

**DYNAMICS OF MAJOR NUTRIENTS IN A
CALCAREOUS VERTIC HAPLUSTEPTS UNDER
AICRP-LTFE SOILS**

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ABSTRACT

Most of the research information related to available forms of major nutrients are short-term studies. Cultivating soil for long period of time is changing major nutrient status. Losses of major nutrients 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 major nutrient constraints in sustaining soil health and productivity in major soil cropping system of the sub-agro-ecological zones. Junagadh is one of the centers representing medium black calcareous soil (*Vertic haplustepts*). These soils are difficult to manage from fertility point of view. In view of the above the following broad objectives were set:

- (1) To know the status of major nutrients (N, P, K, S) fractions in soils under AICRP- LTFE.
- (2) To find out the depletion of major nutrients fractions in the soil under investigation.
- (3) Modeling the dynamics of major nutrient fractions in 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 haplustepts* calcareous medium black clayey soils of Junagadh. The samples were subjected to fractionation of major nutrients viz., N, P, K, and S. The major nutrients, 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 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, N, P, K, S content and major nutrients 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 content and T₈ the lowest in groundnut pod while T₂ recorded highest content and T₉ the lowest in groundnut haulm. The T₈ registered the highest content while control the lowest both in wheat grain and straw. In groundnut pod, phosphorus content decreased while in haulm it increased, likewise in wheat grain phosphorus content was increased but in straw it decreased after a period of 8 years. The content of potash

after 4th year of cycles showed increase while after 8th year cycle it declined in groundnut and wheat. In groundnut, sulphur content increased after 4th year while it declined after 8th year. In wheat, sulphur content declined after 4th and 8th year.

With respect to forms of nitrogen it can be deduced that there was a decline in soil nitrogen levels. Ammonical-N & nitrate -N status of LTFE soils in general decreased after long run, but it increased in treatment T₁₀ due to fixation of atmospheric nitrogen by Rhizobium bacteria. Whereas Available-N status in treatments which received FYM (T₈, T₉), marginally increased. Available status of P in LTFE soils was also decreased after long run, but that was also increased in treatments where FYM application was there *i. e.* T₈ & T₉. There was overall increase in Inorganic-P & Total-P status, but status of Available-P decreased due to calcareous soil, but due to chelating effect of organic material in treatments T₈ & T₉ there was increase in the availability of phosphorus after long run in the LTFE soils. The application of FYM also maintained or increased potassium status of LTFE soils. In treatments of FYM (T₈, T₉), the status of potassium fractions increased. In case of sulphur status of LTFE soils, FYM also played a vital role. It maintained availability of sulphur in soils, but more increment after a long run was observed in T₁₁, where P source was SSP which contains 13 % S.

The Available form of nitrogen was found in maximum proportion. At initial stage Ca-P fraction was predominant but after long run picture was changed and maximum proportion was recorded as a Reductant soluble-P. Whereas HNO₃ soluble-K was recorded the highest in proportion among different forms of potassium and

maximum proportion among sulphur forms was as Non-sulphate & Organic forms of sulphur.

Correlations:

The Available-N exhibited positive relationship with Nitrate-N & Ammonical-N. Available-P ascribed significant positive relationship with Inorganic-P, Saloid bound-P, reductant-P & Occluded-P. Available-K form of potassium depicted significant positive relationship with all other forms of potassium, while Heat soluble-S form revealed significant positive relationship only with water soluble-S fraction of sulphur.

The Available-N and Ammonical-N forms of nitrogen ascribed positive relationship with groundnut yield and negative with wheat yield. Whereas phosphorus forms exhibited positive relationship with wheat yield and negative with groundnut yield. Most of the potassium forms also ascribed positive relationship with groundnut yield, while water soluble-S fraction of sulphur exhibited significant positive relationship with groundnut yield and negative with wheat yield. Available-N exhibited significant positive relationship with P content of pod, K content of haulm, N content of grain & S content of grain and straw. Available-P increased K content of groundnut pod & N, P, K content of wheat straw. Most of the fractions of potassium facilitate N, P, K and S translocation from soil to groundnut and wheat crops. Heat soluble-S also ascribed significant positive relationship with P content in wheat straw.

Available-N form had positive interaction with Ca-P, Available-P, Fe-P and negative with Inorganic-P and it exhibited positive interaction with all fractions of potassium. Available-P also

revealed positive interaction with all forms of potassium. Available-K ascribed significant positive interaction only with water soluble-S.

Available-N and Available-K ascribed significant positive relationship with soil pH & negative with soil EC. Whereas Available-P and Available-S exhibited negative relationship with soil pH & positive with soil EC.

The available forms of major nutrients influenced by other forms were subjected to stepwise regression and multiple correlation and regression analysis. The prediction models were based on multiple correlation and regression analysis over a cycle of 1, 4 and 8 years. Total-N & Nitrate-N forms influenced on Available-N to maximum extent. The Fe-P influenced maximum on available-P. All forms of K influenced on available-K at some extent and Sulphate-S had maximum impact on Heat soluble-S. Soil pH had more impact on available N, P, K & S than soil EC.

Path co-efficient:

The Nitrate-N & Ammonical-N forms ascribed maximum direct positive effect on Available-N. Saloid-P exhibited maximum direct positive effect on Available-P. Whereas HNO_3 soluble-K ascribed maximum direct & indirect positive effect on Available-K. Total-S exhibited maximum direct effect on Heat soluble-S.

It has been deduced from the results, that the crop available forms of major nutrients *viz.* nitrogen, phosphorus, potassium & sulphur ascribed depletion over time irrespective of fertilizer treatments, except in treatments which received FYM along with inorganic fertilizers. Application of FYM not only sustains fertility, but also increases soil fertility status as like here in P_2O_5 status of the LTFE soil in treatment which received FYM, increased available-P status in

LTFE soil from low category to high category. The combined application of FYM and inorganic fertilizers in continuous manner, have sustained the crop yield. The dynamics of major nutrients along with its forms exhibited both trend, negative & positive with varying magnitude according to the soil. The total form in case of N, the Fe-P form in case of P, most of the forms in case of K and sulphate-S forms in case of S had the maximum influence on available forms of major nutrients.

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CERTIFICATE-III

Date: 26/04/2010

This is to certify that the thesis entitled "DYNAMICS OF MAJOR NUTRIENTS IN A CALCAREOUS VERTIC HAPLUSTEPTS UNDER AICRP-LIFE SOILS" submitted by Mr. RAJANI ASHOKKUMAR VALLABHBHAI to Junagadh Agricultural University, Junagadh in partial fulfillment to the requirements for the degree of Ph.D. in the subject of SOIL SCIENCE AND AGRICULTURAL CHEMISTRY after recommendation by the external examiner was defended by the candidate before the following members of examination committee. The performance of candidate in the oral examination was satisfactory; we therefore recommended that the thesis be approved.


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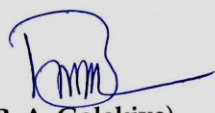

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C O N T E N T

CHAPTER	TITLE	PAGE
I	INTRODUCTION	1 - 13
II	REVIEW OF LITERATURE	14 - 63
III	MATERIALS AND METHOD.....	64 - 74
IV	RESULTS AND DISCUSSION	75 - 193
V	GENERAL DISCUSSION.....	194- 206
VI	SUMMARY AND CONCLUSION.....	207- 215
	REFERENCES.....	216- 255
	APPENDIX	i-xxvii

CHAPTER-I

INTRODUCTION

In the soil, the nutrient elements are distributed in the different discrete chemical forms, which often exist in a state of dynamic equilibrium and constitute the pool from which plants draw it. Soil available form of nutrient is that fraction whose variation in amount is responsible for significant change in yield and response (Bray, 1948). The availability of these soil forms, however, involves not only their chemical and physical nature but also the ability of plant to “Forage” them with its root system. Available nutrient constitutes only a small portion of the total nutrient present in soil.

Major or macro-nutrients are so called because these are required in large quantities, more than that of iron. These nutrients include C, H, O, N, P, K, Ca, Mg and S. Nitrogen, phosphorus and potassium are also termed as primary nutrients because of their larger requirement by the plants and S is termed as secondary nutrient because of their moderate requirement by plants.

With globalization, Indian agriculture is passing through a critical phase. It is confounded with increasing crop production, sustainability and environmental quality issues. Answers to these questions can be sought by the long-term experiments, which are valuable repositories of information regarding the sustainability of intensive agriculture. Sustainability in crop production has always been tuff task. It requires a deep knowledge and wisdom of pedo-edepho-meteorological interactions under investigation. Besides irrigation, nutrient management is the single most important factor affecting crop yields for the particular genotype. It is more so in the intensive cropping.

Many factors influence the complex chemical, physical and biological processes that govern soil fertility and productivity are important. Changes in fertility caused by imbalanced fertilizer use, acidification, and alkalinity and declining soil organic matter may take several years to appear. These properties in turn can be influenced by external factors such as atmospheric pollution, global climatic changes or land use management practices. Long-term experiments provide the best possible means of studying changes in soil properties, nutrient dynamics and processes identifying emerging trends in nutrient imbalances and deficiencies and to formulate future strategies for maintaining soil health. In fact, agricultural scientists have recognized the long-term sites as invaluable tools in the study of agro-ecosystem dynamics. But, renewed emphasis on such studies has arisen from the growing notion that “certain soil processes are long-term in nature and must be studied as such”. Higher production of crop can be achieved only through increase in the intensity of cropping and increase in the productivity per unit area per unit time. With rapid depletion of soil nutrient reserves under intensive cropping ensuring supply of all essential nutrients to crops in a balanced proportion assumes great significance.

In view of growing importance of long-term experiments for addressing current and future agricultural and environmental issues Dave *et al.*, (2000), Powlson *et al.*, (1998) and Swarup and Wanjari (2001) made extensive efforts to review and document available data on (i) yield trend analysis, soil properties and key sustainable indicators such as organic carbon and pH under long-term experiment which cannot be measured from short term studies and (ii) identified regional fertility constraints and opportunities to increase agricultural productivity through integrated plant nutrient supply.

Nitrogen is an important element for plant life. In the importance it comes only next to carbon, hydrogen and oxygen as it figures in the composition of proteins, nucleic acid, growth hormones, vitamins etc. It is also one of the main structural components of a living organism.

Soil nitrogen is primarily in the organic fraction of the soil. The atmosphere above the soil contains 79% nitrogen, but this nitrogen can only be used directly by leguminous plants, which have symbiotic nitrogen-fixing microorganisms, such as *Rhizobium*, in nodules on their roots. In the lithosphere, igneous rocks are the main source of soil nitrogen (Stevenson, 1986).

Only a small proportion of total N is present in the available forms (NH_4^+ and NO_3^-) in the soil. Nitrate is first reduced to ammonium level in a series of steps in order to be absorbed by the plants. The average Indian soil contains about 0.05 percent nitrogen. Nitrogen occurs in soil as inorganic and organic compounds. Nitrates and nitrites of calcium, potassium etc. are the main inorganic forms of nitrogen while organic form chiefly the proteins.

The mineral N of the soil exists as NH_4^+ , NO_3^- and sometimes NO_2^- either in soil solution, on exchange sites of soil particles or as NH_4^+ held by clay minerals. Some gaseous nitrogen may also be found in the soils atmosphere and dissolved in soil solution.

In most of the soils, the bulk of nitrogen is as an organic form and usually near the surface. The inorganic forms of nitrogen include nitrite which is usually a transitional stage between nitrate and ammonium, and is easily removed. Nitrogen also occurs as exchangeable ions, fixed forms

and traces of gaseous forms such as dinitrogen and nitrogen monoxide and elemental nitrogen.

The Indian soils have very low nitrogen content because of the tropical climate. The alluvial soils of the North-Western tract of the Indo-Gangetic plains are silty with low nitrogen level, because of the high temperatures and low rain fall. In the north-eastern and eastern regions high temperatures accelerate the loss of nitrogen and thus, nitrogen accumulation in soils is low. In mid-north, the climatic conditions are conducive to nitrogen accumulation. The high mean annual temperature of the central and peninsular India hinders nitrogen accumulation in the soils. Jenny and Raychaudhuri (1960) attributed the low levels of nitrogen in Indian soils primarily to climate and secondarily to cropping.

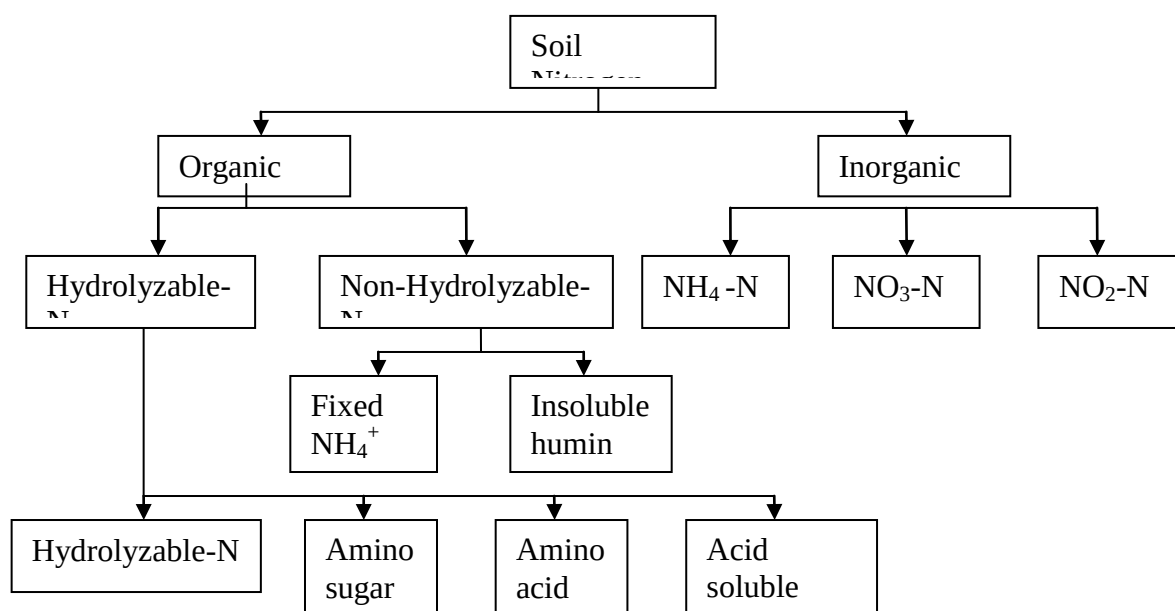


Fig. 1.1: Flow diagram of different form of soil-N.

(Source: Tusneem and Patrick, 1971)

Jenny (1930) showed that the soil nitrogen content decreased with the increase in the annual temperature and approaches zero as a limit. At any given temperature, the content of soil nitrogen increases

with the increase in humidity and approaches a limit fixed by the temperature. Nitrogène content observed to be high in soils under cultivation of a crop with an extensive root-system.

The total nitrogen in soils generally varies from 0.02 to 0.44 per cent. Due to tropical climate, the Indian soils are poor in total N, which varies from 0.04 to 0.12 per cent. Nitrogen in soil exists in two major forms: (i) organic and (ii) inorganic nitrogen. The inorganic forms (NH_4 , NO_3 and NO_2) are very important from crop nutrient point of view, because plant root takes up nitrogen from the soil mostly as NO_3 and to some extent as $\text{NH}_4\text{-N}$. The NO_2 form is unstable and is usually present in soil in lesser extent.

Phosphorus is essential nutrient for the plant growth. The importance of phosphorus in maintenance of soil fertility and improving crop productivity is well recognized in Indian soils, most of which are either deficient or marginal in P status. Soils are also known to vary widely in their capacity to supply phosphorus to plants. Only a small fraction of total P in soil is found in plant available form. Their bioavailability in the soil is governed by several factors like, soil pH, texture, moisture, lime content, applied nutrients, etc. Besides this, the fact that the forms in which these nutrients, particularly phosphorus exists in the soil, is also a factor which contributes the complication in the mode of its availability.

The crop response to P has been a controversial issue especially for cotton (Oosterhuis, 2001) and groundnut in the soils of Gujarat (Golakiya, 1998). The mania of organic farming has made this issue a moot point. To clarify this aspect, the study of the changes in the fractions of P at regional level and in a site specific LTFE will provide a sound base. The ultimate answer to anti-fertilizer arguments is to be sought from the dynamics of the forms of P on large scale over a period of time.

The knowledge of the various forms of phosphorus present in a soil and condition under which these became available to the plants is a prerequisite in assessing the availability of phosphorus in the soil and crop response to applied P Fertilizers (Kothandaraman and Krishnamoorthy, 1979). Since the different forms of soil phosphorus have different solubility under different soils environmental conditions; the availability in the soil and the uptake of phosphorus by crops should largely depend upon the different factors prevailing in and through the soils (Narayanasamy and Biswas, 2000). Thus, knowledge of the dynamics of P in soil is helpful in understanding the soil processes influencing the availability of this nutrient and its uptake by plant.

Pools of soil P:

Phosphorus present in soil may be categorized into the following four groups (Barber 1984):

- (i) Phosphorus in ions and compounds in the soil solution;
- (ii) Phosphorus adsorbed on the surface of inorganic soil constituents;
- (iii) Phosphorus minerals, both crystalline and amorphous; and
- (iv) Phosphorus as a component of soil organic matter.

Solution P: This form is the one occurring in minimal quantity, yet directly affects the P availability to plants. Besides the concentration, the form (species) in which P occurs in soil solution is also of paramount importance, as plant roots can absorb and utilize H_2PO_4^- and HPO_4^{2-} forms only.

Inorganic P: These compounds present in soil contribute to the groups (ii) and (iii) stated above and are (a) those containing Fe and Al-phosphate; (b) those containing Ca-phosphate; and (c) those combined with the silicate minerals. Some common soil phosphate minerals are listed in Table 1.1. In

soils above pH 7, Ca-P is the dominant species, while, in acid soils Fe-P and Al-P are the dominant forms.

Organic P: Variable portion of the total P present in soil is in the organic form. The quantity of it is mainly dependent on the content of organic matter in soil. Organic phosphorus is generally the esters of orthophosphoric acid (Anderson, 1980). Phosphate esters are present in both plants and animals mainly as (i) inositol phosphates, (ii) phospholipids, (iii) nucleic acid, (iv) nucleotides and (v) sugar phosphates. The first three are the dominant groups of organic P in soils.

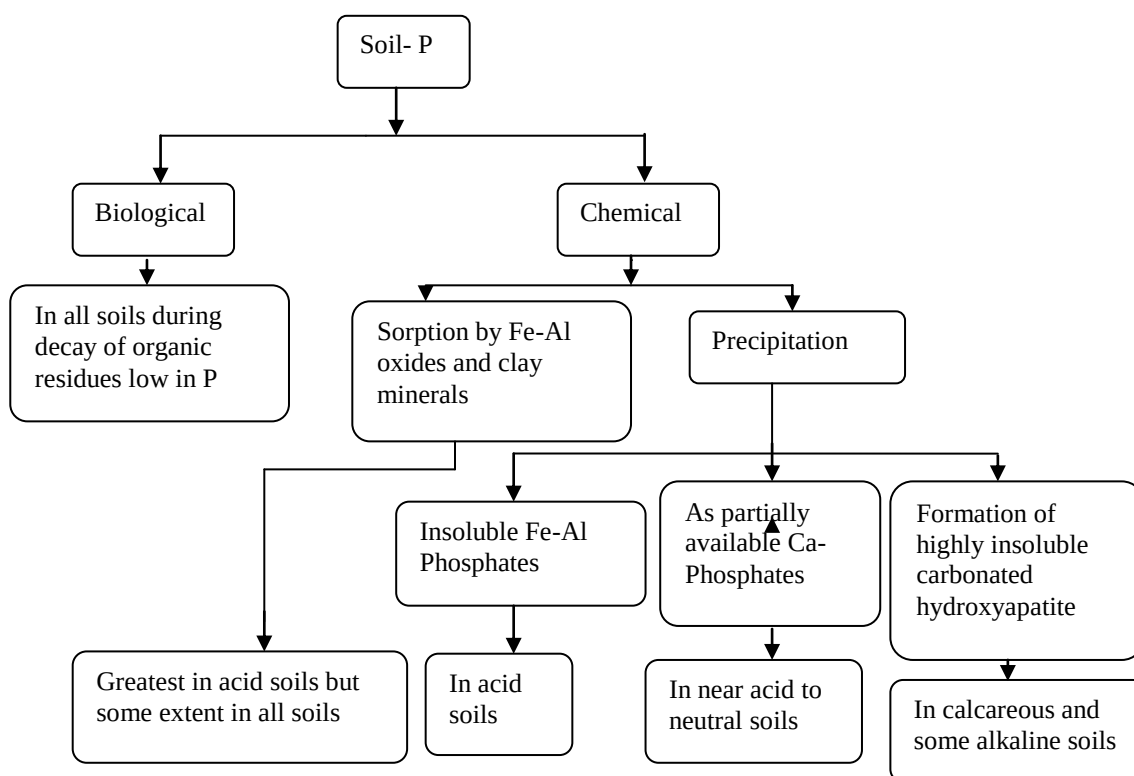


Fig. 1.2: Schematic presentation of phosphorus transformation in soils.

Table 1.1: Common soil phosphate minerals

Calcium phosphate	
(i)	Fluorapatite [$\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2$] $\text{Ca}_3(\text{PO}_4)_2$, CaF_2
(ii)	Hydroxyapatite [$\text{Ca}_{10}(\text{PO}_4)_6\text{OH}_2$] $\text{Ca}_3(\text{PO}_4)_2$, $\text{Ca}(\text{OH})_2$
(iii)	Tricalcium phosphate [$\text{Ca}_3(\text{PO}_4)_2$]
(iv)	Octacalcium phosphate [$\text{Ca}_8\text{H}_2(\text{PO}_4)_6 \cdot 5\text{H}_2\text{O}$]
(v)	Dicalcium phosphate [CaHPO_4]
(vi)	Dicalcium phosphate dihydrate [$\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$]
Aluminium phosphates	
(i)	Variseite [$\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$]
(ii)	Potassium taranakite [$\text{H}_6\text{K}_3\text{Al}_5(\text{PO}_4)_8 \cdot 18\text{H}_2\text{O}$]
(iii)	Berlinite [AlPO_4]
Iron phosphate	
(i)	Strengite [$\text{FePO}_4 \cdot 2\text{H}_2\text{O}$]
(ii)	Vivianite [$\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$]

The nature and reactions of organic P in soils are not well examined and documented as in case of inorganic soil P. It is known that phosphatase enzymes play a major role in mineralization (dephosphorylation) of organic phosphate-esters in soil (Yaduvanshi and Tripathi, 1985). Phosphatases are a wide spectrum of enzymes produced by microorganisms and plant roots that

catalyze the hydrolysis of esters and release P in inorganic form which becomes available to plants.

The total-P content in Indian soils ranges from 100-2000 ppm (Tandon 1987). The total P in soil consists of inorganic P and organic P forms. The inorganic P constitutes a dominant part of total P, it being 30-95 per cent of total P in soil. The inorganic P can be further divided into different pools. Phosphorus bound to aluminium (Al-P), iron (Fe-P) and calcium (Ca-P) constitutes the major active form of inorganic P. The relatively less active are the occluded and reductant-soluble forms of P. All these forms exist in all soils but generally Al-P and Fe-P are more abundant in acid soils while Ca-P dominates in neutral-alkaline soils. Various forms of P are interrelated and contribute to the pool of plant-available-P according to their physicochemical properties such as composition, solubility, surface area, age, etc.

Potassium (K) is absorbed by plants in larger amounts than any other nutrient except N. Although total soil content exceeds crop uptake during a growing season, in most cases only a small fraction of it available to plants. Total soil K content ranges between 0.5 to 2.5% and it is lower in coarse-textured soils formed from sandstone or quartzite and higher in fine textured soils formed from rocks high in K-bearing minerals.

The potassium is mobile in plant, unlike other major elements, it's not the integral part of the plant component but, it acts as a catalyst for carbohydrate and nitrogen metabolism, protein synthesis as well as formation, break down and translocation of starch. It also regulates the activity of other essential elements in plant. It neutralizes physiologically important organic acid and activates various enzymes promoting the growth of meristematic tissues. It also plays an important role in monitoring the water balance in plants.

After introduction of high yielding varieties and intensive and multiple cropping system along with use of high analysis nitrogenous and phosphatic fertilizers on long run resulting now the soils are started depleting in potassium from high to medium and up to low levels as evidenced by soil testing and crop response (Tandon and Sekhon, 1988 and Prasad, 1992a). In such conditions crop may respond to potassium application.

Dynamics of soil potassium:

The potassium immediately available to the plants is of course present in the soil solution. However, the concentration of soil solution K is not sufficient to meet the demand of plant at any time, thus the replenishment of the solution from other phases of K is of great importance in determination the K fertility status of the soil. So the amount of K present in soil solution depends on dynamic equilibrium between various forms of K and perhaps more on the rate of release from reserve phase (Wicklander, 1954).

Form of soil potassium:

Potassium in soils can't be easily characterized in terms of different forms because its state throughout the soil is essentially ionic (K^+). Sharp distinction between various forms of K is not possible and often there is an overlap between these forms (Scott and smith, 1987). There exists a dynamic equilibrium between different forms of soil K (**Fig. 3**).

Among the major nutrients, sulphur has been recognized as an essential nutrient to plants and this was demonstrated more than one and half century ago by Justus Von Liebig in Germany. Its role in plant growth has been well documented (Hoagland and Novelli, 1954). Sulphur, inspite of being essential for physiological and metabolic activities of the plants, is an integral part of certain vitamins and enzymes which are important to life cycle of the plants.

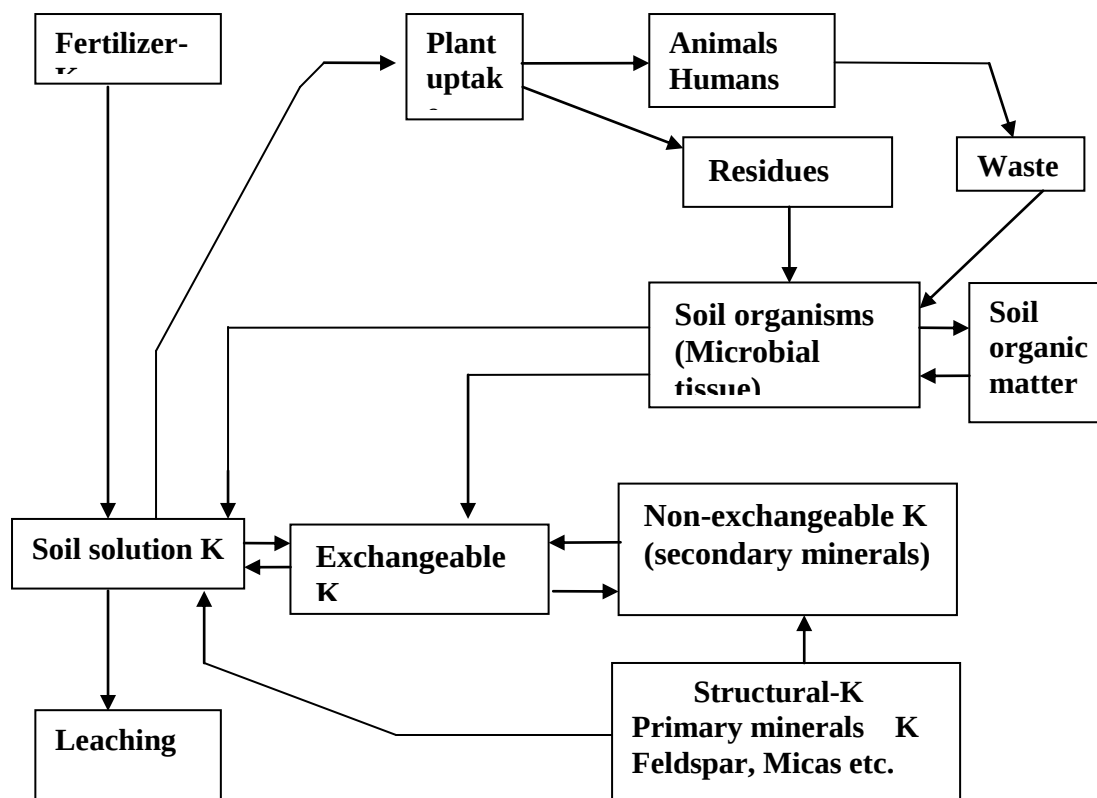


Fig. 1.3: The dynamics between various forms of soil K

When sulphur is in insufficient amount both quantity and quality of the crops are reduced. It also plays an important role in the synthesis and formation of certain essential amino-acids like cysteine, cystine and methionine, the building blocks for the proteins. In the absence of sufficient sulphur, several essential enzymatic activities and physiological functions are inhibited. Thus maintenance of an optimum level of sulphur in the soil in relation to other nutrients is essential for maximum crop production and its quality aspects.

Sulphur, being vitally important for complete life cycle of plants, its presence in adequate quantities in the soil and in the form available

to plants is very essential. The plants suffer due to this element. Physiologically, plants grown on deficient soil S are small, especially short with slender stalks, pale green to pale yellow in colour resulting into immature fruit formation. The deficiency of sulphur has been reported for most of the crops in all over the world (Andrew *et al.* 1952; Annon, 1967; Kanwar, 1967; Chapman, 1975 and Tandon, 1986) and has been found in arid, semi arid and humid regions of the world (Ensminger, 1958). The usage of fertilizers like, super phosphate, ammonium sulphate, sulphate of potash and organic materials such as, FYM, compost and green manure to add sulphur incidentally, being associated with these material in the soils, a good response of crop to application of elemental sulphur or sulphur containing materials have been reported in Punjab, Rajasthan, Gujarat, Uttar Pradesh, Himachal Pradesh Bihar and other parts of the country (Kanwar, 1963; Venkateswarlu, 1963; Chopra and Kanwar, 1966; Pathak and Bhardwaj, 1968; Dube and Misra, 1970; Reddy and Mehta, 1970; Singh, 1971; Joshi *et al.* 1973; Dhillon and Dev, 1976; Aulakh *et al.* 1977 (a,b) and Tandon, 1986). But information on several interacting factors influencing the availability of sulphur is inadequate.

Sulphur exists in soil as free and adsorbed sulphate and in diverse organic and inorganic compounds. In the humid region it is in the organic forms, while in arid soils the sulphate salts of calcium, magnesium, sodium and even potassium predominate (Kanwar, 1976). Knowledge of different forms of sulphur and factors affecting their distribution throughout the root zone penetration is essential in improving the sulphur nutrition of the crops growing with diversified root system.

During past period of research on major nutrients in soils a least information was available about different forms of major nutrients and it's dynamic in LTFE soils. Most of the research information related to available forms of major nutrients was from short-term studies. Cultivating soil during long period of time is changing major nutrient resources. The nutrient losses from soil are, in fact gradual and some times hidden. It is therefore not easy to recognize and understand the physical, chemical and biological processes leading to such major nutrient constrains in sustaining soil health and productivity in major soil cropping system of the sub-agro-ecological zones. In view of the growing concept of sustaining soil health, the research work on the following areas had been taken up.

- (1) To know the status of major nutrients (N, P, K, S) fractions in soils under AICRP- LTFE soil.
- (2) To find out the depletion of major nutrients fractions in the soil under investigation.
- (3) Modeling the dynamics of major nutrient fractions in LTFE soils.

CHAPTER – II

REVIEW OF LITERATURE

Generally two to three crops are being produced annually per unit area under intensive cultivation. This intensive cropping system removes large amount of nutrients from the soils. Increased application of chemical fertilizers and farmyard manure has been the major input in sustaining fertility status of the soils. Continuous application of chemical fertilizers and farmyard manure may have their effect on soil physical, chemical as well as biological properties. These effects can only be monitored through long-term fertilizer experiments. This has been particularly true in the soils of Saurashtra, which have abundant free lime. It is therefore imperative to have a close look towards the interrelations among the fractionations of major nutrients in the soil. This may give a better understanding of processes/dynamics of soil major nutrients in and through the lithosphere. In this context a review pertaining to the present investigation is narrated under the following subheads:

- 2.1 Chemistry (adsorption and desorption) of nitrogen, phosphorus, potassium and sulphur in soils.
- 2.2 Factor affecting the availability of nitrogen, phosphorus, potassium and sulphur in soils.
- 2.3 Status of nitrogen, phosphorus, potassium and sulphur in soils.
- 2.4 Interactions of different major nutrients in soils.
- 2.5 Forms of nitrogen, phosphorus, potassium and sulphur in soils.
- 2.6 Depletion and increase of nitrogen, phosphorus, potassium and sulphur under intensive cropping.
- 2.7 The major nutrient availabilities, forms and relationship with soil properties in LTFE's.

2.1 CHEMISTRY (ADSORPTION AND DESORPTION) OF NITROGEN, PHOSPHORUS, POTASSIUM AND SULPHUR.

NITROGEN: Soil clay particles and organic matter have a predominantly negative charge which is capable of attracting and holding positively charged cations e.g. NH_4^+ . These charges are referred to as cation exchange sites and they arise in several ways. On micaceous clays they occur through substitution of one structural cation for another of a lower valency. For amorphous clay minerals additional negative charges are created by the presence of weak acids on the clay surfaces. The negative charges of organic matter are derived from carboxyl and phenolic groups which behave like weak acids (Nommik and Vahtras, 1882). Cation exchange is a reversible process with the cations in solution in equilibrium with those on the exchange sites. Therefore NH_4^+ held in the soil on the exchange sites is protected from leaching but is still in a plant available form.

Ammonium ions can be held between layers of micaceous clays in positions not readily accessible for exchange with solution cations. Such positions occur between structural layers of micas, intergraded hydrous micas and vermiculites or in the wedge zones formed as mica is weathered and the layers start to expand. Due to the affinity of the clay surface charges for NH_4^+ and the position of these ions, they are not easily exchanged with other cations and so they are referred to as fixed or non exchangeable (Nommik and Vahtras, 1882). This form of NH_4^+ can be released slowly into solution and so become available to the plants if the concentration in solution decreases. Fixation of

NH_4^+ may be of significance following the application of fertilizers to soils containing micaceous clays but with time this N can be recovered by crop plants (Preston, 1982).

Anion exchange can also occur where NO_3^- ions are held electrostatically to positive charges which occur on some soil colloids (e.g. iron and aluminium oxides and hydroxides on kaolinite and allophane). This is less common and is important only in some tropical and volcanic soils (Cameron and Haynes, 1986).

PHOSPHORUS: Knowledge of the amount and distribution of P in soils would provide a logical basis for consideration of the P requirements of different crops. Many workers have tried to study the distribution of various inorganic forms of P in soil. Marked variation in the different forms of inorganic P is due to genetic differences among soils (Chang and Jackson, 1958; Bapat *et al.*, 1965). The organic matter, calcium carbonate and sesqui-oxides appear to be guiding factors in determining the distribution of forms of P (Mishra and Ojha, 1969).

Working with the different forms of iron, aluminium and calcium phosphates, Basu and Mukharjee (1969) concluded that in general the availability of phosphorus decrease as $\text{Ca-P} > \text{Al-P} > \text{Fe-P}$. Very little P is present in the soil solution, its concentration being less than 0.1 ppm P ($0.5 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ of plough layer) except in the sodic or heavily fertilized soils. As the P is drawn from it, largely through diffusion, it is replenished by the solid phase pool of available P. Fertilizer P is added to change this pool. The Al-P and Fe-P fractions are the major contributors to plant available P under moist situations. This can be so even where Ca-P is much more abundant than Al-P or Fe-P. The forms of phosphates are also considered as determining factors in this respect (Satyanarayana *et al.*, 1970).

In wetlands the ferric and reductant soluble phosphate are the potential sources of available P for rice (Mandal, 1979). While Doharey *et al.*, (1980) suggested that all the inorganic P fractions have combined effect on available P of soil. The Al-P was found to be more important fraction contributing towards available phosphorus, followed by RS-P and Saloid-P (Agrawal *et al.*, 1987). Similar results also were observed by Subramanian and Kumaraswamy (1989) in a continuous cropping and fertilization experiment. In an acid Alfisol, lime application increased available P both before and after the crop to the extent of 82.2 and 125.8 percent, respectively (Sood and Bhardwaj, 1992).

Patel *et al.*, (1994) reported that a large part of Gujarat is having medium and deep black soils, which have smectite as the dominant clay mineral; Illite and kaolinite were found to be the other two associated minerals. The deep black soils derived from trap rocks containing a ferruginous smectites belonging to the beidellite- nontronite series. The total P is rather poorly correlated with available P in soils and therefore total P is rarely used to describe a soils P-fertility status. Similarly Koria *et al.*, (2000) noted that RS-P fraction seems to be major source for replenishing pool of available phosphorus.

The soils derived from the parent materials having high P, contain higher amount of total P. The P content is generally higher in soils developed on granite, gneiss followed by shales with basic intrusion, lime stones with intrusions of micaceous schist and quartzite and a major fraction of total P is present in clay (Tiwari, 2002).

POTASSIUM: It is generally agreed that plants take up K from or via soil solution. Of the different forms of soil K, the soluble and exchangeable forms contribute to the pool of readily available K, while the initially nonexchangeable K (NEK) serves as a reserve source of K. Only 1-2% of total soil K is generally present as readily available forms in soil. Some of these secondary minerals also act as a fixer of plant available K (Bertsch and Thomas, 1985).

Potassium status and distribution in soil is almost entirely governed by soil mineralogy (*Fanning et al.*, 1989). The mineral sources of K in soils are the dioctahedral micas: muscovite, glauconite and hydrous or illite; the trioctahedral mica, namely biotite and phlogopite; and the feldspars, namely sanidine, orthoclase and microcline (Schulze, 1989). Indeed, the native soil K status depends, not only on parent material of the soil, but also on the subsequent stage of weathering of the parent material. That is, the weathering history of a mineral phase, rather than its mere presence, may be an important factor to be reckoned with while relating the plant availability of soil K to the soil mineralogy (Sanyal, 2000).

Microcline is the most common potash feldspar in soils. The feldspar may contribute 5-25% of the silt and sand fraction of soils, and may be less than 5% of the clay fraction of most agricultural soils. Their rate of K release by weathering is very slow, compared to that characterizing the micas.

Among the micas, biotite is more weatherable than muscovite. This is because of a shortened K-O bond in muscovite. Further, the (OH) groups of the octahedron in biotite are vertical to the basal plane, causing interlayer K to be less tightly bound in biotite than in muscovite. The presence of Fe^{2+} ion in biotite that oxidizes during

weathering reduces the structural stability due to charge imbalance. Weathering of micas/feldspars leads to the formation of secondary minerals with simultaneously release of K (Sparks and Huang, 1985; Sparks, 1987; Liu *et al.*, 1997; Springob, 1999). As one moves from micas to vermiculites via illite, the CEC increases, while fixation of added K through lattice entrapment leads to enrichment of the NEK pool, coupled with a fall in the CEC of the soil.

Results of numerous studies (Bertsch and Thomas, 1985; Bhonsle *et al.*, 1992; Olk *et al.*, 1995), suggest that for soils with trioctahedral mica parent material and a low intensity of weathering, K release to soil solution is rather high. For soils of dioctahedral mica parent material, and a moderate state of weathering, K release is less, but it is least for soils of low mica content or intensive weathering. Indeed, while formulating sound K fertilizer recommendations, it is imperative that the above K release characteristics of the soils given due consideration.

SULPHUR: The SO_4^{2-} adsorption capacity of a soil is decreased by increasing soil pH and P content (Ensminger, 1954; Kamprath *et al.*, 1956). Adsorbed SO_4^{2-} occurs on the positively charged exchange sites at edges of clay mineral, organic matter, and Fe and Al oxides (Chao *et al.*, 1962). Soil S exists in organic compounds, and adsorbed and in soil solution as SO_4 . Because plant absorb SO_4 from the soil solution, replenishment from organic and adsorbed sources is important in determining S supply to the plant. Temperate region soils ordinarily contain between 0.1 and 2.0g S kg^{-1} (Brady, 1974). Sulphate retention in arid soils is enhanced by Ca (Barrow, 1972; Ryden and Syers, 1976). Representative soils from arid regions contain more S than those from humid regions (0.8 and 0.4mg kg^{-1} , respectively) (Brady, 1974). However, a slower second stage of SO_4^{2-} adsorption also exists,

rendering initially adsorbed SO_4^{2-} less available over time (Barrow and Shaw, 1977). The predominant mineral form of S in arid soils is gypsum. Organic S comprises most (> 90% of the total) of S in most soils.

Ultisols, Alfisols and Oxisols have a high adsorption capacity due to an abundance of Fe and Al oxides and typically low pH. Binding is due both to electrostatic attraction and ligand exchange mechanism (Marsh *et al.*, 1987; Marciano Martiner and Mc Bride, 1989) and highly dependent on the occurrence of positive charge on the soil colloids. Sulphate adsorption occurs rapidly, with nearly complete adsorption in minutes (Rajan, 1978) to days (Marciano-Martiner and Mc Bride, 1989). Marciano-Martiner and Mc Bride (1989) proposed that the stimulation in SO_4^{2-} adsorption arose from the bonding of a SO_4 Ca complex to the oxide surface by micro-organic ligand and attraction of the Ca to a negatively charged hydroxyl. The range in water soluble SO_4 S concentration of surface horizons of Ultisols was 0.09 to 0.16 mM and in the argillic horizon, 0.20 to 0.36 mM (Camberato and Kamprath, 1986).

2.2: FACTOR AFFECTING THE AVAILABILITY OF NITROGEN, PHOSPHORUS, POTASSIUM AND SULPHUR IN SOILS.

NITROGEN:

Soil Reaction: Sonkar *et al.*, (1999) while studying the physicochemical changes in the properties of mine spoils due to a 54-month old even-aged plantation of different tree species were investigated at a site in Madhya Pradesh, India. The maximum increase in organic matter and available nitrogen was under *Cassia siamea* followed by *Dalbergia sissoo*, *Albizia procera*, *Leucaena leucocephala* and *Eucalyptus tereticornis*. However, *E. tereticornis* recorded the maximum decrease in the soil pH followed by *C. siamea* in these mine

spoils. Among different tree species *E. tereticornis* recorded maximum survival, collar diameter and height followed by *C. siamea*, *A. procera* and *D. sissoo* while the minimum was observed in *Prosopis* sp. followed by *Albizia lebbeck*. There was a highly significant positive correlation between plant height and organic matter/available nitrogen and pH and significant negative correlation between collar diameter and soil pH/organic matter and available nitrogen.

Arunachalam and Arunachalam (2000) had taken up a laboratory experiment and analyzed the effect of soil pH on N mineralization in soils collected from regrowing forest stands of three different ages at higher altitude of Meghalaya. Generally, the ammonium concentration decreased with increasing soil pH, while nitrate concentration increased. Ammonification and nitrification ratio in the soil was observed to be 0.58, 0.72 and 2.97 in 7, 13 and 16 year old forest respectively. The net N mineralization showed a weak positive relation with soil pH.

Organic Matter: Sethi *et al.*, (1978) studying sand-mixed cultivated bog soils, the degree of humification and total nitrogen content of the organic matter increased. The relative amounts of non hydrolysable, heterocyclically bound nitrogen increased to a greater extent than total hydrolysable nitrogen. During these changes the distribution pattern of organically bound nitrogen in the different nitrogen fractions became similar to that observed for isolated humic acids of podzolic soils or chernozems. The absolute amount of amino-acid-nitrogen per g organic matter also increased under cultivation, but no typical change in the distribution pattern of the different amino acids was observed. However, a typical change did occur in the distribution pattern of amino sugars. The ratio of glucosamine to galactosamine in the older

cultivated soil was about 2.5, as compared to about 1 in the original raised peat.

Nitrogen occurs mostly in organic matter, and is usually quickly nitrified after the organic matter is decomposed. The NO_3 produced is susceptible to some leaching, but more importantly, to runoff during overland flow and accumulation in a play environment, where denitrification can occur (Schlesinger *et al.*, 1990).

Pallo (1992) while studying the three soil units in Burkina Faso classified as Haplic Lixisols, Ferric Lixisols and Eutric Gleysols found that the organic matter consisted mostly of humin, with inherited humin being the major component. Hydrolysable N represented the main form of the total N. The coefficients of rank correlation between the organic matter fractions and N forms indicate that the total humin is mostly correlated with the non-hydrolysable N. It seems therefore that the climatic conditions which already lead to the formation of the humin also induce the formation of the non-hydrolysable N. Since this N form is protected from rapid microbial release, readily explains the deficiency of this major element in the soils studied.

Fengmin *et al.*, (1998) investigated the effect of organic matter on nitrogen content in soils derived from loess in NW China. The results indicated that available N and total N content were correlated positively and significantly with organic matter content.

Szajdak *et al.*, (2002) investigated the influence of shelterbelts in agricultural landscape on transformation of inorganic and organic forms of nitrogen in soil, as well as on chemical structure of humic acids (HA) in order to understand their role biogeochemical barriers. The study area was located in the Agroecological Landscape Park in Turew, Poland. The soils were classified as Hapludalfs, Glossudalfs,

Ochraqualfs and Histosols (type-mucky, subtype-muckous). In all analyzed soil samples, regardless of the sampling period, the amount of total N, urease activity, concentration of ammonium and nitrates were much higher in the mineral-organic soil than in the mineral soils. The transformation of different forms of nitrogen in the soil under shelterbelt was strongly connected with the humification process and the molecular structure of HAs.

Calcium Carbonate: Jullius *et al.*, (1982) carried out experiment at Makerere Farm in China on an acid-infertile soil to investigate the effect of CaCO_3 on N-fixation. The effect of ash on nodulation was comparable to that of CaCO_3 with a depressive effect on the other parameters measured. Potassium alone or in combination with CaCO_3 at rates equivalent to that in the ash caused even greater reduction of nitrogen.

Seddiky and Rashidi (1989) had studied CaCO_3 and nitrogen levels (soluble, total and exchangeable) in four pedons in various landscapes in the Arbil plain. CaCO_3 was shown to decrease nitrogen markedly, particularly total and exchangeable N, and also reduce N retention in the soils.

Soil Texture: Lakhani and Mehta (1971) studying alluvial soils (termed goradu soils on account of their colour and texture) ranging from well drained loamy sands to rich loams were sampled in 24 locations in Kaira district at about 8 weeks after the tobacco harvest in May. Of the methods used for determining N-supplying capacity, a modification of Truog's alkaline permanganate method gave better correlation with the uptake of N by sorghum plants growing in pots than determinations of total N, soil organic matter content, NO_3

content, available N release of NO₃ or initial NO₃ + NO₃ released during incubation.

Hassink *et al.*, (1993) investigated effect of soil texture on carbon (C) and nitrogen (N) mineralization rates in grassland soils in Swifterbant, Netherlands. The percentage of mineralized organic N was higher in sandy soils than in loams and clays, this was not observed for C. Two mechanisms of physical protection of organic N were distinguished. In clay soils physical protection of organic material by its location in small pores was significant. In sandy soils, organic material was protected by its association with clay particles. In loams both mechanisms played an important role. The protected organic material associated with clay particles consisted of amorphous undefined material that did not stain with acridine orange, indicating a high degree of decomposition, while the non-protected organic material present in the sand fraction consisted of plant debris that stained intensely with acridine orange. Physically protected organic matter had a lower C: N ratio than organic matter that was not physically protected.

Temperature and Rainfall: Das *et al.*, (1992) collected and cultivated and virgin soil samples from 23 sites in Orissa (India) analyzed their total nitrogen, humus and organic carbon contents, and finally correlated with ten year mean values of rainfall and temperature. Organic carbon increased with rainfall ($r=0.5$) and decreased with temperature ($r=-0.3$). Virgin soils had higher values of total nitrogen, organic carbon and humus than cultivated soils when rainfall was above 1050 millimeters. Values were lower when rainfall was below 1050 millimeters.

Biological Nitrogen Fixation:

Pahwa *et al.*, (2001) was conducted a pot culture experiment using red soil (Alfisol) during 1993/94 and 1994/95 in Jhansi, Uttar Pradesh, India to investigate the effect of biological nitrogen fixation on the quality and yield of pure and mixed stands of *C. ciliaris* and *S. hamata*. Eight treatments were used in the experiment, consisting of 3 systems of growing pastures (pure stand of *C. ciliaris*, pure stand of *S. hamata* and mixed stand of both pastures at 1:1 ratio) and 3 types of inoculation (uninoculated control, *C. ciliaris* inoculated with *Azospirillum lipoferum* strain-1 and *S. hamata* inoculated with *Bradyrhizobium* strain J-9). The results showed significant increases in the biomass production of pure stands of *C. ciliaris* and *S. hamata* inoculated with nitrogen fixing bacteria. Among the various treatments, the mixed stand of *C. ciliaris* and *S. hamata* inoculated with nitrogen fixing bacteria recorded the highest fresh and dry matter yield, nitrogen uptake and crude protein accumulation.

PHOSPHORUS: In addition to P fertilization and organic manuring, introduction of legumes in the cropping system (Singh and Singh, 1969; Singh and Faroda, 1987) also increased the available P status of soil. Application of weedicides was also found to have a desirable effect in enhancing P availability and this might be due to the stimulatory effect of weedicides on soil microorganism (Yaduvanshi *et al.*, 1985). Besides, inclusion of a legume in the cropping system also increases the available P status of soil.

The available phosphorus status of the soil was found to enhance with the addition of FYM, either alone (Singh *et al.*, 1983) or in combination with nitrogen (Bharguvanshi, 1988) or phosphorus (Havanagi and Mann, 1970; Mandal and Mandal, 1973). Farmyard manure itself contains considerable amount of P and its response has

been observed to be universal (Gattani *et al.*, 1976; Mohammed Sherif *et al.*, 1974; Meek *et al.*, 1979). Many of the soil properties influence P availability in the soil. It includes the nature and amount of soil components like clay, organic matter and hydrous oxides of iron and aluminium, concentration and valences of the constituent cations and pH of the soil system. The increase in the available phosphorus status of soil due to the addition of P has been found to be universal (Sharma and Meelu, 1975; Anand Swarup and Ghosh, 1979). Addition of N alone decreased the available P status of soil due to enhanced crop removal (Bajwa and Paul, 1978). Similarly findings from many other centres of long-term fertilizer experiments have shown that the available phosphorus under N alone treatment was even comparable to that of control (Nambiar, 1985)

Increased rates of P application has resulted in considerable buildup of soil available phosphorus as reported by several workers (Singh and Balasubramanian, 1983; Campbell *et al.*, 1984; Rao *et al.*, 1984; Patel *et al.*, 1989)

Summarization of results of the long-term fertilizer experiments by Nambiar (1985) revealed that there was a considerable build up in the available P content of alluvial, red loam and sub mountain soils of Punjab, Ranchi and Palampur due to the application of increasing rates of phosphorus. Similar were the results from the black soil of Coimbatore centre (Subramanian, 1986; Muthuswamy *et al.*, 1990).

Incorporation of crop residues and green manures were also found to have a positive influence in improving the available P status of soil (Badanur *et al.*, 1990).

