	227 T7/III	0.040	0.023	4.665	5.34	10.07	25254	25243.93	0.040
76	228 T7/IV	0.025	0.023	5.492	3.54	9.08	29568	29558.92	0.031
77	229 T8/I	0.032	0.022	5.254	8.40	13.71	30641	30627.29	0.045
78	230 T8/II	0.030	0.024	7.466	8.18	15.70	32458	32442.30	0.048
79	231 T8/III	0.045	0.038	5.011	6.67	11.76	30215	30203.24	0.039
80	232 T8/IV	0.024	0.025	6.972	4.11	11.13	29261	29249.87	0.038
81	233 T9/I	0.032	0.025	5.670	6.36	12.09	32564	32551.91	0.037
82	234 T9/II	0.035	0.021	7.132	6.65	13.83	34154	34140.17	0.041
83	235 T9/III	0.029	0.027	5.466	0.63	6.15	32541	32534.85	0.019
84	236 T9/IV	0.025	0.025	7.010	5.98	13.04	33541	33527.96	0.039
85	237 T10/I	0.043	0.025	4.588	6.42	11.08	27564	27552.92	0.040
86	238 T10/II	0.032	0.021	5.895	8.10	14.05	28256	28241.95	0.050
87	239 T10/III	0.045	0.035	5.004	8.17	13.26	27564	27550.74	0.048
88	240 T10/IV	0.032	0.032	6.267	8.93	15.26	28215	28199.74	0.054
89	241 T11/I	0.032	0.021	5.549	7.58	13.18	27564	27550.82	0.048
90	242 T11/II	0.042	0.031	5.754	8.08	13.91	26254	26240.09	0.053
91	243 T11/III	0.045	0.023	4.755	7.45	12.28	27564	27551.72	0.045
92	244 T11/IV	0.025	0.045	5.793	8.39	14.25	28215	28200.75	0.051
93	245 T12/I	0.042	0.027	5.004	6.53	11.60	23564	23552.40	0.049
94	246 T12/II	0.032	0.022	5.389	5.70	11.14	25251	25239.86	0.044
95	247 T12/III	0.044	0.015	4.500	5.47	10.03	26245	26234.97	0.038
96	248 T12/IV	0.031	0.026	5.177	4.66	9.89	26215	26205.11	0.038
97	301 T1/I	0.018	0.031	9.600	8.32	17.97	24560	24542.03	0.073
98	302 T1/II	0.030	0.031	8.664	7.32	16.04	25256	25239.96	0.064

99	303 T1/III	0.028	0.045	8.113	6.80	14.99	26546	26531.01	0.056
100	304 T1/IV	0.019	0.034	10.164	8.43	18.64	25864	25845.36	0.072
101	305 T2/I	0.012	0.024	9.330	8.41	17.77	26541	26523.23	0.067
102	306 T2/II	0.014	0.024	8.427	5.99	14.46	27548	27533.54	0.052
103	307 T2/III	0.014	0.029	8.484	6.82	15.35	28415	28399.65	0.054
104	308 T2/IV	0.032	0.031	6.786	8.02	14.87	29178	29163.13	0.051
105	309 T3/I	0.010	0.021	7.594	7.01	14.64	24561	24546.36	0.060
106	310 T3/II	0.014	0.031	7.120	5.55	12.71	25124	25111.29	0.051
107	311 T3/III	0.024	0.024	8.247	7.06	15.35	23467	23451.65	0.065
108	312 T3/IV	0.013	0.033	8.895	6.74	15.68	26254	26238.32	0.060
109	313 T4/I	0.027	0.036	7.299	6.18	13.55	26465	26451.46	0.051
110	314 T4/II	0.029	0.021	8.254	7.33	15.63	22154	22138.37	0.071
111	315 T4/III	0.029	0.034	8.754	6.08	14.90	26425	26410.10	0.056