Tiwari *et al.*, (2002) and Vats *et al.*, (2001) recorded that build up of available P status was significant under 100% optimum NPK plus

organic matter treatment and this may be attributed to the influence of organic manure in increasing the available P in soil through complexing of cations like Ca^{2+} , Mg^{2+} , Fe^{3+} and Al^{3+} , which are mainly responsible for the fixation of phosphorus.

POTASSIUM:

Soil moisture has important role in K fixation and release behaviour. Drying of soil causes fixation of added K (Grewal and Kanwar, 1967), but it is also known to promote its release (Kadrekar and Kibe, 1973). Response of K has been found in many areas in the country, the extent being generally higher with rice than in wheat.

Ghosh and Biswas (1978) observed that continuous application of K raised the available K status in most situations. Soil acidity is another factor affecting K availability in lateritic soils. Negi *et al.*, (1981) found that available K increased significantly with application of potassium, the increase being higher than K applied with FYM than K alone.

It has been shown that percentage of potassium saturation (PPS) on clay complex gives a better indication of K availability as compared to other forms of K. Potassium saturation in most of the laterite soils is found to be low ranging from 1 to 3 per cent. Presence of low potash bearing minerals coupled with adverse soil conditions like soil acidity determines the K availability in these soils. In general, laterite soils are dominant in kaolinite type of clay minerals with limited mica content. Moreover, release of K from these meager quantities of mica and its conditions, the K selective binding sites are occupied by Al and Al-hydroxy cations and their polymers, and the extent to which these exist is a function of soil pH (Panda and Koshy, 1982).

Depletion of exchangeable or available K on exhaustive or continuous cropping without supplying K and build up in soil fertilized

with K has been reported by some workers on alluvial soils (Biswas *et al.*, 1977; Subbarao and Ghosh, 1983).

Kaushik *et al.*, (1984) observed that the available K decreases due to continuous application of N fertilizer alone or in combination with P. Patel *et al.*, (1986) found that 72 per cent of WSK and 78 per cent of exchangeable K was decreased due to intensive cropping of groundnut-wheat sequence in medium black calcareous soils. Chakravarti *et al.*, (1987) also found that the K content of soil to be decreased due to continuous cropping.

Sharma and Singh (1989) conducted field experiment on acid soil of Meghalaya, as three potato based cropping systems found that increase in N, P and decrease in K in the soil. However, available NPK increased significantly in all systems over their initial status.

Roy *et al.*, (1990) observed after two years of cropping indicated build up of K in all the forms of K, the percentage increase in exchangeable K content over initial soil value (112 Kg K₂O ha⁻¹) was 6, 8, 18, and 22 at 20, 40, 60, and 80 Kg K₂O ha⁻¹ levels, respectively.

Rao and subramaniam (1990) conducted field experiment in an Altisol at Bangalore to study the depletion and build up pattern of soil potassium. The depletion of potassium in K untreated plots ranged from 45 to 78 Kg ha⁻¹ of available K and 20 to 130 Kg ha⁻¹ of non-exchangeable K. Highest depletion occurred in carrot-okra-tomato cropping sequence and there was significant build up of soil potassium in K treated soils.

Thakur *et al.*, (1990) conducted field experiment on a sandy clay loam soil of Ranchi. They observed that the potassium balance was negative in all crop sequence and a negative K balance at different levels of fertilizer application.

Prasad (1993a) observed that the highest positive K balance (21.2 Kg K₂O ha⁻¹) was obtained in the groundnut-oat cropping sequence and lowest in ragi-lentil (7.9 Kg K₂O ha⁻¹) at 80 Kg K₂O ha⁻¹ application. Prasad (1993b) also observed that in most of crop rotation the gain of available K increased with increasing levels of applied K. positive balance of available K was obtained in K treated soils and negative balance was noted in K untreated soil in all the cropping sequences during crop growth.

Subbarao *et al.*, (1993) reported that the available K decreased in optimum and high N and P treated plots (without K) by 43 Kg ha⁻¹. Addition of optimum amount of K also resulted in decreased whereas high rate rose. Tiwari *et al.*, (1998) reported that the application of K to the crop significantly increased available status of K in soil. Split application also increased K status in soil than the other time schedule treatments; and Santhy *et al.*, (1998) observed that available K was negatively balanced due to continuous cropping with a decrease of 22 per cent from the initial level.

Malewar *et al.*, (1999) observed that the oilseed based crop sequence showed differential effect on the availability of N, P and K in soil. The available N, P and K in soil increased over initial content after the cycles.

SULPHUR: Sulphate adsorption is negligible in surface soils because little adsorption occurs at soil pH and phosphate levels conducive to crop plant growth (Kamprath *et al.*, 1956). Therefore, most of the effective SO₄²⁻ adsorption in cultivated soils occurs in acid argillic horizons, which often retain enough S to support plant growth. The depth of the argillic horizon, in part determines the plant availability of S accumulated in that soil layer. The depth of crop rooting also

influences the amount of S accessible to the crop in soils with subsoil accumulation of SO_4^{2-} .

Sulphur commonly limits crop production in the sub humid and humid regions of the Pacific North-west. Low atmospheric deposition of S ($<6 \text{ kg ha}^{-1} \text{ Yr}^{-1}$), low S-containing surface irrigation water and basalt, granite, and volcanic ash parent materials have resulted in soil S that have low total S content and low S bioavailability (Rasmussen and Kresge, 1986). Sulphur responses in cereals are dependent on having adequate N availability (Koehler, 1965) and high yield potential (Raming *et al.*, 1975). High rainfall and winter coastal areas, coupled with low S deposition create S deficient conditions in cereals, forage, fruit and vegetable production (Rasmussen and Kresge, 1986). In contrast, arid soils in the Western United States with high accumulation of soluble SO_4^{2-} , low leaching potential under non-irrigated conditions, or that are irrigated with high SO_4^{2-} -containing ground water respond less frequently to S fertilization.

2.3: Status of nitrogen, phosphorus, potassium and sulphur in soils.

NITROGEN: Danier and Langham (1936) determined total nitrogen and organic matter in cropped, virgin and drifted soils of the southern high plains of America. The drift soil had on an average 24.5% less organic matter and 28% less nitrogen than the virgin soil. The organic matter-nitrogen ratios were determined and it was found that this ratio in the cropped soil was 22.47 in the virgin it was 23.30, while the average ratio in the drifts was 24.44. Since the total nitrogen and organic matter in the soil profile decreases rapidly with depth, the data clearly proved the great necessity for retaining these in the surface soil. As a result of cropping and wind erosion, the organic matter in the cultivated soils decreased by 18% and the nitrogen decreased by 15%. Very little

difference occurred in the nitrogen and organic matter content of the cropped and virgin subsurface soils.

Singh and Dixit (1972) studied ten soil samples of soil from different regions. Native fixed NH_4 ranged from 11.8 to 37.4 ppm, which represented 6.4 and 10.8 % of the total N in the top soil and subsurface soil, respectively. Fixed $\text{NH}_4\text{-N}$ /total N and C: N ratios tended to decrease with depth.

Nishita and Haug (1973) studied the content and distribution of different forms of N in several alkaline soils under different plant associations at Nevada Test Site. In the surface layers (0.0-7.6 cm) the order of N forms was $\text{NO}_2\text{-N}$ (not detectable) < extractable $\text{NH}_4\text{-N}$ < $\text{NO}_3\text{-N}$ < fixed $\text{NH}_4\text{-N}$ < organic N. Total N was greatest in the surface layer and decreased sharply in the second layer (7.6-15.2 cm). Below this layer, the total-N content varied slightly. The amount of fixed $\text{NH}_4\text{-N}$ varied somewhat with different soils, but only slightly within any given soil profile. The $\text{NH}_4\text{-N}$ fixation was lower under plants than in bare soil. The N content in soil was influenced by plant species, the highest being under *Krameria parvifolia* Benth and the lowest under *Larrea tridentata*. The higher organic matter content plus the higher exchangeable K under plants was considered to cause the lower $\text{NH}_4\text{-N}$ fixation.

Raju and Mukhopadhyay (1973) studied all the soils representing different agro-climatic regions of West Bengal for different forms of nitrogen. They found native fixed NH_4 , which ranged from 0.61 to 2.28 m.e. 100g^{-1} to contribute 61 to 100% of the mineral nitrogen of the soils. As a fraction of total nitrogen, it varied from 4.90 to 54.06%, while the inorganic nitrogen contributed substantially (6.30 to 54.70%) to total N.

Mahajan and Kanwar (1974) examined distribution on various forms of nitrogen in typical saline-alkali soils of Punjab and Haryana. They found total N, NO₃-N and NH₄-N to vary from 27 to 291, 7 to 22.5 and 0 to 7 ppm, respectively.

Aulakh and Dev (1976) studied the contents of total-N, ammonical-N, and nitrate-N in the five soil series and found these to range between 41 and 627, 0 and 16.8, 0.5 and 30 ppm, respectively. Total N values were highest in normal cultivated soils, followed by the barren sandy soil, and lowest in the saline sodic soil. In all soils total N content was highest in the surface layers where the organic matter content was high. Both ammonia and nitrate-N content were distributed uniformly throughout the soil profiles, except in the saline sodic soil where nitrate nitrogen accumulated in the surface layer.

An assessment of the nitrogen fertility status of soils of India has been made on the basis of 9.2 million soil tests carried out in more than 250 soil testing laboratories during the past decade with a coverage extending to nearly 99% of the total number of districts and Union Territories in the country. The index of available nitrogen has been the percentage organic matter content in the plough layer. Soils of 62.5% of the districts and Union Territories have been found to be low in available nitrogen and 32.6% come in the medium class. Only 18 districts located in north-eastern hills and in Himalayan regions representing 4.9% of the total of 365 districts have a high nitrogen status (Ghosh and Hasan, 1980).

Singh *et al.*, (1981) studied the content of total soil N, organic C and C: N ratios of cultivated Tanzanian soils and found these were to range from 0.24-0.49, 3.1-5.8 and 10.7-15.0%, respectively, in the surface horizons and decreased with depth. Native fixed NH₄-N accounted for

2.3-3.0% of total soil N in surface horizons, while the quantities of fixed $\text{NH}_4\text{-N}$ decreased with depth, its contribution to total soil N increased. Exchangeable $\text{NH}_4\text{-N}$ ranged from 15 to 32 and $\text{NO}_3\text{-N}$ from 26 to 73 $\mu\text{g g}^{-1}$ soil in surface horizons, and both decreased with depth. Exchangeable-N accounted for 1.1-2.4% of total soil N. Over 97% of total soil N was organically bound. Of the total soil N in the surface horizons, 29.0-79.0% was acid hydrolysable. Hydrolysable $\text{NH}_4\text{-N}$, hexosamine-N, serine plus threonine, α -amino acid-N, identified-N and unidentified-N in the surface horizons were in the ranges 14.5-22.4, 4.8-9.2, 0.2-5.8, 4.0-16.7, 23.3-48.8 and 0.3-41.5%, respectively, of total soil N. Distribution patterns of the organic-N fractions in the profiles varied among soils. Sixteen amino acids were identified which accounted for 82-100% of the α -amino acid-N fraction in the soils, glycine and alanine alone accounted for 35-40%.

All the organic-N fractions were transformed to varying degrees during aerobic incubation. An investigation was under taken to study the fertility status of the soil of the Agricultural Research Station, G.A.U., Amreli. About 24 surface soil samples were taken and analyzed during 1982. From the fertility point of view, the soils fall in low to medium class with respect to total N. The majority (70.2 per cent) of soil samples fall under the medium class of total N. None of the sample falls in high class for total N. (Anonymous, 1983).

Patel *et al.*, (1983) studying the fertility status of three locations was evaluated in relation to geographic situation and cultivation practices. Soils of the foothills of Mount Girnar (Junagadh) had the highest N contents, while those of the coastal alluvial region (Mahuva) were predominantly rich in K. Soils of Jamnagar had the lowest

nitrogen contents. The nutrient content normally decreased with increasing depth.

Evdokimova and Dronova (1989) investigated the dynamics of various forms of nitrogen compounds in different forest types in the southern taiga subzone in Moscow. The most favourable nitrogen regime occurs in forests of mixed type, especially in a spruce (picea/broad leaved forest) on brown forest soil.

Narain *et al.*, (1989) studied the status of different N forms on two sites at different elevations in Uttar Pradesh. Mineral nitrogen and fixed ammonium as per cent of total nitrogen were higher in agricultural fields of Selakui than at Fakot. A good relationship was observed between total nitrogen and mineral forms of nitrogen and between clay content and fixed ammonium. These relationships were closer at Selakui (Low elevation) than at Fakot (Higher elevation).

Datta *et al.*, (1990) while studying the characteristics of soils supporting cinchona plants following clear felling of natural forests in the Darjeeling hills, West Bengal (India) found soils to be acidic and rich in organic carbon and available nitrogen.

Dhar *et al.*, (1992) studied the effect of sand mineralogy on total and available nitrogen status of Udic and Typic Ustochrept pedons from Madhya Pradesh, India. They found both soils to be deficient in available nitrogen. The Udic Inceptisol was characterized by staurolite and tourmaline, and the Typic Inceptisol by hornblende, staurolite and tourmaline. Sand mineralogy and elemental analysis indicated that the 2 pedons had good inherent fertility.

Grewal *et al.*, (1992) analyzed 446 samples collected through 10 x 10 grids, to evaluate the spatial variability in the available N content, in soils of Haryana. Using classical statistical analysis techniques they

found of a normal distribution of available N content with a mean of 186 kg ha⁻¹, standard deviation 71.7 kg ha⁻¹, and coefficient of variation 38.5. The range was from 28 to 440 kg ha⁻¹, with 10% samples extremely low (100 kg ha⁻¹), 24% very low (100-150 kg ha⁻¹), 22% low (150-200 kg ha⁻¹), 26% moderately low (200-250 kg ha⁻¹) and 18% medium (250-500 kg ha⁻¹) in available N.

Gil Sotres *et al.*, (1993) studied the distribution of different forms of N in very young (0 to 7 year old) reclaimed soils from the Meirama lignite mine in northwest Spain. Total N increased rapidly with soil age, mainly in the humic acid fraction. Acid hydrolysis indicated that amino acid N and a hydrolysable unknown form of N increased with soil age. All these data suggest that there is rapid stabilization of organic N during the first few years of evolution of these mine soils, to the extent that distribution of N forms in the 7-year-old soil is very similar to that of native soils.

Maliwar and Timbadia (1993) collected 76 surface soil samples of saline-sodic soils from coastal and interior areas from Vallabhipur to Maliya and Amreli, Liliya and Lathi talukas of interior areas of Saurashtra. The available N was ranged from 188 to 439 Kg ha⁻¹.

Yefimov and Tsarenko (1993) determined the potential fertility of virgin peat soils in their organic matter and total nitrogen contents. The effective fertility of drained peat soils depends on the transformation of the organic matter and nitrogen resources. The transformation of organic matter and nitrogen resources of drained lowland peat soils by soil-climatic zones of Russia, from the extreme north to the southern boundary of their distribution, was established. Similar processes of transformation of organic matter and nitrogen occur in developed soils located in different soil-climatic zones. There is a decrease in the content

of easily hydrolyzable and an increase in the amount of difficultly hydrolyzable organic nitrogen-bearing compounds, as well as the accumulation of mineral forms of nitrogen. With a similar botanical composition of peat, identical drainage conditions, and method of utilizing the bog, the intensity of these processes depends on the latitude of its location and increases from north to south on the European continent.

Mahendran *et al.*, (1994) studied surface and sub-surface soil samples pertaining to various soil sub-groups in the Tirunelveli-Kattabomman, V. O. Chidambaranar and Kanyakumari districts of Tamil Nadu (India) to assess the fertility level and to prepare a soil fertility capability classification.

All the soils of three districts are low in available nitrogen. In order to evaluate the available nutrient status in the soils of Junagadh district, soil samples were collected from 12 main representative soil groups of the district during 1992. It was revealed that the soils of Junagadh district varied in available N from 75.3 to 329.3 Kg ha⁻¹ with a mean value of 188.9 Kg N ha⁻¹. More than 97 per cent samples fall in low and 3 per cent samples in medium category (Anno., 1995).

Singaraval *et al.*, (1996) studied nutrient status of the coastal saline soils of Tamilnadu. The data on nutrient status showed that the soils are low in organic carbon and low to medium in available nitrogen.

Mahendran *et al.*, (1997) also studied surface and subsurface soil samples pertaining to 7, 9 and 4 soil subgroups in Tirunelveli, Tuticorin and Kanyakumari districts, respectively, to assess soil fertility and prepare the soil fertility capability classification. All the soils were found to be low in available nitrogen.

Pandey *et al.*, (1999) studied the effect of soil aggregation the distribution of organic carbon and total nitrogen. They found that with the reduction in the content of soil macro aggregates there was a reduction in the content of total organic carbon and total nitrogen.

Korikanthimath *et al.*, (2000) collected soils from various cardamom (*Elettaria cardamomum*) plantations in Kodagu District (Karnataka, India) and assessed them for their nutrient status. The soils were acidic (5.0 to 6.6 pH) in nature with high organic carbon content, which decreased with depth of the soil. The soils were medium (56.82%) to high (43.18%) in available nitrogen. The soil profile collected from cardamom fields indicated relatively higher level of available nitrogen and organic matter than those from uncultivated area due to recycling of organic materials in the former. The organic carbon content was correlated positively and significantly with available nitrogen content.

Saha *et al.*, (2000 a) studied the depth wise distribution of organic carbon and different forms of nitrogen in 24 soil profile from Tarai region of West Bengal, India. Depth wise distribution of nitrogen forms showed a similar trend to that of organic carbon. Available N content in the surface soils ranged from 52 to 220 mg kg⁻¹ and accounted for 0.087% of total N with respect to available N status of the surface soil in most of the pedons soils collected from the cultivated area were low (<250 kg ha⁻¹), and the pedons from tea gardens and forest area were medium (250-500 kg ha⁻¹).

Sellamuthu *et al.*, (2000) studied soils of sugarcane-growing areas of Uttiramerur taluka, Kancheepuram District, Tamil Nadu, India. The available nitrogen content was low in 96% of the surface and in 98% of the subsurface soil samples.

Patel (2004) collected soil samples from Surendranagar district of Gujarat and found low in available nitrogen. It was ranging from 57 to 282 with a mean value of 157.5 Kg ha⁻¹.

PHOSPHORUS: Phosphorus content of the lithosphere has been reported to be 0.28 percent (Clarke, 1920), which is considerably higher than that in the Indian soils. The total P content in the Indian soils ranges from 100 to 2000 ppm (Tandon 1987).

However in certain cases, P concentration and its uptake were found to be increased with native lime content (Sutaria and Patel, 1987). This happened in case of groundnut because it's a calcicole legume which absorbs high calcium in doing so same fraction of Ca might be dissolved from sparingly soluble calcium phosphates.

In general available P decreased with increasing CaCO₃. The magnitude of decrease depends upon surface area of CaCO₃ rather than its total amount. Smaller the particle size more surface area, higher will be the surface reactivity and lesser the available P (Patel and Kanzaria, 1985).

POTASSIUM: In general calcareous soils are well supplied with potassium. This may be because these soils are located in the arid and semiarid regions where buildup of cations and base saturation is a common feature due to reduced leaching losses. Different forms of K like water soluble, NH₄OAc, HCl and H₂SO₄ extractable K exhibited positive correlation with soils having CaCO₃ less than 10%. But as CaCO₃ content rise to more than 30% extractable K showed significantly negative correlation with CaCO₃ (Padalia, 1977).

Potassium fertility status of some Indian states having predominantly calcareous soils shows that most of the calcareous soils of India are medium to high in their available soil test K (Tandon and

Sekhon 1988). Some of the pockets in Tamil Nadu and Bihar are deficient in available K. Subba Rao Srinivasa Rao (1996) reviewed the K status of different agro-ecological regions of India and reported that the agro-ecological regions with predominantly calcareous soils were medium to high in exchangeable as well as nonexchangeable K.

Water soluble and NH_4OAC extractable K increased sharply with increase in CaCO_3 of these soils. Tomar (1986) reported significant positive relationship between calcium carbonate and HNO_3 soluble and total K in calcareous soils of Junagadh and Rajkot districts of Gujarat. However in pot culture study on effect of different levels of lime on K content in index leaf of maize grown in clayey Vertic Haplustepts (Jadav and Golakiya, 1993), decrease in content of K in the leaves was noted with increase in levels of lime. Bhatt, (1993) observed that interaction effect of native lime and potassium was found significant. It was indicated that application of K @ 25 ppm in combination with lime up to 30.5 per cent gave the maximum response even under medium status of available K in soil.

Shallow black soils originated from limestone showed lower levels of $\text{HNO}_3\text{-K}$ compared to other soils (Patel *et al.*, 1993). It indicates that variations in K content among the soils and excess lime contents were not exactly associated with lower total K content. Despite higher lime and clay content, coastal fallow saline soils showed larger exchangeable, $\text{HNO}_3\text{-K}$ and total K. Similarly the available K forms of some calcareous Vertisols of Madhya Pradesh indicated a variation in the soil test value among soils of similar origin. The variation in the K forms are highly correlated with plant mobilization rates of soil K ($r=0.90\text{-}0.93$). The soil with higher CaCO_3 content showed larger K

release in different extractants and plant mobilized K as compared to the soil with lower CaCO_3 (Srinivasa Rao and Takkar 1997).

Some of the available forms of K in calcareous benchmark series showed a wide variation among the series. Calcareous vertisol series Sarol and Noyyal showed higher available form of K compared to other soil series. Again among calcareous soils, smectitic Vertisois and Vertic sub groups maintained higher exchangeable forms of K compared to illitic Entisois and Inceptisols. Illitic sols showed higher nonexchangeable forms of K. All these calcareous soils except Sarol and Noyyal may suffer from K deficiency because of their lower level of readily available K status such as CaCl_2 K and citric acid and 1.38 N H_2SO_4 extractable K (Srinivasa Rao *et al.*, 2000).

SULPHUR: The heat soluble sulphur which is considered to be available to plants and obtained after heating the soil with water at 98° to 102°C and extracting it with 1 percent NaCl solution (Williams and Steinbergs, 1959) is one of the important fractions of sulphur.

Organic form of sulphur is estimated from the soil using NaH_2PO_4 extracting solution (Bardsley and Lancaster, 1960). In humid and semi-arid regions, it is mostly found in the form of organic compounds, while in arid region as an inorganic compound mostly as sulphate salts of different cations like calcium, magnesium, sodium and potassium.

The total sulphur is one of which is estimated from the soil by digesting it with $\text{KNO}_3 + \text{HNO}_3$ (Chaudhary and Cornfield, 1966). The total sulphur content of the soil depends on genetic soil type, humus content, mechanical composition and parent materials. It increases with increase in organic matter. It is quite high in tidal marsh and peat soils.

In some soils it ranges up to 2300 ppm (Olivero, 1960; Mackenzie *et al.*, 1967) and even up to 5500 ppm (Fleming and Alexander, 1961) in tidal marsh soils.

Reddy and Mehta (1970) while studying sulphur status of 10 cultivated soils of Gujarat, reported very low and narrow range *viz*, 20 to 62 ppm with an average of 33.7 ppm organic sulphur in the soils of Kaira and Baroda districts.

According to Val'nikov (1970), total sulphur content in peat, grey and dark grey forest soils of Totar, USSR was 290 to 600 ppm in surface horizons of laggolic profile but higher than chernozemic and podzolic soils of Alberta (Lowe, 1965) while reviewing sulphur status of European soils. Trocme (1972) reported that total sulphur content ranged from 100 ppm in sandy soils (low in organic matter) to 800 ppm in soils rich in organic matter or calcium carbonate. Marsonia (1980) reported range of 28.1 to 806.3 ppm with an overall average of 123.7 ppm in the selective soils of Saurashtra region.

In the soils of Hissar, available sulphur was reported to be 17.9 ppm (Singh and Singh, 1975), whereas, in the soils of Kaira and Baroda districts of Gujarat, it varied from 22.00 to 54.00 ppm with an average 40.00 ppm (Reddy and Mehta, 1970).

Mukhopadhyay and Mukhopadhyay (1980) studied twelve profiles of five major soil zone of West Bengal and observed that total sulphur ranged from 18.7 to 333.2 ppm with an average of 130.6 ppm in different textured soils varying from loamy sand, sandy loam, loam and clayey.

Prasad *et al.*, (1983) noted a range of 621 to 2310 ppm total sulphur in the surface soils of sandy clay loam to clayey through sandy clay in texture and moderately acid to alkaline in soil reaction (pH 5.6 to

7.8). Dwivedi *et al.*, (1983) observed that heat soluble sulphur ranged from 17.3 to 39.0 ppm with a mean of 25 ppm and constituted 19.0 percent of the total sulphur in five different types of soils of Uttar Pradesh.

Qureshi (1987) worked in the soil of Junagadh and Rajkot districts of Saurashtra region and reported that in combined soil, the heat soluble sulphur content varied from 5.78 to 127.88 ppm with a mean of 24.63 ppm.

Singh (1995) studied mean available sulphur content in 7048 soil surface samples representing major all the soil group and agro-climatic regions of Madhya Pradesh, ranged from 4.9 to 43 mg S kg⁻¹ soil.

Gowrisankar and Shukla (1998) worked on five hundred surface soil samples collected from ten major soil series of Delhi, India and stated that the available S content of most of the soils was observed in the high range with a mean value of 50.34 mg/kg.

Mali and Raut (2001) had conducted a study to evaluate the available sulphur supplying capacity in relation to the physico-chemical characteristics of oilseed dominated soils, Vertisols (116), Inceptisols (25) and Entisols (171) collected from Latur district, Maharashtra, India, and stated that the available sulphur content in Vertisols ranged from 31.4 to 122.0 with an average of 51.0 ppm.

2.4: Interactions of different major nutrients in soils:

Korter *et al.*, (1963) observed a linear relationship between organic carbon levels and total sulphur and sulphate sulphur contents of mineral and peat soils.

In set of 15 field trials on rice in Bihar, application of 20 Kg K_2O ha⁻¹ in combination with N resulted in a mean yield increase of 300 Kg ha⁻¹ over 40 Kg N, 750 Kg ha⁻¹ over 80 Kg N and 910 Kg ha⁻¹ over 120 Kg N thus clearly demonstrating the positive N x K interaction (Umar *et al.*, 1986). This is also an example of a cation (K^+)-cation (NH_4^+) interaction because in rice soils most of the N is present in NH_4^+ form. This study indicated that K does not compete with NH_4^+ for selective binding sites. Ajay *et al.*, (1970) working with tomatoes in hydroponics and Mengel *et al.*, (1976) working with rice also concluded that K^+ does not compete with NH_4^+ in the absorption process.

The organic carbon of European soils from 75 to 90 percent of the total sulphur and the variations in organic matter content as reviewed by Trocme (1972).

Singh *et al.*, (1981) observed significant positive correlation between total phosphorus and total sulphur, sulphate sulphur and water soluble sulphur.

Singh *et al.*, (1992) reported that total content of nitrogen ranged from 212 to 1841 mg/kg, and was positively correlated to organic carbon.

Mandal *et al.*, (1997) observed that the organic sulphur showed a positive and highly significant correlation with total N.

Trivedi *et al.*, (1998) stated that different forms of sulphur in general decreased with depth and showed a significant positive relationship with organic carbon content.

Randhawa and Arora (2000) while working on sandy and loam soils, a highly significant positive interaction was obtained between P and S in terms of total P uptake at lower rates of S

application; higher rate of S resulted in a decreased total P uptake in both the soils.

Sharma *et al.*, (2000) showed that total nitrogen had significant and positive correlation with all forms of soil sulphur. Singh *et al.*, (2000) observed the organic and non-sulphate sulphur had a significant positive relationship with organic carbon.

Singh and Singh (2007) studied distribution of different forms of nitrogen and sulphur in some representative soil profiles of mid-western U.P. Nitrogen forms gave significant positive correlation with sulphur forms *i.e.* total S and organic S. Sulphur forms also gave significant positive correlation with nitrogen forms *i.e.* total N and organic N.

2.5: Forms of nitrogen, phosphorus, potassium and sulphur in soils:

NITROGEN: Nitrogen forms in soil have been viewed as a means of assessing the dynamics and sustainability of its bioavailable forms. The availability of nutrients is determined by the dynamic equilibrium 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 forms of nitrogen is reviewed as under.

Nath and Deori (1976) studied soils of Arunachal Pradesh falling under different altitudes. The content organic matter and different forms of nitrogen increase with an increase in elevation due to high rainfall and luxurious growth of vegetation. The C: N ratio varied from 4.9 to 22.2 at different elevation.

Minhas and Bora (1982) studied the effect of altitude on the organic carbon content and the forms of nitrogen present in soils of

Himachal Pradesh. With increase in the altitude, the organic carbon and the total, available, ammonical, nitrate nitrogen increased and the correlations were highly significant. They also showed that the total nitrogen was highly dependent on organic carbon content and the available nitrogen was mainly dependent on the total nitrogen of the soil.

Sahrawat (1982) studied mineralization of soil organic N in nine Philippine rice soils having a wide range in organic carbon (0.64 to 12.8%) and total N contents (0.070 to 0.560%) by measuring production of ammonical N under water logged incubation at 30 °C for 2 weeks. The mineralisable N released in these soils ranged from 26 to 438 $\mu\text{g g}^{-1}$ of soil and was highly and positively correlated with the organic carbon ($r=0.897^{**}$) and total N ($r=0.912^{**}$) content. Presumably organic carbon and total N content of soils may be good indices for potentially mineralisable nitrogen in wetland rice soils.

Sahrawat (1983) studied surface samples of 39 diverse Philippine soils representing a wide range of pH, organic matter and texture to determine the relationships between ammonification of organic nitrogen and soil properties. Simple correlation analysis showed that ammonium production was correlated highly significantly with total nitrogen ($r=0.94^{**}$), organic carbon ($r=0.91^{**}$) and C: N ratio ($r=-0.46^{**}$). Multiple regression analysis showed that organic matter accounted for most of the variation in mineralisable nitrogen.

Saha and Mukhopadhyay (1983) studied changes in the amounts of soluble nitrate, exchangeable and fixed ammonium due to wetting and drying cycles imposed after addition of ammonium sulfate in soil incubated under three moisture levels. Higher amounts of exchangeable and fixed ammonium forms were present after two wetting/drying

cycles than one cycle. The highest fixation of added ammonium was observed under waterlogged conditions and least under 50% of moisture holding capacity.

Saha and Mukhopadhyay (1985) further studied the effect of liming acid soils on inorganic and organic-N transformations and showed that increase in pH due to liming was associated with increase in the amount of fixed ammonium, exchangeable ammonium and soluble nitrate nitrogen over the corresponding unlimed soils. Moreover, the total hydrolysable organic nitrogen decreased considerably during mineralization and amino acid-N fraction contributed most to the mineralized or available-N content. Part of the mineralized ammonium apparently was converted to fix by clay.

Singh and Datta (1988) stated that total and other forms of nitrogen (available, ammonical and nitrate) increase with increase in altitude. Multiple correlation study showed 89% of the variation in the total nitrogen content, which was due to associative influence of altitude, organic carbon, total nitrogen, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$.

Singh *et al.*, (1992) collected soil samples from surface horizons and profiles from across Haryana state, India in order to study nitrogen forms and their distribution. Total N ranged from 150 to 1000 ppm, organic N 108 to 711 ppm, fixed $\text{NH}_4\text{-N}$ 9 to 380 ppm, and available N from 38 to 272 ppm. In general, the total, organic and fixed $\text{NH}_4\text{-N}$ decreased with depth in all profiles, whereas there was no consistent trend in the distribution of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ in surface soils. Organic carbon gave significant positive correlation with total N, organic N, fixed $\text{NH}_4\text{-N}$ and available N. Fixed $\text{NH}_4\text{-N}$ and available N were positively correlated with clay content. Organic carbon and mineral N were the prime factors affecting available N status of these soils.

Walia *et al.*, (1998) observed that the total N was positively correlated with organic carbon of soils of different landforms but did not follow consistent pattern of distribution within the profile in majority of the soils due to leaching of N and fluvial characteristics. Mineral N (NH_4^+ , NO_3^-) accounted for 0.6 to 4.2 per cent of total N which was dominated by $\text{NH}_4\text{-N}$. Some soils have nearly same available N content despite large variation in other factors in soils such as C: N ratio of organic matter, texture, mineralogy and bulk density. Thus probably be attributed to similar N mineralization rates in these soils. The C: N ratio of surface soils varied from 8 to 13.5 and decreased from hills to plains.

Satisha *et al.*, (2000) studied nutrient status of soils of slope lands in Mizoram, India. The results showed that the soils had low to medium available nitrogen. The total and available N had significant negative correlations with altitude. Silt had a positive influence on total N, organic carbon and available N.

Kundu *et al.*, (2001) conducted experiment during 2000 to determine forms and availability of mineral nitrogen at Bhubaneswar, Orissa, India in 12 soils under 5 water regimes, viz. 20, 40, 60, 80 and 100 % saturation. The $\text{NO}_3\text{-N}$ dominated at 40% saturation, where as $\text{NH}_4\text{-N}$ dominated at 60 % saturation. Averaged over the soils, mineral nitrogen availability was lowest at 60-80% saturation. The mineral N availability at 4 -100% saturation was negatively correlated with pH and electrical conductivity (EC) of soil. In soils at 100% saturation, where mineral N was in NH_4 form, the dependence of N availability on pH as well as EC was best described by power type equation. In partially saturated soils, the mineral N was either in NO_3 or in NO_3 plus NH_4 forms.

Marian and Kachhave (2009) conducted an experiment on "Nitrogen fraction and their relationship under sorghum sunflower cropping sequence in a typic haplustert". The result of these studied revealed that the combined application of organic + inorganic fertilizers caused significant increase in available nutrients status of the soil. All nitrogen fractions were increased significantly in all treatment combinations.

PHOSPHORUS: In soils, phosphorus present in both organic and inorganic forms, organic form comprises with inositol phosphate esters. The phosphate bound to aluminum (Al-P), iron (Fe-P) and calcium (Ca-P) and ionic forms of phosphate (PO_4^{3-} , HPO_4^{2-} and H_2PO_4^-) in soil solution constitutes the major active forms of inorganic phosphorus. Relatively less active forms of inorganic P are occluded and reductant. The all forms of P exist in all soils but Al-P and Fe-P (8-10% of total P) are more abundant in acid soils, while Ca-P dominates in calcareous soils. Savani (1981) reported that Ca-P may constitute 40-50% or even more of total-P in calcareous soils depending up on the available P and native lime content of the soil.

Investigations carried out in long-term fertilizer experiments in India by Agarwal *et al.*, (1987); Subramanian and Kumaraswamy (1989) and Udayasoorian and Sree Ramulu (1991) confirmed the general trend that in neutral and calcareous soils Al-P and Ca-P would dominate and in acid soils Fe-P would be the dominant fraction. In a field experiment on acid Alfisol (Sood and Bhardwaj, 1992), lime application increased appreciably the content of Al-P (100.1%), followed by Ca-P (68.5 %), Fe-P (39.3 %), organic-P (36.2%) and Saloid-P (25.6 %). On the other hand, application of inorganic P increases the content by about 100 percent. The effect of P application was more pronounced in organic and total P

build up than that of lime application. Increasing levels of P increased the activities of different P fractions (Santhy, 1995).

Tarafdar *et al.*, (2006) stated that the available p status was much less (0.3-0.9 % of total P) in arid soil. Maximum P was reported in NaHCO₃ extractable fraction (46.3-59.6 % of total P) followed by HCl extractable fractions (24.4-41.2 % of total P). In general, considerable reduction in water soluble P, NaHCO₃-P and HCl extractable-P was observed due to differences in vegetation.

Singh and Sharma (2007) observed that in soils of different Agro-ecological zones of Punjab, content the least amount of P in Saloid whereas the maximum P was found in Calcium-bound fraction. Phosphorus in the Al-P fraction was higher than Fe-P. On an average, the content of Saloid-P, Al-P, Fe-P and Ca-P were 2.9, 20.0, 5.3 and 243 mg Kg⁻¹, respectively.

POTASSIUM: More than 90 per cent of the total potassium is present as mineral or lattice K. it is structural component of K bearing minerals. The total potassium content of mineral soil range from 0.04 to 2.90 per cent (Jackson, 1964).

Ammonium acetate is most widely used extractant now a day. The soils of Indo-Gangetic plain are generally rich in available K (Ramamoorthy and Bajaj, 1969). The median value for clay fraction is 2.46 for silt is 0.73 and for sand is 0.21 per cent. Very high amount of total potassium in different fractions of Uttar Pradesh and north western India soils is observed by Mehrotra *et al.*, (1973) and Sekhon (1985).

According to Ghosh and Hasan (1976) 38% of the soils are high, 42% medium and only 22% are low in potassium. Non exchangeable

potassium is held between adjacent tetrahedral micas and transitional and amorphous clay minerals (Sparks and Huang, 1985).

The exchangeable K refers as the K adsorbed to exchange site and normally extracted with salt solution such as NH_4OAc , MgCl_2 , NaCl or CaCl_2 (McLean and Watson, 1985). Potassium in soils can not be easily characterized in terms of different forms because its state throughout the soil is essentially ionic (K^+). Sharp distinction between various forms of K is not possible and often there is an overlap between these forms (Sott and Smith, 1987).

In order to availability of K to plants and microbes the different forms are water soluble or solution K, exchangeable K, nonexchangeable or fixed K and mineral or lattice K (Sparks, 1987).

Generally it is extracted with hot N HNO_3 . The illite dominated soils of Indo-Gangetic plain generally contain high amount of nonexchangeable K (1150 mg/Kg) followed by smectite and Kaolinite (Sekhon *et al.*, 1992 and Bhonsle *et al.*, 1992). Similar to nonexchangeable K, the total contents are also highest in illitic soils of Rajasthan, Punjab, Haryana and part of Uttar Pradesh (Sekhon *et al.*, 1992). On an average, these soils contain 1.72 per cent but differ greatly (0.35 to 2.75%) from place to place.

It is usually found in very low quantities ($\sim 0.2\%$ of the total K). For arid and semi-arid region soils the water soluble K varies between 2 to 56 (mg/Kg) of soil in 1:2 soil water ratio and 0.1 to 2.8 (mmol/l) in saturation extract. The medium values for saturation extract K water soluble K of Haryana soils are 0.25 (mmol/l) and 9.8 mg/g soil respectively as reported by Singh and Shanwal (1997). The nonexchangeable K in Haryana soils ranges from 131 to 1625 mg/Kg soil with a medium value of 562 mg/Kg soil (Singh and Shanwal, 1997).

The soils of Haryana, Punjab, part of Rajasthan, Gujarat and Uttar Pradesh have varied content of available K (Singh and Kuhad, 1989 and Shanwal and Dutta, 2000a).

The values of total K in Haryana soils range from 0.11 to 4.0 per cent and the median value is 1.25 per cent (Singh and Shanwal, 1997 and Shanwal and Dutta, 2001a). The total K increases with the decreasing particle size.

SULPHUR: Williams and Steinbergs (1959) carried out an extensive studies on the forms of sulphur in the soils of Australia, and recognized the following important fractions of sulphur in the soils *viz.*, (i) sulphate sulphur (ii) water soluble sulphur (iii) humus sulphur (iv) reducible sulphur (v) organic sulphur (vi) heat soluble sulphur (vii) and ignition sulphur. The works conducted are reviewed in the following pages.

This fraction of sulphur is extracted with 0.15 percent CaCl_2 (Williams and Steinbergs, 1959). Generally, the inorganic sulphur is presented as sulphate and very little as sulphide. In well drained soils of humid and arid regions, nearly all the sulphur is combined with organic matter and little as sulphate in surface soils (Kanwar, 1963). Several workers have reported low amounts of sulphate sulphur in the surface horizons than those in lower horizons. This fraction of sulphur is extracted with 1 percent NaCl (Williams and Steinbergs, 1959). They reported a range of 0.2 to 102 ppm of water soluble sulphur in Australian soils.

The earth crust contains about 0.06 per cent sulphur. It is mostly present as sulphides, sulphates and organic combination with carbon and nitrogen (Kanwar, 1976). In humid and semi-arid regions, it is mostly found in organic compounds while in

arid region, as sulphate salts of different cations like calcium, magnesium, sodium and potassium.

Marsonia (1980) reported a range of 4.5 to 727.5 ppm with an overall average of 97.8 ppm in some of the selective soils of Saurashtra region.

Dwivedi *et al.*, (1983) observed a range of 14.1 to 36.5 ppm with mean of 22.5 ppm of water soluble sulphur in five different type soils of Uttar Pradesh.

Singh and Sharma (1983) reported that average water soluble sulphur was 34.1 and 27.0 ppm for surface and subsurface soils, respectively. The range being 17 to 50 ppm of water soluble was higher in surface soils.

Dwivedi *et al.*, (1983) reported that organic fraction of sulphur accounted to 17.1 to 26.1 percent of total sulphur (24 to 42.8 ppm). On an average 31.0, 30.8 and 31.8 ppm of organic sulphur was reported, respectively in Gunga flat, Gunga upland (loam and sandy loam) and Western low lands in Uttar Pradesh. Prasad *et al.*, (1983) reported 405 to 2114 ppm of organic sulphur in the Uttar Pradesh.

Singh and Sharma (1983), while working with surface and subsurface soil samples of Uttar Pradesh, reported that organic sulphur varied from 20.8 to 60.0 ppm with a mean of 43.8 ppm for surface and 36.5 ppm for subsurface soils. Organic sulphur contributed, on an average 28.4 and 25.6 percent of total sulphur (range 14.6 to 35.4 percent) in surface and subsurface soils, respectively.

Dwivedi *et al.*, (1983) found a range of 14.8 to 320 ppm with a mean of 23.2 ppm of sulphate sulphur in five different

types of soils which constituted 11.4 to 20.7 percent of the total sulphur.

Singh and Sharma (1983) reported that surface and subsurface soil samples ranged from 1.0 to 32.5 ppm and 10.9 to 23.9 ppm of sulphate sulphur (corresponding average content being 22.7 and 16.0 ppm) amounted to 10.3 to 10.7 percent and 7.9 to 15.5 percent of the total sulphur in the soils of Uttar Pradesh.

Reddy *et al.*, (1985), while studying fifty five surface soils representing broadly red, black and alluvial soil with varying texture (from loamy sand to clay) of five districts of Andhra Pradesh, found 104 to 661 ppm with an average of 310 ppm of organic sulphur constituting 89 percent of the total (348ppm) and also observed that organic sulphur content was lower in loamy sand and sandy loam and higher in silty clay or sandy clay soils.

Zucher and Zech (1985) reported that total amount of sulphur ranged from 526 to 735 ppm in the surface horizons of uncultivated soil profiles in northern Bavaria.

Qureshi (1987) reported that organic sulphur in the combine soils of Junagadh and Rajkot districts of Saurashtra region ranged from 12.45 to 442.63 ppm with mean of 84.82 ppm. Total sulphur ranged from 41.0 to 584.25 ppm with an average of 142.95 ppm. Sulphate sulphur varied from 2.50 to 158.75 ppm with a mean of 20.15 ppm and water soluble sulphur ranging 4.12 to 123.60 ppm with an average of 21.57 ppm and reflected that higher amount of mean water soluble sulphur content was observed in Junagadh district soils as compared to Rajkot district soils.

Hari Ram *et al.*, (1993) analyzed surface and subsurface samples, collected from 22 rice growing field in Kanpur, Aligarh and Mathura, Uttar Pradesh, India and reported that the organic sulphur content accounted for 26 percent (range 17-31%) of total sulphur.

Surface and subsurface samples were collected from 22 rice growing fields in Kanpur, Aligarh and Mathura, Uttar Pradesh, India. Total S content averaged 153 and 148 mg/kg of surface and subsurface samples, respectively (Hari-Ram *et al.*, 1993).

Kher and Singh (1993) reported that organic sulphur made up 43 to 71.3 percent of total sulphur. The organic fraction (18.0 to 80.0 ppm) was 32.1 percent of total sulphur (Singh *et al.*, 1995).

In alluvial region water soluble sulphur ranged between 13 to 50 ppm (Rattan *et al.*, 1995).

Gowrishankar and Shukla (1999) reported the total S content in Inceptisols of Delhi, India, ranged from 99.6 to 355.4 mg/kg with a mean value of 220.3mg/kg.

Sharma *et al.*, (2000) found that respective ranges of calcium chloride extractable (sulphate) sulphur were 10.1 to 47.5, 3.7 to 56.2 and 3.7 to 47.5 mgkg⁻¹ in Alfisols, Inceptisols and Mollisols in some parts of Western Uttar Pradesh.

Raut and Mali (2003) observed the organic sulphur content in Vertisols, Inceptisols and Entisols ranged from 0.4 to 36.8, 3.4 to 21.8 and 0.8 to 30.4 with a mean of 11.0, 12.4 and 10.1 mg/kg respectively.

In a long-term experiment, initiated in winter season of 1986-87 at the University of Agriculture Sciences, Bangalore

under AICRP-LTFE, the result indicated that the sulphate sorption behavior of a different fertilized Kandic Paleustalf soil over the last decade varied according to the variations in apparent S balance and available S status in the soil (Sammy Reddy *et. al.*, 2003).

Sammy Reddy *et. al.* (2003) also revealed that the sulphate sorption maxima and maximum buffering capacity of the soil were negatively correlated with the available S in the soil.

Raut and Mali (2003) when worked on the soil of Latur district Maharashtra, India, reported that the available sulphur showed an average content of 51.0, 53.6 and 48.0 mg/kg in Vertisols, Inceptisols and Entisols, respectively.

Bikram and Das (2008) studied forms of sulphur and their relationship with soil properties in Entisol, Inceptisols and Alfisols of Assam. They found that Entisol contained lowest and Alfisols the Highest level of all the fractions of S. Organic S (79.61-82.34 %) constituted the dominant form of S in all the orders followed by non-sulphate sulphur (11.9-17.08 %). Water soluble and adsorbed S constituted 3.50 and 0.74 % of total S pool. All forms of S were positively and significantly linked with total S excluding non-sulphate S in Entisols and Alfisols. The soil organic carbon was positively correlated with all forms of S except non-sulphate S.

2.6: Depletion and increase of nitrogen, phosphorus, potassium and sulphur under intensive cropping:

NITROGEN: Balagopalan *et al.*, (1986) collected soil samples in 1983 from three depth viz. 0-15, 15-50 and 50-100 cm in semi-evergreen forest and a plantation established in 1976. The results indicated that there was higher oxidation of organic matter in the plantation. Surface soil

samples showed decreased organic C, total N, available N and $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$.

Aziz *et al.*, (1988) studied changes of N forms after urea application at a recommended rate on eight different calcareous soils cropped to wheat. Measurements taken were: total N, inorganic N, $\text{NO}_3\text{-N}$, mineralized N and non-exchangeable NH_4 in relation to N-indices of wheat plant, namely: dry matter yield, N uptake and % N in grain. The results showed that the range of inorganic N losses (one month after planting) over all the soils was from 22.0 - 65.0% of the N applied. The estimation of soil mineralized N (2 weeks incubation) gave higher correlation coefficients with N indices than other N forms. However, the relationships were improved by adding $\text{NO}_3\text{-N}$ fraction to mineralized N. The contribution of non-exchangeable NH_4 to plant N requirement varied, and ranged from 2.6 to 21.9 mg kg^{-1} soil. The results also indicate that the different forms of N in the native soils gave the best correlation with N indices.

Suresh *et al.*, (1995) conducted field experiments during the kharif and rabi seasons of 1991-92 to study the effect of nitrogen (N) sources on the availability of different inorganic N forms in a Typic Ustropept wetland rice soil in Tamil Nadu. The results showed that the $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$ and available N content of the soil declined with crop growth during both seasons. Increasing levels of N application up to 175 kg N ha^{-1} increased the $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$ and available N content of the soil. Application of neem cake coated urea (NCU) recorded the lowest content of $\text{NO}_3\text{-N}$ in the soil during both seasons. Among the applied N sources, NCU followed by urea gypsum, prilled urea + green leaf manure showed the highest $\text{NH}_4\text{-N}$ and available N concentrations in the soil in both seasons.

Sarkar and Singh (1997) found that treatment receiving inorganic fertilizer also observed higher amount of organic carbon content in comparison to the unfertilized plots. The increase in O. C. content due to use of fertilizers can be attributed to higher contribution of biomass to the soil in form of greater root biomass through crop stubbles and residues.

Fueki and Konno (2000) studied the changes of soil chemical properties, such as total carbon content, total nitrogen content and available nitrogen in two paddy fields (LP) and heavy clayey soil (HP) in Hokkaido, Japan to determine the long term decrease of soil nitrogen supplying power with time (1967 to 1999). Results showed that the decrease of total carbon and total nitrogen in subsoil of LP from 1967 to 1977 led to a rapid decomposition of peat. Although the decomposition rate dropped off, the decline of available nitrogen was observed in the subsoil of HC 100. Although the degree was less than that in the subsoil of LP.

Katyal *et al.*, (2003) reported that the plots which received FYM @ 20 t ha⁻¹ recorded the highest organic carbon content followed by 100 % NPK + FYM @ 10 t ha⁻¹. This might have been due to the direct incorporation of organic matter, better root growth and more plant residue addition on realizing higher crop yields.

Sihag *et al.*, (2005) studied effect of chemical fertilizer and organic manures on the amount and distribution of nitrogen in soil after two cycle of rice-wheat cropping system. Application of chemical fertilizer alone or their combined use with organic manures significantly increased crop yield and all the forms of nitrogen over control or their initial status. Among various N fractions, amino acid nitrogen was dominant N fraction.

Varalakshmi *et al.*, (2005) find out that the organic carbon, available N, P, K content of soil were significantly improved with the use of 100 % recommended fertilizer + 7.5 t FYM ha⁻¹ in groundnut-finger millet cropping system.

Gathala *et al.*, (2007) find out that the addition of organic matter over three years resulted in higher organic carbon content of the soil compared to unfertilized control plot.

Shabir and Narinder (2009) reported that integrated nutrient management in wheat significantly improved in soil properties and fertility status. In treatment comprising of 100 % Rec. NPK + Vermicompost + Zinc + PSB improved O. C. content of soil from 3.0 to 4.6 g/Kg soil, available nitrogen from 197.0 to 219.0 Kg/ha.

PHOSPHORUS: The removal of phosphorus by crop is only marginal compared to the other two major nutrients and hence continuous addition of phosphatic fertilizers is bound to increase the concentration of total P in the soil and several workers have noticed similar results (Jones and Ruckman, 1973; Ryan and Zahard, 1980).

Through several studies, it is now well established that a dynamic equilibrium tends to exist among the different fraction of P in soil. Inter-conversion is a distinct possibility under natural soil conditions. Additionally the type of plant grown on the site also influences the transformation of P in soil. Jain and Sarkar (1979) found that Ca-P and Fe-P got converted to Saloid-P and Al-P after wheat harvest. They were of the opinion that it was due to exudation of HCO₃⁻ and H⁺ by wheat roots, which helps in conversion of Ca-P and Fe-P to Saloid-P and Al-P. The buildup of total P was significant when P fertilizers were applied along with FYM (Rahate *et al.*, 1979). Similarly Dhillon and Dev (1988) reported that in a calcareous soil the Saloid-P improved on cropping in low P soils and declined in high P soils. The status of Saloid-P was

lowered after *Kharif* crops i. e. rice, maize and pearl millet and improved on growing *rabi* crop i. e. wheat. Iron-P was depleted due to rice but improved after maize and pearl millet. Ca-P continued to decrease due to growing of these crops and the decline was more in rice-wheat rotation.

Tomar *et al.*, (1987) observed that without manure a major fraction of the fertilizer P was transformed into Ca-P and pre-incubation of phosphatic fertilizers with cattle dung and pyrites increased the availability of P.

Tripathi and Minhas (1991) reported that addition of FYM increased transformation of phosphorus. While addition of higher levels of N had adverse effects on it (Upadhyay *et al.*, 1991). In sandy clay Entisol, Dakhore *et al.*, (1993) investigated that under unmanured farming, the depletion of inorganic P forms from original levels followed the order: Saloid-P > Al-P > Fe-P > Ca-P. The N and K additions reduced and P applications increased amounts of inorganic, active, organic and total P. Gupta *et al.*, (1999) investigated that application of P alone and in combination with FYM increased the contents of total P and different P fractions.

In a field experiment Gupta *et al.*, (1999) reported that application of P alone and in combination with FYM increased the contents of total P and different P fractions. An increase in available P content was observed at higher P levels in association with FYM.

In the field experiment, Saha *et al.*, (2000 b) reported that the addition of FYM had a beneficial effect on grain and straw yields as well as P-uptake.

Setia and Sharma (2007) found that the application of P (17.5 or 135 Kg P ha⁻¹) increased all the forms, irrespective of growth stage

whereas, N (120 and 180 Kg ha⁻¹) and K (0 and 33.2 Kg ha⁻¹) application caused decrease in the P fraction. Olsen-P in control plot (N₀P₀K₀) decreased from its initial status of 6.50 to 5.75 mg Kg⁻¹ after 22 cycle of maize-wheat sequence. The relative abundance of inorganic P fraction was in order of Saloid-P < Fe-P < Al-P < Ca-P.

Shabir and Narinder (2009) reported that integrated nutrient management in wheat significantly improved in soil properties and fertility status. In treatment comprising of 100 % Rec. NPK + Vermicompost + Zinc +PSB improved available P from 13.0 to 19.1 Kg/ha.

POTASSIUM: Patel *et al.*, (1986) found that 72 per cent of WSK and 78 per cent of Exchangeable K was decreased due to intensive cropping of groundnut- wheat sequence in medium black calcareous soils.

Minhas and Sood (1994) observed that the negative balance of potassium at the highest level of NPK (150%) fertilizer applied in potato-maize-potato cropping sequence.

Patel *et al.*, (1994b) conducted field experiment involving intensive cropping to study the available potassium status in soil. They observed that the potassium was in negative balance in the soil. It was decreased to initial status in all treatments. Patel *et al.*, (1994c) conducted a field experiment for two years to study the nutrient change in soil fertility status under summer groundnut-rainy season pearl millet crop sequence. The total-N showed positive balance at high fertility levels, whereas available phosphorus and potassium showed negative balance in the soil.

Patel and Golakiya (1996) reviewed that soils of Gujarat are drifting gradually towards negative K balance. Crops are responding to K fertilizer on irrigated and intensive cultivated area.

Bannu Sood *et al.*, (2008) reported that continuous application of chemical fertilizers and amendments improved all the potassium fractions in soil over control. Continuous application of urea (100 % N) alone resulted in zero yield. Significant positive relationship among the different forms of soil potassium in 0-0.15 m depth. All the potassium fractions exhibited significant positive relationship with yield and potassium uptake by maize except the non-exchangeable-K.

Shabir and Narinder (2009) reported that integrated nutrient management in wheat significantly improved soil properties and fertility status. In treatment comprising of 100 % Rec. NPK + Vermicompost + Zinc +PSB improved available K from 113.0 to 130.4 Kg/ha.

SULPHUR: Clarson and Ramaswami (1992) reviewed that long-term extensive use of sulphur-free and high analysis fertilizers has resulted in the appearance of sulphur deficiencies. They recorded a net negative balance of 60 kg total S ha⁻¹ from the non-sulphur applied plot of sorghum on the Typic Ustropept.

It was recorded that intensive cropping with continuous use of 100% NPK without S resulted in depletion of total S concentrations by 18.13% over control in a 27 years old long-term experiment, involving a fixed rotation of soybean-wheat-fodder maize and use of fertilizers and organic manures on a Typic Haplustert soil at Jabalpur. (Anonymous, 2000-01)

It was recorded that intensive cropping with continuous use of 100% NPK without S resulted in depletion of total S concentrations by 10.7% over control in a 13 years old long-term experiment, involving a fixed rotation of finger millet-maize-fodder cowpea and use of

fertilizers and farmyard manures on a Kandic Paleustalf soil at Bangalore. (Anonymous, 2000-01)

Singh *et al.* (2001) reported that the continuous use of SSP increased the available and total-S in all the treatments. Build up in S status was mostly through organic S fraction.

Alok Tiwari *et al.* (2002) studied the status of soil nutrients, their depletion and build-up and crop productivity after 28 years (1972-2000) of intensive cropping under various fertilizer and manurial treatments on Typic Haplusterts soils of Jabalpur. They showed that the omission of S in the fertilizer schedule has caused a continuous depletion in the available S status of soil.

2.7 The major nutrients availabilities, forms and relationship with soil properties in LTFE's:

Calcareous soils are notorious for the low phosphorus availability. This is mainly due to the reactions of soluble phosphorus with calcium forming calcium phosphates of varying solubility and to absorption of phosphates by CaCO_3 . This is evident from reports of many workers. Akabari *et al.*, (1981) reported continuous decrease in available P with increasing lime levels of the soil in incubation study.

Reddy *et al.*, (1985), while studying the total sulphur content of surface soils of Andhra Pradesh representing red, black, and alluvial soil group with texture varying from loamy sand to clayey, reported that total sulphur varied from 141 to 705 ppm with mean of 348 ppm. They also observed that total-S content was higher in heavy soil (silty loam and sandy clay) and relatively lower in loamy and sandy loam soils.

Pal *et al.*, (1987) found that irrespective of cropping and N-fertilization, the amount of available N significantly decreased and

fixed $\text{NH}_4\text{-N}$ increased with increase in the period of investigation. A substantial decrease in the amount of total hydrolysable N due to cropping was noted and the amount of decrease was less in the N-fertilized than the unfertilized soil.

Bansal and Jain (1988) observed that a maximum decrease in all forms of K from their initial content because of cropping with sufficient N and P without K. The depletion of K from non-exchangeable form is enhanced with higher yields and crops removals under long-term experiments and continuous cropping system.

Singh *et al.* (1999) studied the effect of decade long fertilizer and manurial treatments on the productivity and soil fertility of an important cropping system of rice-wheat. The result showed a higher available S content with the application of NPK with FYM than other fertilizer treatments and control.

Balaguravaih *et al.*, (2005) conducted an experiment on influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rainfed groundnut in Alfisol. They observed that O. C. content was low initially and decrease further in different treatments, except in treatment which received FYM along with half recommended dose of fertilizers. Application of FYM or groundnut shells alone improved the O. C. status marginally. Phosphorus availability increased by 2.05 to 2.9 times over initial level with the continuous use of inorganic fertilizers over years. Potassium availability however decreased over initial level of 155 Kg ha^{-1} in all treatments except in those which received FYM.

The available water soluble and heat soluble sulphur (S) content over the profile depth up to 120 cm were investigated by Setia and Sharma (2005) in long-term experiment, which was continuously cropped for 22 years with maize-wheat sequence. The maximum amount of S was found in water soluble form. The amount of all the forms of S increased with the application of $40 \text{ Kg P}_2\text{O}_5 \text{ ha}^{-1}$ but trend reversed with the application of $80 \text{ Kg P}_2\text{O}_5 \text{ ha}^{-1}$, irrespective of N levels. Application of $40 \text{ Kg K}_2\text{O ha}^{-1}$ at all the levels of N and P

resulted in decline in all the forms of S. The accumulation of sulphur was lower in the NPK treated plots than N and NP-treated plots.

Sihag *et al.*, (2005) studied effect of chemical fertilizer and organic manures on the amount and distribution of phosphorus fractions in soil after two cycles of rice-wheat cropping system. The amount of P recovered in Saloid-P, Al-P and Ca-P form increased significantly with the application of inorganic fertilizers and their combined use with organic materials over control. The highest amount of all the forms of P was recorded under farm yard manure. Average across treatments, Saloid-P constituted about 2% of the total P. The Al-P and Fe-P accounted for 8.4 and 12.1 % of the total P, respectively. The Ca-P accounted for nearly 44 % of the total P.

CHAPTER - III

MATERIALS AND METHOD

The AICRP LTFE started some 8 years back on calcareous *Vertic haplustepts* soils at Junagadh. It's a high time to study the soils with respect to the major nutrients status and its fractions. We presume that there was a definite change in major nutrients status and its fraction according to treatments imposed so far. Moreover, soils of the all treatments of long term fertilizer were also analyzed for major nutrients fraction. It was the purpose to ventilate the dynamics of major nutrients at farm (LTFE) level through studying the interrelations among major nutrients 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 the 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 with following treatments:

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 + FYM @ 10 t/ha to 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 + 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 the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh. Junagadh is situated at 21.5° N latitude and 70.5° 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 ($^{\circ}\text{C}$)	30.6 - 37.6	29.5 - 36.8	31.6 - 39.7
Min ($^{\circ}\text{C}$)	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 Haplustepts. 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 Haplustepts 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 periods (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)

Replication : 4 (Four)

Design : Randomized block design.

Plot size	: Crop:	<u>Groundnut</u>	<u>Wheat</u>
	Gross =	10m x 20 m.	10 m x 20 m.
	Net =	06 m x 16 m.	6.75m x 16 m.

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 major nutrients 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 analytical method used.

Physical Parameters	Properties	Methodology	Reference
Texture	Clayey	International pipette method	Piper (1950)
Depth	70.0 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)	5.5	Wet oxidation	Walkley & Black (1935)
CaCO ₃ (g kg ⁻¹)	480	Rapid titration method	Puri (1963)
Total N (%)	0.047	Macro-Kjeldhal	Piper (1966)

		digestion	
Av.- N (kg ha ⁻¹)	271.23	Alkaline permanganate method	Subbiah and Asija (1956)
Av.- P ₂ O ₅ (kg ha ⁻¹)	25.51	Colorimetry	Olsen <i>et al.</i> (1954)
Av.- K ₂ O (kg ha ⁻¹)	363.57	Flame photometry Neutral normal ammonium acetate	Jackson (1979)
Av.- Sulphur (ppm)	12.42	CaCl ₂ extractable turbidimetry	Chopra and Kanwar (1976)
CEC (Cmol (P ⁺) kg ⁻¹)	27.30	Sodium saturation method	Chapman (1965)
Ex.- Ca (Cmol (P ⁺) kg ⁻¹)	22.40	Versanate EDTA titration	Schewardzenbach and Biederman (1948)
Ex.- Mg (Cmol (P ⁺) kg ⁻¹)	3.60	Versanate EDTA titration	- do -
Micronutrients : (ppm)			
Cu	0.98	DTPA extractable	Lindsay and Norvell (1978)
Mn	4.01	Atomic	
Zn	1.22	Absorption	
Fe	1.78	Spectrophotometer	

3.4 Major nutrient fractions:

(I) Forms of Nitrogen:

The soil samples were analyzed to determine forms of nitrogen on the basis of method mentioned below.

- (A) **Total Nitrogen:** Total nitrogen was determined by the modified Kjeldhal method (Jackson, 1973).
- (B) **Available nitrogen:** Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956).
- (C) **Ammonical nitrogen:** Ammonical nitrogen was determined by Richardson's method (Richardson, 1938) N.B. - It's modification of Olsen method.
- (D) **Nitrate nitrogen:** Nitrate nitrogen was determined after Olsens extraction for ammonia (Olsen, 1929).
- (E) **Organic carbon:** Organic carbon was determined by wet oxidation method (Walkley & Black, 1935).

(II) Forms of phosphorus:

The soil samples were analyzed to determine forms of Phosphorus on the basis of method mentioned below.

- (A) **Total Phosphorus:** The total-P was determined by digesting 1.0 g, of 0.15 mm sieved, oven dried soil with HNO_3 and HClO_4 acids and then followed vanadomolybdate method (Hesse, 1971).
- (B) **Total inorganic phosphorus:** The inorganic-P was extracted with Conc. HCl (Hesse, 1971) and the P in solution was determined with chlorotannous reduced molybdophosphoric blue colour method in HCl system (Jackson, 1973).
- (C) **Organic phosphorus:** The difference between total and inorganic-P was reported as organic-P.
- (D) **Fractions of the inorganic phosphorus:** The fractions of the inorganic-P, which includes Saloid bound-P, Al-P, Fe-P, Reductant soluble-P, Occluded-P and Calcium-P were extracted successively by the method of Chang and Jackson (Peterson and

Corey, 1966) and the blue colour was also developed as detailed by them.

All the colorimetric reading was recorded on double beam spectrophotometer.

(III) **Forms of potassium:** The soil samples were analyzed to determining forms of potassium on the basis of methods described below.

(A) **Water soluble potassium:** Water soluble potassium was extracted from 1:2 soil : water ratio, after shaking in a mechanical shaker for two hours and then allowing it to stand for a period of sixteen hours as per the procedure described by Mc Lean's (1960).

(B) **Available potassium:** A five gram soil sample was shaken with neutral normal ammonium acetate (25 ml) and extracted as per the method suggested by Hanway and Heidal (1952) and potassium was determined from the extract by a flame photometer (Jackson, 1973).

(C) **Nitric acid soluble potassium (1N HNO₃ soluble K):** This was extracted from soil with 1 N HNO₃ in the ratio 1:10 (Soil:HNO₃) and boiled for 10 minutes as per the procedure described by Wood and Deturk (1941)

(D) **Exchangeable potassium:** It was calculated by deducting the values of water-soluble potassium from those of available potassium.

(E) **Reserve potassium:** Reserve potassium was calculated by deducting available potassium from the nitric acid soluble potassium.

(F) **Total potassium:** It was estimated as per the method suggested by Pratt (1951). 0.1 gm soil was digested in 5 ml hydrofluoric acid and 0.5 ml perchloric acid in a platinum crucible. After cooling, 5 ml of (6 N) HCl and 5 ml of water were added and then boiled gently. When residue had completely dissolved in hydrochloric acid, it was transferred into 100 ml volumetric flask and volume was made at the mark and stoppered and shaken by up and down.

(IV) **Form of sulphur:**

The prepared soil samples were analyzed for determining fraction of sulphur by adopting standard methods as described below.

- (A) **Total sulphur:** The total sulphur content in the soil was determined by using digesting solution containing potassium nitrate and nitric acid, a method followed by Chaudhary and Cornfield (1966), and modification of the method used by Butters and Chenery (1959).
- (B) **Organic sulphur:** The organic sulphur content in soils was estimated as per method adopted by Bardsley and Lancaster (1965) by shaking soil with 1 N hydrochloric acid and filtering the suspension, soil residue washed after distilled water was leached with 1 N calcium acetate solution and subsequently with distilled water. After drying, the known quantities of residue mixed with known quantity of sodium bicarbonate and ignited at 500° C. The content was then leached with known volume of sodium hydrogen phosphate extractant.

- (C) **Sulphate sulphur:** The sulphate sulphur was determined as per the standard procedure adopted by Williams and Steinbergs (1959) using 0.15 per cent calcium chloride solution for extraction.
- (D) **Water soluble sulphur:** The water soluble sulphur was estimated using one per cent sodium chloride solution as an extractant as per the procedure followed by Williams and Steinbergs (1959).
- (E) **Heat soluble sulphur:** It was also estimated by using standard procedure as per the method adopted by Williams and Steinbergs (1959) by heating soils with distilled water initially and followed by extraction through one per cent sodium chloride.
- (F) **Non-sulphate sulphur:** The non-sulphate sulphur was estimated by differences between the total sulphur and sum of organic and sulphate sulphur.

***Depletion percent:** These nutrients depleted from soil by different cycles were calculated by the formula:

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

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 values of test at 5 and 1 per cent level of significance were 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 the procedure suggested by Cochran and Cox (1967).

- (2) **Correlation Co-efficient:** Correlation co-efficient the relationships between two or more series of variable were also determined.
- (3) **Regression:** To quantify combined 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 Lu, 1959)

CHAPTER - IV

RESULTS AND DISCUSSION

The studies of the nutrient dynamics involve intricate chemistry of a substrate. Nutrient dynamics assumes special importance in the rainfed agriculture which is a usual practice in Saurashtra region. Use of fertilizer is limited, rate and extent of soil processes varies with the season and nutrient turnover is also slow due to marginal fertility of soils. Thus the understandings of dynamics of nutrients in such cases help formulate the fertilizer package of field crops for sustainable crop production. We tried here to explore the dynamics of major nutrient's fractions, their inter-relations among themselves and with soil properties. Interesting statistical and mathematical tools are applied to qualify and quantify this 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 fertilization on the dynamics of major nutrients over 8 years period. It has been presumed that data generated through LTFE soil will enhance the precision of this study. Our ultimate aim here is to know the turnover of major nutrient fractions over a period of time. The variables operating in the system varied with soil treatments, crop and time span. The nutrient wise findings are narrated here under with brief discussion.

4.0 Yield & nutrient content of groundnut and wheat crops.

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 + FYM @ 10 t ha⁻¹ to groundnut and 100% NPK to wheat (T₈) and pod yield of groundnut also statistically at par with T₂, T₃ and T₄. 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, but numerically higher pod yield was recorded under T₈ in 4th year pooled result and haulm yield was also recorded numerically higher under T₈ in 1st year result (Table 4.0.1, 4.0.2 and Fig. 4.01).Where as in 1st year, numerically higher pod yield was recorded under 100 % N P of recommended doses in Groundnut-Wheat sequence (T₆) and numerically higher haulm yield in 4th year pooled result was recorded under T₃ (150 % N P K of RD in G'nut-Wheat sequence).

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

Treat.	Groundnut pod yield (kg ha ⁻¹)		
	1 st year	4 year pooled	8 year pooled
T ₁	962.00	972.25	929.81
T ₂	984.75	1042.31	1001.63
T ₃	916.25	1032.19	1041.53
T ₄	1048.00	1060.94	1012.31
T ₅	929.25	1050.06	993.63
T ₆	1101.75	988.81	890.03
T ₇	927.50	950.50	855.59
T ₈	916.25	1060.25	1093.56
T ₉	875.75	1006.56	995.81
T ₁₀	963.50	1028.00	981.69

T ₁₁	1017.25	1062.31	983.34
T ₁₂	968.25	902.69	782.28
S.Em.±	74.12	38.53	33.60
C.D. @ 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

Treat.	Groundnut haulm yield (kg ha ⁻¹)		
	1 st year	4 year pooled	8 year pooled
T ₁	1790.50	2104.63	2233.09
T ₂	2018.25	2272.94	2395.44
T ₃	1758.00	2366.25	2532.50
T ₄	1985.75	2158.94	2365.22
T ₅	1676.50	2088.94	2282.19
T ₆	1969.50	2343.00	2382.97
T ₇	1693.00	2048.81	2104.94
T ₈	1888.00	2292.81	2614.66
T ₉	1693.00	2154.06	2458.47
T ₁₀	2002.00	2247.88	2364.31
T ₁₁	1871.50	2272.94	2421.50
T ₁₂	1725.50	2062.88	2059.06
S.Em.±	131.39	83.39	68.93
C.D. @ 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

Treat.	Wheat grain yield (kg ha ⁻¹)		
	1 st year	4 year pooled	8 year pooled
T ₁	1589.00	1626.00	2039.69
T ₂	1908.50	2049.80	2467.38
T ₃	1878.50	2137.10	2525.81
T ₄	1806.50	1952.70	2343.22
T ₅	1856.50	2010.50	2472.78
T ₆	1718.75	1907.25	2343.25
T ₇	1111.00	1185.50	1448.66
T ₈	1898.25	2290.00	2887.91
T ₉	1289.25	1937.75	2587.16

T ₁₀	1419.00	1872.35	2307.47
T ₁₁	1608.75	1995.10	2435.66
T ₁₂	1309.25	1322.50	1677.16
S.Em.±	107.36	104.11	88.57
C.D. @ 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

Treat.	Wheat straw yield (kg ha ⁻¹)		
	1 st year	4 year pooled	8 year pooled
T ₁	2696.75	2234.75	2704.69
T ₂	3090.25	2540.69	3325.88
T ₃	2847.25	2672.75	3441.06
T ₄	2650.25	2425.31	3164.84
T ₅	2819.50	2472.31	3237.31
T ₆	2696.75	2287.94	3043.59
T ₇	1921.25	1461.69	2042.84
T ₈	2766.00	2509.50	3911.41
T ₉	2141.25	2185.44	3205.47
T ₁₀	2581.00	2283.69	3111.66
T ₁₁	2963.00	2559.63	3268.94
T ₁₂	2072.00	1624.31	2119.94
S.Em.±	155.89	110.57	121.74
C.D. @ 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 8 years (Table 4.0.3, 4.0.4 and Fig. 4.0.1), whereas, significantly the highest grain & straw yield were recorded under T₂ (100 % N P K of RD) in first year result and grain & straw yield under T₈ & T₃ respectively, in 4th year pooled result.

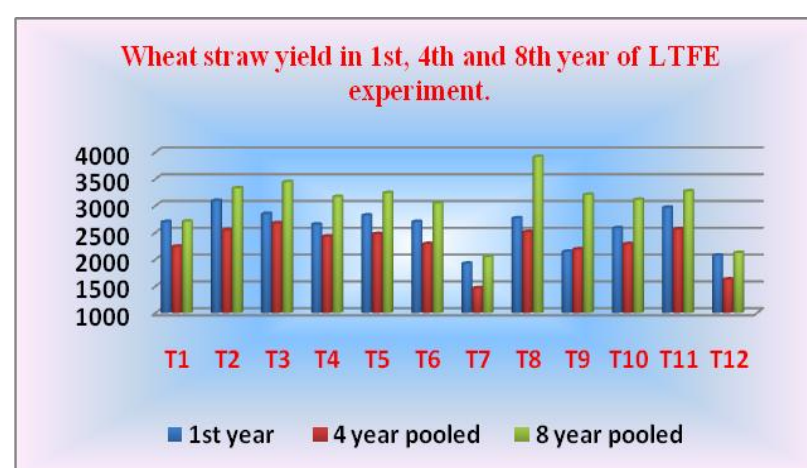
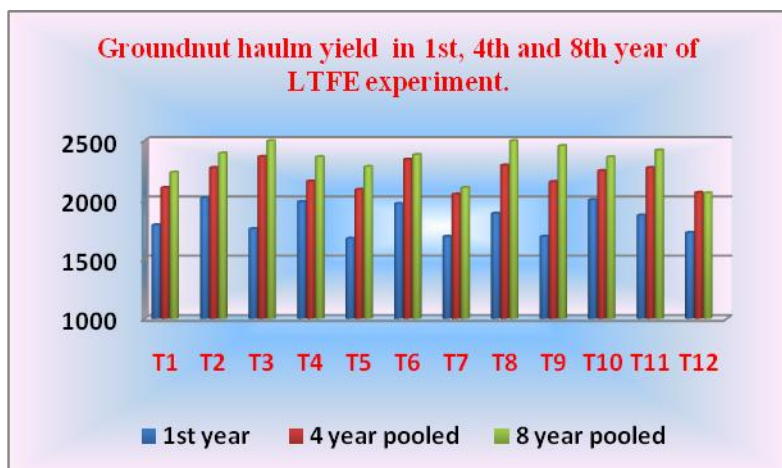
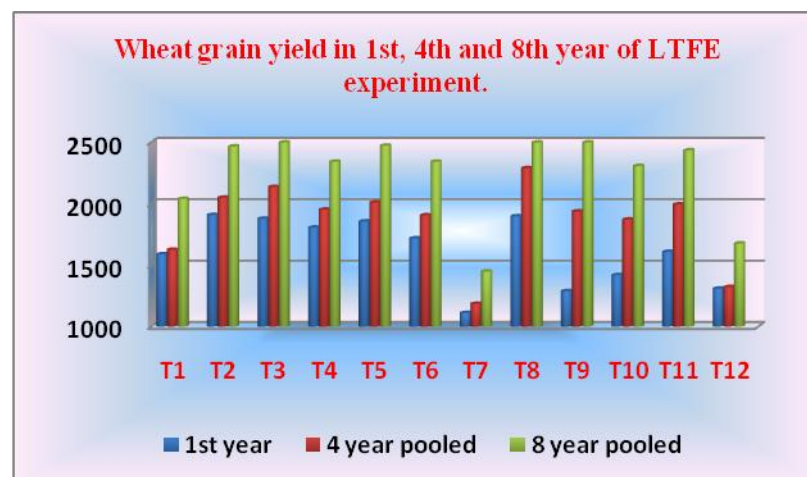
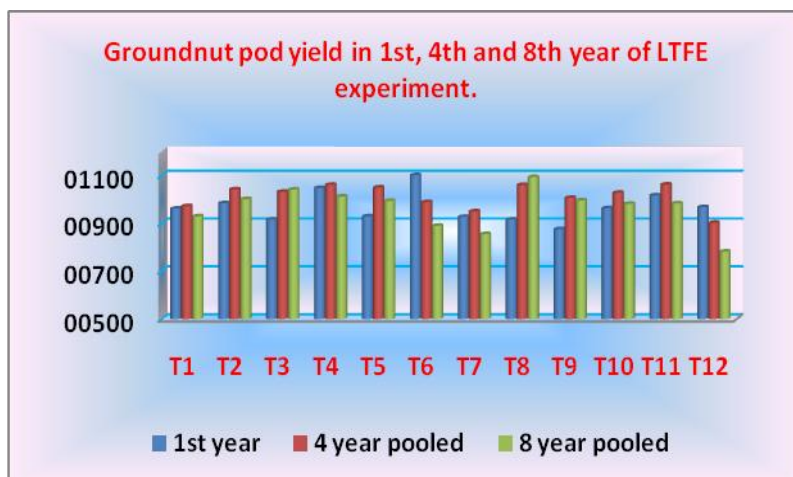


Fig. 4.0.1: Yield (kg ha^{-1}) of groundnut and wheat crop sequence in 1st, 4th and 8th year of LTFE.

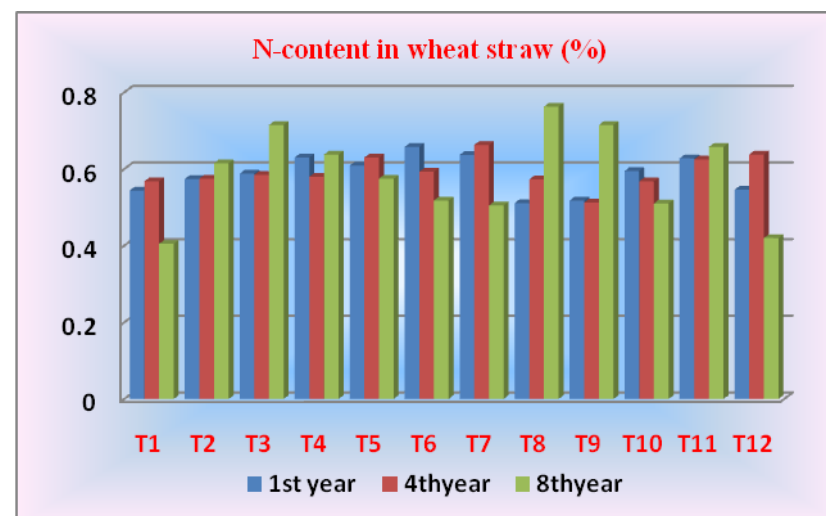
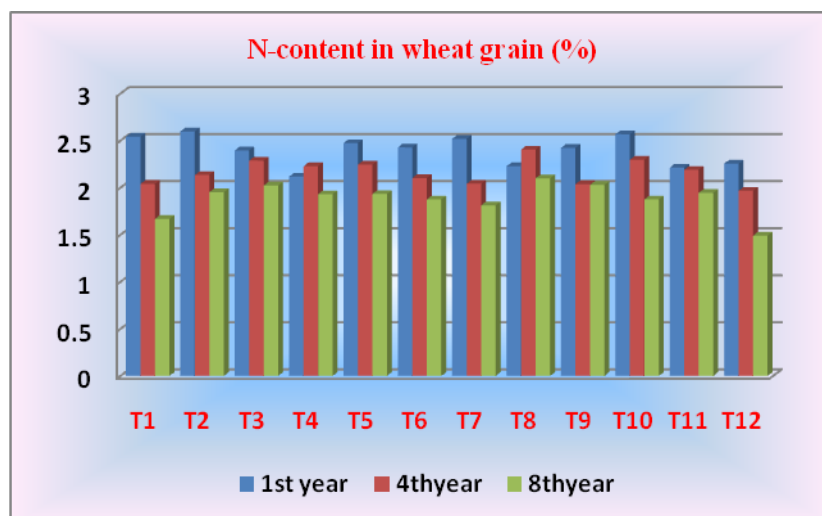
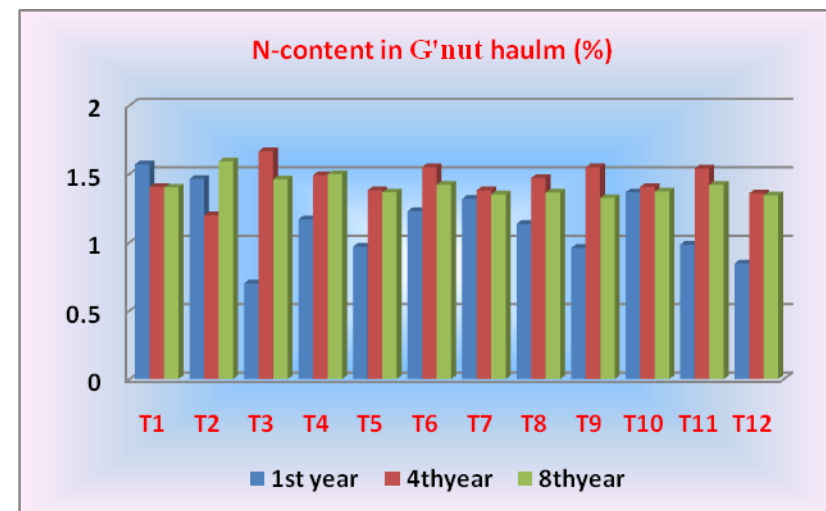
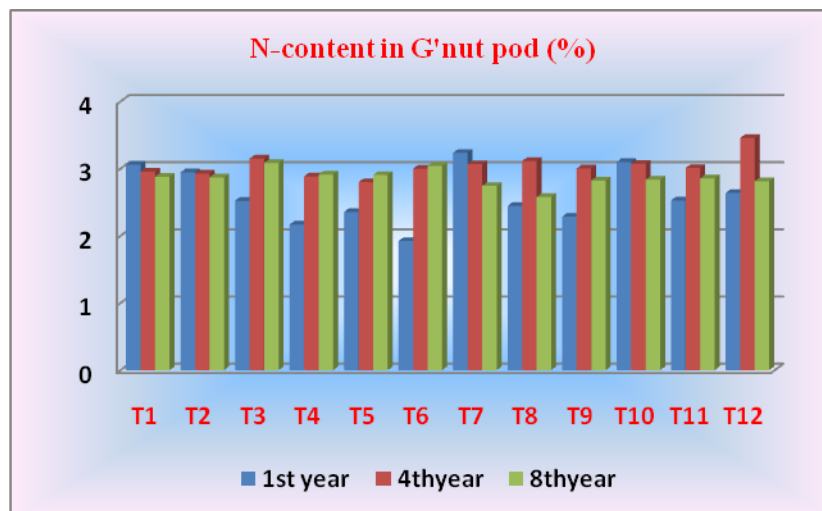


Fig. 4.0.2: Nitrogen content (%) in groundnut and wheat in 1st, 4th and 8th year of LTFE.

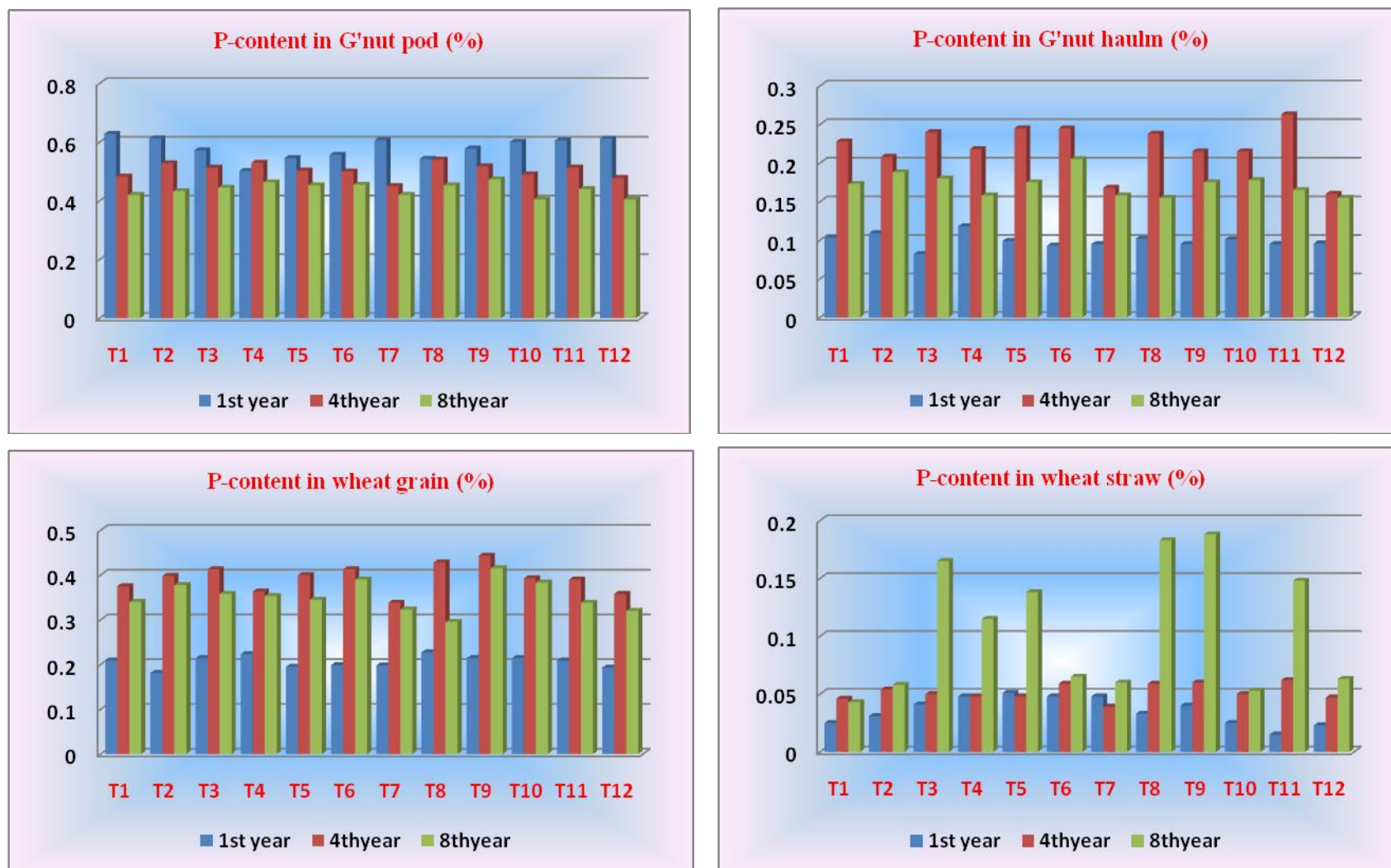


Fig. 4.0.3: Phosphorus content (%) in groundnut and wheat in 1st, 4th and 8th year of LTFE.

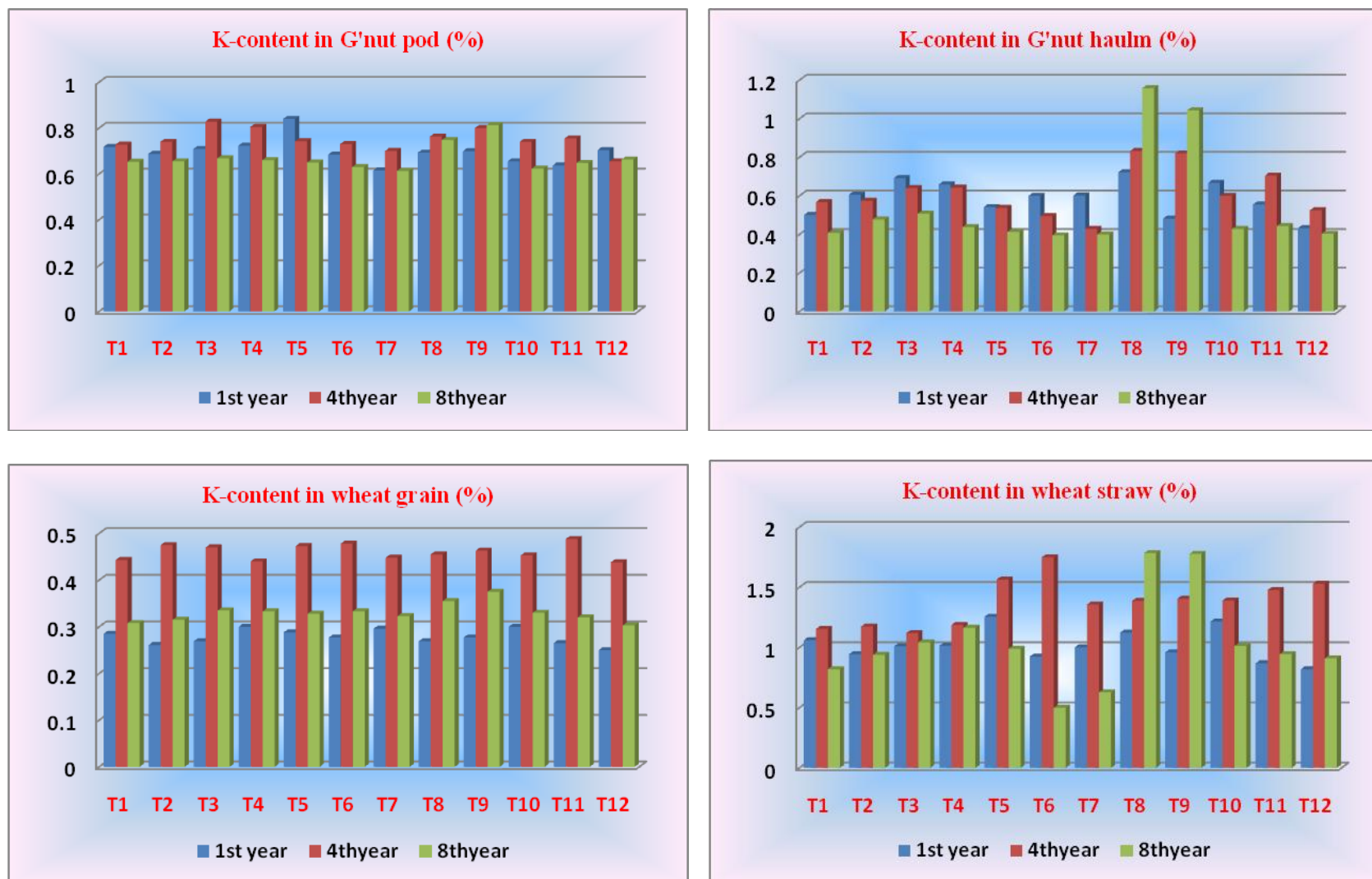


Fig. 4.0.4: Potassium content (%) in groundnut and wheat in 1st, 4th and 8th year of LTFE.

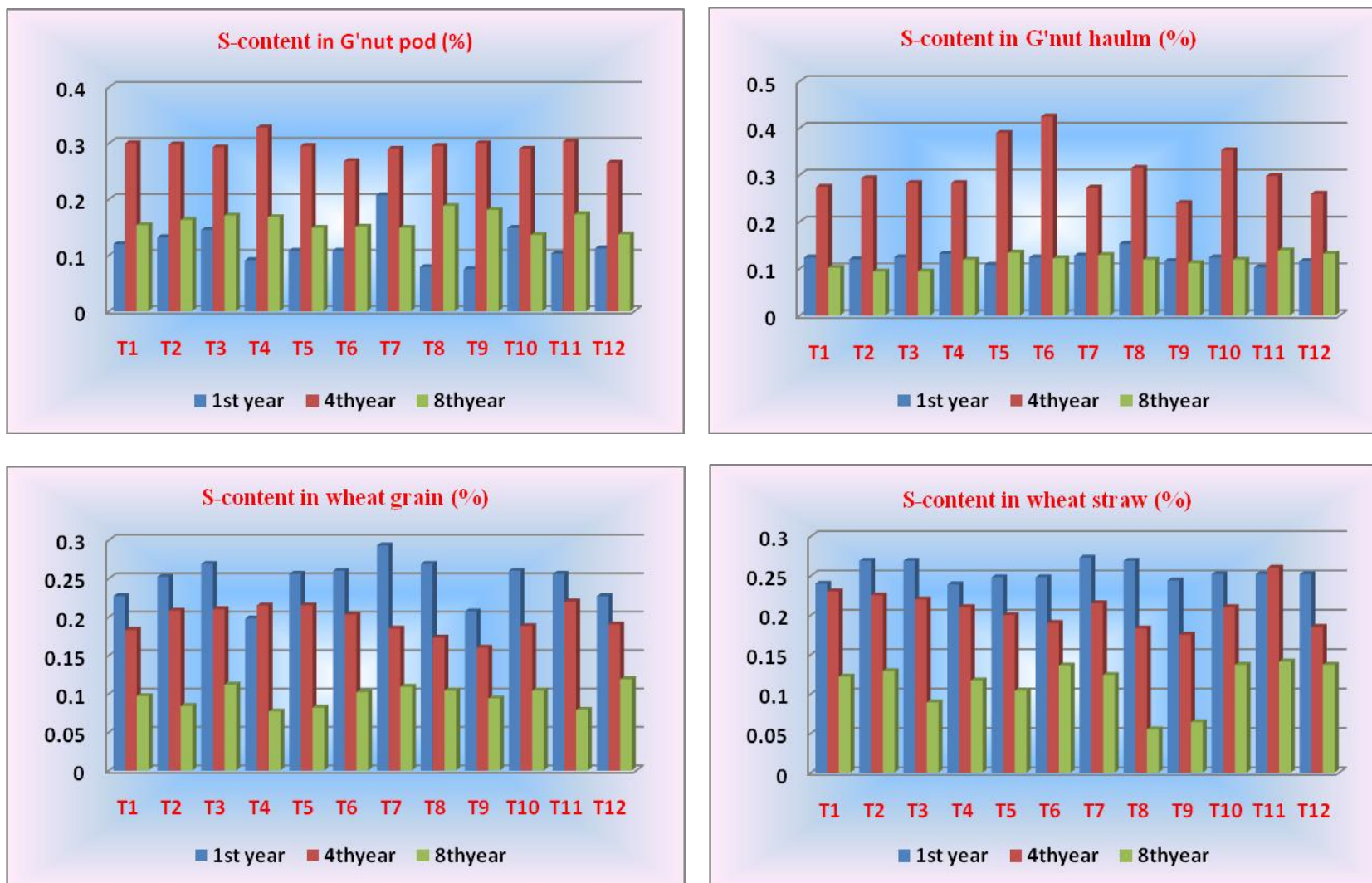


Fig. 4.0.5: Sulphur content (%) in groundnut and wheat in 1st, 4th and 8th year of LTFE.

4.0.2.1 N content in Groundnut

Treatment differences were found non significant in the pooled one for both pod and haulm concentration of nitrogen (Table 4.0.5, 4.0.6 and Fig.4.0.2). However, interactions between year and treatment were found significant. In 1st years, in pod the concentration of N 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 1st year experimentation.

4.0.2.2 N content in Wheat

One thing was very distinct that, in long terms the wheat grain N concentration decreased from 2.40 to 1.89 per cent (Table 4.0.7, 4.0.8 and Fig.4.02). Although the pooled differences among treatments were not significant but year x treatment interaction differences were significant and grain nitrogen percent was obtained highest in T₂ in initial years and lowest in T₁₂ (Control) at 8th years, while straw nitrogen concentration was highest in T₈ and lowest in T₁ at 8th years. At first year of experiment, significantly the highest nitrogen content in wheat grain recorded under treatment No. 2 *i. e.* application of 100 % N P K of recommended doses in G'nut-Wheat sequence, while in straw it was recorded highest under treatment of 100 % N only (T₇), but it was non significant. Whereas at 4th year of experiment N content in grain recorded significantly highest under the T₁₀, while N content in straw was higher under T₇ and it was also non significant. The N content in both (grain & straw) after 8 year pooled was recorded significantly higher under the application of 10 t FYM + 50 % RD of N P K (T₈).

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

Treat.	Content of N % in groundnut pod			
	1 st year	4 th year	8 th year	pooled
T ₁	3.060	2.955	2.880	2.965
T ₂	2.945	2.928	2.870	2.914
T ₃	2.523	3.150	3.085	2.919
T ₄	2.168	2.885	2.913	2.655
T ₅	2.355	2.800	2.905	2.687
T ₆	1.923	3.000	3.040	2.654
T ₇	3.235	3.068	2.743	3.015
T ₈	2.445	3.113	2.578	2.712
T ₉	2.285	3.003	2.823	2.703
T ₁₀	3.100	3.073	2.835	3.003
T ₁₁	2.528	3.010	2.855	2.798
T ₁₂	2.638	3.458	2.813	2.969
S.Em.±	0.152	0.144	0.088	0.157
C.D. @ 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. @ 5 %	0.368

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

Treat.	Content of N % in groundnut haulm			
	1 st year	4 th year	8 th year	pooled
T ₁	1.570	1.405	1.400	1.458
T ₂	1.463	1.198	1.590	1.417
T ₃	0.700	1.665	1.460	1.275
T ₄	1.168	1.490	1.498	1.385
T ₅	0.968	1.380	1.365	1.238
T ₆	1.228	1.548	1.420	1.398
T ₇	1.318	1.380	1.350	1.349
T ₈	1.135	1.470	1.363	1.323
T ₉	0.958	1.548	1.323	1.276
T ₁₀	1.365	1.405	1.370	1.380
T ₁₁	0.983	1.540	1.420	1.314
T ₁₂	0.845	1.358	1.343	1.182
S.Em.±	0.093	0.078	0.046	0.107
C.D. @ 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. @ 5 %	0.211

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

Treat.	Content of N % in wheat grain			
	1 st year	4 th year	8 th year	pooled
T ₁	2.543	2.040	1.668	2.083
T ₂	2.598	2.135	1.953	2.228
T ₃	2.395	2.288	2.023	2.235
T ₄	2.118	2.228	1.930	2.092
T ₅	2.473	2.245	1.933	2.217
T ₆	2.428	2.103	1.875	2.135
T ₇	2.520	2.043	1.813	2.125
T ₈	2.228	2.405	2.100	2.244
T ₉	2.423	2.038	2.030	2.163
T ₁₀	2.568	2.298	1.875	2.247
T ₁₁	2.213	2.190	1.945	2.116
T ₁₂	2.255	1.968	1.490	1.904
S.Em.±	0.092	0.061	0.032	0.083
C.D. @ 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. @ 5 %	0.185

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

Treat.	Content of N % in wheat straw			
	1 st year	4 th year	8 th year	pooled
T ₁	0.544	0.568	0.405	0.506
T ₂	0.574	0.575	0.615	0.588
T ₃	0.588	0.585	0.715	0.629
T ₄	0.630	0.580	0.638	0.616
T ₅	0.609	0.630	0.575	0.605
T ₆	0.658	0.593	0.518	0.589
T ₇	0.637	0.663	0.505	0.602
T ₈	0.511	0.573	0.763	0.615
T ₉	0.518	0.513	0.715	0.582
T ₁₀	0.595	0.568	0.510	0.558
T ₁₁	0.628	0.625	0.658	0.637
T ₁₂	0.546	0.638	0.420	0.535
S.Em.±	0.045	0.041	0.023	0.047
C.D. @ 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. @ 5 %	0.106

4.0.3.1 P content in Groundnut

Overall phosphorus concentration in groundnut pod showed declining trend from 0.58 to 0.4 per cent overtime. The Y x T interaction 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).

4.0.3.1 P content in Wheat

Phosphorus concentration in wheat grain increased in a span of 4 years and was stable after 8 year and in wheat straw increased 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 treatments 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). The content of P in wheat grain at first year was recorded significantly higher in T₈ and T₉ at 4th & 8th year of experiment, respectively. The P content in wheat straw was recorded significantly higher under T₄ at first year and it was recorded significantly higher under T₁₁ & T₂ after the 4th & 8th year of experiment, respectively.

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

Treat.	Content of P % in groundnut pod			
	1 st year	4 th year	8 th year	pooled
T ₁	0.628	0.483	0.420	0.510
T ₂	0.613	0.528	0.433	0.524
T ₃	0.572	0.513	0.445	0.510
T ₄	0.502	0.530	0.463	0.498
T ₅	0.546	0.503	0.453	0.500
T ₆	0.557	0.500	0.455	0.504
T ₇	0.607	0.450	0.420	0.492
T ₈	0.543	0.540	0.453	0.512
T ₉	0.578	0.518	0.473	0.523
T ₁₀	0.601	0.490	0.405	0.499
T ₁₁	0.606	0.513	0.440	0.520
T ₁₂	0.612	0.478	0.405	0.498
S.Em.±	0.021	0.016	0.012	0.019
C.D. @ 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. @ 5 %	0.04623

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

Treat.	Content of P % in groundnut haulm			
	1 st year	4 th year	8 th year	pooled
T ₁	0.103	0.228	0.173	0.168
T ₂	0.109	0.208	0.188	0.168
T ₃	0.082	0.240	0.180	0.167
T ₄	0.118	0.218	0.158	0.164
T ₅	0.099	0.245	0.175	0.173
T ₆	0.093	0.245	0.205	0.181
T ₇	0.095	0.168	0.158	0.140
T ₈	0.102	0.238	0.155	0.165
T ₉	0.095	0.215	0.175	0.162
T ₁₀	0.101	0.215	0.178	0.165
T ₁₁	0.095	0.263	0.165	0.174
T ₁₂	0.096	0.160	0.155	0.137
S.Em.±	0.004	0.015	0.010	0.011
C.D. @ 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. @ 5 %	0.029

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

Treat.	Content of P % in wheat grain			
	1 st year	4 th year	8 th year	Pooled
T ₁	0.209	0.375	0.340	0.308
T ₂	0.181	0.398	0.378	0.319
T ₃	0.214	0.413	0.358	0.328
T ₄	0.223	0.363	0.353	0.313
T ₅	0.195	0.400	0.345	0.313
T ₆	0.199	0.413	0.390	0.334
T ₇	0.198	0.338	0.323	0.286
T ₈	0.227	0.428	0.295	0.316
T ₉	0.214	0.443	0.415	0.357
T ₁₀	0.214	0.393	0.383	0.330
T ₁₁	0.209	0.390	0.338	0.312
T ₁₂	0.193	0.358	0.320	0.290
S.Em.±	0.009	0.015	0.011	0.014
C.D. @ 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. @ 5 %	0.034

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

Treat.	Content of P % in wheat straw			
	1 st year	4 th year	8 th year	pooled
T ₁	0.025	0.046	0.043	0.038
T ₂	0.031	0.054	0.058	0.047
T ₃	0.041	0.050	0.165	0.085
T ₄	0.048	0.048	0.115	0.070
T ₅	0.051	0.048	0.138	0.079
T ₆	0.048	0.059	0.065	0.057
T ₇	0.048	0.039	0.060	0.049
T ₈	0.033	0.059	0.183	0.091
T ₉	0.040	0.060	0.188	0.096
T ₁₀	0.025	0.050	0.053	0.042
T ₁₁	0.015	0.062	0.148	0.075
T ₁₂	0.023	0.047	0.063	0.044
S.Em.±	0.003	0.005	0.006	0.018
C.D. @ 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. @ 5 %	0.0134

4.0.4.1 K content in Groundnut

The pooled differences as well as interactions were significant (Table 4.0.13, 4.0.14 & Fig.4.04). In pooled, the 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 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. The 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 T₆ 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, 4.0.16 & Fig.4.04). 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 the 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, 4.0.18 & Fig.4.05).