112	316 T4/IV	0.032	0.038	10.170	7.37	17.61	25154	25136.39	0.070
113	317 T5/I	0.025	0.033	9.016	7.42	16.49	26254	26237.51	0.063
114	318 T5/II	0.025	0.043	8.299	5.86	14.23	24548	24533.77	0.058
115	319 T5/III	0.023	0.034	7.344	5.30	12.70	26458	26445.30	0.048
116	320 T5/IV	0.027	0.026	9.894	7.36	17.30	28214	28196.70	0.061
117	321 T6/I	0.033	0.031	8.459	6.40	14.92	24564	24549.08	0.061
118	322 T6/II	0.028	0.038	8.388	9.29	17.74	24564	24546.26	0.072
119	323 T6/III	0.025	0.041	8.645	6.58	15.29	29785	29769.71	0.051
120	324 T6/IV	0.038	0.049	9.536	9.43	19.06	26215	26195.94	0.073
121	325 T7/I	0.022	0.021	7.555	6.16	13.76	26458	26444.24	0.052
122	326 T7/II	0.033	0.026	8.760	5.29	14.11	25564	25549.89	0.055
123	327 T7/III	0.025	0.040	8.241	4.88	13.18	26847	26833.82	0.049
124	328 T7/IV	0.023	0.039	8.068	9.34	17.47	27546	27528.53	0.063
125	329 T8/I	0.025	0.034	8.433	6.77	15.27	23564	23548.73	0.065
126	330 T8/II	0.024	0.049	11.618	7.27	18.96	26468	26449.04	0.072
127	331 T8/III	0.017	0.038	8.536	5.42	14.01	27584	27569.99	0.051
128	332 T8/IV	0.014	0.038	10.824	6.55	17.43	29157	29139.58	0.060
129	333 T9/I	0.034	0.032	8.254	5.77	14.09	31215	31200.91	0.045
130	334 T9/II	0.035	0.039	8.318	5.31	13.70	28546	28532.30	0.048
131	335 T9/III	0.034	0.044	6.536	4.81	11.42	28458	28446.58	0.040
132	336 T9/IV	0.034	0.038	8.286	5.75	14.11	32145	32130.89	0.044
133	337 T10/I	0.029	0.033	9.087	7.25	16.40	28561	28544.60	0.057
134	338 T10/II	0.026	0.038	9.433	7.06	16.56	27548	27531.44	0.060
135	339 T10/III	0.031	0.025	9.337	7.59	16.98	32154	32137.02	0.053
136	340 T10/IV	0.024	0.033	8.350	6.84	15.25	25145	25129.75	0.061
137	341 T11/I	0.019	0.031	9.472	9.84	19.36	28145	28125.64	0.069
138	342 T11/II	0.027	0.037	10.093	6.90	17.06	26145	26127.94	0.065
139	343 T11/III	0.031	0.032	9.587	8.03	17.68	25215	25197.32	0.070
140	344 T11/IV	0.030	0.036	12.817	8.36	21.25	26245	26223.75	0.081
141	345 T12/I	0.017	0.033	9.433	6.07	15.55	26245	26229.45	0.059
142	346 T12/II	0.025	0.025	7.536	8.64	16.22	24561	24544.78	0.066
143	347 T12/III	0.022	0.036	8.696	5.04	13.80	22546	22532.20	0.061
144	348 T12/IV	0.020	0.032	8.645	4.97	13.67	25125	25111.33	0.054

APPENDIX : VI

Different Soil Properties in LTFE experimental soils of 1st, 4th and 8th cycles of groundnut and wheat crop sequence

Sr. no.	Treatment	pH	EC	OC	Av. N	Av. P	Av. K ₂ O	Av. S.