Table 4.0.13: Potassium content of groundnut pod in 1st, 4th and 8th year of LTFE

Treat.	Content of K % in groundnut pod			
	1 st year	4 th year	8 th year	pooled
T ₁	0.718	0.728	0.653	0.699
T ₂	0.688	0.740	0.655	0.694
T ₃	0.709	0.828	0.668	0.735
T ₄	0.723	0.805	0.660	0.729
T ₅	0.840	0.743	0.650	0.744
T ₆	0.684	0.730	0.630	0.681
T ₇	0.615	0.700	0.613	0.642
T ₈	0.693	0.763	0.748	0.734
T ₉	0.699	0.800	0.813	0.771
T ₁₀	0.655	0.740	0.623	0.672
T ₁₁	0.637	0.755	0.648	0.680
T ₁₂	0.704	0.655	0.663	0.674
S.Em.±	0.035	0.032	0.024	0.027
C.D. @ 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. @ 5 %	0.0866

Table 4.0.14: Potassium content of groundnut haulm in 1st, 4th and 8th year of LTFE

Treat.	Content of K % in groundnut haulm			
	1 st year	4 th year	8 th year	pooled
T ₁	0.501	0.568	0.408	0.492
T ₂	0.606	0.575	0.478	0.553
T ₃	0.692	0.640	0.508	0.613
T ₄	0.659	0.643	0.438	0.580
T ₅	0.541	0.538	0.413	0.497
T ₆	0.600	0.495	0.395	0.497
T ₇	0.602	0.428	0.400	0.476
T ₈	0.722	0.833	1.158	0.904
T ₉	0.482	0.820	1.043	0.781
T ₁₀	0.667	0.600	0.428	0.565
T ₁₁	0.555	0.705	0.443	0.567
T ₁₂	0.432	0.525	0.403	0.453
S.Em.±	0.028	0.034	0.033	0.081
C.D. @ 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. @ 5 %	0.0890

Table 4.0.15 Potassium content of wheat grain in 1st, 4th and 8th year of LTFE

Treat.	Content of K % in wheat grain			
	1 st year	4 th year	8 th year	pooled
T ₁	0.285	0.443	0.308	0.345
T ₂	0.261	0.475	0.315	0.350
T ₃	0.269	0.470	0.335	0.358
T ₄	0.300	0.440	0.333	0.357
T ₅	0.288	0.473	0.328	0.363
T ₆	0.277	0.478	0.333	0.362
T ₇	0.296	0.448	0.323	0.355
T ₈	0.269	0.455	0.355	0.360
T ₉	0.277	0.463	0.375	0.371
T ₁₀	0.300	0.453	0.330	0.361
T ₁₁	0.265	0.488	0.320	0.358
T ₁₂	0.250	0.438	0.303	0.330
S.Em.±	0.008	0.016	0.007	0.010
C.D. @ 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. @ 5 %	0.031167

Table 4.0.16 Potassium content of wheat straw in 1st, 4th and 8th year of LTFE

Treat.	Content of K % in wheat straw			
	1 st year	4 th year	8 th year	pooled
T ₁	1.061	1.155	0.820	1.012
T ₂	0.945	1.175	0.940	1.020
T ₃	1.011	1.120	1.043	1.058
T ₄	1.015	1.188	1.165	1.123
T ₅	1.256	1.565	0.990	1.270
T ₆	0.925	1.750	0.500	1.058
T ₇	1.002	1.358	0.628	0.996
T ₈	1.124	1.388	1.785	1.432
T ₉	0.960	1.405	1.778	1.381
T ₁₀	1.216	1.390	1.013	1.206
T ₁₁	0.869	1.478	0.945	1.097
T ₁₂	0.820	1.530	0.910	1.087
S.Em.±	0.070	0.062	0.041	0.153
C.D. @ 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. @ 5 %	0.1657

4.0.5.2 S Content in Wheat

Overall sulphur concentration in wheat grain and straw declined overtime (Table 4.0.19, 4.0.20 & Fig.4.0.5). Although the pooled differences among treatments were not significant but Y x T interaction were significant. The highest values was recorded under application of 100 % N of recommended doses in G'nut -Wheat sequence of initial year in

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

Treat.	Content of S % in groundnut pod			
	1 st year	4 th year	8 th year	pooled
T ₁	0.120	0.300	0.154	0.191
T ₂	0.132	0.298	0.163	0.198
T ₃	0.145	0.293	0.171	0.203
T ₄	0.091	0.328	0.168	0.196
T ₅	0.108	0.295	0.149	0.184
T ₆	0.108	0.268	0.151	0.175
T ₇	0.207	0.290	0.149	0.215
T ₈	0.079	0.295	0.188	0.187
T ₉	0.075	0.300	0.181	0.185
T ₁₀	0.149	0.290	0.136	0.192
T ₁₁	0.103	0.303	0.173	0.193
T ₁₂	0.112	0.265	0.137	0.171
S.Em.±	0.013	0.018	0.008	0.015
C.D. @ 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. @ 5 %	0.0380

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.

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

Treat.	Content of S % in groundnut haulm			
	1 st year	4 th year	8 th year	pooled
T ₁	0.124	0.275	0.102	0.167
T ₂	0.120	0.293	0.094	0.169
T ₃	0.124	0.283	0.094	0.167
T ₄	0.132	0.283	0.119	0.178
T ₅	0.108	0.390	0.134	0.210
T ₆	0.124	0.425	0.122	0.224
T ₇	0.128	0.273	0.129	0.177
T ₈	0.153	0.315	0.119	0.196
T ₉	0.116	0.240	0.112	0.156
T ₁₀	0.124	0.353	0.119	0.198
T ₁₁	0.103	0.298	0.139	0.180
T ₁₂	0.116	0.260	0.132	0.169
S.Em.±	0.011	0.028	0.007	0.019
C.D. @ 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. @ 5 %	0.0502

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

Treat.	Content of S % in wheat grain			
	1 st year	4 th year	8 th year	pooled
T ₁	0.227	0.183	0.097	0.169
T ₂	0.252	0.208	0.084	0.181
T ₃	0.269	0.210	0.112	0.197
T ₄	0.198	0.215	0.077	0.163
T ₅	0.256	0.215	0.082	0.184
T ₆	0.260	0.203	0.102	0.188
T ₇	0.293	0.185	0.109	0.196
T ₈	0.269	0.173	0.104	0.182
T ₉	0.207	0.160	0.094	0.154
T ₁₀	0.260	0.188	0.104	0.184
T ₁₁	0.256	0.220	0.079	0.185
T ₁₂	0.227	0.190	0.119	0.179
S.Em.±	0.017	0.014	0.004	0.012
C.D. @ 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. @ 5 %	0.0365

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

Treat.	Content of S % in wheat straw			
	1 st year	4 th year	8 th year	pooled
T ₁	0.240	0.230	0.122	0.197
T ₂	0.269	0.225	0.129	0.208
T ₃	0.269	0.220	0.089	0.193
T ₄	0.239	0.210	0.117	0.189
T ₅	0.248	0.200	0.104	0.184
T ₆	0.248	0.190	0.136	0.191
T ₇	0.273	0.215	0.124	0.204
T ₈	0.269	0.183	0.055	0.169
T ₉	0.244	0.175	0.064	0.161
T ₁₀	0.252	0.210	0.137	0.200
T ₁₁	0.252	0.260	0.141	0.218
T ₁₂	0.252	0.185	0.137	0.191
S.Em.±	0.016	0.018	0.007	0.012
C.D. @ 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. @ 5 %	0.0412

4.1 Different forms of the nitrogen in soil

4.1.1 Total nitrogen

The Total nitrogen showed significant difference among treatment in 4thyear, 8th year and when pooled over years and only non-significant result were observed in 1st year (Table 4.1.1). Overall Total nitrogen increased overtime (Fig 4.1.1). In 4th, 8th year and pooled, the highest value of total nitrogen was observed under application of FYM @ 25 t/ha to groundnut only (T₉). The Year x treatment interaction was also found significant. Fengmin *et al.*, (1998) investigated the effect of organic matter on nitrogen content in soils derived from loess in NW China. The results indicated that Available N and Total N content were correlated positively and significantly with organic matter content.

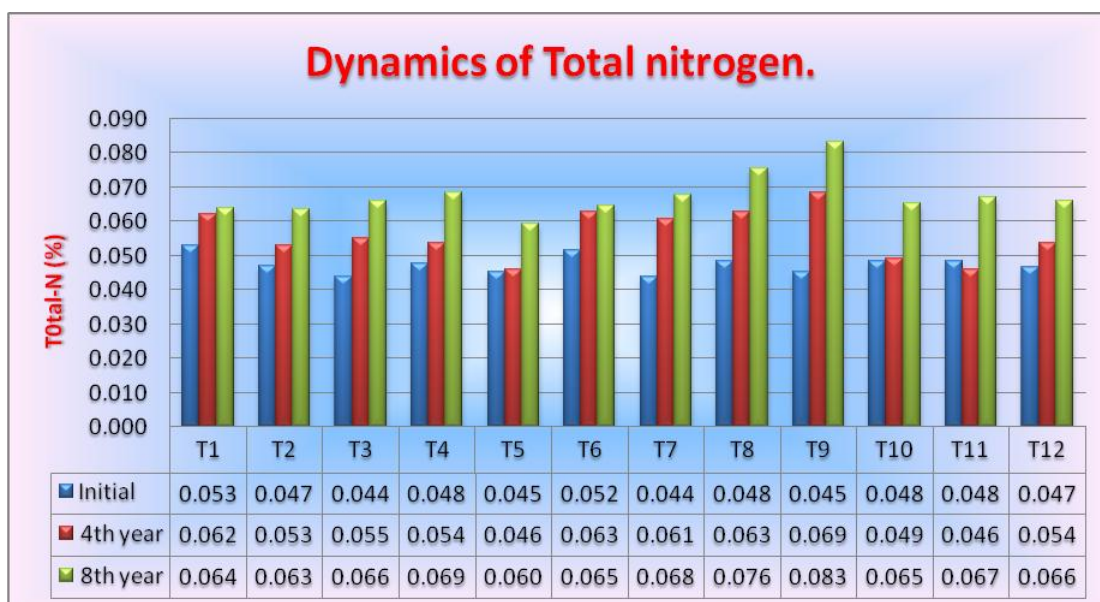


Fig.4.1.1 Status (%) of Total nitrogen in the LTFE soils in 1st, 4th & 8th years.

Table 4.1.1: Status of Total-N (%) in soils of LTFE in 1st, 4th and 8th year

Treat.	Total-N (%)			
	1 st year	4 th year	8 th year	Pooled
T ₁	0.0530	0.0621	0.0640	0.06
T ₂	0.0472	0.0530	0.0634	0.05
T ₃	0.0440	0.0550	0.0660	0.05
T ₄	0.0478	0.0537	0.0685	0.06
T ₅	0.0453	0.0459	0.0595	0.05
T ₆	0.0517	0.0627	0.0646	0.06
T ₇	0.0439	0.0608	0.0679	0.06
T ₈	0.0485	0.0627	0.0756	0.06
T ₉	0.0453	0.0685	0.0834	0.07
T ₁₀	0.0485	0.0492	0.0653	0.05
T ₁₁	0.0485	0.0459	0.0672	0.05
T ₁₂	0.0465	0.0537	0.0659	0.06
S.Em.±	0.0041	0.0040	0.0030	0.0028
CD @ 5%	NS	0.0115	0.0086	0.0082
C.V.%	17.2200	14.3400	8.8100	13.08
Mean	0.0475	0.0561	0.0676	0.0570
Y * T	S.Em.±	0.0037	C.D. @ 5 %	0.0105

4.1.2 Organic carbon (O.C.)

The Organic carbon showed significant difference in 4th year, 8th year and pooled result and it was recorded higher under application of FYM @ 25 t/ha to groundnut only (T₉) followed by T₈, T₆, T₁, T₄, T₃ and T₁₂ (Table 4.1.2 & Fig. 4.1.2). In long term, there seems to be an increase in soil O. C. after 4th and 8th year experimentation. Year x treatment interaction also found significant. Balaguravaih *et al.*, (2005) found that application of FYM or groundnut shells alone improved the O. C. status marginally. There was overall increased in O. C. status of LTFE soils after 4th and 8th year as compared to initial status of soil (1st year). FYM application improved soil physical condition, ultimately root growth increases and more biomass added to the soil, seems to increases organic carbon status of the particular soil.

Table 4.1.2: Status of O.C. (%) in soils of LTFE in 1st, 4th and 8th year

Treat.	O.C. (%)			
	1 st year	4 th year	8 th year	Pooled
T ₁	0.615	0.720	0.743	0.69
T ₂	0.548	0.615	0.735	0.63
T ₃	0.510	0.638	0.765	0.64
T ₄	0.555	0.623	0.795	0.66
T ₅	0.525	0.533	0.690	0.58
T ₆	0.600	0.728	0.758	0.70
T ₇	0.510	0.705	0.788	0.67
T ₈	0.563	0.728	0.878	0.72
T ₉	0.525	0.795	0.968	0.76
T ₁₀	0.563	0.563	0.758	0.63
T ₁₁	0.563	0.533	0.780	0.63
T ₁₂	0.540	0.623	0.765	0.64
S.Em.±	0.048	0.047	0.034	0.0323
CD @ 5%	N.S.	0.134	0.099	0.0927
C.V.%	17.242	14.361	8.716	13.06
Mean	0.551	0.650	0.785	0.6620
Y * T	S.Em.±	0.0432	C.D. @ 5 %	0.1215

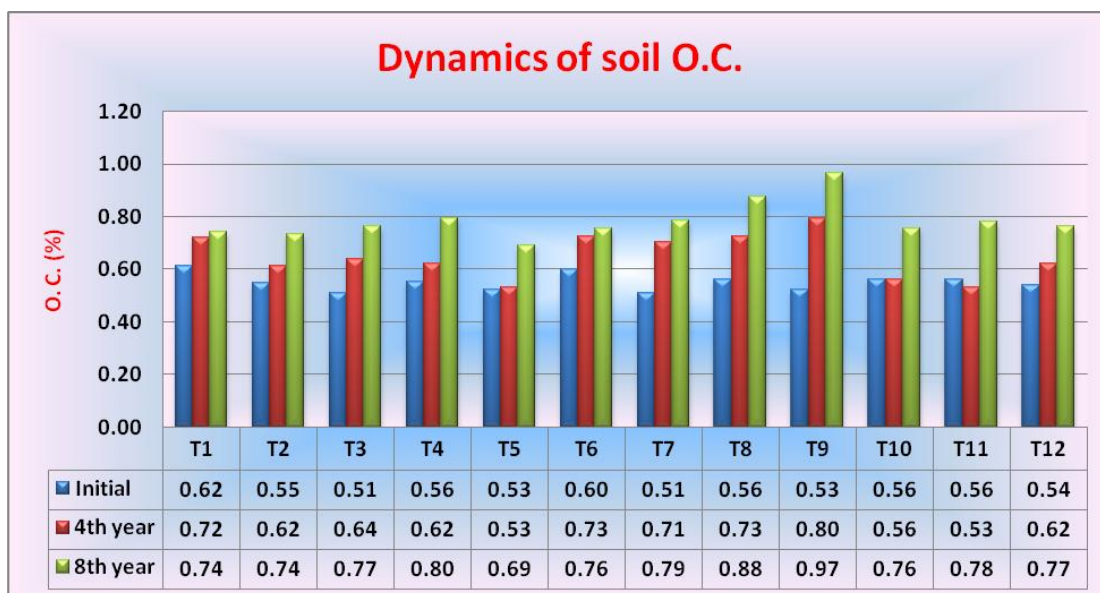


Fig. 4.1.2: Status of O.C. (%) in soils of LTFE in 1st, 4th and 8th year

4.1.3 Ammonical nitrogen

The Ammonical nitrogen showed significant difference due to treatments in 1st, 4th and 8th year, the Y x T interaction was also found significant. In first year, the highest value was recorded in plot of T₃ followed by T₆, T₁₁ and T₉, while in 4th and 8th year the highest value was recorded in treatment T₁ i. e. 50 % NPK of recommended dose and T₇ i. e. 100 % N of recommended dose, respectively. Whereas when pooled over years, the highest value of Ammonical N was found in treatment which received 150 % NPK of recommended dose of groundnut-wheat sequence (T₃), followed by T₁, T₄, T₇ and T₁₀. In long run, there was a slight decreased in overall Ammonical nitrogen status of the LTFE soil (Table 4.1.3 & Fig. 4.1.3). The results are supported by earlier works of Sihag *et al.*, (2005), Balagopalan *et al.*, (1986), who observed that surface soil samples showed decrease in NH₄-N and Suresh *et al.*, (1995), they observed that, increasing levels of N application up to 175 kg N ha⁻¹ increased the NH₄-N content of the soil. There was overall decrease in Amm.-N status of LTFE soils after a span of 8 years, but here it was interesting that in T₁, T₇ & T₁₀ Amm.-N status

of that soils improved, that might be due to low crop yield under T₁ & T₇ and atmospheric-N fixation by Rhizobium bacteria in soil of T₁₀.

Table 4.1.3: Status of Ammonical-N (ppm) in soils of LTFE in 1st, 4th and 8th year

Treat.	Ammonical-N (ppm)			
	1 st year	4 th year	8 th year	Pooled
T ₁	29.0000	59.5000	54.2500	47.58
T ₂	40.2500	47.2500	40.2500	42.58
T ₃	71.7500	49.0000	27.7500	49.50
T ₄	28.0000	54.2500	54.2500	45.50
T ₅	29.7500	40.2500	29.7500	33.25
T ₆	71.0000	24.2500	22.7500	39.33
T ₇	31.5000	49.0000	56.0000	45.50
T ₈	35.0000	43.7500	31.5000	36.75
T ₉	54.2500	33.2500	19.2500	35.58
T ₁₀	35.0000	44.7500	50.7500	43.50
T ₁₁	56.0000	24.0000	26.2500	35.42
T ₁₂	38.5000	24.5000	21.0000	28.00
S.Em.±	2.509	2.627	2.664	8.88
CD @ 5%	7.224	7.564	7.670	NS
C.V.%	11.579	12.770	14.739	12.94
Mean	43.3333	41.1458	36.1458	40.2083
Y * T	S.Em.±	2.6008	C.D. @ 5 %	7.3083

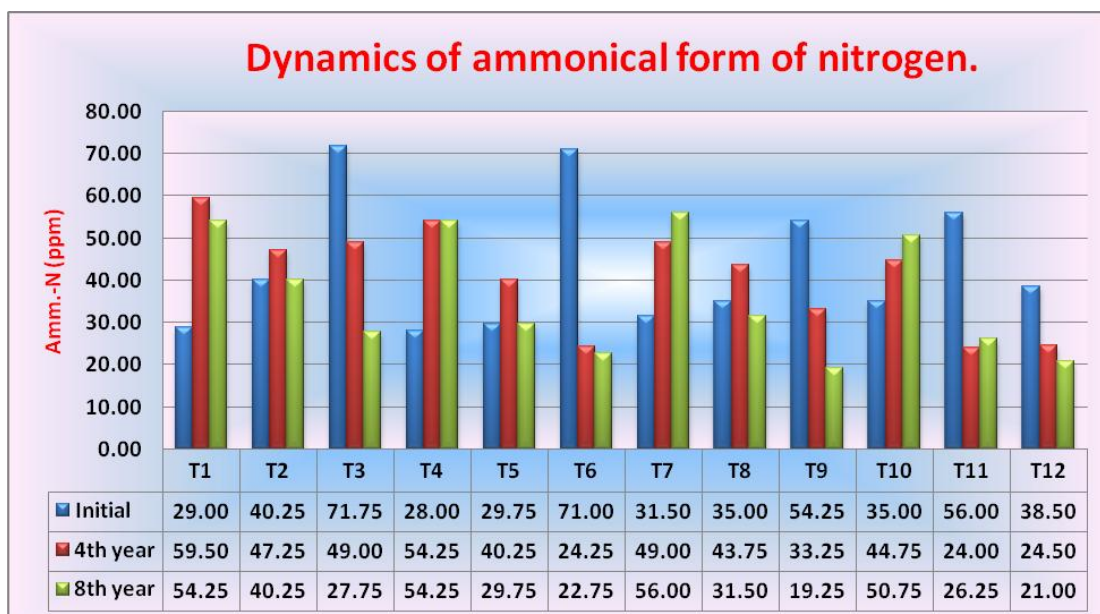


Fig. 4.1.3: Status of Ammonical-N (ppm) in soils of LTFE in 1st, 4th and 8th year

4.1.4 Nitrate nitrogen

The data presented in table 4.1.4 and Fig. 4.1.4 depicted that there were significant differences found in status of Nitrate-N in LTFE soils at initial (1st year), after 4th and 8th year, due to various treatments. The Y x T interaction and when pooled over years also showed significant difference among treatments. Initially (1st year) the highest value recorded in plot of T₁₁, after four years it was highest in plot which received only 100 % N (T₇) it might be due to low crop production & ultimately low uptake of NO₃-N. Same result was also found when pooled over years. After 8th year the highest value recorded in plot comprising treatment number ten *i. e.* 50 % NPK + Rhizobium + PSM to groundnut and 100 % NPK to wheat (T₁₀), it might be due to fixation of atmospheric nitrogen by Rhizobium bacteria. There was overall decrease in status of Nitrate-N after 4th year as compare to initial value and marginal increase after 8th year as compare to that in 4th year. Balagopalan *et al.*, (1986) also reported similar results *i. e.* overall decrease of nitrate nitrogen in surface soil samples.

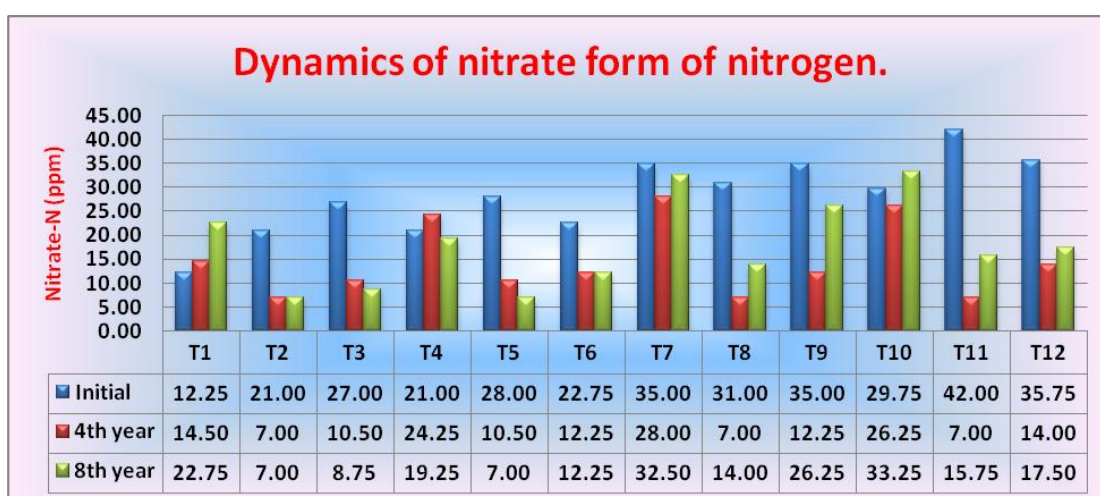


Fig. 4.1.4: Status of Nitrate-N (ppm) in soils of LTFE in 1st, 4th and 8th year

Table 1.1.4: Status of Nitrate-N (ppm) in soils of LTFE in 1st, 4th and 8th year

Treat.	Nitrate-N (ppm)			
	1 st year	4 th year	8 th year	Pooled
T ₁	12.2500	14.5000	22.7500	16.50
T ₂	21.0000	7.0000	7.0000	11.67
T ₃	27.0000	10.5000	8.7500	15.42
T ₄	21.0000	24.2500	19.2500	21.50
T ₅	28.0000	10.5000	7.0000	15.17
T ₆	22.7500	12.2500	12.2500	15.75
T ₇	35.0000	28.0000	32.5000	31.83
T ₈	31.0000	7.0000	14.0000	17.33
T ₉	35.0000	12.2500	26.2500	24.50
T ₁₀	29.7500	26.2500	33.2500	29.75
T ₁₁	42.0000	7.0000	15.7500	21.58
T ₁₂	35.7500	14.0000	17.5000	22.42
S.Em.±	1.5956	1.2337	1.4848	3.96
CD @ 5%	4.5943	3.5522	4.2752	11.61
C.V.%	11.2500	17.0700	16.4800	14.26
Mean	28.3750	14.4583	18.0208	20.2847
Y * T	S.Em.±	1.4460	C.D. @ 5 %	4.0634

4.1.5 Available nitrogen

The Available nitrogen status of LTFE soils showed significant difference among the treatments after span of 8 year but it was non-significant at initial stage and after 4 years of experiment and also when pooled over years. The significant highest value after 8 years was recorded in treatments which received FYM (T₈ & T₉). Same treatments also showed increased available N content at 4th year and when pooled over years. This result was in confirmation with the finding of Varalakshmi *et al.*, (2005) who reported that available N significantly improved with the use of 100 % recommended fertilizer + 7.5 t FYM ha⁻¹ in groundnut- finger millet cropping system. There was overall decreased in available N status of soil after a period of 8 years.

Table 4.1.5: Status of Available-N (kg ha⁻¹) in soils of LTFE in 1st, 4th and 8th year

Treat.	Available-N (kg ha ⁻¹)			
	1 st year	4 th year	8 th year	Pooled
T ₁	252.84	252.84	222.66	242.78
T ₂	296.35	264.60	223.44	261.46
T ₃	249.31	217.56	216.78	227.88
T ₄	262.64	286.16	235.59	261.46
T ₅	235.98	219.52	230.89	228.80
T ₆	261.46	254.02	213.64	243.04
T ₇	299.88	246.57	236.77	261.07
T ₈	264.21	257.54	268.52	263.42
T ₉	261.46	266.56	268.52	265.51
T ₁₀	292.04	263.82	230.89	262.25
T ₁₁	292.04	235.59	234.02	253.89
T ₁₂	286.55	223.83	220.30	243.56
S.E.m.±	23.5347	23.2603	9.2511	11.45
CD @ 5%	NS	NS	26.6371	NS
C.V.%	17.3500	18.6800	7.9200	15.79
Mean	271.2313	249.0507	233.5013	251.26111
Y * T	S.E.m.±	19.8369	C.D. @ 5 %	NS

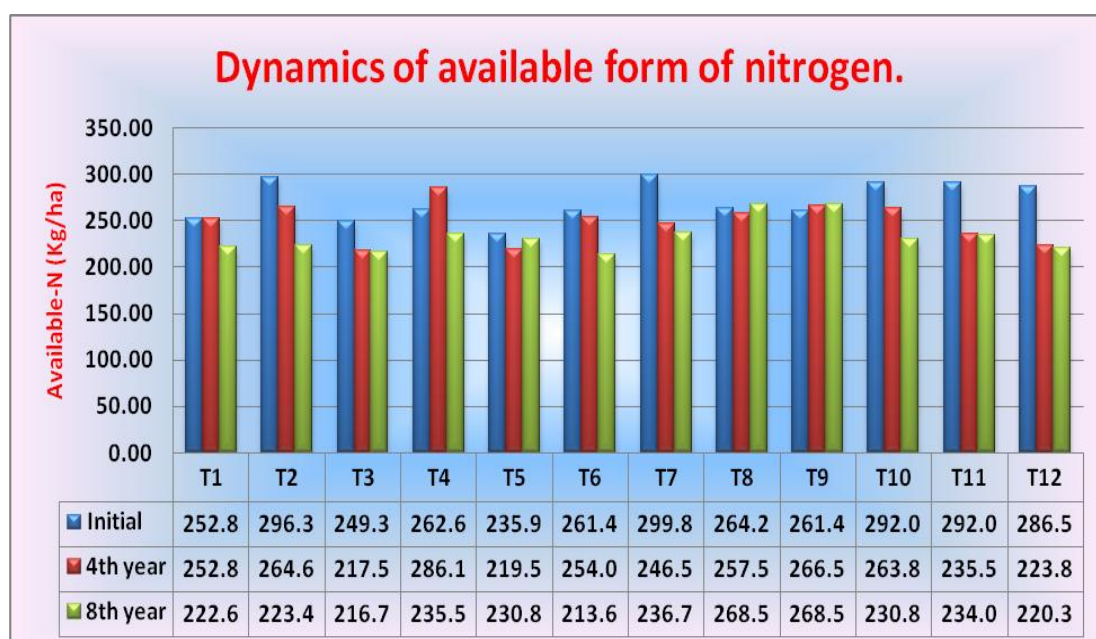


Fig. 4.1.5: Status of Available-N (kg ha⁻¹) in soils of LTFE in 1st, 4th and 8th year

4.1.6: Depletion per cent of different forms of nitrogen

Table-4.1.6: Per cent depletion of different forms of nitrogen after 8 groundnut-wheat sequence in LTFE soils.

Treat.	Total-N	O.C.	Amm.-N	Nitr.-N	Av.-N
T ₁	-20.698	-20.732	-87.069	-85.714	11.938
T ₂	-34.340	-34.247	0.000	66.667	24.603
T ₃	-50.057	-50.000	61.324	67.593	13.050
T ₄	-43.231	-43.243	-93.750	8.333	10.299
T ₅	-31.492	-31.429	0.000	75.000	2.159
T ₆	-24.855	-26.250	67.958	46.154	18.291
T ₇	-54.525	-54.412	-77.778	7.143	21.046
T ₈	-55.957	-56.000	10.000	54.839	-1.632
T ₉	-84.254	-84.286	64.516	25.000	-2.699
T ₁₀	-34.657	-34.667	-45.000	-11.765	20.940
T ₁₁	-38.680	-38.667	53.125	62.500	19.866
T ₁₂	-41.698	-41.667	45.455	51.049	23.119

In LTFE soils after a span of eight year the Total nitrogen showed negative depletion that means it increased (Table 4.1.6 & Fig. 4.1.6) and that were ranged from -20.69 in T₁ to -84.25 per cent in T₉ (FYM @ 25 t ha⁻¹). Similar results were also found in case of O. C. percent depletion, ranged from -20.73 in T₁ to -84.28 in T₉. These results were also in agreement with the finding of Sihag *et al.*, (2005) that, the application of chemical fertilizer alone or their combined use with organic manures significantly increased all the form of nitrogen over control or their initial status. Among various N fractions, amino acid nitrogen was dominant N fraction. Whereas Ammonical nitrogen showed positive trend in percent depletion, except in T₁, T₄, T₇ and T₁₀ were negative depletion was noted, the highest percent depletion of Ammonical N was noted in T₃. In case of Nitrate nitrogen, all treatments exhibited positive depletion, except T₁ & T₁₀, this might have been attributed to leaching losses and crop uptake mostly this form of nitrogen. Same picture was also found in case of Available nitrogen, where the highest depletion was noted in treatment which received 100 % N P K (T₂) and

negative depletion also noted in both the treatments which received FYM *i. e.* T₈ & T₉.

4.1.7: percent distribution in different fraction of nitrogen.

In LTFE soils the available fraction of nitrogen showed the highest proportion as compared to other two fractions (Fig. 4.1.7a & b) *i. e.* Ammonical-N & Nitrate-N in all the treatments and years (1st, 4th, & 8th year). At initial stage of experiment the highest proportion of Available-N was recorded in T₁ & T₇ (73 %), after four year it was recorded highest in T₁₁ (77 %) and after eight year it was noted highest in T₅ (74 %). Next to Available-N fraction, proportion of Ammonical-N fraction noted higher than Nitrate-N fraction and it was found higher in T₃ (34 %) at initial year, in T₁ (32 %) after 4th year and 8th year of the experiment. In case of Nitrate-N fraction, the highest proportion was recorded at initial stage in T₁₁ (18 %), after 4th year in T₇ (15%) and after 8th year also in T₇ (17 %).

Thus, the proportion of the Available-N in T₁, T₄, T₇ and T₁₀ was decreased from 73% to 56%, 70% to 59%, 67% to 54% and 67% to 55%, respectively, after a span of 8 year, whereas it remain stable in T₂. In all other treatments, the proportion of Available-N was increased after 8 years of experimentation as compared to initial year and the highest increment was noted in T₃ *i. e.* from 53% to 73%. In case of proportion of the Ammonical-N fraction, it was decreased in T₃, T₆, T₉, T₁₁ & T₁₂; whereas it was remain stable in T₈ and increased in T₁, T₂, T₄, T₅, T₇ & T₁₀ after 8 years. Proportion of the Nitrate fraction of the nitrogen was decreased in most of the treatments, except T₁ & T₁₀, which were increased after 8 years.

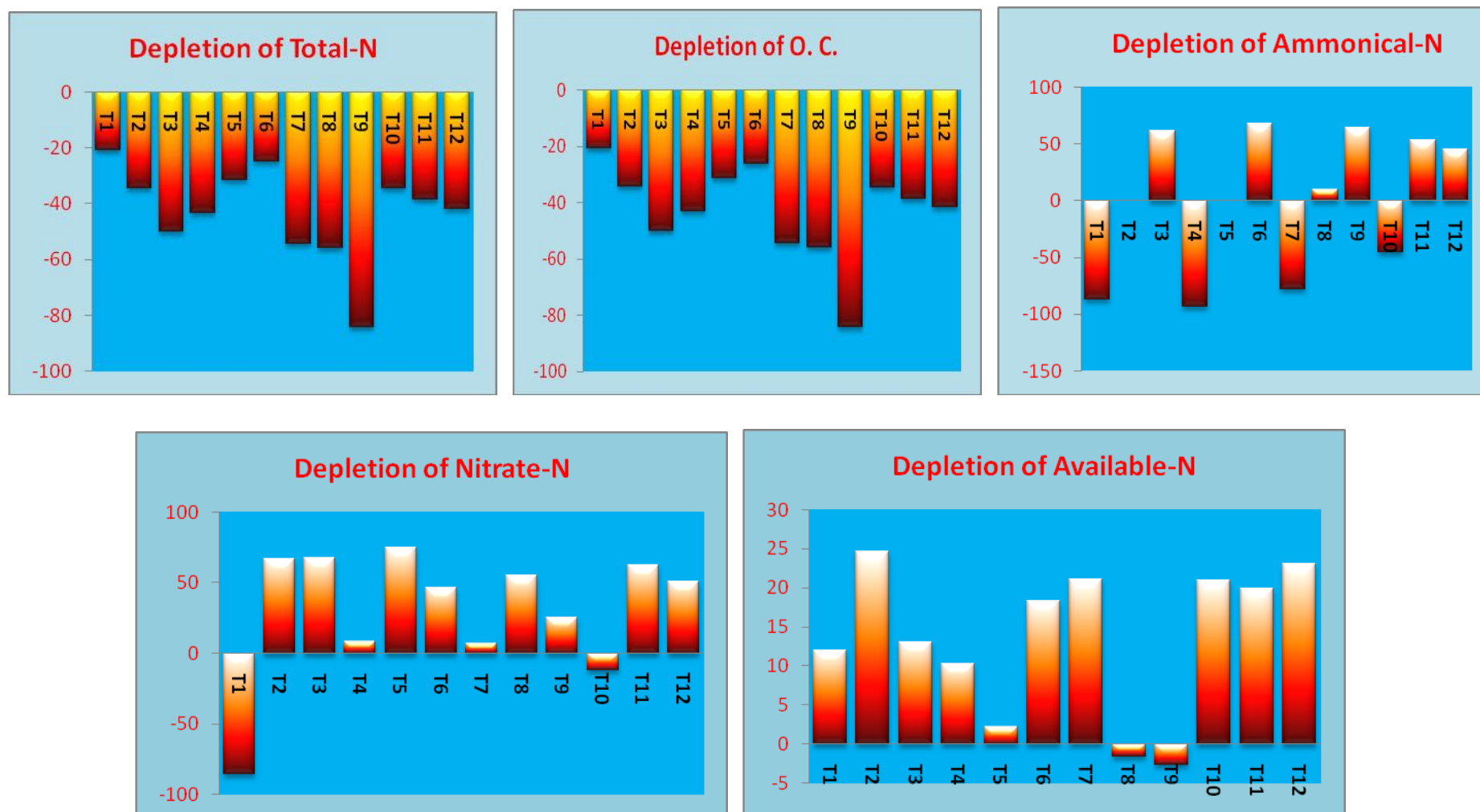


Fig.4.1.6: Depletion (%) of different forms of nitrogen after 8 groundnut-wheat sequence in LTFE soils.

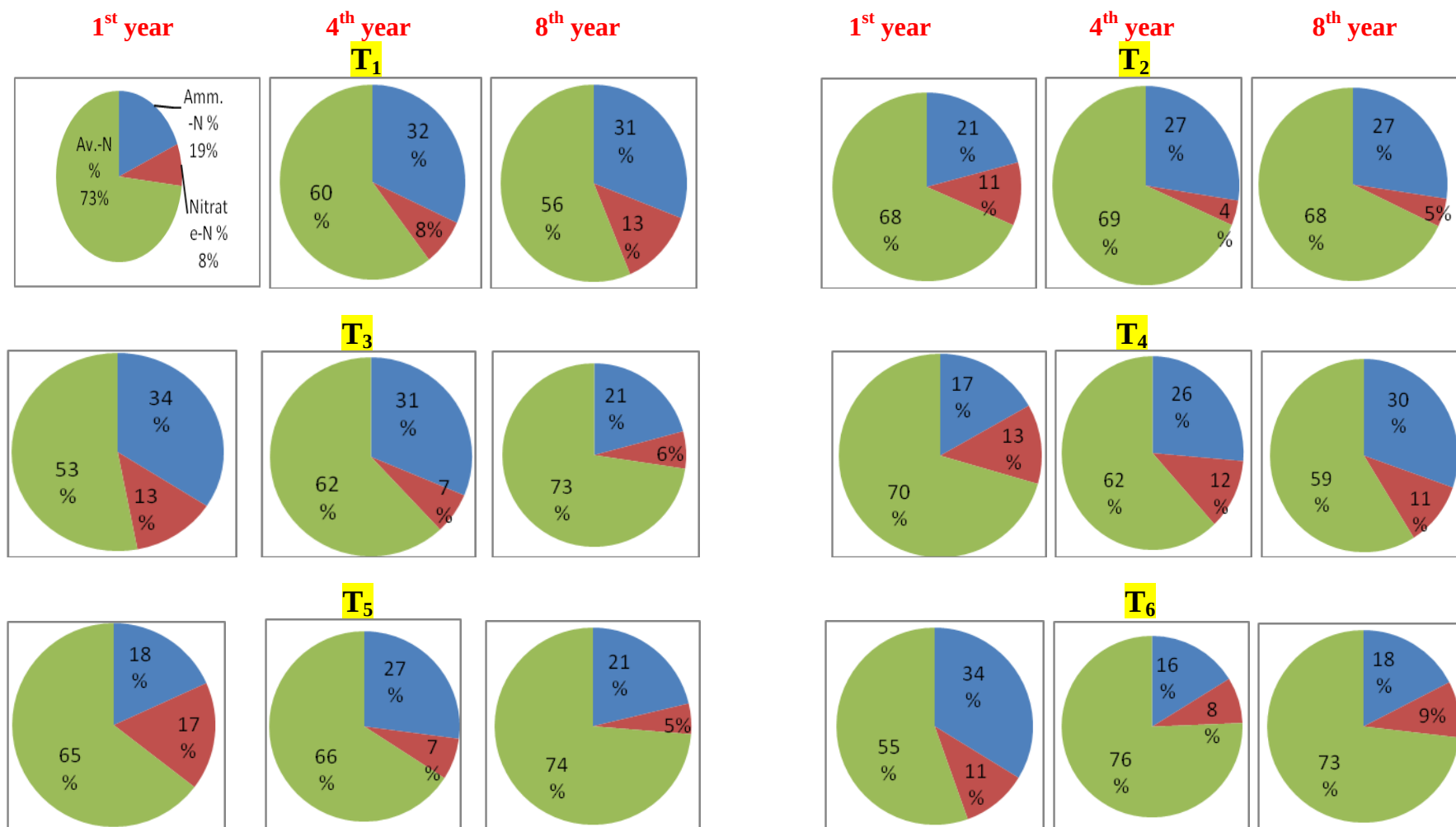


Fig. 4.1.7a: Percent distribution in different fractions of nitrogen in 1st, 4th and 8th years in the LTFE soils.

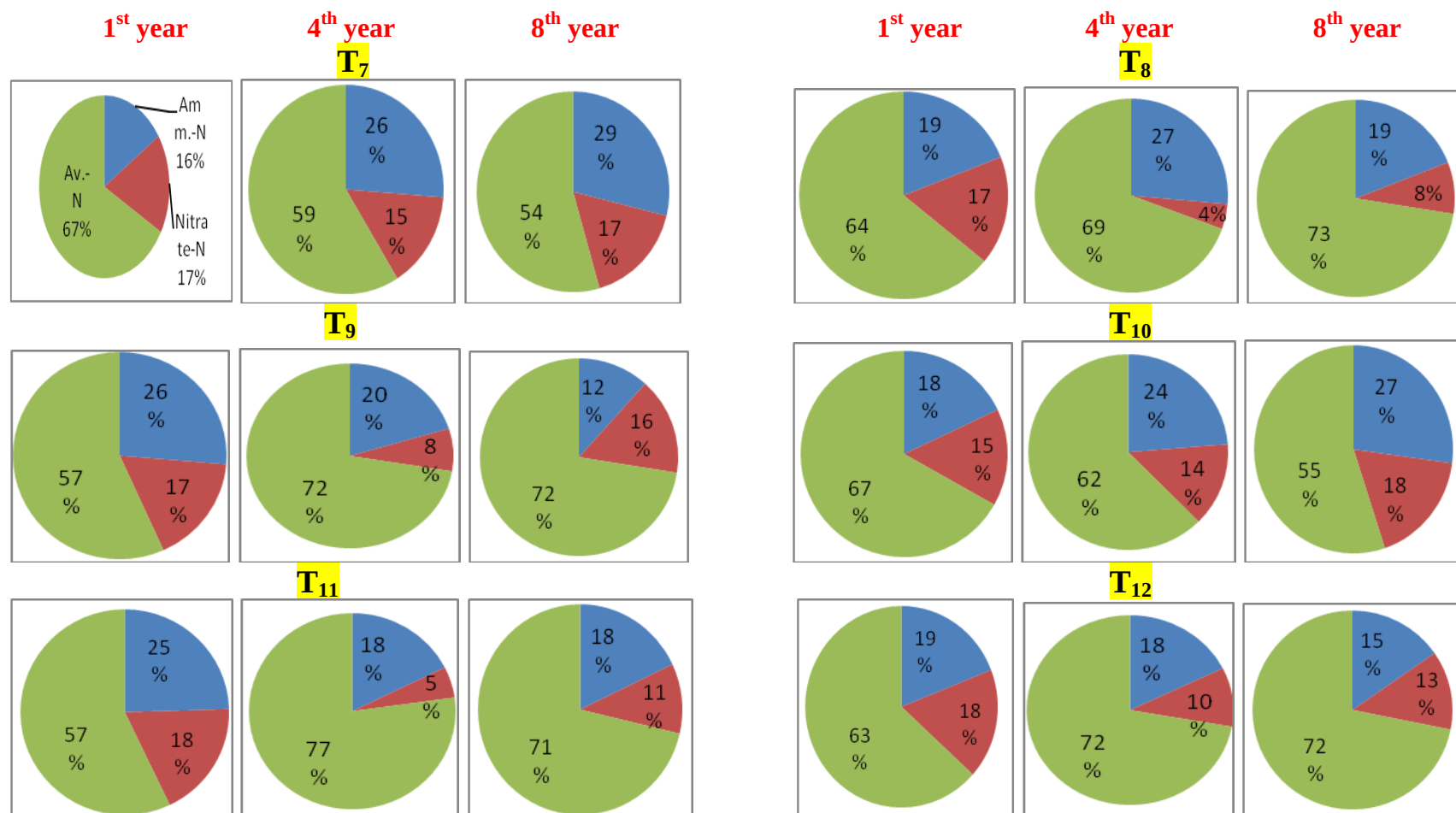


Fig. 4.1.7b: Percent distribution in different fractions of nitrogen in 1st, 4th and 8th years in the LTFE soils.

4.2: Forms of phosphorus:

4.2.1: Inorganic Phosphorus:

Inorganic fraction of phosphorus in LTFE soils was significantly affected due to various treatments after 4th & 8th, year and when pooled over years (Table 4.2.1 & Fig. 4.2.1). After 4 years of cropping sequence, it showed significantly higher value in treatment T₂ and it was significantly higher than control (T₁₂), T₁₁, T₁₀, T₇, T₅, & T₁ and at par with T₈, T₉, T₃, T₄, & T₆. Whereas after 8 years of cropping sequence significantly the highest value was recorded in treatment which received FYM @ 10 t ha⁻¹ + 50% recommended dose of NPK (T₈) and it was significantly higher than all other treatments except T₁ & T₉, which were at par. Similar results were also found when pooled over the years. The overall inorganic forms of phosphorus increased after the span of 8 years as compare to initial value. Similar result was reported by Gupta *et al.*, (1999) who reported that application of P alone and in combination with FYM increased the contents of total P and different P fractions. The Y x T interaction was also significant.

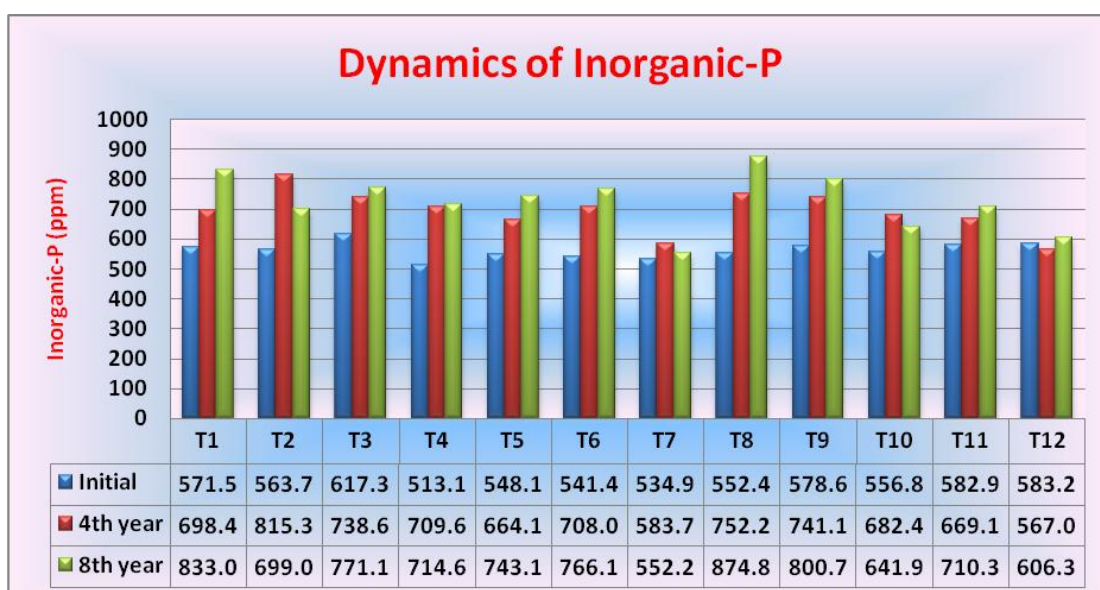


Fig. 4.2.1: Status of Inorganic-P (ppm) in soils of LTFE in 1st, 4th and 8th year

Table-4.2.1: Status of Inorganic-P in LTFE soils at initial, after 4th year and 8th year.

Treatments	Inorganic-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	571.5035	698.4775	833.0425	701.01
T ₂	563.7500	815.3500	699.0050	692.70
T ₃	617.3150	738.6500	771.1250	709.03
T ₄	513.1750	709.6050	714.6450	645.81
T ₅	548.1425	664.1450	743.1075	651.80
T ₆	541.4000	708.0550	766.1975	671.88
T ₇	534.9150	583.7025	552.2825	556.97
T ₈	552.4000	752.2350	874.8125	726.48
T ₉	578.6500	741.1675	800.7800	706.87
T ₁₀	556.8075	682.4925	641.9325	627.08
T ₁₁	582.9075	669.1725	710.3600	654.15
T ₁₂	583.2625	567.0075	606.3825	585.55
S.Em.+	28.9243	38.7997	29.0147	32.18
CD @ 5%	NS	111.7175	83.5432	94.39
CV %	10.2900	11.1800	7.9900	9.86
Mean	562.0190	694.1717	726.1394	660.776694
Y x T	S.Em.+	32.5775	CD @ 5%	91.5443

4.2.2: Total phosphorus:

The data presented in table 4.2.2 (Fig. 4.2.2) revealed that the status of Total P at initial stage of experiment was varied and after 4th year was significantly affected due to various treatments, but it was non-significant due to treatments after 8th year and when pooled over years. At initial stage i.e.1st year of experiment, the highest value was recorded in T₇ & after 4th year it was recorded in T₈ (50% NPK + FYM @ 10 t ha⁻¹ to G'nut & 100% NPK to wheat). These results were confirmative with the finding of Rahate *et al.*, (1979), that buildup of total P was significant when P fertilizers were applied along with FYM. The Y x T interaction was also significant. There was overall increase in the status of Total-P after four year as compared to initial status, but marginally overall P status decreased after 8th year as compared to 4th year and Y x T interaction was found significant.

Table-4.2.2: Status of Total-P (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Total-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T₁	945.2500	1555.6250	1242.6250	1247.83
T₂	842.2500	2039.3750	1687.3750	1523.00
T₃	927.1250	1633.5000	1638.2500	1399.63
T₄	779.0000	1702.1250	1486.8750	1322.67
T₅	744.5000	1337.0000	1526.2500	1202.58
T₆	902.0000	1284.3750	1511.2500	1232.54
T₇	1406.8750	1365.3750	1280.5000	1350.92
T₈	927.1250	2112.5000	1417.3750	1485.67
T₉	887.1250	1401.6250	1456.1250	1248.29
T₁₀	1045.2500	1546.5000	1518.7500	1370.17
T₁₁	895.2500	1766.2500	1451.5000	1371.00
T₁₂	948.2500	1513.5000	1440.2500	1300.67
S.Em.+	83.7328	136.4743	87.6201	118.46
CD @ 5%	241.0951	392.9557	NS	NS
CV %	17.8600	17.0100	11.9100	15.75
Mean	937.5000	1604.8125	1471.4271	1337.91319
Y x T	S.Em.+	105.3782	CD @ 5%	296.1172

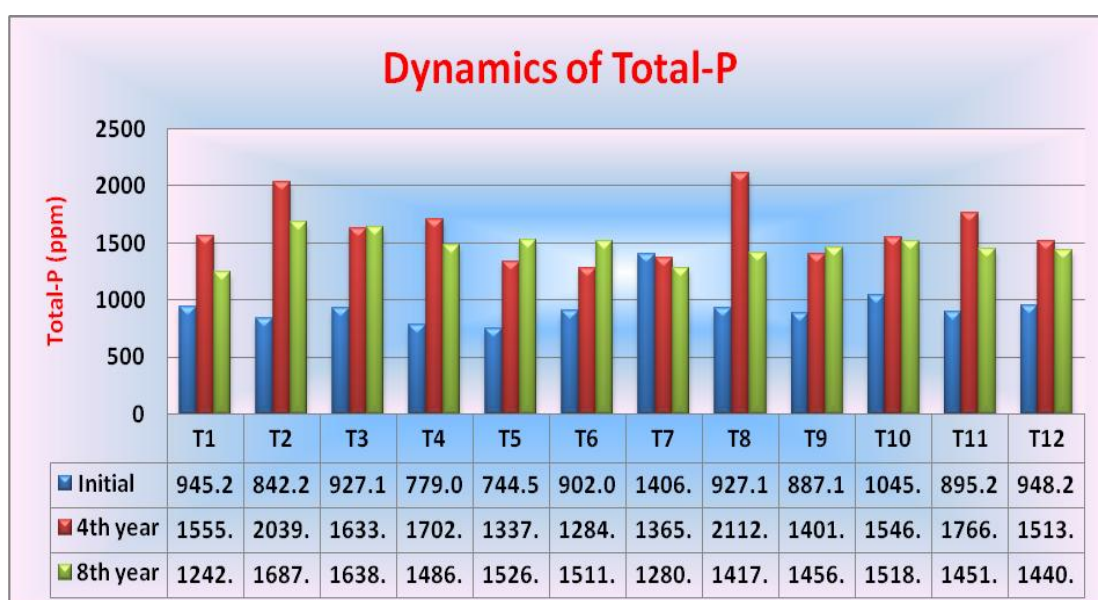


Fig. 4.2.2: Status of Total-P (ppm) in soils of LTFE in 1st, 4th and 8th year

4.2.3: Fe-P:

Iron bound P was significantly affected by treatments after 4th year & 8th year (Table 4.2.3 & Fig. 4.2.3). Initial status (1st year) also significantly differ in Fe-P, but it was not affected by treatments when

pooled over years. The Y x T interaction was found significant. At initial stage, the highest value was recorded in plot of T₄, followed by T₁₁, T₅, T₁₂, and T₇, after 4th year it was the highest in T₅ (NPK as per soil test) followed by T₁₂, T₁₁, T₆, T₇, T₃ & T₁ and after 8th year it was the highest in T₃ (150% NPK) followed by T₆, T₄ , T₁₂ & T₂ . There was much decrease in overall status of Fe-P after 4th & 8th years as compared to initial status of the experimental field. Similar result was also reported by Setia and Sharma (2007) who reported that the N (120 and 180 Kg ha⁻¹) and K (0 and 33.2 Kg ha⁻¹) application caused decrease in the P fraction. The overall decreased in status of Fe-P after a span of 8 years, seems to be inter conversion of Fe-P to other forms like Saloid-P & Reductant soluble-P due to calcareousness of LTFE soils.

Table-4.2.3: Status of Fe-P (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Fe-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	83.8875	11.4813	7.9313	34.43
T ₂	74.7438	6.7438	10.6688	30.72
T ₃	57.8250	12.0125	20.7250	30.19
T ₄	113.8000	11.2188	15.9125	46.98
T ₅	100.4813	18.1125	8.6688	42.42
T ₆	67.4875	12.5250	19.0438	33.02
T ₇	91.6438	12.4750	7.9063	37.34
T ₈	54.9063	8.5438	3.3813	22.28
T ₉	82.1313	5.3000	8.3813	31.94
T ₁₀	73.6875	7.3750	8.4875	29.85
T ₁₁	103.3813	16.5250	7.8313	42.58
T ₁₂	92.4438	16.6188	12.5875	40.55
S.Em.+	7.5579	1.1168	0.8108	6.18
CD @ 5%	21.7618	3.2156	2.3346	NS
CV %	18.2000	19.2900	14.7900	25.21
Mean	83.0349	11.5776	10.9604	35.1909
Y x T	S.Em.+	4.4357	CD @ 5%	12.4645

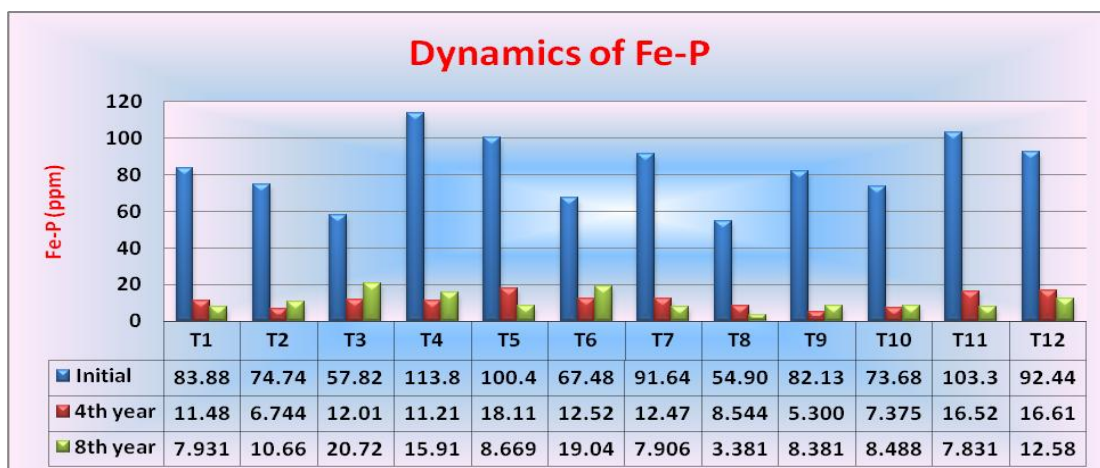


Fig. 4.2.3: Status of Fe-P (ppm) in soils of LTFE in 1st, 4th and 8th year

4.2.4: Reductant soluble-P:

The data presented in table 4.2.4 (Fig. 4.2.4) depicted that overall increase in soil status of Reductant soluble P after 4th & 8th year and it was also significantly affected by treatment combination, but it was not affected due to treatments when pooled over years. In initial (1st year) soil content of Reductant-P was the highest in T₆, in 4th year it was in T₄ and in 8th year was in T₉ (Only FYM @ 25 t ha⁻¹ to G'nut only). Similar trend was reported by Sihag *et al.*, (2005) that the highest amount of all the forms of P was recorded under farm yard manure. The Y × T interaction was also found significant.

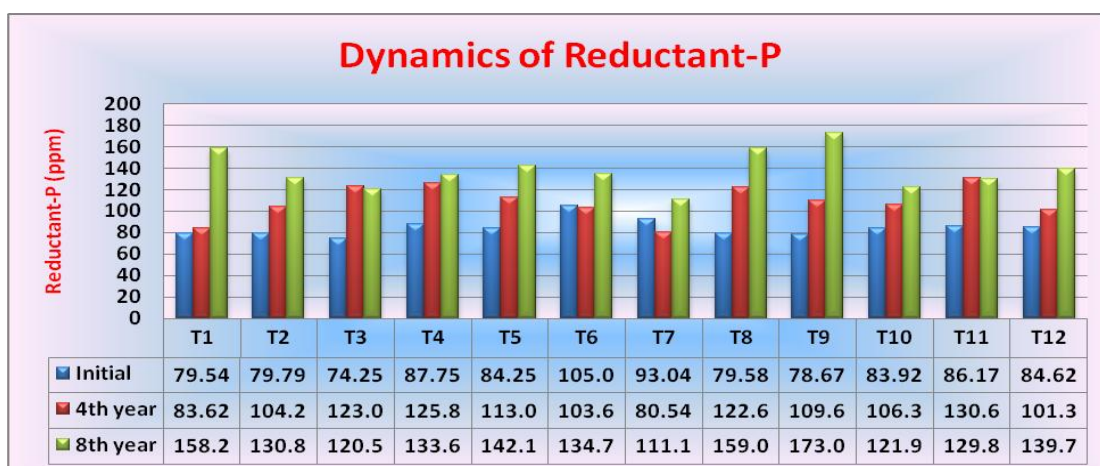


Fig. 4.2.4: Status of Reductant soluble-P (ppm) in soils of LTFE in 1st, 4th and 8th year

Table-4.2.4: Status of Reductant-P (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Reductant-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	79.5416	83.6250	158.2083	107.12
T ₂	79.7916	104.2916	130.8333	104.97
T ₃	74.2500	123.0416	120.5000	105.93
T ₄	87.7500	125.8749	133.6249	115.75
T ₅	84.2500	113.0000	142.1249	113.12
T ₆	105.0000	103.6250	134.7083	114.44
T ₇	93.0416	80.5416	111.1250	94.90
T ₈	79.5833	122.6250	158.9999	120.40
T ₉	78.6666	109.6666	173.0833	120.47
T ₁₀	83.9166	106.3750	121.9166	104.07
T ₁₁	86.1666	130.6249	129.8749	115.56
T ₁₂	84.6250	101.3750	139.7083	108.57
S.Em.₊	4.8531	9.8147	11.6270	8.79
CD @ 5%	13.9737	28.2598	33.4781	NS
CV %	11.4600	18.0500	16.8600	16.70
Mean	84.7152	108.7222	137.8923	110.4432
Y x T	S.Em.₊	9.2208	CD @ 5%	25.9108

4.2.5: Occluded-P:

Occluded-P status of LTFE soils was affected significantly by treatments. The initial status also showed significant difference, but was found non-significant when pooled over years (Table 4.2.5 & Fig. 4.2.5). At initial stage of experimentation, the significantly highest value of Occluded-P was recorded in soils which received 50 % N P K doses of recommended to G'nut-Wheat sequence (T₁), Whereas significantly the highest value was recorded in T₉ (25 t FYM ha⁻¹ to G'nut only) after 4 & 8 year completion of experiment. Similar trend was also reported by Sihag *et al.*, (2005). The highest amount of all the forms of P was recorded under farm yard manure. The Y x T interaction was significant. Overall decrease in status of Occluded P was recorded after 4 years, but after that it was increased.

Table-4.2.5: Status of Occluded-P (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Occluded-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	8.8250	3.5313	5.1813	5.85
T ₂	3.2250	3.9563	7.5688	4.92
T ₃	5.0250	3.1875	5.8625	4.69
T ₄	5.6375	3.5438	7.1938	5.46
T ₅	5.6813	6.1375	5.9625	5.93
T ₆	4.0688	2.9688	7.3563	4.80
T ₇	5.0563	4.4500	7.6938	5.73
T ₈	5.4875	3.6938	5.2750	4.82
T ₉	4.1688	6.1938	9.4063	6.59
T ₁₀	4.1813	3.4813	6.2125	4.63
T ₁₁	7.7625	4.0125	7.2313	6.34
T ₁₂	5.5375	3.1813	7.6500	5.46
S.Em.+	0.4675	0.3646	0.6336	0.79
CD @ 5%	1.3461	1.0498	1.8243	NS
CV %	17.3500	18.1000	18.4100	18.44
Mean	5.3880	4.0281	6.8828	5.4329
Y x T	S.Em.+	0.5010	CD @ 5%	1.4077

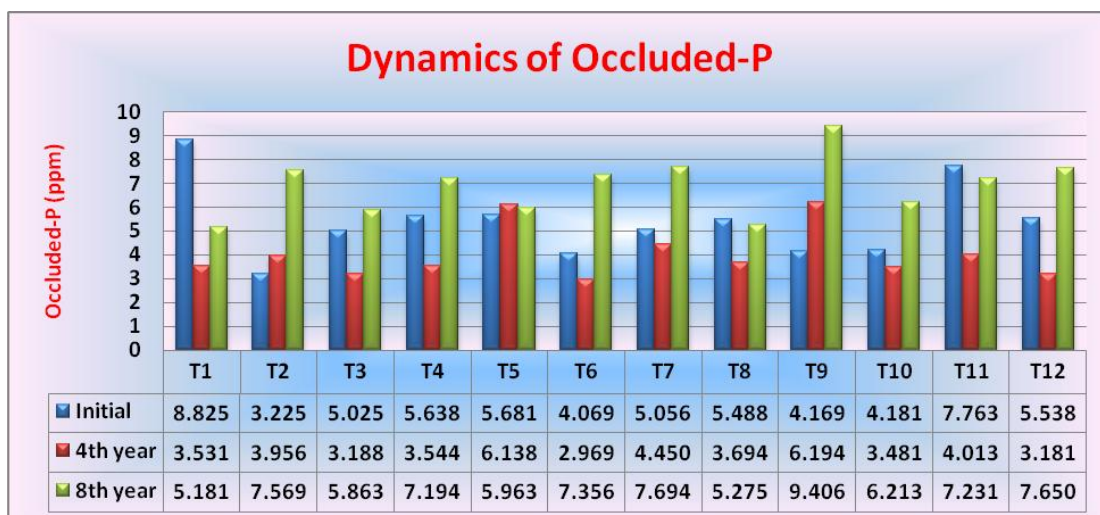


Fig. 4.2.5: Status of Occluded-P (ppm) in soils of LTFE in 1st, 4th and 8th year

4.2.6: Ca-P:

The data presented in table 4.2.6 (Fig. 4.2.6) revealed that content of Ca-P in LTFE soils was significantly affected by application of various levels of NPK fertilizers and other combination of biological

materials. It was also significantly differed at initial stage of experiment, but it was found non-significant when pooled over years. After four G'nut-wheat cropping sequence, Ca-P status of soil was found significantly higher in treatment, which received 50% NPK + FYM @ 10 t ha⁻¹ to G'nut & 100 % NPK to wheat (T₈), whereas it was significantly higher in treatment which received only 50 % NPK of R. D. of G'nut-wheat in case of after eight G'nut-wheat cropping sequence. Sihag *et al.*, (2005) also reported that the amount of P recovered in Ca-P form increased significantly with the application of inorganic fertilizers and their combined use with organic materials over control. The Y × T interaction also showed significant variation in Ca-P content of the LTFE soils

Table-4.2.6: Status of Ca-P (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Ca-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	165.5688	86.9438	111.0250	121.18
T ₂	187.0938	76.1813	54.7438	106.01
T ₃	176.9750	103.8125	40.1000	106.96
T ₄	177.9688	71.4438	61.9938	103.80
T ₅	184.3938	74.9625	64.8563	108.07
T ₆	189.7188	111.2438	51.9313	117.63
T ₇	184.9750	73.6375	75.1813	111.26
T ₈	163.7125	138.6438	76.0250	126.13
T ₉	177.2250	116.1875	71.4750	121.63
T ₁₀	178.1500	85.4750	55.9688	106.53
T ₁₁	171.7125	101.1938	91.6500	121.52
T ₁₂	165.6125	104.0813	81.9125	117.20
S.E.m. ₊	5.7064	6.0527	6.4383	10.82
CD @ 5%	16.4307	17.4278	18.5380	NS
CV %	6.4500	12.7000	18.4600	10.66
Mean	176.9255	95.3172	69.7385	113.9937
Y x T	S.E.m. ₊	6.0732	CD @ 5%	17.0658

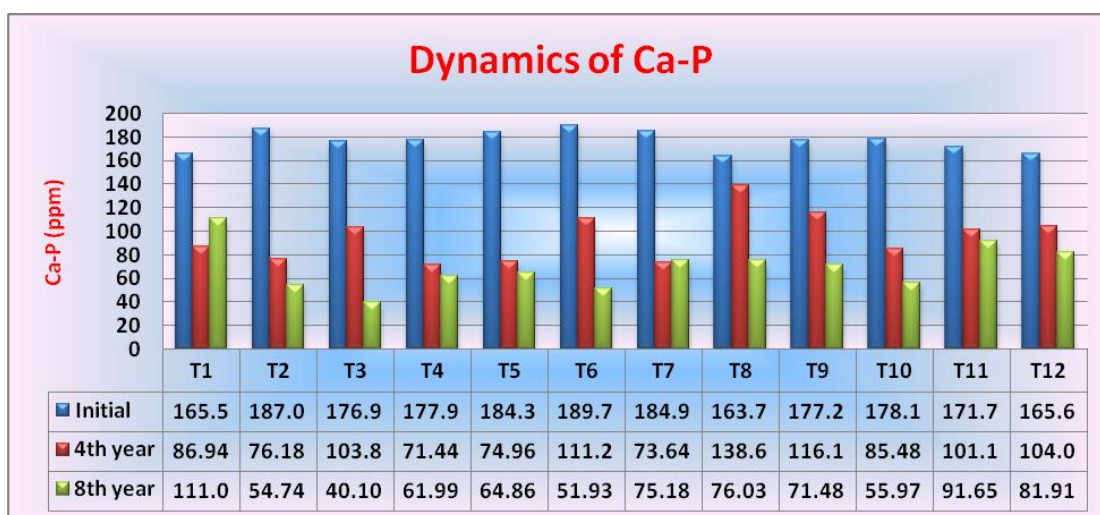


Fig. 4.2.6: Status of Ca-P (ppm) in soils of LTFE in 1st, 4th and 8th year

4.2.7: Organic-P:

At initial stage of the experiment, the status of the Organic-P was significantly higher in plot of T₇, but it was the significantly highest in plot of T₈ & T₂ after 4 & 8 year of experiment (Table 4.2.7 & Fig. 4.2.7), respectively. When pooled over years, it was found non-significant. The Y x T interaction was also significant. There was overall increased in Organic-P status of the soil after 8 year of experiment as compared to initial status, it might be due to addition of organic matter through crop residue. Gupta *et al.*, (1999) investigated that application of P alone and in combination with FYM increased the contents of different P fractions.

4.2.8: Saloid bound-P:

The data presented in table 4.2.8 (Fig.4.2.8) indicated that at initial stage, after 4th & 8th year of investigation, Saloid bound P content of soil varied significantly under various treatment combinations. At initial stage it was recorded highest in treatment T₄, but found highest in T₈ & T₉ after 4 & 8 years of experiment, respectively. When pooled over years it was non-significant and Y x T interaction was significant. Overall

Table-4.2.7: Status of Organic-P (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Organic-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T₁	373.7465	857.1475	409.5825	546.83
T₂	278.5000	1224.0250	988.3700	830.30
T₃	309.8100	894.8500	867.1250	690.60
T₄	265.8250	992.5200	772.2300	676.86
T₅	196.3575	672.8550	783.1425	550.79
T₆	360.6000	576.3200	745.0525	560.66
T₇	871.9600	781.6725	728.2175	793.95
T₈	374.7250	1360.2650	542.5625	759.18
T₉	308.4750	660.4575	655.3450	541.43
T₁₀	488.4425	864.0075	876.8175	743.09
T₁₁	312.3425	1097.0775	741.1400	716.85
T₁₂	364.9875	946.4925	833.8675	715.12
S.Em.±	89.2706	146.4268	92.0629	112.57
CD @ 5%	257.0403	421.6124	265.0803	NS
CV %	47.5500	32.1600	24.7100	33.19
Mean	375.4810	910.6408	745.2877	677.1365
Y x T	S.Em.±	112.3768	CD @ 5%	315.7835

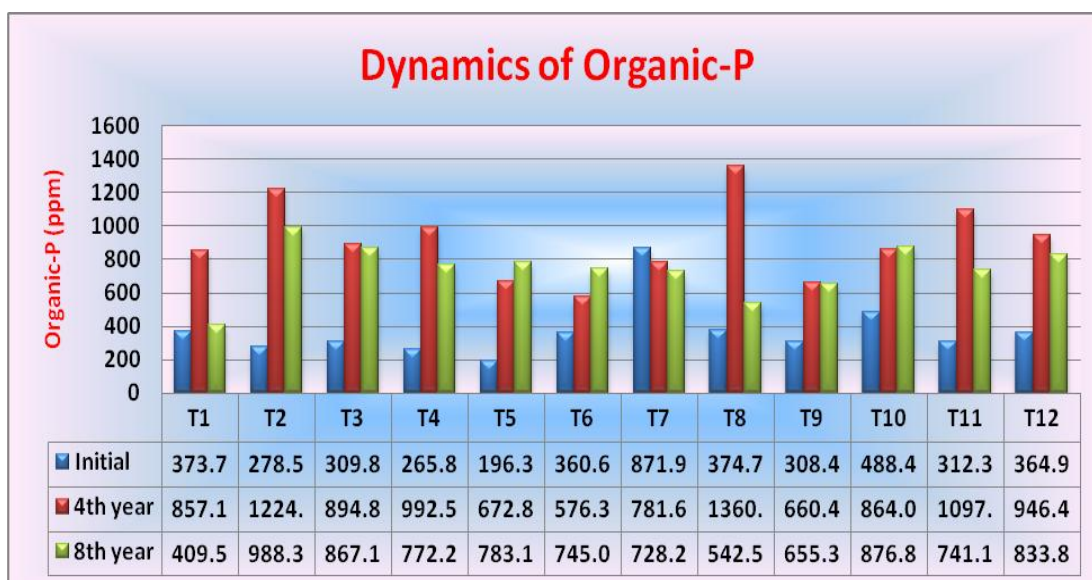


Fig. 4.2.7: Status of Organic-P (ppm) in soils of LTFE in 1st, 4th and 8th year

Status of this form of P increased up to 4 year and then it remained stable. Gupta *et al.*, (1999) reported similar trend that application of P alone and in combination with FYM increased the contents of different P fractions.

Table-4.2.8: Status of Saloid -P (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Saloid bound-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	6.9438	11.1838	5.2750	7.80
T ₂	4.5638	13.3025	10.5900	9.49
T ₃	3.9625	15.9375	10.7088	10.20
T ₄	9.1375	13.6875	7.9638	10.26
T ₅	1.9500	11.4463	7.5825	6.99
T ₆	1.9000	14.9188	12.0388	9.62
T ₇	4.5900	10.1138	8.2350	7.65
T ₈	3.9700	16.1625	28.4750	16.20
T ₉	4.2125	16.1025	33.5275	17.95
T ₁₀	2.3625	11.1638	11.6375	8.39
T ₁₁	3.5813	10.0938	4.5888	6.09
T ₁₂	3.9875	11.2138	6.7938	7.33
S.E.m.+	0.4190	1.2312	0.9737	2.97
CD @ 5%	1.2064	3.5450	2.8036	NS
CV %	19.6600	19.0200	15.8500	19.08
Mean	4.2634	12.9439	12.2847	9.83065
Y x T	S.E.m.+	0.9380	CD @ 5%	2.6358

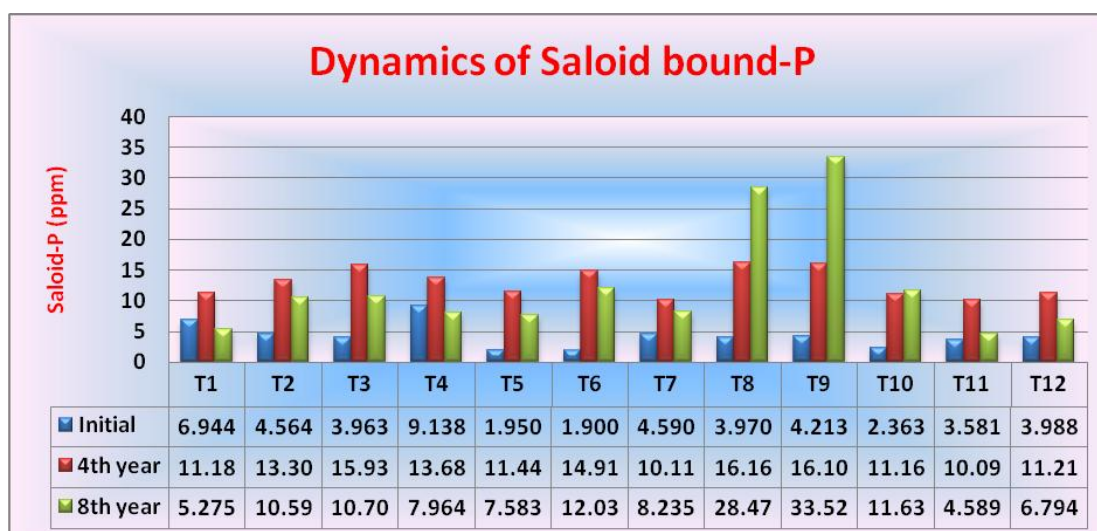


Fig. 4.2.8: Status of Saloid bound-P (ppm) in soils of LTFE in 1st, 4th and 8th year

4.2.9: Al-P:

At initial stage of the experiment, Al-P status of soil differed significantly and the highest value (8.45) of Al-P was recorded in the soils which received 50 % N P K doses of recommended to G'nut-Wheat

sequence (T₁) and it was at par with T₂ (Table 4.2.9 & Fig. 4.2.9). After 4 & 8 years of experiment, it was also significantly affected by various treatment combinations. The highest value (6.825 ppm) was recorded in T₂ after 4th year and 5.738 ppm in T₈ after 8th year. After 4th year T₂ was at par with T₉ and after 8th year T₈ was at par with T₃. This result is in conformity with finding of Sihag *et al.*, (2005) who recorded that the amount of P recovered in Al-P form increased significantly with the application of inorganic fertilizers and their combined use with organic materials over control. When pooled over years, it was non-significant, but Y x T interaction was found significant. There was overall decreased in Al-P status of LTFE soils after a span of 8 years, it might be due to inter-conversion of Al-P to other fractions like Saloid-P & Reductant-P, which were increased after a span of 8 years due to calcareousness of LTFE soils.

Table-4.2.9: Status of Al-P (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Al-P (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	8.4500	3.1200	4.1000	5.22
T ₂	7.5125	6.8250	4.1338	6.16
T ₃	3.1875	4.7825	4.8150	4.26
T ₄	6.1375	3.2575	3.3763	4.26
T ₅	6.9813	4.4375	3.0575	4.83
T ₆	5.5375	4.2750	3.7950	4.54
T ₇	3.9375	4.2138	3.3450	3.83
T ₈	5.8500	2.8950	5.7388	4.83
T ₉	3.6750	6.6500	3.9450	4.76
T ₁₀	5.4500	4.7750	2.5625	4.26
T ₁₁	4.6500	5.0825	3.3825	4.37
T ₁₂	4.2438	4.3763	2.9150	3.85
S.Em.+	0.4948	0.4332	0.3655	0.78
CD @ 5%	1.4247	1.2473	1.0524	NS
CV %	18.1000	19.0100	19.4200	18.90
Mean	5.4677	4.5575	3.7639	4.5963
Y x T	S.Em.+	0.4344	CD @ 5%	1.2206

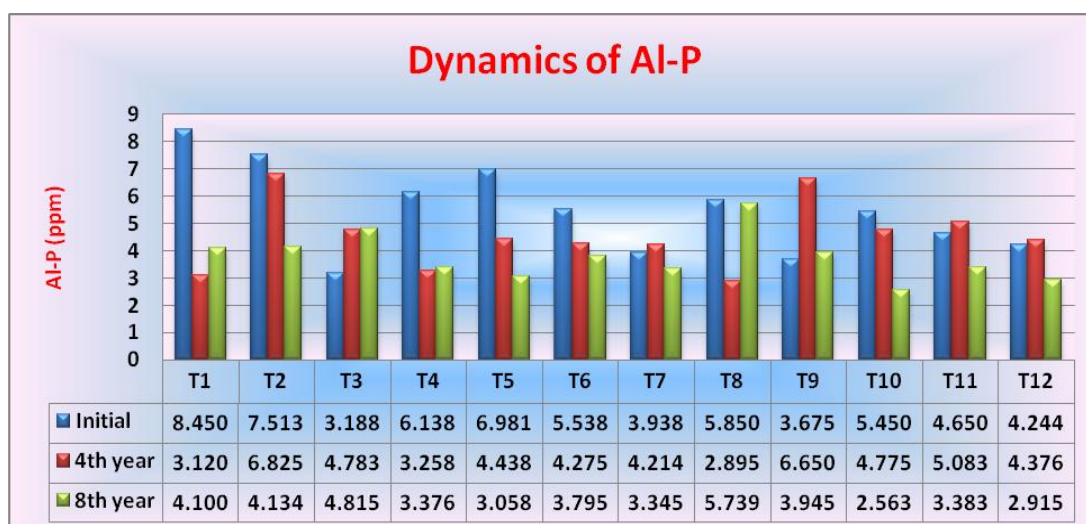


Fig. 4.2.9: Status of Al-P (ppm) in soils of LTFE in 1st, 4th and 8th year

4.2.10: Available P₂O₅:

The data presented in table 4.2.10 (Fig 4.2.10) revealed that Available P₂O₅ content of LTFE soils at initial stage was almost same in all plots of treatments i. e. non-significant difference in Available P₂O₅ status of LTFE soils at initial stag. After 4th, 8th year and when pooled over years, it was found significantly affected due to treatments. The significantly highest value 45.98, 121.53 and 66.11 Kg ha⁻¹ P₂O₅ were recorded under T₉ (25 t FYM to G'nut only) after 4th, 8th years & when pooled over years, respectively. The Y x T interaction was also found significant. Tripathi and Minhas (1991) reported that addition of FYM increased transformation of phosphorus. This result was confirmative with the finding of Varalakshmi *et al.*, (2005) who reported that Available P significantly improved with the use of 100 % recommended fertilizer + 7.5 t FYM ha⁻¹. Overall, there was decreased in status of Available P₂O₅ of in LTFE soils under all treatments, except treatments which were received FYM i. e. T₈ & T₉, where status was increased due to release of organic acids from FYM which make conversion of fixed-P to plant available forms.

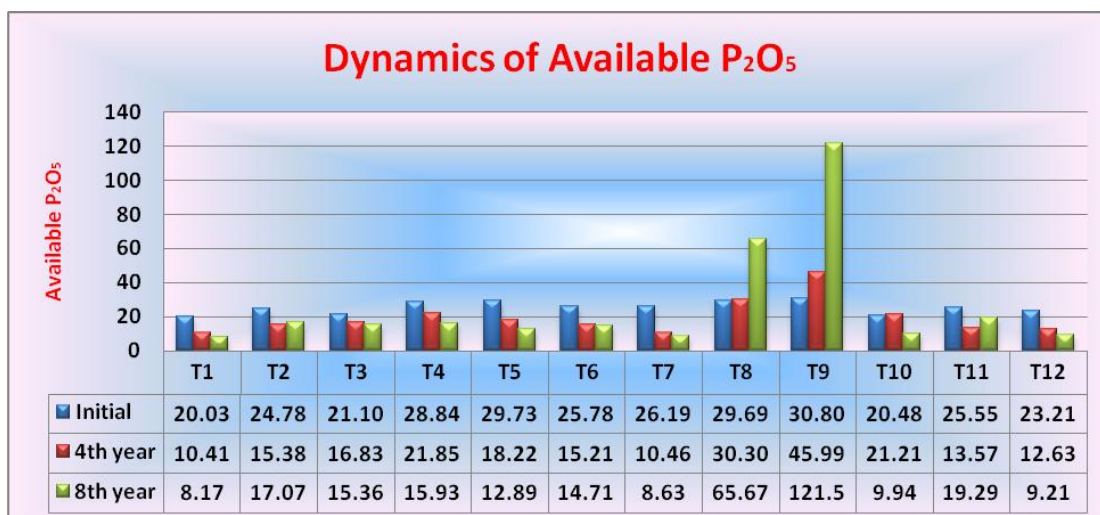


Fig. 4.2.10: Status of Available P_2O_5 (kg ha⁻¹) in soils of LTFE in 1st, 4th and 8th year

Table-4.2.10: Status of Available P_2O_5 (kg ha⁻¹) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Available P_2O_5 (kg ha ⁻¹)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	20.0311	10.4131	8.1689	12.87
T ₂	24.7760	15.3760	17.0687	19.07
T ₃	21.0955	16.8251	15.3632	17.76
T ₄	28.8412	21.8521	15.9274	22.21
T ₅	29.7260	18.2229	12.8881	20.28
T ₆	25.7762	15.2093	14.7091	18.56
T ₇	26.1866	10.4644	8.6306	15.09
T ₈	29.6876	30.3031	65.6717	41.89
T ₉	30.8032	45.9869	121.5330	66.11
T ₁₀	20.4799	21.2109	9.9386	17.21
T ₁₁	25.5454	13.5678	19.2873	19.47
T ₁₂	23.2114	12.6316	9.2076	15.02
S.E.m.+	3.0506	1.4574	1.5017	9.62
CD @ 5%	NS	4.1963	4.3239	28.22
CV %	23.9100	15.0700	11.3200	17.95
Mean	25.5133	19.3386	26.5329	23.7949
Y x T	S.E.m.+	2.1359	CD @ 5%	6.0019

4.2.11: Depletion per cent of different forms of phosphorus

After a span of 8 year most of the phosphorus fraction depicted negative trend in percent depletion in LTFE soils, except Al-P, Fe-P, Ca-P & Available P, where positive depletion recorded (table 4.2.11 & Fig. 4.2.11a,b). Inter-conversion is a distinct possibility under

natural soil conditions. Additionally the type of plant grown on the site also influences the transformation of P in soil. Jain and Sarkar (1979) found that Ca-P and Fe-P got converted to Saloid-P and Al-P after wheat harvest. They were of the opinion that it was due to exudation of HCO_3^- and H^+ by wheat roots, which helps in conversion of Ca-P and Fe-P to Saloid-P and Al-P. The removal of phosphorus by crop is only marginal compared to the other two major nutrients and hence continuous addition of phosphatic fertilizers is bound to increase the concentration of total P in the soil and several workers have noticed similar results (Jones and Ruckman, 1973; Ryan and Zahard, 1980). In case of Al-P and Fe-P maximum depletion percent were noted in T_1 and T_4 , respectively, while lowest per cent depletion were noted in T_3 (150 % NPK) in both the fractions. Whereas in case of Ca-P and Available-P, the highest positive per cent depletion were recorded in T_3 & T_7 , respectively, and it was lowest in T_1 & T_3 respectively. In Available P fraction negative per cent depletion also noted in treatments which were FYM *i. e.* T_8 & T_9 . In case of Total-P, positive per cent depletion was noted only in treatments which did not receive P & K nutrition through fertilizers (T_7).

4.2.12: Percent distribution in different fractions of phosphorus.

Different fractions of Inorganic-P were found in varying proportions in LTFE soils (Fig. 4.2.12a& b). At the initial stage of experiment, Ca-P fraction was recorded higher in proportion followed by Reductant soluble-P & Fe-P. The Saloid-P, Al-P & Available-P were almost 1-2 % in proportion. After 4th & 8th years the picture somewhat changed, *i. e.* the proportion of Reductant soluble-P increased by 4-5 % as compared to Ca-P and Saloid-P. The Occluded-P was recorded round about 2 % in proportion.

Table-4.2.11: Per cent depletion of different forms of phosphorus after 8 groundnut-wheat sequence in LTFE soils.

Treat.	Total-P	Inorg.-P	Saloid-P	Al-P	Fe-P	Red.-P	Occl.-P	Ca-P	Org.P	Av.-P
T1	-31.460	-45.763	24.032	51.479	90.545	-98.900	41.289	32.943	-9.588	59.219
T2	-100.341	-23.992	-132.046	44.975	85.726	-63.969	-134.690	70.740	-254.890	31.108
T3	-76.702	-24.916	-170.252	-51.059	64.159	-62.290	-16.667	77.341	-179.889	27.173
T4	-90.870	-39.260	12.845	44.990	86.017	-52.279	-27.605	65.166	-190.503	44.775
T5	-105.003	-35.568	-288.846	56.204	91.373	-68.694	-4.950	64.827	-298.835	56.644
T6	-67.544	-41.522	-533.618	31.467	71.782	-28.294	-80.799	72.627	-106.615	42.935
T7	8.983	-3.247	-79.412	15.048	91.373	-19.436	-52.163	59.356	16.485	67.042
T8	-52.879	-58.366	-617.254	1.902	93.842	-99.791	3.872	53.562	-44.790	-121.210
T9	-64.140	-38.388	-695.905	-7.347	89.795	-120.021	-125.637	59.670	-112.447	-294.546
T₁₀	-45.300	-15.288	-392.593	52.982	88.482	-45.283	-48.580	68.583	-79.513	51.472
T₁₁	-62.133	-21.865	-28.133	27.258	92.425	-50.725	6.844	46.626	-137.284	24.498
T₁₂	-51.885	-3.964	-70.376	31.311	86.384	-65.091	-38.149	50.540	-128.465	60.331

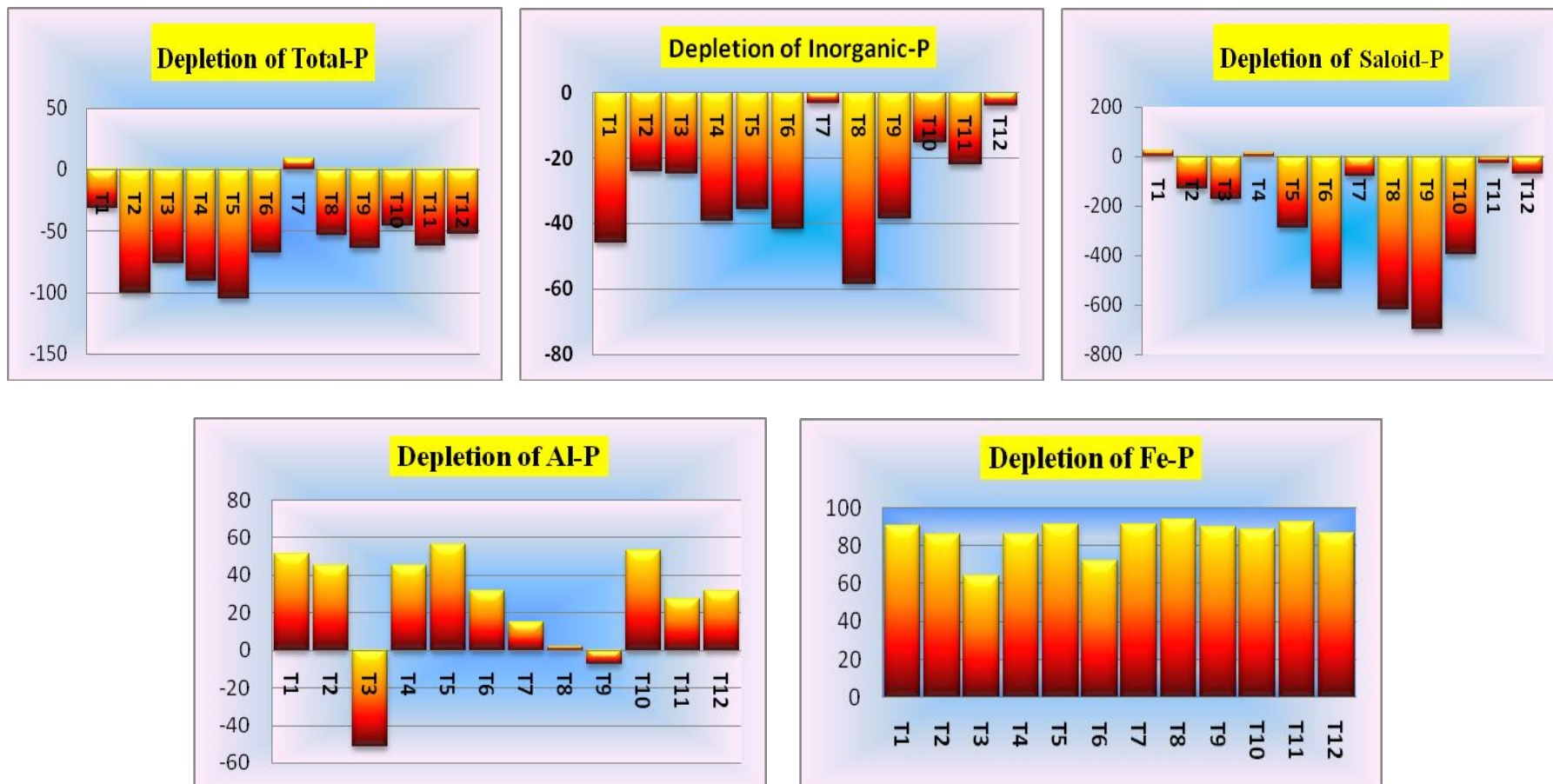


Fig.4.2.11a: Depletion (%) of different forms of phosphorus after 8 groundnut-wheat sequence in LTFE soils.

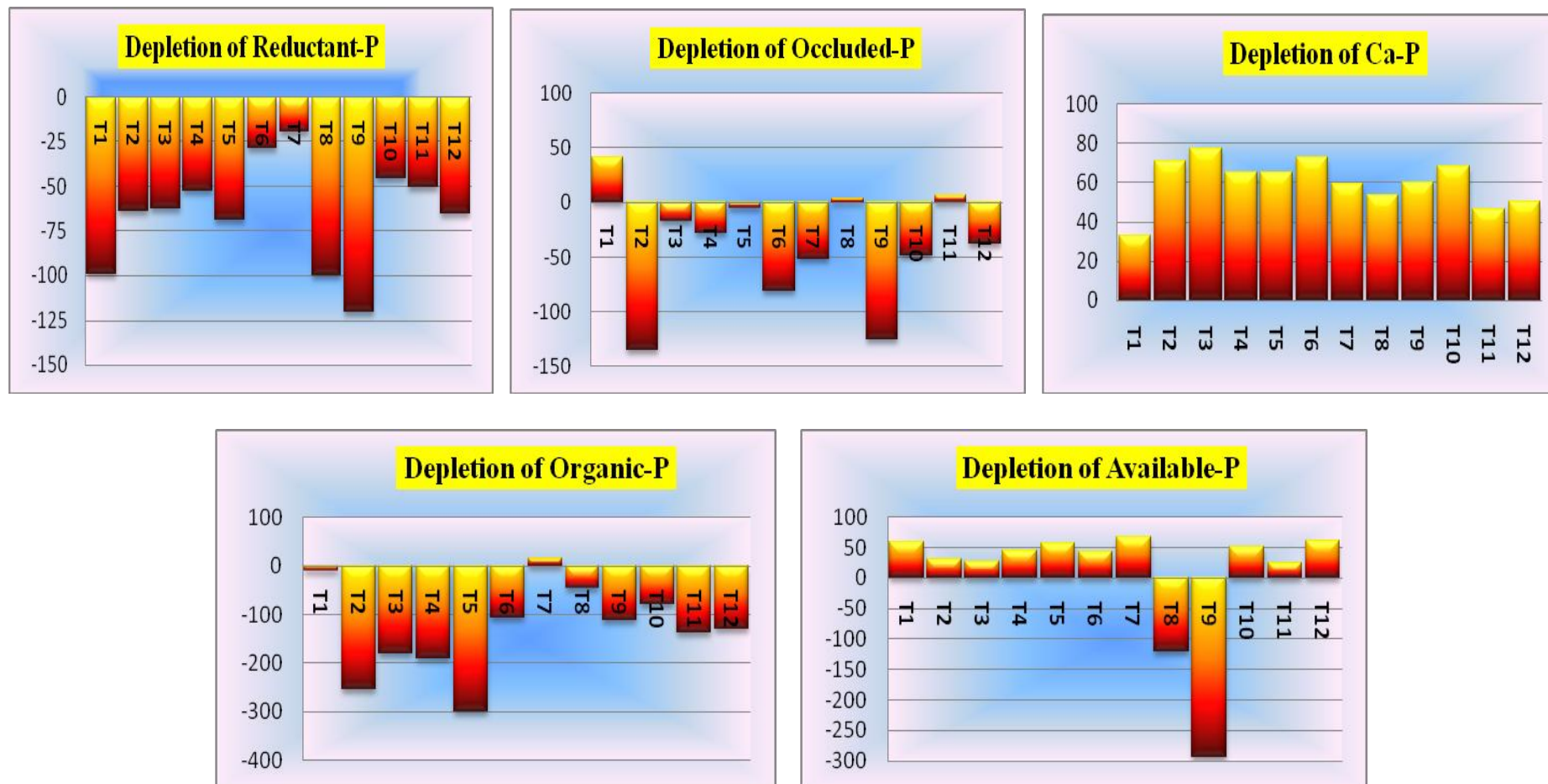


Fig.4.2.11b: Depletion (%) of different forms of phosphorus after 8 groundnut-wheat sequence in LTFE soils.

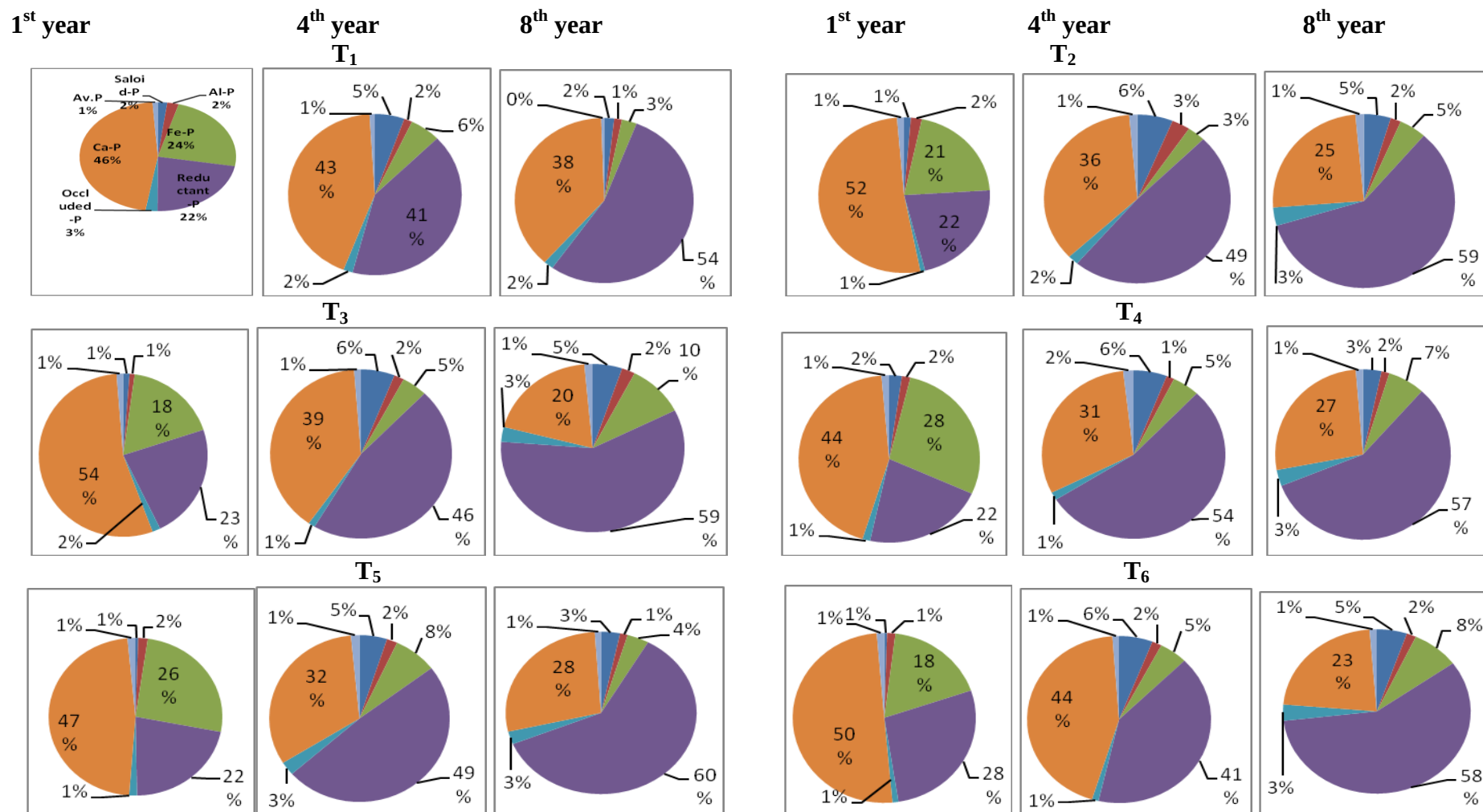


Fig. 4.2.12a: Percent distribution in different fractions of inorganic-P in 1st, 4th and 8th years in the LTFE soils.