1	101 T1/I	8.00	0.18	0.57	152	12.80	134	12.72
2	102 T1/II	8.01	0.21	0.63	183	7.68	196	9.54
3	103 T1/III	7.97	0.265	0.72	123	10.24	206	6.36
4	104 T1/IV	7.98	0.265	0.6	186	12.80	206	12.72
5	105 T2/I	8.03	0.215	0.54	133	12.80	144	12.72
6	106 T2/II	8.04	0.275	0.6	167	7.68	144	9.54
7	107 T2/III	8.05	0.21	0.66	144	7.68	144	12.72
8	108 T2/IV	8.04	0.22	0.63	158	7.68	144	9.54
9	109 T3/I	8.01	0.25	0.57	144	7.68	144	12.72
10	110 T3/II	8.05	0.23	0.72	185	10.24	144	9.54
11	111 T3/III	7.91	0.2	0.63	148	10.24	155	6.36
12	112 T3/IV	7.91	0.2	0.54	169	7.68	155	9.54
13	113 T4/I	9.80	0.27	0.54	181	20.48	165	9.54
14	114 T4/II	9.80	0.29	0.57	192	20.48	165	12.72
15	115 T4/III	9.30	0.14	0.6	169	20.48	165	9.54
16	116 T4/IV	9.50	0.14	0.75	169	23.04	175	9.54
17	117 T5/I	8.01	0.26	0.66	186	12.80	144	12.72
18	118 T5/II	8.05	0.26	0.45	144	7.68	165	9.54
19	119 T5/III	7.91	0.2	0.63	163	15.36	144	12.72
20	120 T5/IV	7.91	0.2	0.66	185	7.68	144	9.54
21	121 T6/I	8.00	0.28	0.51	150	7.68	155	9.54
22	122 T6/II	8.02	0.25	0.6	174	12.80	175	6.36
23	123 T6/III	7.91	0.22	0.75	180	12.80	165	9.54
24	124 T6/IV	7.91	0.21	0.63	180	10.24	144	12.72
25	125 T7/I	8.04	0.27	0.48	164	7.68	144	19.08
26	126 T7/II	8.02	0.26	0.51	139	7.68	134	12.72
27	127 T7/III	7.91	0.21	0.57	170	7.68	144	15.90
28	128 T7/IV	7.91	0.22	0.75	189	10.24	144	19.08
29	129 T8/I	8.02	0.24	0.54	180	7.68	134	12.72
30	130 T8/II	8.04	0.22	0.66	141	7.68	144	9.54
31	131 T8/III	7.81	0.21	0.63	194	12.80	144	9.54
32	132 T8/IV	8.01	0.21	0.75	225	10.24	155	6.36
33	133 T9/I	8.10	0.34	0.51	170	25.60	144	9.54
34	134 T9/II	8.00	0.32	0.54	174	30.72	144	12.72
35	135 T9/III	7.77	0.17	0.3	159	28.16	155	6.36
36	136 T9/IV	7.77	0.17	0.72	141	25.60	155	6.36
37	137 T10/I	8.01	0.32	0.63	167	7.68	144	19.08
38	138 T10/II	8.02	0.35	0.51	158	12.80	134	12.72
39	139 T10/III	7.70	0.17	0.66	185	15.36	165	15.90
40	140 T10/IV	7.87	0.16	0.6	189	10.24	155	15.90
41	141 T11/I	7.89	0.33	0.48	175	7.68	155	9.54
42	142 T11/II	7.69	0.34	0.51	178	10.24	134	3.36
43	143 T11/III	7.88	0.16	0.9	167	7.68	144	6.36
44	144 T11/IV	7.97	0.17	0.72	192	12.80	144	6.36
45	145 T12/I	8.02	0.33	0.48	211	28.16	144	6.36
46	146 T12/II	8.00	0.21	0.66	163	20.48	144	6.36
47	147 T12/III	7.99	0.21	0.3	185	25.60	144	6.36
48	148 T12/IV	7.99	0.21	0.72	167	17.92	144	9.54

49	201 T1/I	8.00	0.2	0.66	143	6.66	181	59.34
50	202 T1/II	8.00	0.25	0.63	124	14.80	190	59.34
51	203 T1/III	7.89	0.35	0.72	121	19.98	181	56.76
52	204 T1/IV	7.89	0.35	0.72	160	14.80	215	38.70
53	205 T2/I	8.00	0.3	0.69	158	21.46	224	38.70
54	206 T2/II	8.01	0.4	0.69	119	17.02	215	59.34
55	207 T2/III	7.98	0.25	0.69	138	23.68	164	59.34
56	208 T2/IV	7.98	0.25	0.66	146	13.32	207	59.34
57	209 T3/I	8.00	0.25	0.57	135	26.64	233	59.34
58	210 T3/II	8.02	0.23	0.81	143	25.16	233	54.18
59	211 T3/III	7.91	0.2	0.66	154	33.30	190	59.34
60	212 T3/IV	7.91	0.2	0.66	141	27.38	252	38.70
61	213 T4/I	7.85	0.32	0.69	149	21.46	215	54.18
62	214 T4/II	7.93	0.35	0.6	127	19.24	215	38.70
63	215 T4/III	7.89	0.15	0.72	157	23.68	181	56.76
64	216 T4/IV	7.89	0.15	0.75	136	27.38	252	54.18
65	217 T5/I	8.01	0.4	0.69	158	14.80	172	36.12
66	218 T5/II	7.99	0.4	0.63	144	16.28	190	64.50
67	219 T5/III	8.00	0.25	0.66	121	16.28	207	67.08
68	220 T5/IV	8.00	0.25	0.72	132	24.42	224	61.92
69	221 T6/I	7.90	0.35	0.6	151	18.50	164	61.92
70	222 T6/II	7.83	0.4	0.72	146	20.72	181	67.08
71	223 T6/III	7.93	0.35	0.72	127	25.90	164	67.08
72	224 T6/IV	7.93	0.35	0.66	136	25.90	198	59.34
73	225 T7/I	7.85	0.4	0.6	116	7.40	155	64.50
74	226 T7/II	7.90	0.25	0.69	140	17.02	164	41.28
75	227 T7/III	7.96	0.25	0.72	130	15.54	181	61.92
76	228 T7/IV	7.96	0.25	0.69	146	19.98	190	64.50
77	229 T8/I	7.91	0.25	0.75	174	34.78	271	38.70
78	230 T8/II	7.88	0.3	0.63	155	31.82	261	43.86
79	231 T8/III	7.97	0.4	0.81	149	31.08	271	59.34
80	232 T8/IV	7.97	0.4	0.78	166	28.12	299	33.54
81	233 T9/I	8.10	0.2	0.72	146	28.12	271	33.54
82	234 T9/II	8.01	0.3	0.9	140	33.30	327	12.90
83	235 T9/III	7.77	0.2	0.63	154	28.86	308	33.54
84	236 T9/IV	7.77	0.2	0.72	180	22.20	327	12.90
85	237 T10/I	8.03	0.2	0.66	129	14.06	280	59.34
86	238 T10/II	8.03	0.35	0.66	138	16.28	233	54.18
87	239 T10/III	7.87	0.4	0.69	152	14.06	233	38.70
88	240 T10/IV	7.87	0.4	0.66	149	19.98	233	69.66
89	241 T11/I	7.94	0.23	0.66	144	23.68	198	74.82
90	242 T11/II	7.92	0.2	0.69	124	29.60	224	85.14
91	243 T11/III	7.89	0.4	0.63	133	22.20	215	85.14
92	244 T11/IV	7.89	0.4	0.66	154	26.64	243	67.08
93	245 T12/I	8.03	0.35	0.63	132	7.40	181	64.50
94	246 T12/II	8.04	0.2	0.6	135	14.80	181	59.34
95	247 T12/III	7.99	0.34	0.69	130	11.84	207	43.86
96	248 T12/IV	7.99	0.34	0.72	147	18.50	215	41.28
97	301 T1/I	7.28	0.33	0.66	204	15.85	144	24.50