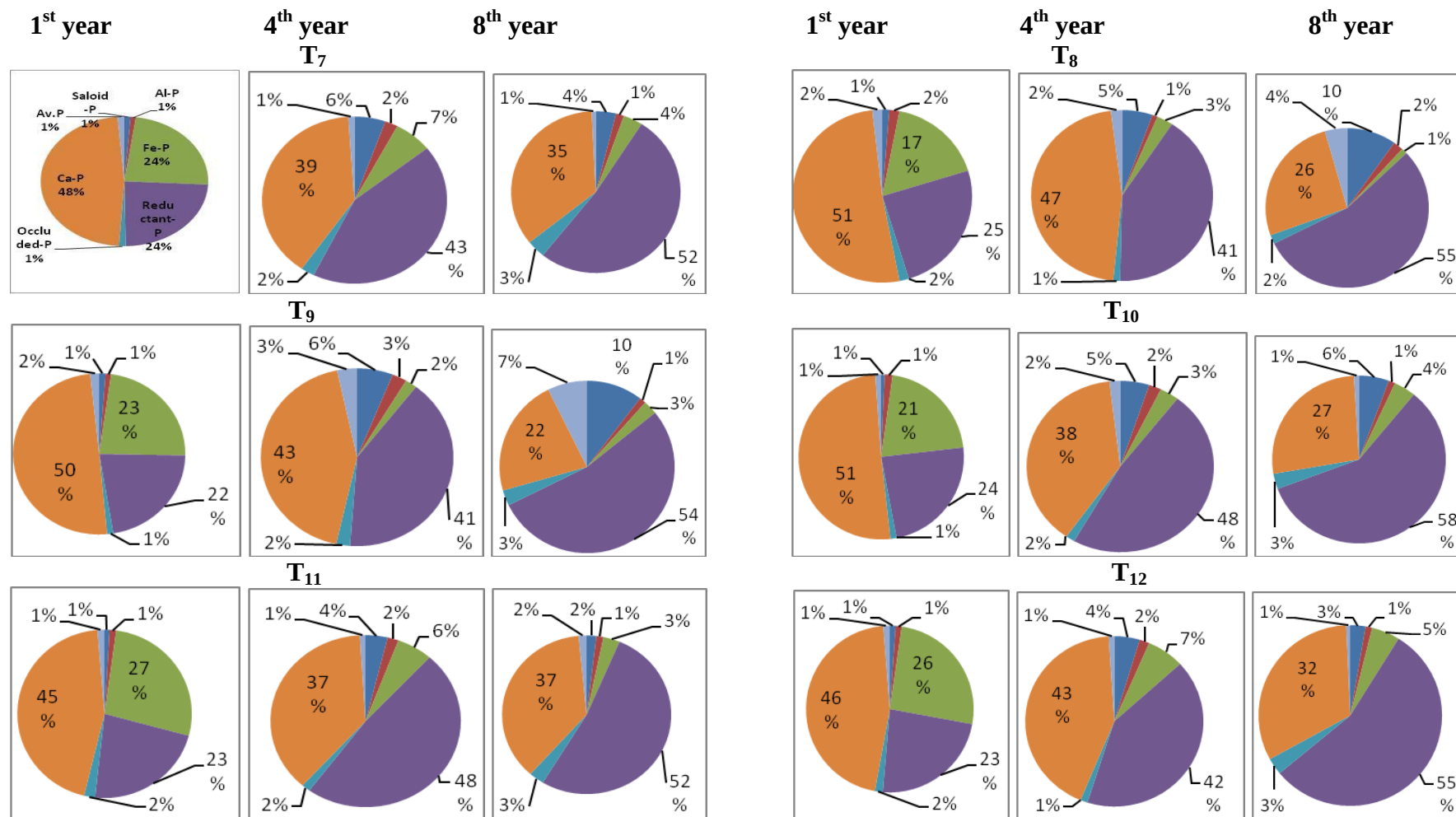


Fig. 4.2.12b: Percent distribution in different fractions of inorganic-P in 1st, 4th and 8th years in the LTFE soils.

4.3: Forms of potassium:

4.3.1: Available K₂O:

Initial status of K₂O in LTFE soils was almost same, but it was affected significantly and found significant differences due to various treatments after 4th, 8th year and when pooled over years (Table 4.3.1 & Fig. 4.3.1). The value of Available K₂O (Kg ha⁻¹) recorded highest value in treatment No. 9 (only FYM @ 25 t ha⁻¹ to G'nut only) in 4th, 8th year and when pooled over years i. e. 521.81, 682.33 and 533.29 Kg ha⁻¹, respectively. There was marginal overall decrease in soil status of Available K₂O after a span of 8 years. Balaguravaih *et al.*, (2005) found similar result and stated that the potassium availability however decreased over initial level of 155 Kg ha⁻¹ in all treatments except in those which received FYM. Santhy *et al.*, (1998) also observed similar trend that Available K was negatively balanced due to continuous cropping with a decrease of 22 per cent from the initial level. The Y x T interaction was significant.

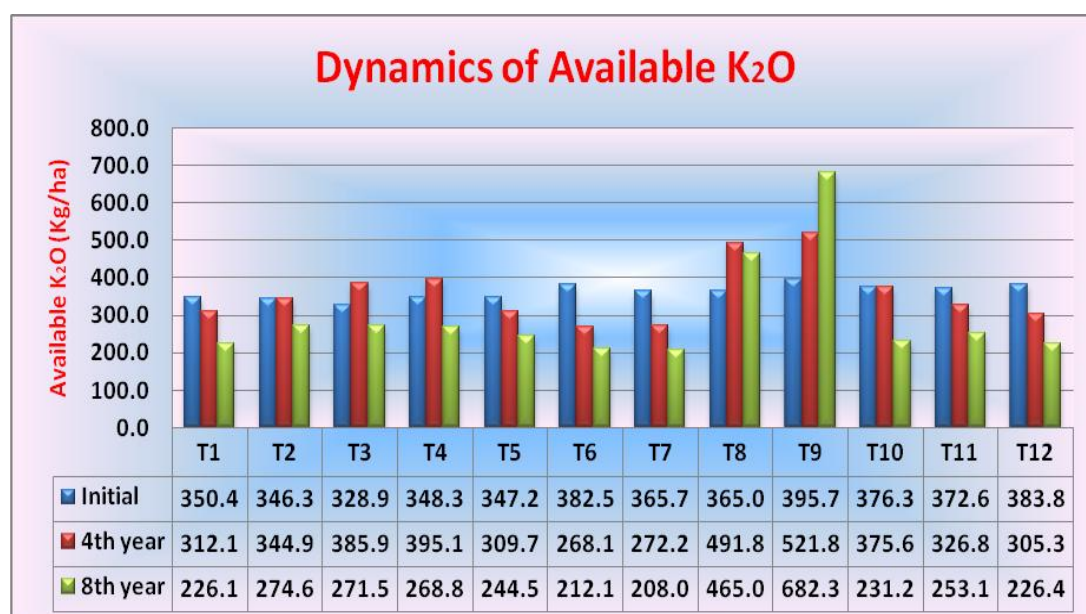


Fig. 4.3.1: Status of Available K₂O (kg ha⁻¹) in soils of LTFE in 1st, 4th and 8th year

Table-4.3.1: Status of Available-K₂O (kg ha⁻¹) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Available K ₂ O (kg ha ⁻¹)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	350.38	312.13	226.07	296.19
T ₂	346.28	344.91	274.56	321.92
T ₃	328.86	385.89	271.49	328.75
T ₄	348.33	395.11	268.76	337.40
T ₅	347.23	309.74	244.51	300.49
T ₆	382.48	268.07	212.07	287.54
T ₇	365.74	272.17	207.97	281.96
T ₈	365.04	491.75	464.96	440.59
T ₉	395.73	521.81	682.34	533.29
T ₁₀	376.33	375.65	231.19	327.72
T ₁₁	372.57	326.81	253.05	317.48
T ₁₂	383.84	305.30	226.41	305.18
S.Em.+	19.9082	16.6912	18.1996	40.79
CD @ 5%	NS	48.0596	52.4028	119.64
CV %	10.9500	9.3000	12.2600	10.78
Mean	363.5669	359.1119	296.9475	339.8754
Y x T	S.Em.+	18.3136	CD @ 5%	51.4619

4.3.2: Available K:

The data presented in table 4.3.2 (Fig. 4.3.2) depicted same results as per Available K₂O in case of Available K.

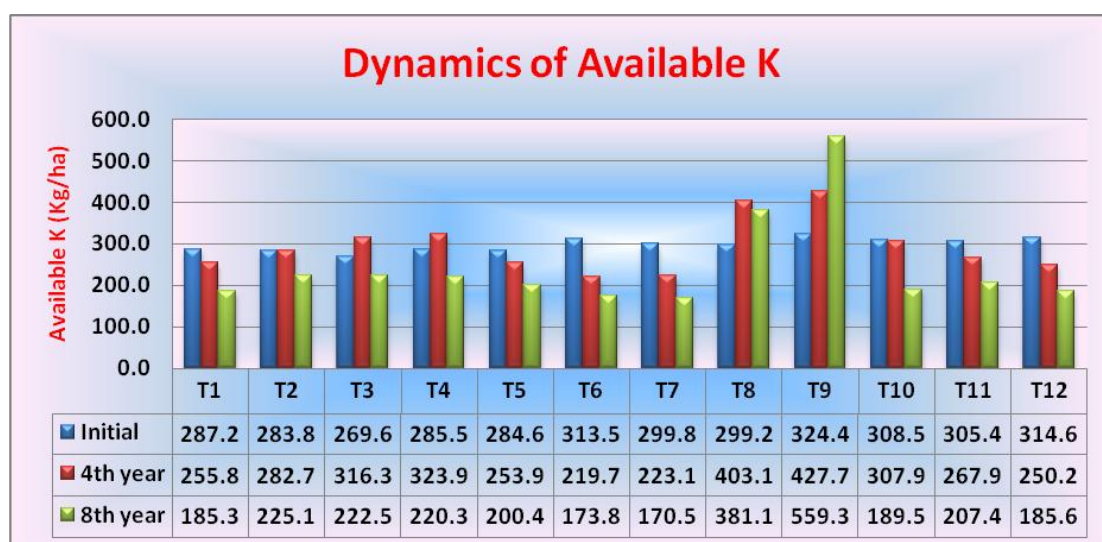


Fig. 4.3.2: Status of Available K (kg ha⁻¹) in soils of LTFE in 1st, 4th and 8th year

Table-4.3.2: Status of Available-K (kg ha⁻¹) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Available-K (kg ha ⁻¹)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	287.19	255.84	185.30	242.78
T ₂	283.84	282.72	225.05	263.87
T ₃	269.56	316.31	222.53	269.46
T ₄	285.51	323.86	220.29	276.56
T ₅	284.62	253.88	200.42	246.31
T ₆	313.51	219.73	173.83	235.69
T ₇	299.79	223.09	170.47	231.12
T ₈	299.21	403.08	381.12	361.14
T ₉	324.36	427.71	559.29	437.12
T ₁₀	308.47	307.91	189.50	268.63
T ₁₁	305.39	267.88	207.42	260.23
T ₁₂	314.63	250.24	185.58	250.15
S.Em.+	16.3182	13.6813	14.9177	33.43
CD @ 5%	NS	39.3931	42.9531	98.06
CV %	10.9500	9.3000	12.2600	10.78
Mean	298.0056	294.3540	243.3996	278.5864
Y x T	S.Em.+	15.0111	CD @ 5%	42.1818

4.3.3: Water soluble K:

Water soluble K status of LTFE soil at initial stage was somewhat different in all plots. After 4th, 8th and when pooled over years it also affected significantly by treatments (Table 4.3.3 & Fig. 4.3.3). In both years (4th & 8th year) and pooled it was found significantly highest in plot which received 25 t FYM ha⁻¹ (T₉), which was at par with T₈ (10 t FYM ha⁻¹). It have been due to transformation of reserve K to water soluble K a dissolving effect of organic acid which was extract of FYM. The Y x T interaction also showed significant differences. Overall content of Water soluble K remains stable after 4 year, but it was marginally decreased after a period of 8 years. This result ascribed to that 72 per cent of WSK was decreased due to intensive cropping of groundnut- wheat sequence in medium black calcareous soils (Patel *et al.*, 1986).

Table-4.3.3: Status of Water soluble-K (kg ha^{-1}) in LTFE soils at initial, after 4th and 8th year.

Treatments	Water soluble-K (kg ha^{-1})			
	Initial	After 4 th year	After 8 th year	Pooled
T₁	11.088	11.088	5.265	9.15
T₂	11.424	11.200	6.942	9.86
T₃	12.095	14.784	8.287	11.72
T₄	12.768	14.112	6.842	11.24
T₅	12.768	9.520	6.170	9.49
T₆	12.544	9.072	5.050	8.89
T₇	12.208	10.528	5.550	9.43
T₈	12.432	17.696	14.560	14.90
T₉	15.680	19.040	18.965	17.90
T₁₀	11.536	13.888	5.835	10.42
T₁₁	11.871	10.976	7.727	10.19
T₁₂	12.767	10.528	5.050	9.45
S.Em._±	0.6160	0.9219	0.6650	1.18
CD @ 5%	1.7737	2.6545	1.9148	3.45
CV %	9.9100	14.5200	16.5800	13.51
Mean	12.4320	12.7027	8.0204	11.0516
Y x T	S.Em._±	0.7465	CD @ 5%	2.0976

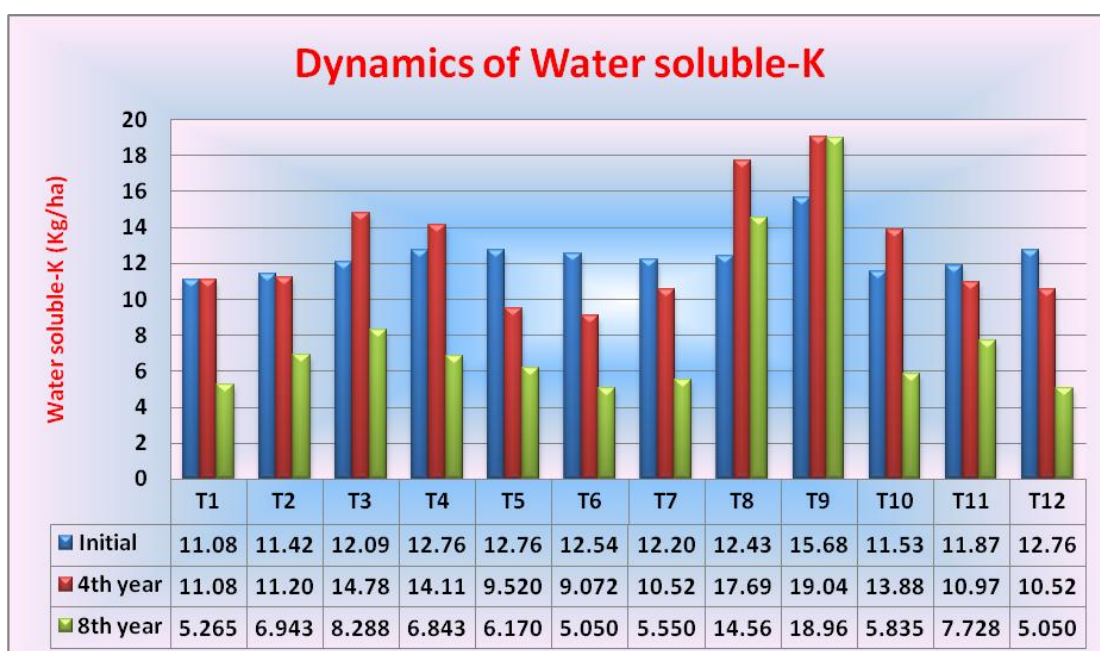


Fig. 4.3.3: Status of Water soluble K (kg ha^{-1}) in soils of LTFE in 1st, 4th and 8th year

4.3.4: Exchangeable K:

The significantly highest values of Exchangeable K were recorded due to application of 25 t FYM ha⁻¹ (T₉) after 4th, 8th year of experiment and when pooled over years, i. e. 408.67, 533.23 & 439.22, respectively (Table 4.3.4 & Fig. 4.34). All plots of LTFE experiment exhibited overall same Exchangeable K value at initial stage of experiment. The Y x T interaction was significant. The overall Exchangeable K status marginally decreased after 8 years. This result was in agreement with finding of Patel *et al.*, (1986) who stated that 78 per cent of Exchangeable K was decreased due to intensive cropping of groundnut-wheat sequence in medium black calcareous soils.

Table- 4.3.4: Status of Exchangeable-K (kg ha⁻¹) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Exchangeable-K (kg ha ⁻¹)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	276.1046	244.7542	180.0383	233.63
T ₂	272.4121	271.5152	218.1087	254.01
T ₃	258.2454	301.5213	214.2432	258.00
T ₄	273.7543	309.7487	213.4485	265.65
T ₅	271.8488	244.3632	191.7310	235.98
T ₆	300.9621	210.6596	164.5208	225.38
T ₇	288.2529	212.5642	164.9172	221.91
T ₈	286.7791	385.3819	366.5568	346.24
T ₉	375.7517	408.6731	533.2355	439.22
T ₁₀	294.0692	294.0198	183.6650	257.25
T ₁₁	291.1633	256.9010	199.6905	249.25
T ₁₂	302.3050	239.7138	179.9220	240.65
S.Em.₊	25.8129	13.2417	13.2593	28.30
CD @ 5%	NS	38.1273	38.1780	83.01
CV %	17.7400	9.4000	11.3200	13.70
Mean	290.9707	281.6513	234.1731	268.9317
Y x T	S.Em.₊	18.4161	CD @ 5%	51.75

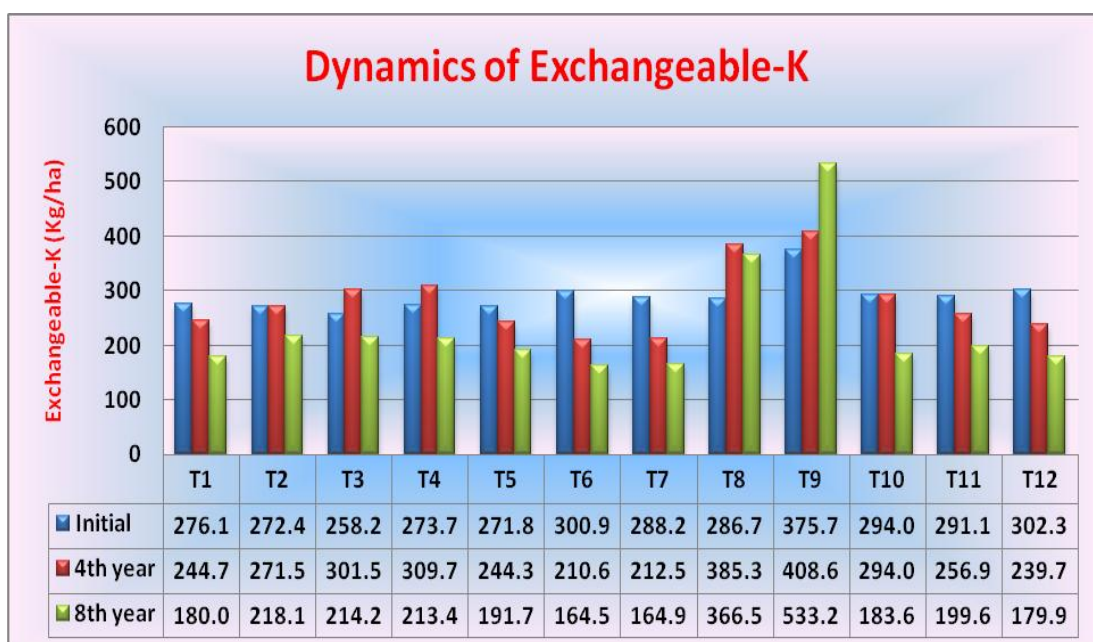


Fig. 4.3.4: Status of Exchangeable K (kg ha⁻¹) in soils of LTFE in 1st, 4th and 8th year

4.3.5: HNO₃ soluble K:

The data presented in table 4.3.5 (Fig.4.3.5) showed that nitric acid soluble K status was significantly different in various plots at initial, after 4th year, 8th year & when pooled over years. Here also, application of 25 t FYM ha⁻¹ increased significantly the content of HNO₃ soluble K in soil. The Y x T interaction was also significant. There were overall decrease after 4th year and then after 8th year in the status of HNO₃ soluble K in soils. Bansal and Jain (1988) also observed similar trend that a maximum decrease in all forms of K from their initial content because of cropping with sufficient N and P without K. The depletion of K from non-exchangeable form is enhanced with higher yields and crops removals under long-term experiments and continuous cropping system.

Table-4.3.5: Status of HNO₃ Soluble-K (kg ha⁻¹) in LTFE soils at initial, after 4th year and 8th year.

Treatments	HNO ₃ Soluble-K (kg ha ⁻¹)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	516.6	414.4	357.0	429.33
T ₂	523.6	509.6	431.2	488.13
T ₃	473.2	536.2	418.6	476.00
T ₄	525.0	583.8	429.8	512.87
T ₅	558.6	449.4	406.0	471.33
T ₆	579.6	411.6	357.0	449.40
T ₇	627.2	383.6	404.6	471.80
T ₈	553.0	695.8	704.2	651.00
T ₉	687.0	754.6	974.1	805.23
T ₁₀	579.6	520.3	380.8	493.57
T ₁₁	544.6	476.0	410.2	476.93
T ₁₂	554.4	449.4	415.6	473.13
S.Em. _±	29.5683	31.0716	24.8441	50.47
CD @ 5%	85.1372	89.4657	71.5346	148.02
CV %	10.5600	12.0600	10.48	11.08
Mean	560.2000	515.3917	474.0917	516.5611
Y x T	S.Em. _±	28.6117	CD @ 5%	80.4195

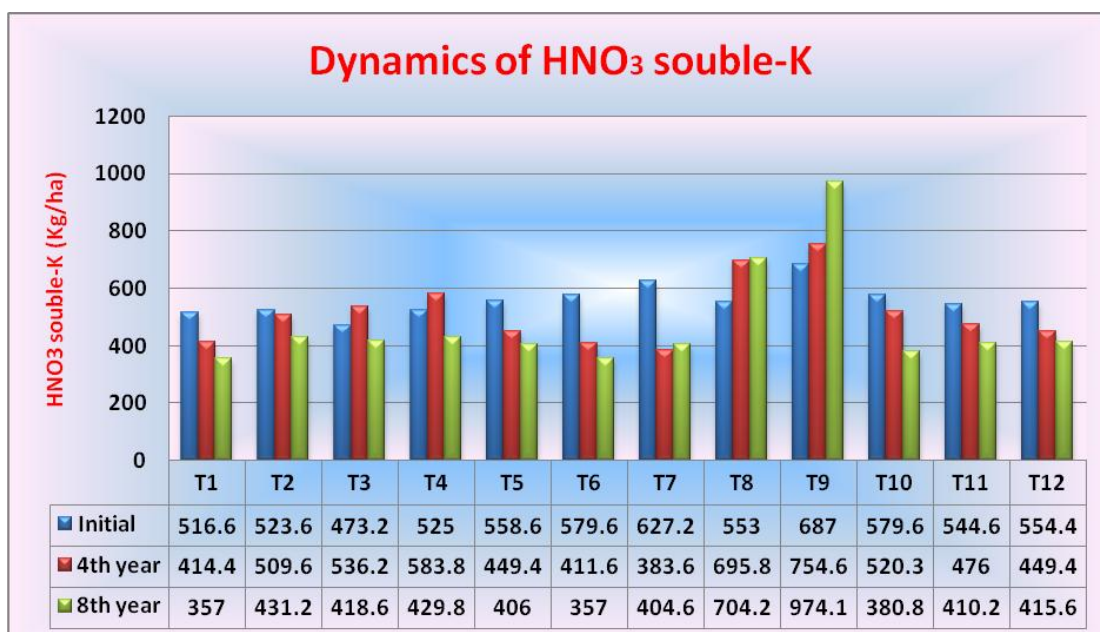


Fig. 4.3.5: Status of HNO₃ soluble K (kg ha⁻¹) in soils of LTFE in 1st, 4th and 8th year

4.3.6: Total K:

The Status of Total K of LTFE soils was also affected significantly due to application of FYM @ 25 t ha⁻¹ (T₉) after 4th year and 8th year of experiment (Table 4.3.6 & Fig. 4.3.6) and it was significantly higher over all other treatments. Whereas at initial year & when pooled over years it was found non-significant. The Y × T interaction was significant. There was also overall decrease in soil status of Total K after a span of 8 years. These results have been in agreement with finding of Bansal and Jain (1988) as explained earlier.

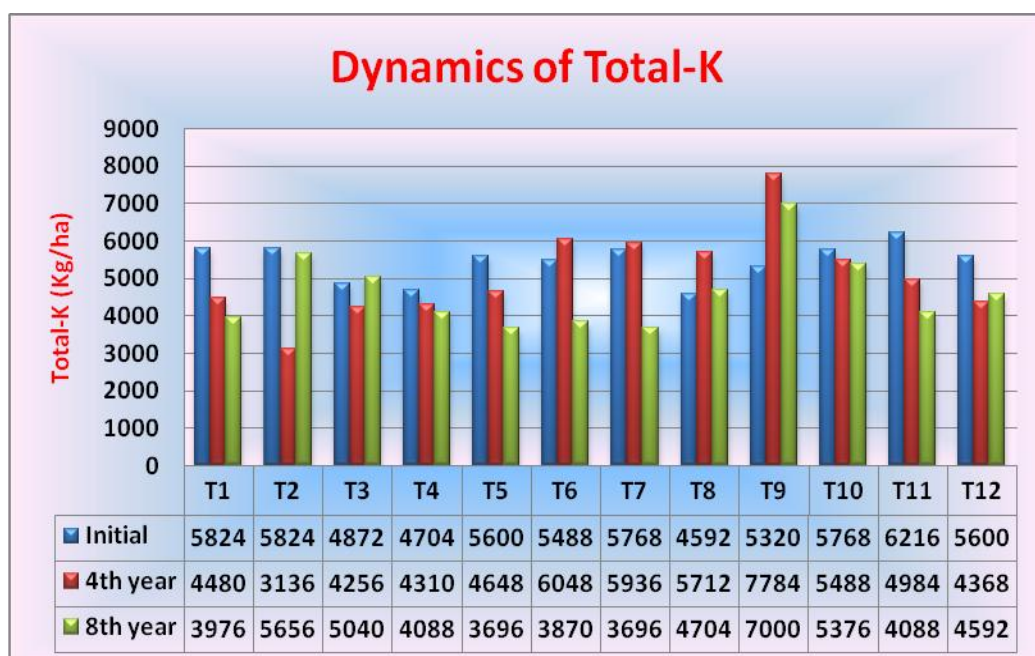


Fig. 4.3.6: Status of Total K (kg ha⁻¹) in soils of LTFE in 1st, 4th and 8th year

Table-4.3.6: Status of Total-K (kg ha⁻¹) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Total-K (kg ha ⁻¹)			
	Initial	After 4 th year	After 8 th year	Pooled
T₁	5824.00	4480.00	3976.00	4760.00
T₂	5824.00	3136.00	5656.00	4872.00
T₃	4872.00	4256.00	5040.00	4722.67
T₄	4704.00	4309.50	4088.00	4367.17
T₅	5600.00	4648.00	3696.00	4648.00
T₆	5488.00	6048.00	3870.00	5135.33
T₇	5768.00	5936.00	3696.00	5133.33
T₈	4592.00	5712.00	4704.00	5002.67
T₉	5320.00	7784.00	7000.00	6701.33
T₁₀	5768.00	5488.00	5376.00	5544.00
T₁₁	6216.00	4984.00	4088.00	5096.00
T₁₂	5600.00	4368.00	4592.00	4853.33
S.Em.+	538.6057	441.0348	455.6448	515.32
CD @ 5%	NS	1269.8886	1311.9558	NS
CV %	19.7100	17.3100	19.6000	18.95
Mean	5464.6667	5095.7917	4648.5000	5069.6527
Y x T	S.Em.+	480.3540	CD @ 5%	1349.8152

4.3.7: Reserve K:

This fraction of potash showed significant differences at initial (1st year), after 4th & 8th year and when pooled over years (Table 4.3.7 & Fig. 4.3.7). After 4th, 8th year and when pooled over years, the significantly highest values were recorded in plot which comprised with application of 25 t FYM ha⁻¹ (T₉) i. e. 326.88, 466.90 and 385.48 Kg ha⁻¹, respectively. The Y x T interaction was found significant and there was overall decrease after 4 year as compared to initial status and slight increase after 8 year as compared to after 4 year. Patel and Golakiya (1996) reviewed that soils of Gujarat are drifting gradually towards negative K balance. Crops are responding to K fertilizer on irrigated and intensively cultivated area.

Table-4.3.7: Status of Reserve-K (kg ha^{-1}) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Reserve-K (kg ha^{-1})			
	Initial	After 4 th year	After 8 th year	Pooled
T₁	229.4074	158.5578	171.6967	186.55
T₂	239.7639	226.8848	206.1488	224.27
T₃	203.6426	219.8947	196.0693	206.54
T₄	239.4857	259.9393	209.5090	236.31
T₅	273.9832	195.5168	205.5840	225.03
T₆	266.0939	191.8684	183.1742	213.71
T₇	327.4111	160.5078	234.1328	240.68
T₈	253.7889	292.7221	323.0832	289.86
T₉	362.6352	326.8869	466.9070	385.48
T₁₀	271.1328	212.3922	191.3000	224.94
T₁₁	239.2127	208.1230	202.7820	216.71
T₁₂	239.7750	199.1582	230.0180	222.98
S.Em.+	22.6217	20.0139	20.8589	22.82
CD @ 5%	65.1355	57.6268	60.0598	66.94
CV %	17.2600	18.1100	17.7500	17.70
Mean	262.1944	221.0377	235.0337	239.4219
Y x T	S.Em.+	21.1927	CD @ 5%	59.5525

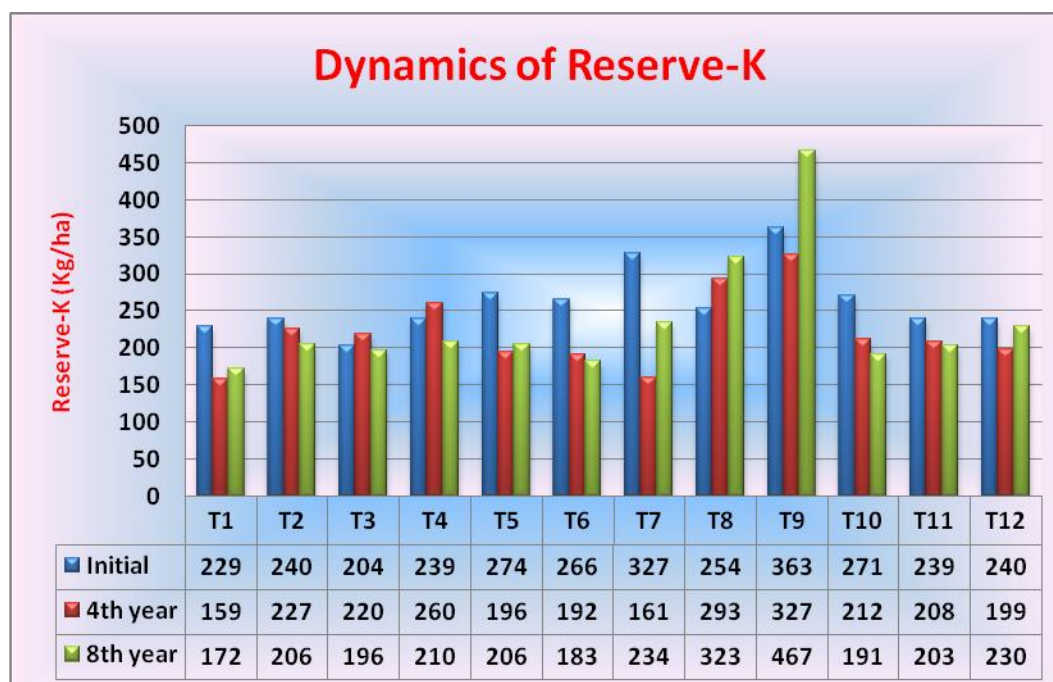


Fig. 4.3.7: Status of Reserve K (kg ha^{-1}) in soils of LTFE in 1st, 4th and 8th year

4.3.8: Depletion per cent of different forms of potassium

It is interesting to see that the data presented in table 4.3.8 and picture shown in Fig. 4.3.8, because all the forms of potassium showed positive percent depletion in all the treatments except treatments which received FYM *i. e.* T8 & T9, which showed negative percent depletion. These results are also alarming us that the only inorganic fertilization can't sustain K fertility status, but addition of organic manures is necessary for sustaining K fertility in the long run. Patel *et al.*, (1986) found that 72 per cent of WSK and 78 per cent of Exchangeable K was decreased due to intensive cropping of groundnut- wheat sequence in medium black calcareous soils. Patel *et al.*, (1994b) conducted field experiment involving intensive cropping to study the available potassium status in soil. They observed that the potassium showed negative balance in the soil. It was decreased to initial status in all treatments.

Table-4.3.8: Per cent depletion of different forms of potassium after 8 groundnut-wheat sequence in LTFE soils.

Treat.	Total-K	W. S. K	Ex. K	HNO3-K	Res. K	Av.- K2O
T ₁	31.731	52.516	34.793	30.894	25.156	35.478
T ₂	2.885	39.229	19.934	17.647	14.020	20.711
T ₃	-3.448	31.483	17.039	11.538	3.719	17.446
T ₄	13.095	46.411	22.029	18.133	12.517	22.844
T ₅	34.000	51.676	29.471	27.318	24.965	29.584
T ₆	29.483	59.742	45.335	38.406	31.162	44.554
T ₇	35.922	54.540	42.787	35.491	28.490	43.138
T ₈	-2.439	-17.117	-27.819	-27.342	-27.304	-27.374
T ₉	-31.579	-20.950	-41.912	-49.374	-28.754	-72.427
T ₁₀	6.796	49.421	37.544	34.300	29.444	38.567
T ₁₁	34.234	34.904	31.416	24.679	15.229	32.080
T ₁₂	18.000	60.446	40.483	25.036	4.069	41.015



Fig.4.3.8: Depletion (%) of different forms of potassium after 8 groundnut-wheat sequence in LTFE soils.

4.3.9: Percent distribution in different fractions of potassium.

The distribution of different fraction of potassium were in order of $\text{HNO}_3\text{-K} > \text{Av.-K} \geq \text{Ex.-K} > \text{WS.-K}$. (Fig. 4.3.9a&b). In all treatment combinations & stage of experiment (Initial, after 4th year & after 8th year) various fraction of potassium were found in the following proportion, $\text{HNO}_3\text{-K}$ round about 40 %, Av.-K & Ex.-K around 22 %, Reserve-K around 17-20 % and WS-K around 1 %. There was no change in picture of percent distribution of various fraction of K among treatments and with advancement in period of experiment.

4.4: Forms of sulphur:

4.4.1: Water soluble-S:

Water soluble form of sulphur in initial soil samples ranged from 9.37 to 13.56 ppm and it was non-significant. Soil samples after 4 years of experiment, showed significant differences in status of W.S.-S due to treatments and the significantly highest value recorded in treatment T_3 and it was at par with T_{11} , T_9 , T_7 , T_5 & T_2 , whereas after 8 years the significantly highest value was found in treatment which received 100 % NPK of recommended dose of G'nut-wheat sequence (P as SSP) *i. e.* T_{11} , it might be due to SSP content 13 % sulphur (Table 4.4.1 & Fig. 4.4.1) and which was also at par with T_4 (100% NPK + Zn SO_4 @ 50 Kg ha^{-1} once in three year to G'nut only *i. e.* 1999, 02, 05, 08....). When pooled over years, it was found non-significant, but $Y \times T$ interaction was significant. There was overall increased in W.S.-S status of LTFE soils after 4 years, but afterward at 8th year it was decreased as compared to initial status. These results have been ascribed to finding of Alok Tiwari *et al.*, (2002) that the omission of S in the fertilizer schedule

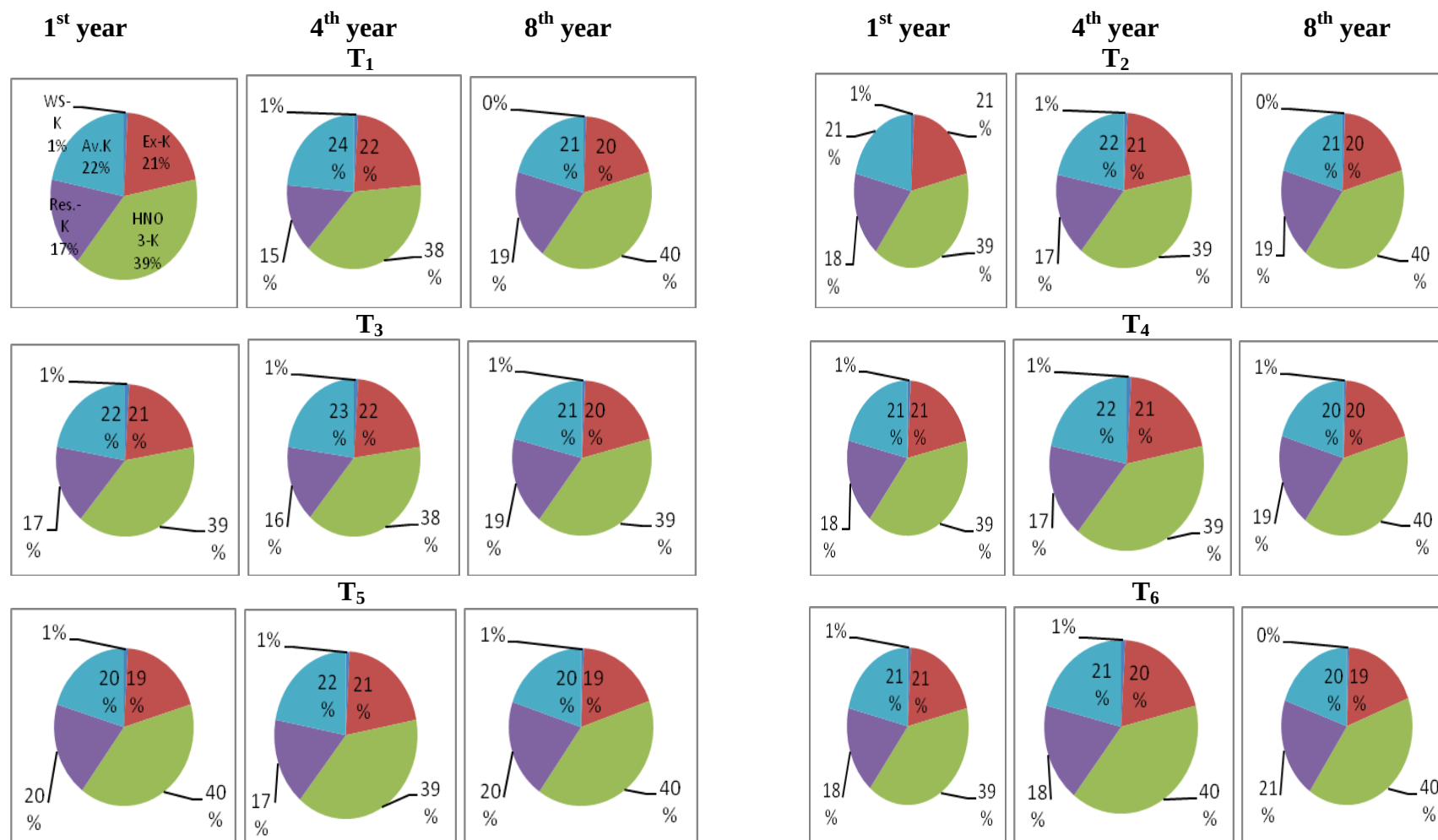


Fig. 4.3.9a: Percent distribution in different fractions of potassium in 1st, 4th and 8th years in the LTFE soils.

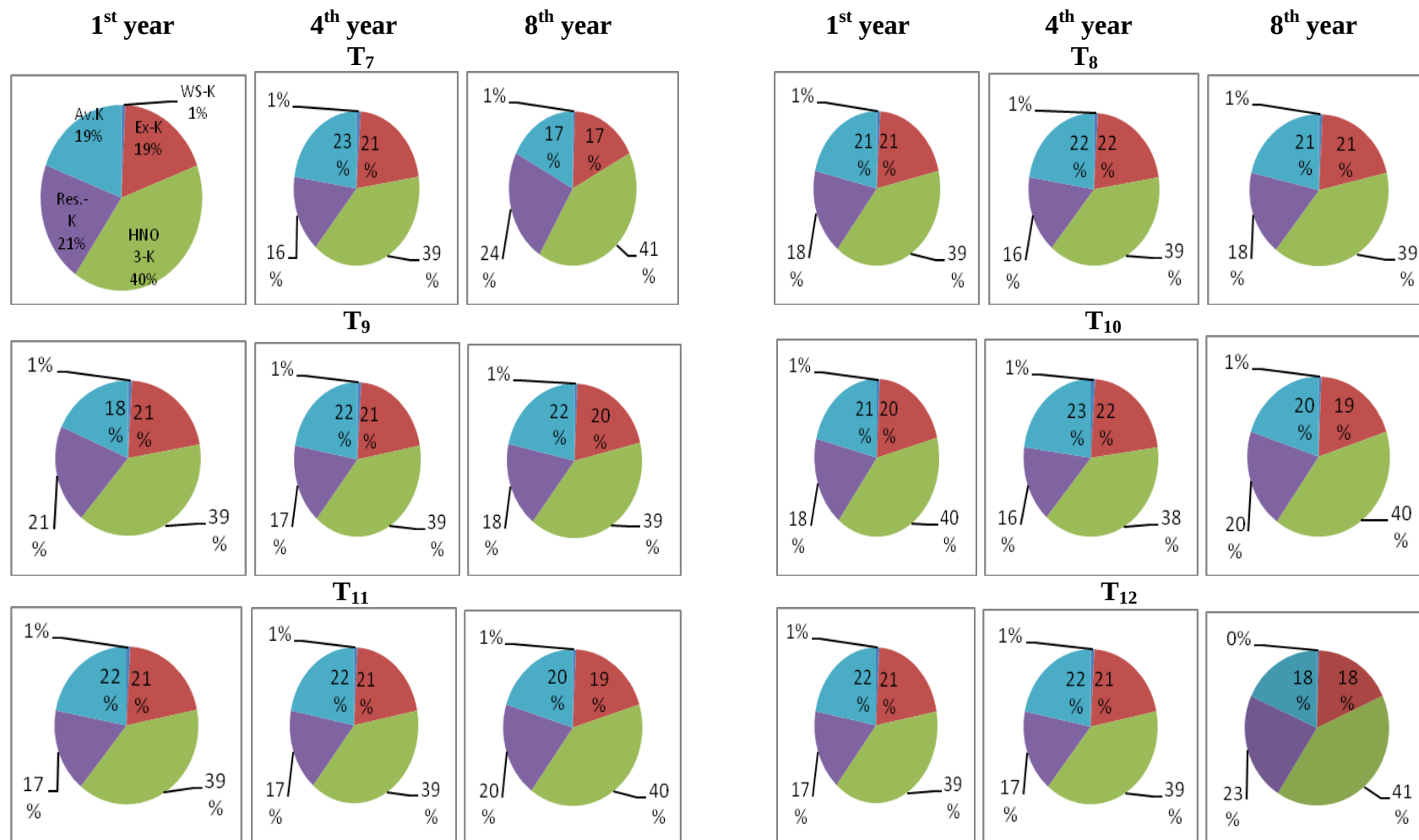


Fig. 4.3.9b: Percent distribution in different fractions of potassium in 1st, 4th and 8th years in the LTFE soils.

has caused a continuous depletion in the available S status of soil.

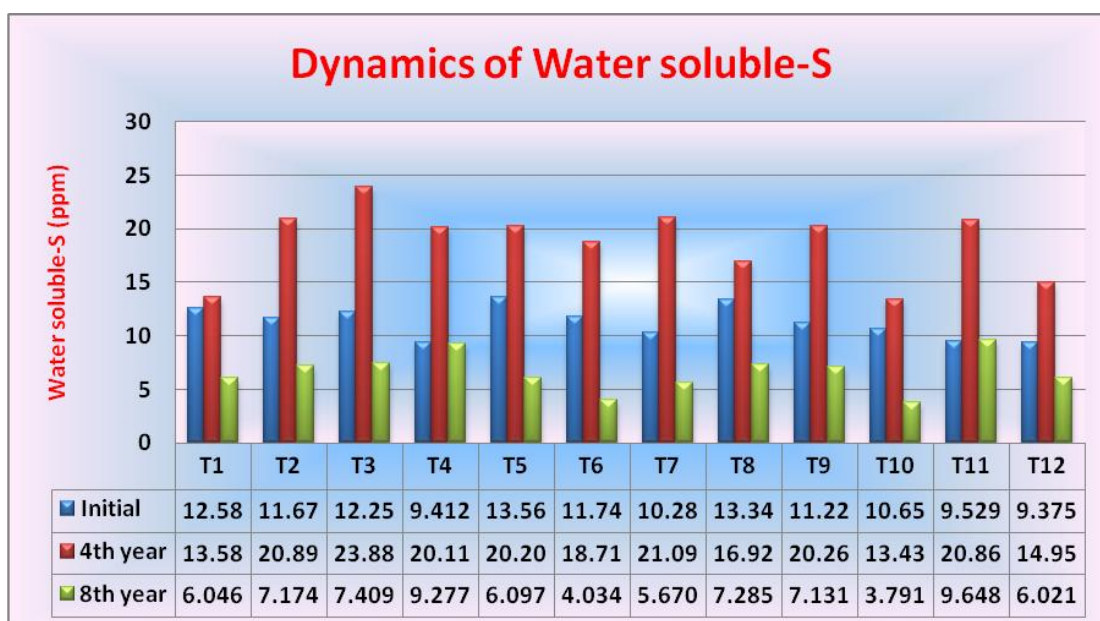


Fig. 4.4.1: Status of Water soluble-S (ppm) in soils of LTFE in 1st, 4th and 8th year

Table-4.4.1: Status of Water soluble-S (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Water soluble-S (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	12.5883	13.5833	6.0458	10.74
T ₂	11.6745	20.8980	7.1740	13.25
T ₃	12.2513	23.8875	7.4085	14.52
T ₄	12.5497	20.1175	9.2770	12.94
T ₅	13.5643	20.2083	6.0965	13.29
T ₆	11.7435	18.7150	4.0340	11.50
T ₇	10.2838	21.0993	5.6703	12.35
T ₈	13.3490	16.9248	7.2845	12.52
T ₉	11.2265	20.2618	7.1305	12.87
T ₁₀	10.6535	13.4310	3.7908	9.29
T ₁₁	9.5293	20.8643	9.6480	13.35
T ₁₂	9.3748	14.9530	6.0210	10.12
S.E.m.+	1.4829	1.2940	0.4798	1.24
CD @ 5%	NS	3.7259	1.3815	NS
CV %	25.6900	13.8100	14.4700	19.13
Mean	11.3042	18.7453	6.6317	12.2270
Y x T	S.E.m.+	1.1695	CD @ 5%	3.2865

4.4.2: Organic-S:

The data of table 4.4.2 (Fig.4.4.2) revealed that Organic S content of initial soil showed significant variation, the highest value recorded in

T₁₂ *i. e.* control. After 4 year the significantly highest value was found in T₈ (10 t FYM ha⁻¹ + 50 % NPK), it was but natural that addition of organic material increases their bound nutrient in the particular soil and it was at par with T₄ (100% NPK + ZnSO₄, once in three years), whereas significantly the highest value of organic S was recorded in control (T₁₂) after 8 year and it was at par with T₁₁ & T₆. Whenever pooled over years, it was found non-significant, but interaction (Y x T) was significant. Overall content of organic S in LTFE soil was increased. Similar result was reported by Singh *et al.*, (2001) that the buildup in S status was mostly through Organic-S fraction.

Table-4.4.2: Status of Organic-S (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Organic-S (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	54.8500	79.3375	100.3625	78.18
T ₂	37.6500	89.7750	94.8625	74.10
T ₃	64.5750	88.5375	109.0750	87.40
T ₄	67.8125	125.3875	82.1375	91.78
T ₅	79.6500	91.8000	115.9750	95.81
T ₆	37.1375	76.0500	124.8500	79.35
T ₇	48.3875	90.7500	77.0625	72.07
T ₈	57.6875	128.4625	85.6750	90.61
T ₉	47.5250	94.1875	110.3250	84.01
T ₁₀	47.5250	94.2375	85.6750	75.81
T ₁₁	72.0625	99.2625	123.5125	98.28
T ₁₂	88.0000	92.9375	134.7025	105.21
S.Em.±	2.4518	5.0420	4.6607	9.46
CD @ 5%	7.0596	14.5176	13.4197	NS
CV %	8.3700	10.5200	8.9900	9.78
Mean	58.5719	95.8938	103.6846	86.05006
Y x T	S.Em.±	4.2093	CD @ 5%	11.8284

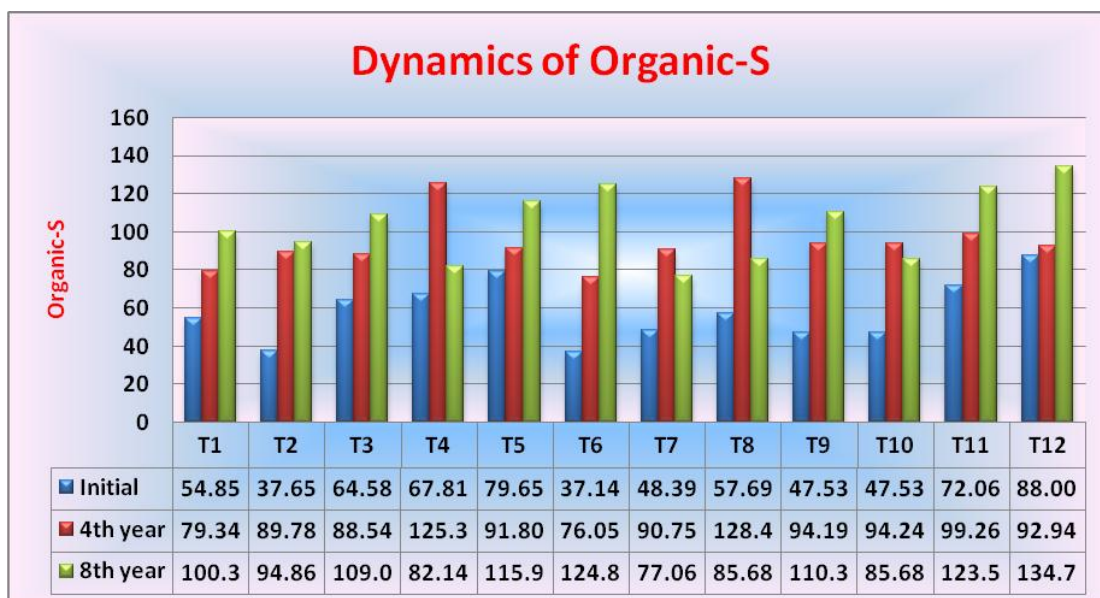


Fig. 4.4.2: Status of Organic-S (ppm) in soils of LTFE in 1st, 4th and 8th year

4.4.3: Sulphate-S:

Initial status of LTFE soils, showed significant variation in Sulphate S and the significantly highest value was recorded in T₁₀. After 4 years of experiment significantly the highest value was found in plot which received 100 % NPK to G'nut-wheat sequence and P source was SSP which contained 13 % S (T₁₁), Whereas after 8 years of experiment, it was found that Sulphate-S content of soil significantly higher in T₉ (FYM @ 25 t ha⁻¹ to G'nut only). This result is in agreement with finding of Trocme (1972) and Korter *et al.*, (1963) who observed a linear relationship between organic carbon levels and Sulphate sulphur contents of mineral and peat soils. The Y x T interaction was also found significant, but it is non-significant when pooled over years. Overall status of this fraction increased after a span of 8 years (Table 4.4.3 & Fig. 4.4.3). Similar trend was also observed by Setia and Sharma (2005) that the amount of all the form of S increased with the application of 40 Kg P₂O₅ ha⁻¹ but trend was reversed with the application of 80 Kg P₂O₅ ha⁻¹, irrespective of N levels.

Table-4.4.3: Status of Sulphate-S (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Sulphate-S (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	8.9810	11.6873	10.7528	10.47
T ₂	7.6745	6.6810	11.1935	8.52
T ₃	8.2780	6.8968	12.2310	9.14
T ₄	6.8250	7.2873	15.0438	9.72
T ₅	8.5343	8.6465	11.3810	9.52
T ₆	6.3718	9.5495	12.0060	9.31
T ₇	5.5750	8.7030	11.3185	8.53
T ₈	5.5215	6.6718	16.4148	9.54
T ₉	5.9905	7.4218	19.5780	11.00
T ₁₀	9.1280	8.9028	11.8968	9.98
T ₁₁	8.9248	12.0093	15.6185	12.18
T ₁₂	6.2873	11.2310	11.2498	9.59
S.Em.±	0.4242	0.5770	1.2439	1.31
CD @ 5%	1.2214	1.6614	3.5816	NS
CV %	11.5600	13.1000	18.8100	16.93
Mean	7.3410	8.8073	13.2237	9.7906
Y x T	S.Em.±	0.8287	CD @ 5%	2.3286

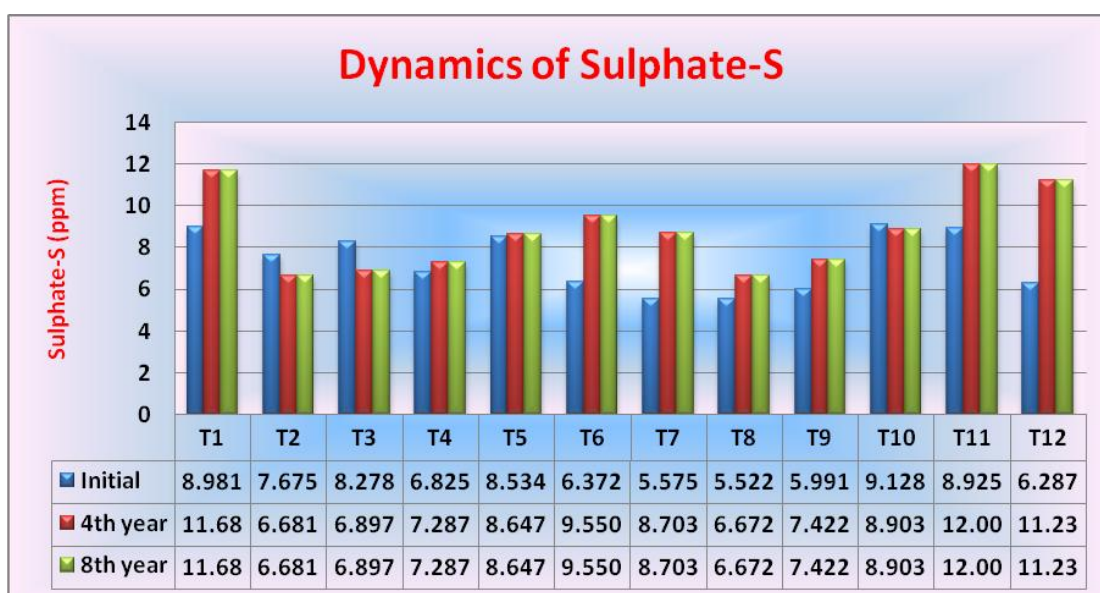


Fig. 4.4.3: Status of Sulphate-S (ppm) in soils of LTFE in 1st, 4th and 8th year

4.4.4: Non-Sulphate-S:

Data of table 4.4.4 (Fig. 4.4.4) revealed that Non-sulphate-S status at initial, after 4 years and after 8 years in soil were significantly varied.

There was the highest value noted at initial stage in plot of T₇. After 4 & 8 year of experiment, it was significantly highest in treatment where 100 % NPK + ZnSO₄ @ 50 Kg ha⁻¹ once in three years was applied (T₄). When pooled over years, effect of different treatments on Non-sulphate-S content in LTFE soils was found non-significant. The Y x T interaction showed significant variation. Overall status of this fraction increased after a span of 4 year. Similar trend was also observed by Setia and Sharma (2005) that the amount of all the forms of S increased with the application of 40 kg P₂O₅ ha⁻¹

Table-4.4.4: Status of Non-Sulphate-S (ppm) in LTFE soils at initial, after 4th year and 8th year.

Treatments	Non-Sulphate-S (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T₁	32.3190	175.9253	152.8348	120.36
T₂	74.8755	145.0440	169.3790	129.77
T₃	76.8470	36.7658	188.8940	100.84
T₄	151.7625	229.0253	213.7188	198.17
T₅	118.8158	208.6035	61.2440	129.55
T₆	106.0908	195.4505	88.1440	129.90
T₇	176.0375	123.5970	122.2190	140.62
T₈	148.7410	124.6658	147.4103	140.27
T₉	69.4845	157.1408	128.2470	118.29
T₁₀	120.1470	185.9098	142.8783	149.65
T₁₁	63.1128	199.3283	116.8690	126.44
T₁₂	116.5128	66.1815	31.3478	71.35
S.Em.+	8.3098	26.3413	15.5677	29.39
CD @ 5%	23.9267	75.8455	44.8247	NS
CV %	15.8900	34.2200	23.9000	28.25
Mean	104.5622	153.9698	130.2655	129.5991
Y x T	S.Em.+	18.3054	CD @ 5%	51.4391

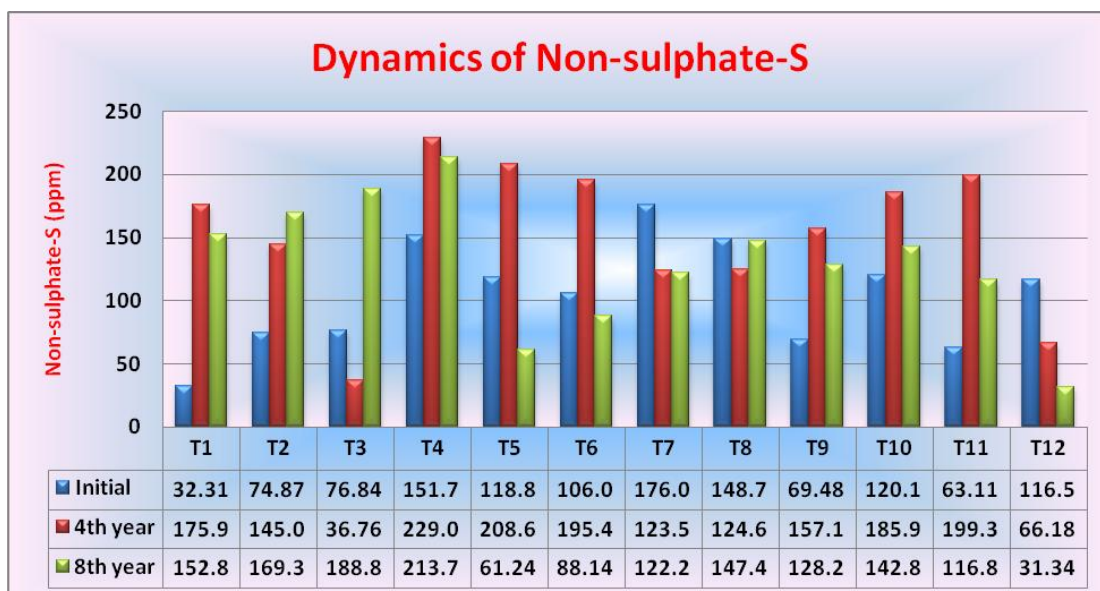


Fig. 4.4.4: Status of Non-sulphate-S (ppm) in soils of LTFE in 1st, 4th and 8th year

4.4.5: Heat soluble-S (available):

It is seen from table 4.4.5 (Fig. 4.4.5) that initial status of H.S.-S differed significantly. The highest value 17.75 and 40.85 ppm, respectively, were recorded due to application of 100 % NPK where P source was SSP which contained 13 % S (T₁₁) after 4th & 8th year. Same result also found when pooled over years. The Y × T interaction also found significant. Overall there was marginal decrease in H.S.-S content after span of 4 years and it was increased after 8 years as compared to initial status. Alok Tiwari *et al.*, (2002) reported the similar result that the omission of S in the fertilizer caused a continuous depletion in the available S status of soil.

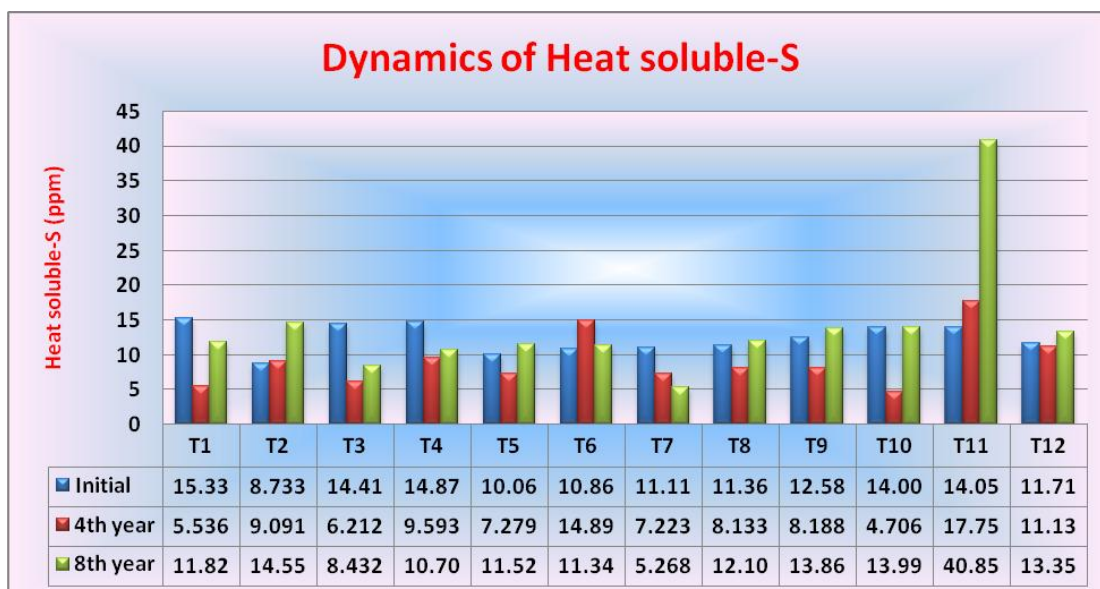


Fig. 4.4.5: Status of Heat soluble-S (ppm) in soils of LTFE in 1st, 4th and 8th year

Table-4.4.5: Status of Heat soluble-S (ppm) in LTFE soils at initial, after 4th year and 8th

Treatments	Heat soluble-S (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	15.3363	5.5358	11.8220	10.90
T ₂	8.7325	9.0910	14.5570	10.79
T ₃	14.4168	6.2120	8.4318	9.69
T ₄	14.8745	9.5928	10.7048	11.72
T ₅	10.0648	7.2788	11.5210	9.62
T ₆	10.8653	14.8953	11.3440	12.37
T ₇	11.1125	7.2225	5.2675	7.87
T ₈	11.3600	8.1325	12.1065	10.53
T ₉	12.5850	8.1880	13.8640	11.55
T ₁₀	14.0043	4.7063	13.9925	10.90
T ₁₁	14.0580	17.7540	40.8530	24.22
T ₁₂	11.7188	11.1330	13.3523	12.07
S.Em.+	0.9978	0.8489	1.0278	2.81
CD @ 5%	2.8730	2.4443	2.9594	8.24
CV %	16.0600	18.5600	14.7000	16.22
Mean	12.4274	9.1451	13.9847	11.8524
Y x T	S.Em.+	0.9614	CD @ 5%	2.7015

4.4.6: Total-S:

Initial status of this soil significantly differed and the highest value (230 ppm) was recorded in T₇. After 4 year sequence of G'nut-wheat, Total-S content also recorded highest in T₄ (100 % NPK + ZnSO₄) and same results showed after completion of 8 year of experiment, but showed non-significant variation when pooled over years, however numerically it was also high in T₄. The Y x T interaction was significant and there was overall increase in Total-S status of soil after 4 & 8 years as compared to initial status. Similar trend was also observed by Setia and Sharma (2005) that the amount of all the fraction of S increased with the application of 40 kg P₂O₅ ha⁻¹.

Table-4.4.6: Status of Total-S (ppm) in LTFE soils at initial, after 4th year and 8th year

Treatments	Total-S (ppm)			
	Initial	After 4 th year	After 8 th year	Pooled
T ₁	96.1500	266.9500	263.9500	209.02
T ₂	120.2000	241.5000	275.4350	212.38
T ₃	149.7000	132.2000	310.2000	197.37
T ₄	226.4000	361.7000	310.9000	299.67
T ₅	207.0000	309.0500	188.6000	234.88
T ₆	149.6000	281.0500	225.0000	218.55
T ₇	230.0000	223.0500	210.6000	221.22
T ₈	211.9500	259.8000	249.5000	240.42
T ₉	123.0000	258.7500	258.1500	213.30
T ₁₀	176.8000	289.0500	240.4500	235.43
T ₁₁	144.1000	310.6000	256.0000	236.90
T ₁₂	210.8000	170.3500	177.3000	186.15
S.Em.+	8.6418	25.0213	14.5334	29.73
CD @ 5%	24.8827	72.0448	41.8466	NS
CV %	10.1400	19.3500	11.7600	15.47
Mean	170.4750	258.6708	247.1738	225.439861
Y x T	S.Em.+	17.4353	CD @ 5%	48.9939

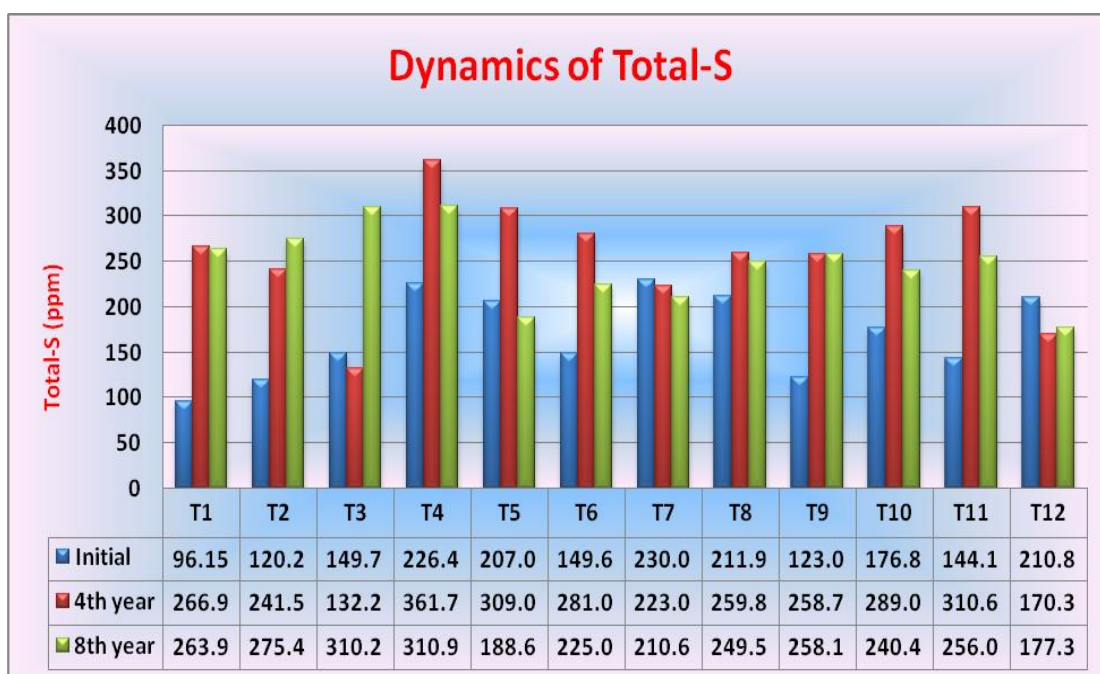


Fig. 4.4.6: Status of Total-S (ppm) in soils of LTFE in 1st, 4th and 8th year

4.4.7: Depletion per cent of different forms of sulphur

Total sulphur depletion percent were found negative in all the treatments except T₅, T₇ and T₁₂. The Water soluble fraction of sulphur showed positive trend in percent depletion except in T₁₁, which received sulphur through SSP (13 % S) and it has lowest positive (1.69) percent depletion in T₄ which was received 50 Kg ZnSO₄ ha⁻¹ once in three years. Depletion percent of Organic S fraction found negative in all treatments and similar trend was also noted in case of Sulphate-S & Non-Sulphate-S, except in treatment T₅, T₆, T₇, T₈ & T₁₂ Non-Sulphate-S showed positive percent depletion. Whereas mixed trend was observed in Heat soluble-S fraction, where maximum positive percent depletion was recorded in T₃ and maximum negative percent depletion was noted in T₁₁ which received P as SSP (13 % S). Alok Tiwari *et al.*, (2002) reported omission of S in the fertilizer schedule which caused a continuous depletion in the available S status of soil.

Table-4.4.7: Per cent depletion of different forms of sulphur after 8 groundnut-wheat sequence in LTFE soils.

Treat.	Total-S	W. S.-S	Org.-S	Sulph.-S	Non-Sul.-S	H. S.-S
T ₁	-174.52	51.97	-82.98	-19.73	-372.89	22.91
T ₂	-129.15	38.55	-151.96	-45.85	-126.21	-66.70
T ₃	-107.21	39.53	-68.91	-47.75	-145.81	41.51
T ₄	-37.32	1.44	-21.12	-120.42	-40.82	28.03
T ₅	8.89	55.05	-45.61	-33.36	48.45	-14.47
T ₆	-50.40	65.65	-236.18	-88.43	16.92	-4.41
T ₇	8.43	44.86	-59.26	-103.02	30.57	52.60
T ₈	-17.72	45.43	-48.52	-197.29	0.89	-6.57
T ₉	-109.88	36.49	-132.14	-226.82	-84.57	-10.16
T ₁₀	-36.00	64.42	-80.27	-30.33	-18.92	0.08
T ₁₁	-77.65	-1.25	-71.40	-75.00	-85.17	-190.60
T ₁₂	15.89	35.77	-53.07	-78.93	73.10	-13.94

4.4.8: Percent distribution in different fractions of sulphur.

Proportion of different sulphur fractions in LTFE soils are depicted with varying picture (Fig. 4.4.8a & b) *i. e.* higher proportion were recorded as Non-Sulphate & Organic fraction of S around 20-60 % followed by Heat Soluble-S around 10 % in proportion. Water soluble and Sulphate-S fractions were recorded about 3-10 % in proportion. Proportion of Non-Sulphate-S fraction increased in T₁, T₂, T₃, & T₄ while it was decreased in T₅, T₆, T₇, T₈, T₁₀ & T₁₂ after a span of 8year. Whereas, proportion of Organic-S fraction increased in T₂, T₅, T₆, T₇, T₈, T₉, T₁₀ & T₁₂, while it was decreased in T₁, T₃, T₄ & T₁₁, after 8 year of experiment as compared to initial status. Proportion of Water soluble-S fraction decreased in almost all the treatment combinations after an 8 year period. Heat soluble fraction of S also exhibited similar trend in all treatments, except T₁₁ & T₁₂ in which it was increased after a span of 8 year. Proportion of Sulphate-S fraction showed decreasing trend in T₁, T₂, T₃, T₄, T₉ & T₁₁, while it remained stable in T₅, T₆, T₈ & T₁₀ and it was increase in T₇ & T₁₂ after 8 year of experimentation.

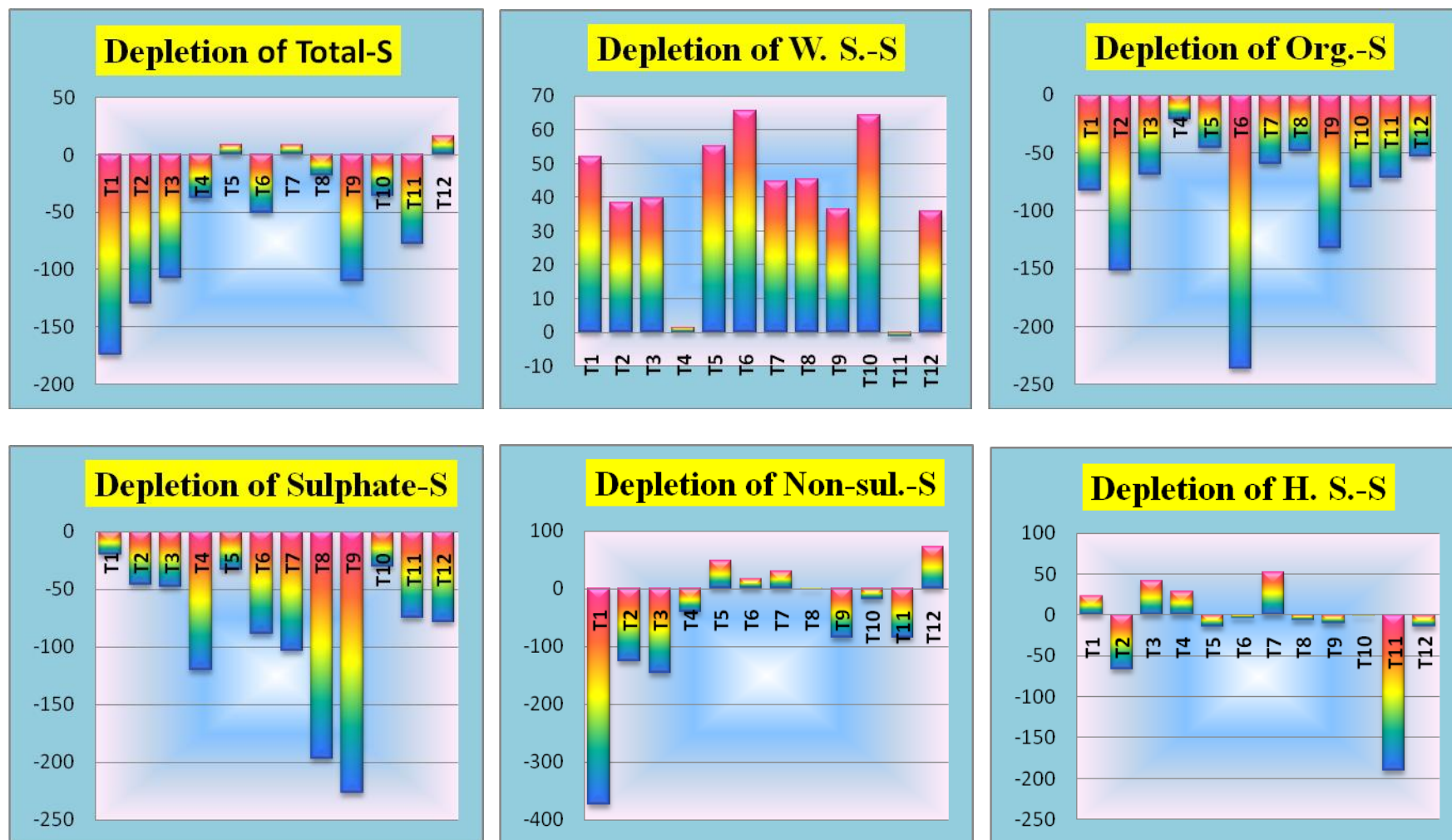


Fig.4.4.7: Depletion (%) of different forms of sulphur after 8 groundnut-wheat sequence in LTFE soils.

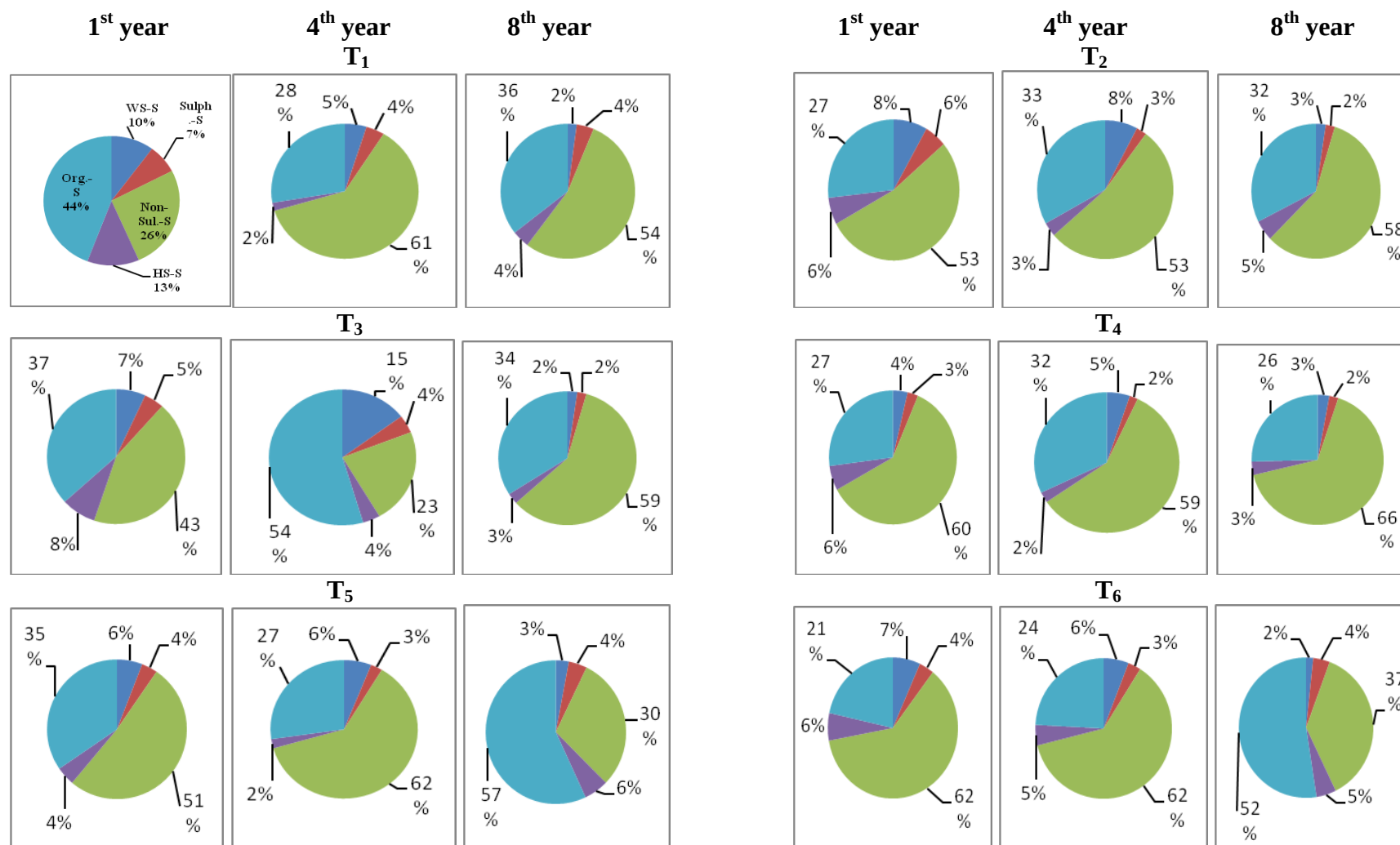


Fig. 4.4.8a: Percent distribution in different fractions of sulphur in 1st, 4th and 8th years in the LTFE soils.

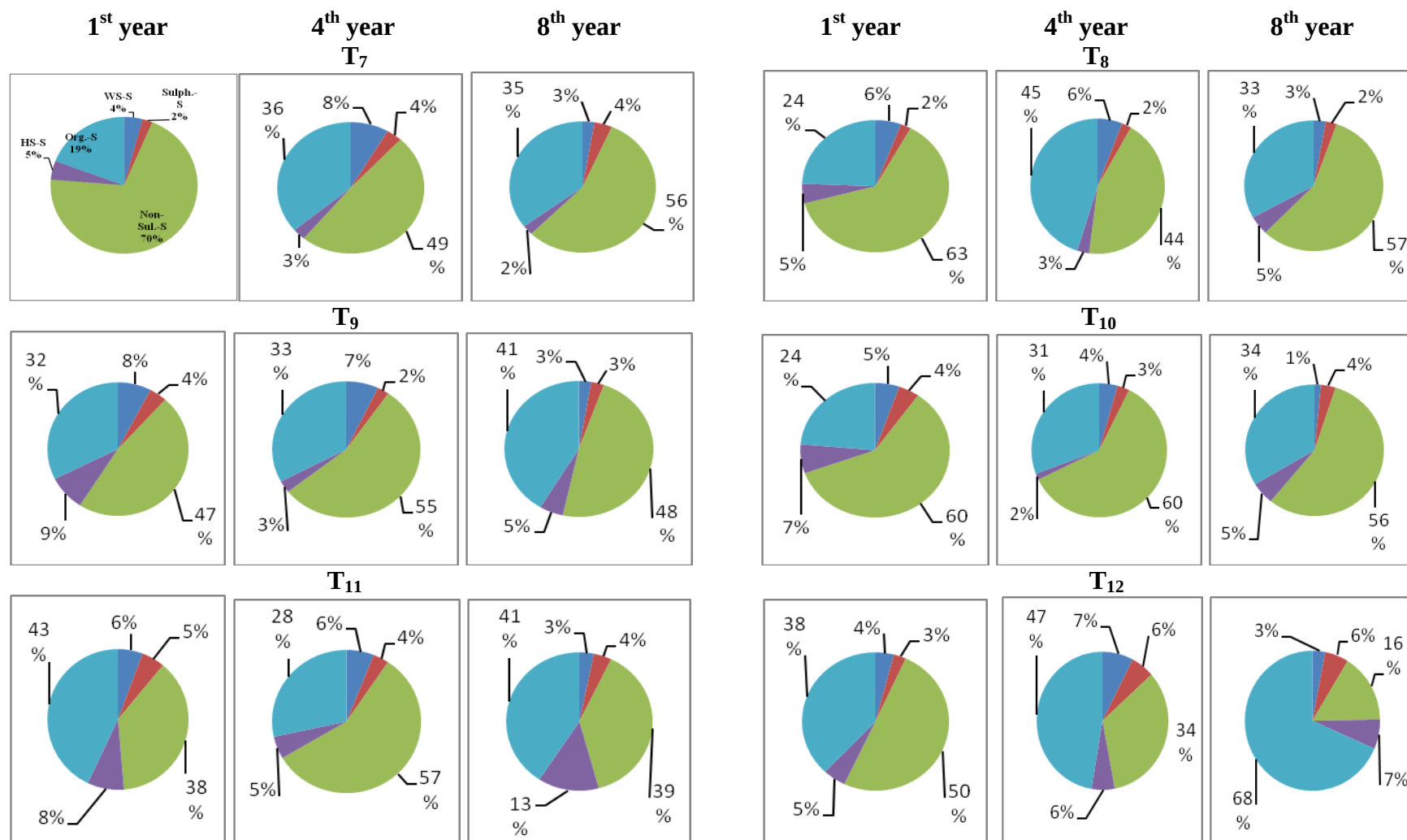


Fig. 4.4.8b: Percent distribution in different fractions of sulphur in 1st, 4th and 8th years in the LTFE soils.

4.5: LTFE-CORRELATION.

4.5.1: Correlation among different forms of N

The Available-N fraction ascribed significant positive relationship only with Nitrate-N fraction ($r = 0.2805$). It also exhibited positive relationship with Ammonical-N fraction, but it was non-significant. Whereas O. C. showed significant positive relationship with Total-N ($r = 0.9995$) and negative with Nitrate-N ($r = -0.2342$). This relationship confirms that only Nitrate & Ammonical fraction of N is importance for availability of nitrogen to the plants. Organic carbon increased total status of N in soils, but it was not importance for Available-N (Table-4.5.1)

4.5.2: Correlation with yield: Nitrogen

The Available-N exhibited significant positive relationship with groundnut pod yield ($r = 0.3275$) and haulm yield ($r = 0.3013$), while negative relationship with wheat grain yield ($r = -0.1958$). Nitrate-N showed negative relationship with wheat grain yield ($r = -0.2083$) and wheat straw yield ($r = -0.2795$). In case of relationship between Ammonical-N and Yield, it was recorded positive with ground nut pod yield ($r = 0.2034$) and negative with wheat grain yield ($r = -0.2272$) & straw yield ($r = -0.2134$). Whereas reverse trend was observed when concerned to relationship between Total-N & yield, it was observed negative with groundnut pod yield ($r = -0.5024$) & haulm yield ($r = -0.5043$) and positive with wheat grain & straw yield ($r = 0.5597$ & 0.4958). Organic carbon also ascribed similar relationship with yield as like Total-N with yield. (Table-4.5.3)

Table 4.5.1: Correlation co-efficient between different forms of N, K & S to among forms of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between		Sr. no.	Correlation between	
	N forms to among forms			K forms to among forms	
1	Organic carbon V/s Total-N	0.9995*	14	W.Soluble-K v/s total-K	0.3101*
2	Organic carbon v/s Amm.-N	-0.1616	15	W. Soluble-K v/s Reserve-K	0.6275*
3	Organic carbon v/s Nitrate-N	-0.2342*	16	Ex.-K v/s HNO3-K	0.9105*
4	Organic carbon v/s available-N	-0.1137	17	Ex.-K v/s Total-K	0.4135*
5	Total-N v/s Amm.-N	-0.1581	18	Ex.-K v/s Reserve-K	0.7397*
6	Total-N v/s Nitrate-N	-0.2332*	19	HNO3-K v/s Total-K	0.4202*
7	Total-N v/s available-N	-0.1129	20	HNO3-K v/s Reserve-K	0.9259*
8	Ammonical-N v/s Nitrate-N	0.3114*	21	Total-K v/s Reserve-K	0.3791*
9	Ammonical-N v/s Available-N	0.1047	S forms to among forms		
10	Nitrate-N v/s available-N	0.2805*	1	Water sol.-S v/s Organic-S	-0.0385
K forms to among forms			2	Water sol.-S v/s Sulphate-S	-0.4122*
1	Available K ₂ O v/s Available-K	1.00*	3	Water sol.-S v/s Total-S	0.1432
2	Available K ₂ O v/s W.Soluble-K	0.8696*	4	Water sol.-S v/s Heat sol.-S	0.1990*
3	Available K ₂ O v/s Ex.-K	0.9651*	5	Water sol.-S v/s Non- sulphate-S	0.1981*
4	Available K ₂ O v/s HNO ₃ -K	0.9392*	6	Org.-S v/s Sulphate-S	0.4019*
5	Available K ₂ O v/s Total-K	0.4037*	7	Org.-S v/s Total-S	0.4356*
6	Available K ₂ O v/s Reserve-K	0.7399*	8	Org.-S v/s Heat soluble-S	0.1337
7	Available-K v/s W.Soluble-K	0.8696*	9	Org.-S v/s Non-Sulphate-S	0.0467
8	Available-K v/s Ex.-K	0.9651*	10	Sulphate-S v/s Total-S	0.2507*
9	Available-K v/s HNO ₃ -K	0.9392*	11	Sulphate-S v/s Heat soluble-S	0.3089*
10	Available-K v/s Total-K	0.4037*	12	Sulphate-S v/s Non-Sulphate-S	0.0569
11	Available-K v/s Reserve-K	0.7399*	13	Total-S v/s Heat soluble-S	-0.1390
12	W. Soluble-K v/s Ex.-K	0.8516*	14	Total-S v/s Non-Sulphate-S	0.9183*
13	W. Soluble-K v/s HNO ₃ -K	0.8086*	15	Heat sol.-S v/s Non-Sulphate-S	-0.0881

Table 4.5.3: Correlation co-efficient between different forms of N and P to G'nut & wheat yield of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between		Sr. no.	Correlation between	
	N forms to yield			P forms to yield	
1	O .C. v/s GPY	-0.5444*	11	Saloid-P v/s WGY	0.3519*
2	O. C. v/s GHY	-0.5060*	12	Saloid-P v/s WSY	0.4183*
3	O. C. v/s WGY	0.5620*	13	Al-P v/s GPY	0.4161*
4	O. C. v/s WSY	0.4960*	14	Al-P v/s GHY	0.4094*
5	Total-N v/s GPY	-0.5024*	15	Al-P v/s WGY	-0.2275*
6	Total-N v/s GHY	-0.5043	16	Al-P v/s WSY	-0.1288
7	Total-N v/s WGY	0.5597*	17	Fe-P v/s GPY	0.4694*
8	Total-N v/s WSY	0.4958*	18	Fe-P v/s GHY	0.4563*
9	Ammonical.-N v/s GPY	0.2034*	19	Fe-P v/s WGY	-0.3402*
10	Ammonical.-N v/s GHY	0.1244	20	Fe-P v/s WSY	-0.3048*
11	Ammonical.-N v/s WGY	-0.2272*	21	Reductant-P v/s GPY	-0.5149*
12	Ammonical.-N v/s WSY	-0.2134*	22	Reductant-P v/s GHY	-0.4846*
13	Nitrate-N v/s GPY	0.1345	23	Reductant-P v/s WGY	0.6038*
14	Nitrate-N v/s GHY	0.1016	24	Reductant-P v/s WSY	0.5605*
15	Nitrate-N v/s WGY	-0.2083*	25	Occluded-P v/s GPY	-0.4858*
16	Nitrate-N v/s WSY	-0.2795*	26	Occluded-P v/s GHY	-0.4346*
17	Available-N v/s GPY	0.3275*	27	Occluded-P v/s WGY	0.5085*
18	Available-N v/s GHY	0.3013*	28	Occluded-P v/s WSY	0.4004*
19	Available-N v/s WGY	-0.1958*	29	Ca-P v/s GPY	0.6113*
20	Available-N v/s WSY	-0.1245	30	Ca-P v/s GHY	-0.4933*
P forms to yield			31	Ca-P v/s WGY	-0.4328*
1	Inorganic-P v/s GPY	-0.3178*	32	Ca-P v/s WSY	-0.3234*
2	Inorganic-P v/s GHY	-0.2654*	33	Organic-P v/s GPY	-0.1314
3	Inorganic-P v/s WGY	0.4650*	34	Organic-P v/s GHY	-0.0763
4	Inorganic-P v/s WSY	0.4935*	35	Organic-P v/s WGY	0.0865
5	Total-P v/s GPY	-0.2108*	36	Organic-P v/s WSY	0.1481
6	Total-P v/s GHY	-0.1466	37	Available-P v/s GPY	0.0080
7	Total-P v/s WGY	0.2153*	38	Available-P v/s GHY	0.0072
8	Total-P v/s WSY	0.2781*-	39	Available-P v/s WGY	0.2948*
9	Saloid-P v/s GPY	0.1926*	40	Available-P v/s WSY	0.3229*
10	Saloid-P v/s GHY	-0.1950*			

4.5.3: Correlation with soil properties: N

The O. C. exhibited significant negative relationship with soil pH, while positive relationship with soil EC ($r = -0.5303, 0.3991$). The Total-N also showed significant negative ($r = -0.5286$) relationship with soil pH and positive with ($r = 0.3972$) soil EC. Whereas Amm.-N ascribed

positive relationship with pH ($r = 0.0432$) & significant negative relationship with EC ($r = -0.2074$), same trend was also observed in case of Nitrate-N fraction. Available nitrogen exhibited significant positive relationship ($r = 0.2358$) with soil pH and negative with ($r = -0.2008$) with soil EC. (Table-4.5.5)

Table 4.5.5: Correlation co-efficient between different forms of N, P, K & S to Soil Properties of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between		Sr. no.	Correlation between	
	N Forms to Soil Properties			K Forms to Soil Properties	
1	O. C. v/s pH	-0.5303*	1	Available K ₂ O v/s pH	0.1938*
2	O. C. v/s EC	0.3991*	2	Available K ₂ O v/s EC	-0.2905*
3	Total-N v/s pH	-0.5286*	3	Available K v/s pH	0.1938*
4	Total-N v/s EC	0.3972*	4	Available K v/s EC	-0.2905
5	Ammonical-N v/s pH	0.0432	5	Water soluble-K v/s pH	0.3991*
6	Ammonical-N v/s EC	-0.2074*	6	Water soluble-K v/s EC	-0.4073*
7	Nitrate-N. v/s pH	0.1021	7	Exchangeable-K v/s pH	0.1816*
8	Nitrate-N v/s EC	-0.2528*	8	Exchangeable-K v/s EC	-0.3056*
9	Available-N. v/s pH	0.2358*	9	HNO ₃ -K v/s pH	0.1112
10	Available-N v/s EC	-0.2008*	10	HNO ₃ -K v/s EC	-0.2440*
P Forms to Soil Properties			11	Total-K v/s pH	0.0853
1	Inorganic-P v/s pH	-0.4449*	12	Total-K v/s EC	-0.2733*
2	Inorganic-P v/s EC	0.2750*	13	Reserve-K v/s pH	0.0046
3	Total-P v/s pH	-0.3329*	14	Reserve-K v/s EC	-0.1586
4	Total-P v/s EC	0.3827*	S Forms to Soil Properties		
5	Saloid-P v/s pH	-0.1913*	1	Water soluble-S v/s pH	0.5003*
6	Saloid-P v/s EC	0.2703*	2	Water soluble-s v/s EC	-0.2986*
7	Al-P v/s pH	0.3907*	3	Organic-S v/s pH	-0.4184*
8	Al-P v/s EC	-0.3236*	4	Organic-S v/s EC	0.4385*
9	Fe-P v/s pH	0.5609*	5	Sulphate-S v/s pH	-0.5844*
10	Fe-P v/s EC	-0.5517*	6	Sulphate-S v/s EC	0.5473*
11	Reductant-P v/s pH	-0.5071*	7	Total-S v/s pH	-0.1699*
12	Reductant-P v/s EC	0.4516*	8	Total-S v/s EC	0.3030*
13	Occluded-P v/s pH	-0.3604*	9	Heat soluble-S v/s pH	-0.1316
14	Occluded-P v/s EC	0.2299*	10	Heat soluble-S v/s EC	0.1782*
15	Ca-P v/s pH	0.5799*	11	Non-Sulphate-S v/s pH	0.01702
16	Ca-P v/s EC	-0.5510*	12	Non-Sulphate-S v/s EC	0.1248
17	Organic-P v/s pH	-0.2290*			
18	Organic-P v/s EC	0.3411*			
9	Available-P v/s pH	-0.0524			
20	Available-P v/s EC	-0.0194			

4.5.4: Correlation between N, P, K, S content in plant parts: Forms of N

Organic carbon exhibited positive relationship with N, P, K content of groundnut haulm ($r = 0.3124, 0.2981, 0.1764$), P content of wheat grain & straw ($r = 0.4863$ & 0.5652) & K content of wheat straw, while showed significant negative relationship with P content of groundnut pod ($r = -0.4563$), N content of wheat grain ($r = -0.4888$), S content of wheat grain & straw ($r = -0.6468$ & -0.6979). Total-N status of LTFE soils ascribed significant positive relationship with N, P, K content of groundnut haulm ($r = 0.3127, 0.2981, 0.1791$), P content of wheat straw ($r = 0.5653$) and K content of wheat straw ($r = 0.1828$) and it also showed negative relationship with P content of groundnut pod ($r = -0.4571$), N content of wheat grain ($r = -0.4872$), S content of wheat grain ($r = -0.6467$) and S content of wheat straw ($r = -0.6993$). Whereas Amm.-N status of LTFE soils exhibited significant negative relationship with N content of groundnut pod, N & P content of groundnut haulm and S content of wheat straw, it showed significant positive relationship with only S content of wheat grain & straw ($r = 0.1885$ & 0.2298). Nitrate-N also showed significant negative relationship with N, P, K, S content of groundnut & wheat except P content of groundnut pod and S content of wheat grain & straw, where significant positive relationship was observed. Available-N ascribed significant positive relationship with P content of pod ($r = 0.3664$), K content of haulm ($r = 0.2630$), N content of grain ($r = 0.3715$), S content of Grain ($r = 0.3043$) and straw ($r = 0.3369$), while it showed negative relationship with N content of haulm ($r = -0.1759$), P content of haulm ($r = -0.2855$) and P content of wheat grain ($r = -0.2324$) (Table-4.5.6)

Table 4.5.6: Correlation co-efficient between different forms of N in LTFE Soils to NPKS Content in G'nut & wheat in the 1st, 4th and 8th year at harvest

Sr. no.	Correlation between N Form to NPKS content		Sr. no.	Correlation between N Form to NPKS content	
1	O.C. v/s CNGP	0.1078	41	Amm.-N v/s CNWG	0.1391
2	O.C. v/s CPGP	-0.4563*	42	Amm.-N v/s CPWG	-0.1439
3	O.C. v/s CKGP	0.0210	43	Amm.-N v/s CKWG	-0.0897
4	O.C. v/s CSGP	0.0885	44	Amm.-N v/s CSWG	0.1885*
5	O.C. v/s CNGH	0.3124*	45	Amm.-N v/s CNWS	-0.0966
6	O.C. v/s CPGH	0.2981*	46	Amm.-N v/s CPWS	-0.3509*
7	O.C. v/s CKGH	0.1764*	47	Amm.-N v/s CKWS	-0.2751*
8	O.C. v/s CSGH	-0.1099	48	Amm.-N v/s CSWS	0.2298*
9	O.C. v/s CNWG	-0.4888*	49	Nitrate-N v/s CNGP	-0.2918*
10	O.C. v/s CPWG	0.4863*	50	Nitrate-N v/s CPGP	0.2937*
11	O.C. v/s CKWG	0.14061	51	Nitrate-N v/s CKGP	-0.1802*
12	O.C. v/s CSWG	-0.6468*	52	Nitrate-N v/s CSGP	-0.4446*
13	O.C. v/s CNWS	0.1069	53	Nitrate-N v/s CNGH	-0.4688*
14	O.C. v/s CPWS	0.5652*	54	Nitrate-N v/s CPGH	-0.5994*
15	O.C. v/s CKWS	0.1786*	55	Nitrate-N v/s CKGH	-0.0672
16	O.C. v/s CSWS	-0.6979*	56	Nitrate-N v/s CSGH	-0.3433*
17	Total-N v/s CNGP	0.1077	57	Nitrate-N v/s CNWG	0.1852*
18	Total-N v/s CPGP	-0.4571*	58	Nitrate-N v/s CPWG	-0.5698*
19	Total-N v/s CKGP	0.0226	59	Nitrate-N v/s CKWG	-0.5091*
20	Total-N v/s CSGP	0.0913	60	Nitrate-N v/s CSWG	0.3341*
21	Total-N v/s CNGH	0.3127*	61	Nitrate-N v/s CNWS	-0.1182
22	Total-N v/s CPGH	0.2981*	62	Nitrate-N v/s CPWS	-0.3267*
23	Total-N v/s CKGH	0.1791*	63	Nitrate-N v/s CKWS	-0.2529*
24	Total-N v/s CSGH	-0.1069	64	Nitrate-N v/s CSWS	0.2965*
25	Total-N v/s CNWG	-0.4872	65	Available-N v/s CNGP	-0.0.869
26	Total-N v/s CPWG	0.4868*	66	Available-N v/s CPGP	0.3364*
27	Total-N v/s CKWG	0.1427	67	Available-N v/s CKGP	0.0124
28	Total-N v/s CSWG	-0.6467*	68	Available-N v/s CSGP	-0.0430
29	Total-N v/s CNWS	0.1099	69	Available-N v/s CNGH	-0.1759*
30	Total-N v/s CPWS	0.5653*	70	Available-N v/s CPGH	-0.2855*
31	Total-N v/s CKWS	0.1828*	71	Available-N v/s CKGH	0.2630*
32	Total-N v/s CSWS	-0.6993*	72	Available-N v/s CSGH	0.0068
33	Amm.-N v/s CNGP	-0.2387*	73	Available-N v/s CNWG	0.3715*
34	Amm.-N v/s CPGP	0.1158	74	Available-N v/s CPWG	-0.2324*
35	Amm.-N v/s CKGP	-0.0507	75	Available-N v/s CKWG	-0.1171
36	Amm.-N v/s CSGP	0.0071	76	Available-N v/s CSWG	0.3043*
37	Amm.-N v/s CNGH	-0.2323*	77	Available-N v/s CNWS	0.0544
38	Amm.-N v/s CPGH	-0.1645*	78	Available-N v/s CPWS	-0.1337
39	Amm.-N v/s CKGH	-0.1224	79	Available-N v/s CKWS	0.0683
40	Amm.-N v/s CSGH	-0.0125	80	Available-N v/s CSWS	0.3369*

4.5.5: Correlation among different forms of-P

Available-P forms significantly correlated with Inorganic-P ($r = 0.2342$), Saloid bound-P ($r = 0.6223$), Reductant soluble-P ($r = 0.2590$), & Occluded-P ($r = 0.2490$). It signifies the importance of Inorganic-P, Saloid bound-P, Reductant-P and Occluded-P in availability of phosphorus in LTFE soils. Inorganic-P fraction exhibited significant positive relationship with Total-P ($r = 0.5252$), Saloid-P ($r = 0.5491$), Reductant-P ($r = 0.5752$), Occluded-P ($r = 0.2861$) and Organic-P ($r = 0.2566$), while it showed significant negative relationship with Ca-P ($r = -0.5336$). Whereas Total-P ascribed significant positive relationship with Saloid-P ($r = 0.4378$) & Reductant-P ($r = 0.4607$) while it exhibited significant negative relationship with Al-P ($r = -0.3188$), Fe-P ($r = -0.6742$), Ca-P ($r = -0.6225$) and Organic-P ($r = -0.9572$). Saloid-P also exhibited significant positive relationship with Reductant-P ($r = 0.4338$) and Organic-P ($r = 0.3106$), while it showed negative relationship with Fe-P ($r = -0.5369$) and Ca-P ($r = -0.5041$). Al-P ascribed significant positive relationship with Fe-P ($r = 0.3582$) and Ca-P ($r = 0.3879$), while it showed significant negative relationship with Organic-P ($r = -0.3100$). Whereas Fe-P significantly negatively correlated with Reductant soluble-P ($r = -0.5218$) and Organic-P ($r = -0.5755$), while it was significantly positively correlated with Ca-P ($r = 0.8177$). Reductant soluble-P exhibited positive relationship with Occluded-P, Organic-P & Available-P, while it showed negative relationship with Ca-P. Occluded-P also showed significant negative relationship with Ca-P and Ca-P exhibited negative relationship with Organic-P. (Table-4.5.2)

Table 4.5.2: Correlation co-efficient between different forms of P to among forms of LTFE soils in the 1st, 4th and 8th year

Sr. no.	Correlation between		Sr. no.	Correlation between	
	P forms to among forms			P forms to among forms	
1	Inorganic-P v/s Total-P	0.5252*	25	Al-P v/s Fe-P	0.3582*
2	Inorganic-P v/s Saloid-P	0.5491*	26	Al-P v/s Reductant-P	-0.2671*
3	Inorganic-P v/s Al-P	-0.1532	27	Al-P v/s Occluded-P	-0.0568
4	Inorganic-P v/s Fe-P	-0.5999*	28	Al-P v/s Ca-P	0.3879*
5	Inorganic-P v/s Reductant-P	0.5752*	29	Al-P v/s Organic-P	-0.3100*
6	Inorganic-P v/s Occluded-P	0.2861*	30	Al-P v/s Available-P	0.1147
7	Inorganic-P v/s Ca-p	-0.5336*	31	Fe-P v/s reductant-P	-0.5218*
8	Inorganic-P v/s Organic-P	0.2566*	32	Fe-P v/s Occluded-P	0.0429
9	Inorganic-P v/s Available-P	0.2342*	33	Fe-P v/s Ca-P	0.8177*
10	Total-P v/s Saloid-P	0.4378*	34	Fe-P v/s Organic-P	-0.5755*
11	Total-P v/s Al-P	-0.3188*	35	Fe-P v/s Available-P	0.0410
12	Total-P v/s Fe-P	-0.6742*	36	Reductant-P v/s Occluded-P	0.2269*
13	Total-P v/s Reductant-P	0.4607*	37	Reductant-P v/s Ca-P	-0.5236*
14	Total-P v/s Occluded-P	-0.0923	38	Reductant-P v/s Organic-P	0.3278*
15	Total-P v/s Ca-P	-0.6225*	39	Reductant-P v/s Available-P	0.2590*
16	Total-P v/s Organic-P	-0.9572*	40	Occluded-P v/s Ca-P	-0.1993*
17	Total-P v/s Available-P	-0.0608	41	Occluded-P v/s Organic-P	-0.1146
18	Saloid-P v/s Al-P	-0.0514	42	Occluded-P v/s Available-P	0.2490*
19	Saloid-P v/s Fe-P	-0.5369*	43	Ca-P v/s Organic-P	-0.5256*
20	Saloid-P v/s Reductant-P	0.4338*	44	Ca-P v/s Available-P	0.0606
21	Saloid-P v/s Occluded-P	0.0839	45	Organic-P v/s Available-P	-0.1487
22	Saloid-P v/s Ca-P	-0.5041*			
23	Saloid-P v/s Organic-P	0.3106*			
24	Saloid-P v/s Available-P	0.6223*			

4.5.6: Correlation with yield: Phosphorus

Available-P status of LTFE soils exhibited significant positive relationship with wheat grain & straw yield ($r = 0.2948$ & 0.3229). All the fractions of phosphorus showed significant positive relationship with wheat yield, except Al-P & Fe-P, which showed negative relationship with wheat yield, but that were positive relationship with groundnut pod & haulm yield. Overall all fractions exhibited negative relationship with groundnut yield, except Ca-P, which positively correlated with groundnut pod yield ($r = 0.6113$). (Table: 4.5.3).