98	302 T1/II	7.31	0.32	0.6	185	15.85	144	21.00
99	303 T1/III	7.26	0.36	0.69	185	25.36	154	28.00
100	304 T1/IV	7.25	0.39	0.72	213	31.70	144	35.00

101	305 T2/I	7.29	0.32	0.72	185	19.02	154	21.00
102	306 T2/II	7.23	0.34	0.69	198	38.04	202	24.50
103	307 T2/III	7.22	0.36	0.75	207	31.70	173	35.00
104	308 T2/IV	7.24	0.37	0.84	201	41.21	173	21.00
105	309 T3/I	7.24	0.4	0.66	201	28.53	163	35.00
106	310 T3/II	7.28	0.4	0.6	207	57.06	192	38.50
107	311 T3/III	7.39	0.35	0.75	188	28.53	173	35.00
108	312 T3/IV	7.33	0.36	0.69	223	44.38	163	35.00
109	313 T4/I	7.26	0.46	0.72	207	57.06	163	31.50
110	314 T4/II	7.29	0.32	0.69	182	47.55	192	14.00
111	315 T4/III	7.21	0.35	0.72	198	47.55	192	21.00
112	316 T4/IV	7.21	0.4	0.63	210	41.21	163	14.00
113	317 T5/I	7.34	0.36	0.69	229	25.36	154	24.50
114	318 T5/II	7.34	0.41	0.69	201	28.53	163	24.50
115	319 T5/III	7.33	0.36	0.69	204	28.53	144	24.50
116	320 T5/IV	7.24	0.32	0.84	201	25.36	163	21.00
117	321 T6/I	7.31	0.33	0.75	198	34.87	116	38.50
118	322 T6/II	7.26	0.34	0.72	216	25.36	125	35.00
119	323 T6/III	7.19	0.39	0.72	207	28.53	163	35.00
120	324 T6/IV	7.21	0.38	0.81	226	34.87	134	17.50
121	325 T7/I	7.26	0.42	0.69	198	15.85	125	17.50
122	326 T7/II	7.27	0.37	0.66	204	12.68	125	24.50
123	327 T7/III	7.26	0.39	0.69	188	12.68	144	24.50
124	328 T7/IV	7.32	0.36	0.66	204	15.85	134	35.00
125	329 T8/I	7.33	0.35	0.75	223	177.52	291	45.50
126	330 T8/II	7.28	0.42	0.9	216	174.35	302	56.00
127	331 T8/III	7.31	0.41	0.96	232	202.88	291	59.50
128	332 T8/IV	7.32	0.4	0.87	241	164.84	250	42.00
129	333 T9/I	7.23	0.37	0.9	232	237.75	464	52.50
130	334 T9/II	7.30	0.35	0.93	232	285.30	440	52.50
131	335 T9/III	7.28	0.37	1.02	235	231.41	403	49.00
132	336 T9/IV	7.31	0.38	0.93	213	228.24	392	49.00
133	337 T10/I	7.33	0.32	0.75	194	22.19	154	28.00
134	338 T10/II	7.22	0.33	0.69	210	31.70	134	14.00
135	339 T10/III	7.25	0.32	0.75	194	22.19	154	14.00
136	340 T10/IV	7.27	0.32	0.6	182	15.85	144	28.00
137	341 T11/I	7.31	0.34	0.63	213	41.21	144	35.00
138	342 T11/II	7.26	0.43	0.72	201	38.04	182	35.00
139	343 T11/III	7.37	0.35	0.69	182	44.38	173	38.50
140	344 T11/IV	7.14	0.5	0.81	229	38.04	154	45.50
141	345 T12/I	7.30	0.39	0.57	226	31.70	154	38.50
142	346 T12/II	7.33	0.37	0.57	191	28.53	144	28.00
143	347 T12/III	7.31	0.42	0.75	213	22.19	154	42.00
144	348 T12/IV	7.33	0.36	0.78	207	22.19	144	28.00