4.5.7: Correlation with soil properties: Phosphorus

All fractions of phosphorus exhibited significant negative relationship with soil pH, except Ca-P, Fe-P & Al-P which positively correlated with soil pH ($r = 0.5799, 0.5609, 0.3907$) and positive relationship with soil EC, except Al-P, Fe-P, Ca-P & Av-P, which were ascribed negative relationship with soil EC. (Table: 4.5.5)

4.5.8: Correlation between N, P, K, S content in plant parts and Forms of P

Available-P status of LTFE soils ascribed significant positive relationship with K content of groundnut pod ($r = 0.3316$), haulm ($r = 0.7110$) and N, P, K content of straw and ascribed significant negative relationship with N content of groundnut pod ($r = -0.1704$) and S content of wheat straw ($r = -0.2469$). Inorganic-P fraction also exhibited significant positive relationship with K & S content of groundnut pod ($r = 0.2052$ & 0.3393), N, P & K content of groundnut haulm ($r = 0.3531, 0.5142$ & 0.2508), P & K content of wheat grain ($r = 0.5720$ & 0.2631) & P, K content of wheat straw ($r = 0.5062, 0.2661$) and showed significant negative relationship with P content of groundnut pod ($r = -0.3390$), N content of wheat grain ($r = -0.3228$), S content of wheat grain ($r = -0.4677$)

and S content of wheat straw ($r = -0.5261$). Exactly same trend was also observed in case of relationship of Saloid bound-P status of LTFE soils with yield of groundnut & wheat. Whereas Al-P exhibited significant positive relationship with P & K content of groundnut pod, K content of haulm, N & S content of grain & S content of wheat straw and negative relationship with P & S content of haulm, P & K content of wheat grain. Fe-P also showed significant relationship with content of N, P, K, S, but that were negative in most of the cases, except P content of groundnut pod, N & S content of grain and S content of straw, which were positive. Reductant soluble-P also showed positive relationship with N, P, K content of haulm ($r = 0.3693, 0.3451, 0.1732$), P & K content of grain and P & S content of straw, while it showed significant negative relationship with P content of pod ($r = -0.4587$), N content of wheat grain ($r = -0.4553$), S content of wheat grain ($r = -0.5751$) and S content of straw ($r = -0.6429$). Whereas Occluded-P exhibited negative relationship with most of the nutrient content in groundnut & wheat. Ca-P status of LTFE soils ascribed significant negative relationship with nutrient content in most of the cases, except P content in groundnut pod, N content in wheat grain and S content in straw, which were positively correlated. Whereas Organic-P exhibited significant positive relationship with N & S content of groundnut pod ($r = 0.4319$ & 0.5677), N, P & S content of groundnut haulm ($r = 0.3268, 0.5823$ & 0.3957), P, K content of wheat grain & straw, while it ascribed negative relationship with P content of groundnut pod, N content of wheat grain, S content of wheat grain & straw, (Table: 4.5.7 a & b).

4.5.9: Correlation among different forms of K

Available K_2O status of LTFE soils exhibited significant positive relationship with Available-K ($r = 1.00$), Water soluble-K (0.8696), Ex.-K (0.9651), HNO_3 soluble-K (0.9392), Total-K (0.4037) and with Reserve-K

Table 4.5.7 a: Correlation co-efficient between different forms of P in LTFE soils to NPKS content in G'nut & wheat in the 1st, 4th and 8th year

Sr. no.	Correlation between P Form to NPKS content		Sr. no.	Correlation between P Form to NPKS content	
1	Inorganic-P v/s CNGP	0.0921	41	Saloid-P v/s CNWG	-0.2129*
2	Inorganic-P v/s CPGP	-0.3390*	42	Saloid-P v/s CPWG	0.6059*
3	Inorganic-P v/s CKGP	0.2052*	43	Saloid-P v/s CKWG	0.5198*
4	Inorganic-P v/s CSGP	0.3393*	44	Saloid-P v/s CSWG	-0.3885*
5	Inorganic-P v/s CNGH	0.3531*	45	Saloid-P v/s CNWS	0.2752*
6	Inorganic-P v/s CPGH	0.5142*	46	Saloid-P v/s CPWS	0.5635*
7	Inorganic-P v/s CKGH	0.2508*	47	Saloid-P v/s CKWS	0.5823*
8	Inorganic-P v/s CSGH	0.1445-0	48	Saloid-P v/s CSWS	-0.5166*
9	Inorganic-P v/s CNWG	-0.3228*	49	Al-p v/s CNGP	-0.0677
10	Inorganic-P v/s CPWG	0.5720*	50	Al-p v/s CPGP	0.3973*
11	Inorganic-P v/s CKWG	0.3613*	51	Al-p v/s CKGP	0.2377*
12	Inorganic-P v/s CSWG	-0.4677*	52	Al-p v/s CSGP	-0.1147
13	Inorganic-P v/s CNWS	0.1385	53	Al-p v/s CNGH	0.0136
14	Inorganic-P v/s CPWS	0.5062*	54	Al-p v/s CPGH	-0.2015*
15	Inorganic-P v/s CKWS	0.2661*	55	Al-p v/s CKGH	0.2327*
16	Inorganic-P v/s CSWS	-0.5261*	56	Al-p v/s CSGH	-0.4322*
17	Total-P v/s CNGP	0.4079*	57	Al-p v/s CNWG	0.4036*
18	Total-P v/s CPGP	-0.3482*	58	Al-p v/s CPWG	-0.3034*
19	Total-P v/s CKGP	0.0527	59	Al-p v/s CKWG	-0.0576
20	Total-P v/s CSGP	0.5996*	60	Al-p v/s CSWG	0.3810*
21	Total-P v/s CNGH	0.3936*	61	Al-p v/s CNWS	0.1206
22	Total-P v/s CPGH	0.6666*	62	Al-p v/s CPWS	-0.1605
23	Total-P v/s CKGH	0.0980	63	Al-p v/s CKWS	0.1042
24	Total-P v/s CSGH	0.3916*	64	Al-p v/s CSWS	0.3201*
25	Total-P v/s CNWG	-0.2699*	65	Fe-P v/s CNGP	-0.3859*
26	Total-P v/s CPWG	0.7257*	66	Fe-P v/s CPGP	0.6664*
27	Total-P v/s CKWG	0.5847*	67	Fe-P v/s CKGP	-0.0256
28	Total-P v/s CSWG	-0.3752*	68	Fe-P v/s CSGP	-0.5805*
29	Total-P v/s CNWS	0.0599	69	Fe-P v/s CNGH	-0.4711*
30	Total-P v/s CPWS	0.3026*	70	Fe-P v/s CPGH	-0.7380*
31	Total-P v/s CKWS	0.2422*	71	Fe-P v/s CKGH	-0.0415
32	Total-P v/s CSWS	-0.3381*	72	Fe-P v/s CSGH	-0.4023*
33	Saloid-P v/s CNGP	0.2006*	73	Fe-P v/s CNWG	0.5342*
34	Saloid-P v/s CPGP	-0.3007*	74	Fe-P v/s CPWG	-0.8359*
35	Saloid-P v/s CKGP	0.3503*	75	Fe-P v/s CKWG	-0.6144*
36	Saloid-P v/s CSGP	0.4414*	76	Fe-P v/s CSWG	0.6355*
37	Saloid-P v/s CNGH	0.3201*	77	Fe-P v/s CNWS	0.0345
38	Saloid-P v/s CPGH	0.5204*	78	Fe-P v/s CPWS	-0.4369*
39	Saloid-P v/s CKGH	0.6223*	79	Fe-P v/s CKWS	-0.2477*
40	Saloid-P v/s CSGH	0.2706*	80	Fe-P v/s CSWS	0.6030*

Table 4.5.7 b: Correlation co-efficient between different forms of P in LTFE soils to NPKS content in G'nut & wheat in the 1st, 4th and 8th year

Sr. no.	Correlation between P Form to NPKS content		Sr. no.	Correlation between P Form to NPKS content	
1	Reductant-P v/s CNGP	0.1236	41	Ca-P v/s CNWG	0.6404*
2	Reductant-P v/s CPGP	-0.4587*	42	Ca-P v/s CPWG	-0.7915*
3	Reductant-P v/s CKGP	-0.0246	43	Ca-P v/s CKWG	-0.4727*
4	Reductant-P v/s CSGP	0.1217	44	Ca-P v/s CSWG	0.7280*
5	Reductant-P v/s CNGH	0.3693*	45	Ca-P v/s CNWS	-0.0579
6	Reductant-P v/s CPGH	0.3451*	46	Ca-P v/s CPWS	-0.5107*
7	Reductant-P v/s CKGH	0.1732*	47	Ca-P v/s CKWS	-0.1391
8	Reductant-P v/s CSGH	-0.0647	48	Ca-P v/s CSWS	0.6786*
9	Reductant-P v/s CNWG	-0.4353*	49	Organic-P v/s CNGP	0.4319*
10	Reductant-P v/s CPWG	0.5116*	50	Organic-P v/s CPGP	-0.2802*
11	Reductant-P v/s CKWG	0.2006*	51	Organic-P v/s CKGP	-0.0098
12	Reductant-P v/s CSWG	-0.5751*	52	Organic-P v/s CSGP	0.5657*
13	Reductant-P v/s CNWS	0.0522	53	Organic-P v/s CNGH	0.3268*
14	Reductant-P v/s CPWS	0.5670*	54	Organic-P v/s CPGH	0.5823*
15	Reductant-P v/s CKWS	0.1456	55	Organic-P v/s CKGH	0.0261
16	Reductant-P v/s CSWS	-0.6429*	56	Organic-P v/s CSGH	0.3957*
17	Occluded-P v/s CNGP	-0.1080	57	Organic-P v/s CNWG	-0.1969*
18	Occluded-P v/s CPGP	-0.1986*	58	Organic-P v/s CPWG	0.6298*
19	Occluded-P v/s CKGP	-0.1755*	59	Organic-P v/s CKWG	0.5413*
20	Occluded-P v/s CSGP	-0.4022*	60	Organic-P v/s CSWG	-0.2672*
21	Occluded-P v/s CNGH	-0.0545	61	Organic-P v/s CNWS	0.0210
22	Occluded-P v/s CPGH	-0.1832*	62	Organic-P v/s CPWS	0.1717*
23	Occluded-P v/s CKGH	-0.0656	63	Organic-P v/s CKWS	0.1846*
24	Occluded-P v/s CSGH	-0.4645*	64	Organic-P v/s CSWS	-0.2051*
25	Occluded-P v/s CNWG	0.3118*-	65	Available-P v/s CNGP	-0.1704*
26	Occluded-P v/s CPWG	0.0416	66	Available-P v/s CPGP	0.0835
27	Occluded-P v/s CKWG	-0.3668*	67	Available-P v/s CKGP	0.3316*
28	Occluded-P v/s CSWG	-0.3970*	68	Available-P v/s CSGP	-0.0664
29	Occluded-P v/s CNWS	0.0021	69	Available-P v/s CNGH	-0.0823
30	Occluded-P v/s CPWS	0.2816	70	Available-P v/s CPGH	-0.1050
31	Occluded-P v/s CKWS	-0.2138	71	Available-P v/s CKGH	0.7110*
32	Occluded-P v/s CSWS	-0.3891	72	Available-P v/s CSGH	-0.1659*
33	Ca-P v/s CNGP	-0.3234*	73	Available-P v/s CNWG	0.1382
34	Ca-P v/s CPGP	0.7350*	74	Available-P v/s CPWG	0.0324
35	Ca-P v/s CKGP	0.0466	75	Available-P v/s CKWG	-0.0166
36	Ca-P v/s CSGP	-0.4121*	76	Available-P v/s CSWG	-0.0587
37	Ca-P v/s CNGH	-0.3931*	77	Available-P v/s CNWS	0.2970*
38	Ca-P v/s CPGH	-0.6268*	78	Available-P v/s CPWS	0.4809*
39	Ca-P v/s CKGH	0.1163	79	Available-P v/s CKWS	0.4654*
40	Ca-P v/s CSGH	-0.2139*	80	Available-P v/s CSWS	-0.2469*

($r = 0.7399$). All other forms were also positively correlated with each other. (Table: 4.5.1).

4.5.10: Correlation with yield: K

Available K_2O & K status of LTFE soils ascribed significant positive relationship with groundnut pod & haulm yield ($r = 0.4208$ & 0.3919). Whereas Water soluble-K exhibited positive relationship with groundnut pod & haulm yield ($r = 0.6051$ & 0.5958) and negative relationship with wheat grain & straw yield ($r = -0.3255$ & -0.1950). The Ex.-K also revealed positive relationship with groundnut pod & haulm yield ($r = 0.4038$ & 0.3808), while HNO_3 soluble-K exhibited positive relationship with groundnut pod yield ($r = 0.3071$) and negative relationship with wheat straw yield ($r = -0.1866$). Total-K also depicted positive relationship with groundnut pod & haulm yield and Reserve-K exhibited positive relationship only with groundnut haulm yield. (Table: 4.5.4)

4.5.11: Correlation with soil properties: K

All the forms of potassium ascribed significant positive relationship with soil pH and showed negative relationship with soil EC. (Table: 4.5.5).

4.5.12: Correlation between N, P, K, S content in plant parts and forms of K

Soil status of Available K_2O revealed significant positive relationship with P & K content of groundnut pod ($r = 0.3710$ & 0.5033), K content of groundnut haulm ($r = 0.7676$), N & S content of wheat grain and N, P, K content of wheat straw. Whereas Available-K also exhibited positive relationship with P, K, S content of groundnut pod, K & S content of groundnut haulm and N, K, S content of wheat grain & straw. Exchangeable-K status of LTFE soils also exhibited significant positive relationship with P & K content of groundnut pod ($r = 0.3536$ &

**Table 4.5.4: Correlation co-efficient between different forms of K and S to
G'nut & wheat yield of LTFE soils in the 1st, 4th and 8th year**

Sr. no.	Correlation between K Form to yield		Sr. no.	Correlation between S Form to yield	
1	Av. K ₂ O v/s GPY	0.4208*	1	Water sol.-S v/s GPY	0.6757*
2	Av. K ₂ O v/s GHY	0.3919*	2	Water sol.-S v/s GHY	0.6669*
3	Av. K ₂ O v/s WGY	-0.0649	3	Water sol.-S v/s WGY	-0.6402*
4	Av. K ₂ O v/s WSY	0.0469	4	Water sol.-S v/s WSY	-0.4962*
5	Av. K v/s GPY	0.4208*	5	Organic-S v/s GPY	-0.4535*
6	Av. K v/s GHY	0.3919*	6	Organic-S v/s GHY	-0.4068*
7	Av. K v/s WGY	-0.0649	7	Organic-S v/s WGY	0.3822*
8	Av. K v/s WSY	0.0469	8	Organic-S v/s WSY	0.3366*
9	Water sol.-K v/s GPY	0.6051*	9	Sulphate-S v/s GPY	-0.6515*
10	Water sol.-K v/s GHY	0.5958*	10	Sulphate-S v/s GHY	-0.6242*
11	Water sol.-K v/s WGY	-0.3255*	11	Sulphate-S v/s WGY	0.6931*
12	Water sol.-K v/s WSY	-0.1950*	12	Sulphate-S v/s WSY	0.5921*
13	Ex.-k v/s GPY	0.4038*	13	Total-S v/s GPY	-0.2107*
14	Ex.-k v/s GHY	0.3808*	14	Total-S v/s GHY	-0.2262*
15	Ex.-k v/s WGY	-0.0781	15	Total-S v/s WGY	0.1978*
16	Ex.-k v/s WSY	0.0240	16	Total-S v/s WSY	0.2463*
17	HNO ₃ -K v/s GPY	0.3071*	17	Heat sol.-S v/s GPY	-0.2395*
18	HNO ₃ -K v/s GHY	0.0155	18	Heat sol.-S v/s GHY	-0.1911*
19	HNO ₃ -K v/s WGY	0.1089	19	Heat sol.-S v/s WGY	0.3040*
20	HNO ₃ -K v/s WSY	-0.1866*	20	Heat sol.-S v/s WSY	0.2310*
21	Total-K v/s GPY	0.2464*	21	Non-sul.-S v/s GPY	-0.0100
22	Total-K v/s GHY	0.2216*	22	Non-sul.-S v/s GHY	-0.0482
23	Total-K v/s WGY	-0.1049	23	Non-sul.-S v/s WGY	0.0231
24	Total-K v/s WSY	-0.0165	24	Non-sul.-S v/s WSY	0.1057
25	Reserve-K v/s GPY	0.1388			
26	Reserve-K v/s GHY	0.1739*			
27	Reserve-K v/s WGY	-0.1019			
28	Reserve-K v/s WSY	-0.1617			

0.4654), K content of groundnut haulm ($r = 0.7063$), N content of grain ($r = 0.3987$), S content of wheat grain ($r = 0.2297$), N content of wheat straw ($r = 0.2459$) and K content of wheat straw ($r = 0.4748$). HNO₃ soluble-K also ascribed positive relationship with P, K content of groundnut pod, K content of groundnut haulm, S content of wheat grain and N, P, K content of wheat straw. Whereas Total-K status of LTFE soils exhibited

Table 4.5.8 a: Correlation co-efficient between different forms of K in LTFE soils to NPKS content in G'nut & wheat in the 1st, 4th and 8th year

Sr. no.	Correlation between		Sr. no.	Correlation between	
	K Form to NPKS content			K Form to NPKS content.	
1	Av.-K ₂ O v/s CNGP	-0.1200	25	Water sol.-K v/s CNWG	0.5096*
2	Av.-K ₂ O v/s CPGP	0.3710*	26	Water sol.-K CPWG	-0.0428
3	Av.-K ₂ O P v/s CKGP	0.5033*	27	Water sol.-K CKWG	0.2094*
4	Av.-K ₂ O v/s CSGP	0.1442	28	Water sol.-K CSWG	0.3961*
5	Av.-K ₂ O v/s CNGH	-0.0532	29	Water sol.-K CNWS	0.2461*
6	Av.-K ₂ O v/s CPGH	-0.0215	30	Water sol.-K v/s CPWS	-0.0138
7	Av.-K ₂ O v/s CKGH	0.7676*	31	Water sol.-K v/s CKWS	0.4670*
8	Av.-K ₂ O v/s CSGH	0.0651	32	Water sol.-K v/s CSWS	0.2548*
9	Av.-K ₂ O v/s CNWG	0.3879*	33	Ex.-K v/s CNGP	-0.1319
10	Av.-K ₂ O v/s CPWG	0.0164	34	Ex.-K v/s CPGP	0.3536*
11	Av.-K ₂ O v/s CKWG	0.1311	35	Ex.-K v/s CKGP	0.4654*
12	Av.-K ₂ O v/s CSWG	0.2404*	36	Ex.-K v/s CSGP	0.0972
13	Av.-K ₂ O v/s CNWS	0.2682*	37	Ex.-K v/s CNGH	-0.0921
14	Av.-K ₂ O v/s CPWS	0.1682*	38	Ex.-K v/s CPGH	-0.0494
15	Av.-K ₂ O v/s CKWS	0.5086*	39	Ex.-K v/s CKGH	0.7063*
16	Av.-K ₂ O v/s CSWS	0.0551	40	Ex.-K v/s CSGH	0.0412
17	Water sol.-K v/s CNGP	-0.1455	41	Ex.-K v/s CNWG	0.3987*
18	Water sol.-K v/s CPGP	0.4564*	42	Ex.-K v/s CPWG	-0.0030
19	Water sol.-K v/s CKGP	0.5041*	43	Ex.-K v/s CKWG	0.1041
20	Water sol.-K v/s CSGP	0.2156*	44	Ex.-K v/s CSWG	0.2297*
21	Water sol.-K v/s CNGH	-0.0623	45	Ex.-K v/s CNWS	0.2459*
22	Water sol.-K v/s CPGH	-0.0273	46	Ex.-K v/s CPWS	0.1489
23	Water sol.-K v/s CKGH	0.6751*	47	Ex.-K v/s CKWS	0.4748*
24	Water sol.-K v/s CSGH	0.1749*	48	Ex.-K v/s CSWS	0.0758

significant positive relationship with P & K content of groundnut pod ($r = 0.2444$ & 0.2324), K content of groundnut haulm ($r = 0.2100$) and N content in wheat grain ($r = 0.2023$). Whereas Reserve-K exhibited positive relationship with P & K content of groundnut pod ($r = 0.2961$ & 0.3053), K content of groundnut haulm ($r = 0.5443$), N content of wheat grain ($r = 0.2784$) and N, P, K content of wheat straw ($r = 0.1843, 0.2411, 0.2783$). (Table: 4.5.8 a, b).

Table 4.5.8 b: Correlation coefficient between different forms of K in LTFE soils to NPKS content in G'nut & wheat in the 1st, 4th and 8th year

Sr. no.	Correlation between		Sr. no.	Correlation between	
	K Form to NPKS content			K Form to NPKS content.	
1	HNO ₃ -K v/s CNGP	-0.1866*	25	Total-K v/s CNWG	0.2023*
2	HNO ₃ -K v/s CPGP	0.3595*	26	Total-K v/s CPWG	-0.1034
3	HNO ₃ -K P v/s CKGP	0.4384*	27	Total-K v/s CKWG	-0.0502
4	HNO ₃ -K v/s CSGP	0.0240	28	Total-K v/s CSWG	0.1613
5	HNO ₃ -K v/s CNGH	-0.0532	29	Total-K v/s CNWS	0.0547
6	HNO ₃ -K v/s CPGH	-0.0981	30	Total-K v/s CPWS	-0.0627
7	HNO ₃ -K v/s CKGH	0.7089	31	Total-K v/s CKWS	0.1376
8	HNO ₃ -K v/s CSGH	-0.0556	32	Total-K v/s CSWS	0.0748
9	HNO ₃ -K v/s CNWG	0.3599*	33	Reserve-K v/s CNGP	-0.2336
10	HNO ₃ -K v/s CPWG	-0.0506	34	Reserve-K v/s CPGP	0.2961*
11	HNO ₃ -K v/s CKWG	0.0010	35	Reserve-K v/s CKGP	0.3053*
12	HNO ₃ -K v/s CSWG	0.1828*	36	Reserve-K v/s CSGP	-0.1115
13	HNO ₃ -K v/s CNWS	0.2447*	37	Reserve-K v/s CNGH	-0.0456
14	HNO ₃ -K v/s CPWS	0.2175*	38	Reserve-K v/s CPGH	-0.1698*
15	HNO ₃ -K v/s CKWS	0.4276*	39	Reserve-K v/s CKGH	0.5443*
16	HNO ₃ -K v/s CSWS	-0.0093	40	Reserve-K v/s CSGH	-0.1834*
17	Total-K v/s CNGP	0.0140	41	Reserve-K v/s CNWG	0.2784*
18	Total-K v/s CPGP	0.2444*	42	Reserve-K v/s CPWG	-0.1173
19	Total-K v/s CKGP	0.2324*	43	Reserve-K v/s CKWG	-0.1422
20	Total-K v/s CSGP	0.0015	44	Reserve-K v/s CSWG	0.0936
21	Total-K v/s CNGH	0.0191	45	Reserve-K v/s CNWS	0.1843*
22	Total-K v/s CPGH	-0.1142	46	Reserve-K v/s CPWS	0.2411*
23	Total-K v/s CKGH	0.2100	47	Reserve-K v/s CKWS	0.2783*
24	Total-K v/s CSGH	0.0097	48	Reserve-K v/s CSWS	-0.0790

4.5.13: Correlation among different forms of S

Heat soluble-S (available-S) exhibited significant positive relationship with Water soluble-S ($r = 0.1990$) and Sulphate-S ($r = 0.3089$), it signified importance of Water soluble-S & Sulphate-S to the plant available sulphur. Water soluble-S showed significant negative relationship with Sulphate-S fraction ($r = -0.4122$). Organic-S was significantly correlated with Sulphate-S and Total-S ($r = 0.4019$ & 0.4356). Sulphate-S also positively correlated with Total-S ($r = 0.2507$), while Total-S positively correlated to Non-sulphate-S ($r = 0.9183$). (Table: 4.5.1)

4.5.14: Correlation with yield: Sulphur

Water soluble sulphur ascribed significant positive relationship with groundnut pod & haulm yield ($r = 0.6757$ & 0.6669), while it revealed negative relationship with wheat grain & straw yield ($r = -0.6402$, -0.4962). Whereas Organic-S fraction exhibited negative relationship with groundnut yield and positive with wheat yield, same trend was also observed in relationship of Sulphate-S, Total-S & Heat soluble-S with yield. (Table: 4.5.4)

4.5.15: Correlation with soil properties: S

Water soluble-S fraction showed significant positive relationship with soil pH ($r = 0.5003$) and negative with soil EC ($r = -0.2986$). Whereas Organic-S fraction exhibited significant negative relationship with soil pH & positive with soil EC, similar trend were also observed in relationship of Sulphate-S, Total-S & Heat soluble-S with soil pH and EC. (Table: 4.5.5)

4.5.16: Correlation between N, P, K, S content in plant parts & forms of S

Water soluble-S exhibited significant relationship with P, K, S content of groundnut pod, N, P, K, S content of groundnut haulm, N, P, K, S content of wheat straw. Organic-S fraction also ascribed significant positive relationship with most of the nutrient content of groundnut & wheat except P content of groundnut pod, N content of wheat grain, S content of wheat grain & straw, which were negatively correlated with Organic-S. Sulphate-S ascribed significant positive relationship with N content of groundnut haulm ($r = 0.2118$), P content of wheat grain ($r = 0.3500$) and N, P, K content of wheat straw, while significant negative relationship with P content of groundnut pod ($r = -0.5075$), S content of groundnut haulm ($r = -0.2093$), N content of wheat grain ($r = -0.4570$) and S content of wheat grain & straw ($r = -0.6445$ & -0.6691). Whereas Total-S status of LTFE soils exhibited significant positive relationship with K & S

content of pod, N, P & S content of haulm, P & K content of wheat grain & straw. Heat soluble-S also showed significant positive relationship with P content of wheat straw, while with other mostly it exhibited negative relationship. Non-sulphate-S fraction also ascribed significant positive relationship with nutrient content of groundnut & wheat in most of the cases. (Table: 4.5.9 a & b)

4.5.17: Correlation between interactions of different forms of two elements

(a) N x P:

The O. C. exhibited significant positive relationship with Inorganic-P ($r = 0.4526$), Total-P ($r = 0.3239$), Saloid-P ($r = 0.5525$), Reductant-P ($r = 0.4952$), Occluded-P ($r = 0.2904$), Organic-P ($r = 0.2140$) and Available-P ($r = 0.2943$), while it ascribed significant negative relationship with Al-P ($r = -0.2361$), Fe-P ($r = -0.5431$) & Ca-P ($r = -0.5344$). Exactly same relationship also was found between Total-N & different fractions of phosphorus. Whereas Ammonical-N revealed significant negative relationship with Saloid bound-P ($r = -0.2801$), Al-P ($r = -0.1896$), Reductant soluble-P ($r = -0.2169$), Occluded-P ($r = -0.2103$) & Available-P ($r = -0.2462$). Whereas Nitrate-N ascribed significant negative relationship with Inorganic-P, Total-P, Saloid-P, Reductant-P & Organic-P, while showed significant positive relationship with Fe-P ($r = 0.5223$) & Ca-P ($r = 0.4521$). Available nitrogen also exhibited Positive relationship with Ca-P ($r = 0.3259$), Available-P ($r = 0.1986$) & Fe-P ($r = 0.3361$), while negative with Inorganic-P ($r = -0.1668$). (4.5.10)

(b) N x K:

Available-N status of LTFE soils ascribed significant positive relationship with all fractions of potassium *i. e.* Av.-K₂O, Av.-K, WS.-K,

Table 4.5.9 a: Correlation co-efficient between different forms of S in LTFE soils to NPKS content in G'nut & wheat in the 1st, 4th and 8th year

Sr. no.	Correlation between		Sr. no.	Correlation between	
	S Form to NPKS content			S Form to NPKS content.	
1	Water sol.-S v/s CNGP	0.1415	25	Organic-S v/s CNWG	-0.5640*
2	Water sol.-S v/s CPGP	0.2531*	26	Organic-S v/s CPWG	0.6645*
3	Water sol.-S v/s CKGP	0.4645*	27	Organic-S v/s CKWG	0.3914*
4	Water sol.-S v/s CSGP	0.6246*	28	Organic-S v/s CSWG	-0.5791*
5	Water sol.-S v/s CNGH	0.1635	29	Organic-S v/s CNWS	-0.0542
6	Water sol.-S v/s CPGH	0.3976*	30	Organic-S v/s CPWS	0.4141*
7	Water sol.-S v/s CKGH	0.1905*	31	Organic-S v/s CKWS	0.0798
8	Water sol.-S v/s CSGH	0.7195*	32	Organic-S v/s CSWS	-0.5481*
9	Water sol.-S v/s CNWG	0.3290*	33	Sulphate-S v/s CNGP	0.0987
10	Water sol.-S v/s CPWG	0.2559*	34	Sulphate-S v/s CPGP	-0.5075*
11	Water sol.-S v/s CKWG	0.6517*	35	Sulphate-S v/s CKGP	-0.702
12	Water sol.-S v/s CSWG	0.4501*	36	Sulphate-S v/s CSGP	-0.0128
13	Water sol.-S v/s CNWS	0.0800	37	Sulphate-S v/s CNGH	0.2118*
14	Water sol.-S v/s CPWS	0.3151*	38	Sulphate-S v/s CPGH	0.1774*
15	Water sol.-S v/s CKWS	0.4163*	39	Sulphate-S v/s CKGH	0.1249
16	Water sol.-S v/s CSWS	0.4587*	40	Sulphate-S v/s CSGH	-0.2093*
17	Organic-S v/s CNGP	0.4736*	41	Sulphate-S v/s CNWG	-0.4570*
18	Organic-S v/s CPGP	-0.5372*	42	Sulphate-S v/s CPWG	0.3500*
19	Organic-S v/s CKGP	0.0964	43	Sulphate-S v/s CKWG	0.0459
20	Organic-S v/s CSGP	0.3674*	44	Sulphate-S v/s CSWG	-0.6445*
21	Organic-S v/s CNGH	0.2794*	45	Sulphate-S v/s CNWS	0.2083*
22	Organic-S v/s CPGH	0.5731*	46	Sulphate-S v/s CPWS	0.6932*
23	Organic-S v/s CKGH	-0.0466	47	Sulphate-S v/s CKWS	0.2173*
24	Organic-S v/s CSGH	0.7972*	48	Sulphate-S v/s CSWS	-0.6691*

Ex.-K, HNO₃ soluble-K, Total-K and Reserve-K. Whereas O. C., Total-N, and Nitrate-N exhibited positive relationship only with Reserve-K ($r = 0.1836, 0.1644$ & 0.1939). (Table: 4.5.11)

(c) N x S:

The O. C. exhibited significant positive relationship with Organic-S ($r = 0.4246$), Sulphate-S ($r = 0.5612$) & Total-S ($r = 0.2084$) and Negative with Water soluble-S ($r = -0.2736$). Exactly same relationship also found between Total-N and different forms of sulphur. Whereas Ammonical-N fraction ascribed only significant negative relationship with Organic-S ($r = -0.3146$), Sulphate-S ($r = -0.2925$) & Heat soluble-S ($r = -0.2924$). Nitrate-N also showed significant negative relationship with-

Table 4.5.9 b: Correlation coefficient between different forms of S in LTFE soils to NPKS content in G'nut & wheat in the 1st, 4th and 8th year

Sr. no.	Correlation between S Form to NPKS content		Sr. no.	Correlation between S Form to NPKS content.	
1	Total-S v/s CNGP	0.1572	25	Heat sol.-S v/s CNWG	-0.0949
2	Total-S v/s CPGP	-0.3597*	26	Heat sol.-S v/s CPWG	-0.1070
3	Total-S v/s CKGP	0.2136*	27	Heat sol.-S v/s CKWG	-0.2437*
4	Total-S v/s CSGP	0.4602*	28	Heat sol.-S v/s CSWG	-0.1638*
5	Total-S v/s CNGH	0.2531*	29	Heat sol.-S v/s CNWS	0.1072
6	Total-S v/s CPGH	0.5356*	30	Heat sol.-S v/s CPWS	0.2623*
7	Total-S v/s CKGH	0.0875	31	Heat sol.-S v/s CKWS	-0.0662
8	Total-S v/s CSGH	0.3280*	32	Heat sol.-S v/s CSWS	-0.0920
9	Total-S v/s CNWG	-0.2724*	33	Non-Sulph.-S v/s CNGP	0.0557
10	Total-S v/s CPWG	0.5230*	34	Non-Sulph.-S v/s CPGP	-0.1490
11	Total-S v/s CKWG	0.4059*	35	Non-Sulph.-S v/s CKGP	0.2015*
12	Total-S v/s CSWG	-0.3371*	36	Non-Sulph.-S v/s CSGP	0.3602*
13	Total-S v/s CNWS	0.1175	37	Non-Sulph.-S v/s CNGH	0.1539
14	Total-S v/s CPWS	0.3137*	38	Non-Sulph.-S v/s CPGH	0.3480*
15	Total-S v/s CKWS	0.2646*	39	Non-Sulph.-S v/s CKGH	0.1099
16	Total-S v/s CSWS	-0.3674*	40	Non-Sulph.-S v/s CSGH	0.2947*
17	Heat sol.-S v/s CNGP	-0.0917	41	Non-Sulph.-S v/s CNWG	-0.0434
18	Heat sol.-S v/s CPGP	-0.0496	42	Non-Sulph.-S v/s CPWG	0.2865*
19	Heat sol.-S v/s CKGP	-0.1437	43	Non-Sulph.-S v/s CKWG	0.2854*
20	Heat sol.-S v/s CSGP	-0.2512*	44	Non-Sulph.-S v/s CSWG	-0.0996
21	Heat sol.-S v/s CNGH	-0.0173	45	Non-Sulph.-S v/s CNWS	0.1419
22	Heat sol.-S v/s CPGH	-0.1533	46	Non-Sulph.-S v/s CPWS	0.1389
23	Heat sol.-S v/s CKGH	-0.0593	47	Non-Sulph.-S v/s CKWS	0.2494*
24	Heat sol.-S v/s CSGH	-0.2442*	48	Non-Sulph.-S v/s CSWS	-0.1219

Water soluble-S ($r = -0.2617$), Organic-S ($r = -0.4164$), Sulphate-S ($r = -0.1874$) & Total-S ($r = -0.2408$). Whereas Available-N fraction revealed significant negative relationship with Organic & Sulphate fraction of sulphur ($r = -0.2619$ & -0.1863). (Table: 4.5.11)

(d) P x K: Available-P & Ca-P exhibited significant positive relationship with all forms of potassium. Whereas Inorganic-P fraction ascribed significant positive relationship with Available- K_2O & K ($r = 0.1784$). Total-P revealed significant negative relationship only with Total-K

Table 4.5.10: Correlation co-efficient between interactions of different forms of two elements in LTFE soils in the 1st, 4th and 8th year

Sr. No.	N X P		Sr. No.	N X P	
1	O. C. v/s Inorganic-P	0.4526*	31	Nitrate-N v/s Inorg.-P	-0.4362*
2	O. C. v/s Total-P	0.3239*	32	Nitrate-N v/s Total-P	-0.4865*
3	O. C. v/s Saloid-P	0.5525*	33	Nitrate-N v/s Saloid-P	-0.3424*
4	O. C. v/s Al-P	-0.2361*	34	Nitrate-N v/s Al-P	-0.0927
5	O. C. v/s Fe-P	-0.5435*	35	Nitrate-N v/s Fe-P	0.5223*
6	O. C. v/s Reductant-P	0.4952*	36	Nitrate-N v/s Reduct.-P	-0.3093*
7	O. C. v/s Occluded-P	0.2904*	37	Nitrate-N v/s Occlud.-P	0.0944
8	O. C. v/s Ca-P	-0.5344*	38	Nitrate-N v/s Ca-P	0.4521*
9	O. C. v/s Organic-P	0.2140*	39	Nitrate-N v/s Organic-P	-0.4036*
10	O. C. v/s Available-P	0.2943*	40	Nitrate-N v/s Available-P	0.0989
11	Total-N v/s Inorganic-P	0.4319*	41	Av.-N v/s Inorganic-P	-0.1668*
12	Total-N v/s Total-P	0.3282*	42	Av.-N v/s Total-P	-0.1496
13	Total-N v/s Saloid-P	0.5770*	43	Av.-N v/s Saloid-P	-0.0284
14	Total-N v/s Al-P	-0.2211*	44	Av.-N v/s Al-P	0.1304
15	Total-N v/s Fe-P	-0.5386*	45	Av.-N v/s Fe-P	0.3361*
16	Total-N v/s Reductant-P	0.4892*	46	Av.-N v/s Reductant-P	-0.1532
17	Total-N v/s Occluded-P	0.2722*	47	Av.-N v/s Occluded-P	-0.0851
18	Total-N v/s Ca-P	-0.5243*	48	Av.-N v/s Ca-P	0.3259*
19	Total-N v/s Organic-P	0.2559*	49	Av.-N v/s Organic-P	-0.1133
20	Total-N v/s Available-P	0.2669*	50	Av.-N v/s Available-P	0.1986*
21	Amm.-N v/s Inorganic-P	-0.1088			
22	Amm.-N v/s Total-P	-0.0891			
23	Amm.-N v/s Saloid-P	-0.2801*			
24	Amm.-N v/s Al-P	-0.1896*			
25	Amm.-N v/s Fe-P	0.0432			
26	Amm.-N v/s Reductant-P	-0.2169*			
27	Amm.-N v/s Occluded-P	-0.2103*			
28	Amm.-N v/s Ca-P	0.1545			
29	Amm.-N v/s Organic-P	-0.0642			
30	Amm.-N v/s Available-P	-0.2462*			

($r = -0.2274$). Whereas Saloid bound-P fraction showed significant positive relationship with all fractions of K, except Total-K. The Al-P also exhibited significant positive relationship with Available-K₂O, Available-K, Water soluble-K, Ex.-K & HNO₃ soluble-K. Whereas Fe-P Showed significant positive correlation with Water soluble-K, HNO₃ soluble-K, Total-K & Reserve-K. Reductant soluble-P did not show any relationship with potassium forms, while Occluded-P exhibited significant negative

relationship only with water soluble-K ($r = -0.2235$) and organic-P only with Total-K ($r = -0.2208$) (Table: 4.5.12)

Table-4.5.11: Correlation co-efficient between interactions of different forms of two elements in LTFE soils in the 1st, 4th and 8th year

Sr. No.	N X K		Sr. No.	N X S	
1	O. C. v/s Av.-K ₂ O	0.1209	1	O. C. v/s W. S.-S	-0.2736*
2	O. C. v/s Av.-K	0.1209	2	O. C. v/s Organic-S	0.4246*
3	O. C. v/s water S.-K	-0.0614	3	O. C. v/s Sulphate-S	0.5612*
4	O. C. v/s Ex.-K	0.0878	4	O. C. v/s Total-S	0.2084*
5	O. C. v/s HNO ₃ -K	0.1616	5	O. C. v/s Heat S.-S	0.1169
6	O. C. v/s Total-K	0.0179	6	O. C. v/s Non-Sulph.-S	0.0244
7	O. C. v/s Reserve-K	0.1836*	7	Total-N v/s W. S.-S	-0.2440*
8	Total-N v/s Av.-K ₂ O	0.1059	8	Total-N v/s Organic-S	0.4130*
9	Total-N v/s Av.-K	0.1059	9	Total-N v/s Sulphate-S	0.5469*
10	Total-N v/s Water S.-K	-0.0700	10	Total-N v/s Total-S	0.2191*
11	Total-N v/s Ex.-K	0.0725	11	Total-N v/s Heat S.-S	0.0997
12	Total-N v/s HNO ₃ -K	0.1434	12	Total-N v/s Non-Sulph.-S	0.0420
13	Total-N v/s Total-K	0.0110	13	Amm.-N v/s W. S.-S	0.0818
14	Total-N v/s Reserve-K	0.1644*	14	Amm.-N v/s Organic-S	-0.3146*
15	Amm.-N v/s Av.-K ₂ O	-0.0812	15	Amm.-N v/s Sulphate-S	-0.2925*
16	Amm.-N v/s Av.-K	-0.0812	16	Amm.-N v/s Total-S	-0.0889
17	Amm.-N v/s Water S.-K	0.0138	17	Amm.-N v/s Heat S.-S	-0.2924*
18	Amm.-N v/s Ex.-K	-0.0546	18	Amm.-N v/s Non-Sulph.-S	0.0479
19	Amm.-N v/s HNO ₃ -K	-0.1175	19	Nitrate-N v/s W. S.-S	-0.2617*
20	Amm.-N v/s Total-K	-0.0613	20	Nitrate-N v/s Organic-S	-0.4164*
21	Amm.-N v/s Reserve-K	-0.1408	21	Nitrate-N v/s Sulphate-S	-0.1874*
22	Nitrate-N v/s Av.-K ₂ O	0.0936	22	Nitrate-N v/s Total-S	-0.2408*
23	Nitrate-N v/s Av.-K	0.0936	23	Nitrate-N v/s Heat S.-S	-0.0224
24	Nitrate-N v/s Water S.-K	0.1012	24	Nitrate-N v/s Non-Sulph.-S	-0.0845
25	Nitrate-N v/s Ex.-K	0.1023	25	Av.-N v/s W. S.-S	0.0603
26	Nitrate-N v/s HNO ₃ -K	0.1516	26	Av.-N v/s Organic-S	-0.2619*
27	Nitrate-N v/s Total-K	0.1386	27	Av.-N v/s Sulphate-S	-0.1863*
28	Nitrate-N v/s Reserve-K	0.1939*	28	Av.-N v/s Total-S	-0.0895
29	Av.-N v/s Av.-K ₂ O	0.3295*	29	Av.-N v/s Heat S.-S	-0.0136
30	Av.-N v/s Av.-K	0.3295*	30	Av.-N v/s Non-Sulph.-S	0.0195
31	Av.-N v/s Water S.-K	0.3223*	31		
32	Av.-N v/s Ex.-K	0.3170*	32		
33	Av.-N v/s HNO ₃ -K	0.3477*	33		
34	Av.-N v/s Total-K	0.2741*	34		
35	Av.-N v/s Reserve-K	0.3186*	35		

Table 4.5.12: Correlation co-efficient between interactions of different forms of two elements in LTFE soils in the 1st, 4th and 8th year

Sr. No.	P X K		Sr. No.	P X K	
1	Inorganic-P v/s Av.-K ₂ O	0.1784*	36	Reductant-P v/s Av.-K ₂ O	0.0598
2	Inorganic-P v/s Av.-K	0.1784*	37	Reductant-P v/s Av.-K	0.0598
3	Inorganic-P v/s W.S.-K	0.0700	38	Reductant-P v/s W.S.-K	-0.1015
4	Inorganic-P v/s Ex.-K	0.1505	39	Reductant-P v/s Ex.-K	0.0481
5	Inorganic-P v/s HNO ₃ -K	0.1586	40	Reductant-P v/s HNO ₃ -K	0.1085
6	Inorganic-P v/s total-K	-0.1103	41	Reductant-P v/s total-K	-0.1530
7	Inorganic-P v/s Res.-K	0.1143	42	Reductant-P v/s Res.-K	0.1467
8	Total-P v/s Av.-K ₂ O	0.0184	43	Occluded-P v/s Av.-K ₂ O	-0.0116
9	Total-P v/s Av.-K	0.0184	44	Occluded-P v/s Av.-K	-0.0116
10	Total-P v/s W.S.-K	-0.0530	45	Occluded-P v/s W.S.-K	-0.2235*
11	Total-P v/s Ex.-K	-0.0042	46	Occluded-P v/s Ex.-K	-0.0181
12	Total-P v/s HNO ₃ -K	-0.0168	47	Occluded-P v/s HNO ₃ -K	0.0673
13	Total-P v/s total-K	-0.2274*	48	Occluded-P v/s total-K	0.0494
14	Total-P v/s Res.-K	-0.0531	49	Occluded-P v/s Res.-K	0.1447
15	Saloid-P v/s Av.-K ₂ O	0.5101*	50	Ca-p v/s Av.-K ₂ O	0.2580*
16	Saloid-P v/s Av.-K	0.5101*	51	Ca-p v/s Av.-K	0.2580*
17	Saloid-P v/s W.S.-K	0.3449*	52	Ca-p v/s W.S.-K	0.3722*
18	Saloid-P v/s Ex.-K	0.4628*	53	Ca-p v/s Ex.-K	0.2697*
19	Saloid-P v/s HNO ₃ -K	0.4519*	54	Ca-p v/s HNO ₃ -K	0.2705*
20	Saloid-P v/s total-K	0.1006	55	Ca-p v/s total-K	0.2521*
21	Saloid-P v/s Res.-K	0.3242*	56	Ca-p v/s Res.-K	0.2460*
22	Al-P v/s Av.-K ₂ O	0.2121*	57	Organic-P v/s Av.-K ₂ O	-0.0397
23	Al-P v/s Av.-K	0.2121*	58	Organic-P v/s Av.-K	-0.0397
24	Al-P v/s W.S.-K	0.2465*	59	Organic-P v/s W.S.-K	-0.0840
25	Al-P v/s Ex.-K	0.2002*	60	Organic-P v/s Ex.-K	-0.0559
26	Al-P v/s HNO ₃ -K	0.1686*	61	Organic-P v/s HNO ₃ -K	-0.0730
27	Al-P v/s total-K	0.1436	62	Organic-P v/s total-K	-0.2208*
28	Al-P v/s Res.-K	0.0969	63	Organic-P v/s Res.-K	-0.0992
29	Fe-P v/s Av.-K ₂ O	0.1316	64	Av.-P v/s Av.-K ₂ O	0.7970*
30	Fe-P v/s Av.-K	0.1316	65	Av.-P v/s Av.-K	0.7970*
31	Fe-P v/s W.S.-K	0.2066*	66	Av.-P v/s W.S.-K	0.6183*
32	Fe-P v/s Ex.-K	0.1470	67	Av.-P v/s Ex.-K	0.7722*
33	Fe-P v/s HNO ₃ -K	0.1665*	68	Av.-P v/s HNO ₃ -K	0.8062*
34	Fe-P v/s total-K	0.1938*	69	Av.-P v/s total-K	0.3138*
35	Fe-P v/s Res.-K	0.1814*	70	Av.-P v/s Res.-K	0.7026*

(e) P x S:

Available form of phosphorus exhibited significant positive relationship only with Sulphate-S fraction ($r = 0.3343$). Whereas Inorganic fraction of P ascribed significant positive relationship with Organic-S ($r =$

0.5171), Sulphate-S ($r = 0.4669$) & Total-S ($r = 0.3674$), while negative with Non-sulphate-S ($r = -0.1715$). Total-P was significantly positive correlated with all fractions of sulphur, except Heat soluble-S. Saloid bound-P revealed significant positive relationship with Organic-S ($r = 0.3988$), Sulphate-S ($r = 0.4608$), Total-S ($r = 0.3385$) & Non-sulphate-S ($r = 0.1856$). Whereas Al-P showed significant positive relationship only with Water soluble-S ($r = 0.2646$), while negative with Organic-S ($r = -0.4142$), Sulphate-S ($r = -0.2372$) & Total-S ($r = -0.2473$). Fe-P also ascribed significant negative relationship with Organic-S, Sulphate-S, Total-S & Non-sulphate-S. Reductant soluble-P also exhibited negative relationship with Water soluble-S ($r = -0.2560$), while positive with Organic-S ($r = 0.5462$), Sulphate-S ($r = 0.5245$) & Total-S ($r = 0.2701$). Whereas Occluded-P showed significant negative relationship with Water soluble-S and positive with Organic-S, Sulphate-S & Heat soluble-S. Ca-P also showed significant relationship with Organic, Sulphate & Total-S, but it was negative. Whereas Organic-P significant positively correlated with Water soluble-S ($r = 0.2326$), Organic-S ($r = 0.4502$), Total-S ($r = 0.3284$) & Non-sulphate-S ($r = 0.1724$). (Table: 4.5.13)

(f) K x S:

Available-K₂O & K exhibited significant positive relationship only with Water soluble-S ($r = 0.2224$). Whereas Water soluble-K fraction ascribed significant positive relationship with Water soluble-S ($r = 0.4178$) & negative with Sulphate-S ($r = -0.2148$). Exchangeable-K fraction showed only significant positive relationship with Water soluble-S ($r = 0.2029$) and HNO₃ soluble-K did not exert any significant relationship with sulphur fractions. Whereas Total-K ascribed negative relationship only with Organic-S ($r = -0.1663$) and Reserve-K did not exhibited any relationship with sulphur fractions. (Table: 4.5.14)

Table 4.5.13: Correlation co-efficient between interactions of different forms of two elements in LTFE soils in the 1st, 4th and 8th year

Sr. No.	P X S		Sr. No.	P X S	
1	Inorg.-P v/s W.S.-S	-0.0317	31	Reductant-P v/s W.S.-S	-0.2560*
2	Inorg.-P v/s Org.-S	0.5171*	32	Reductant-P v/s Org.-S	0.5462*
3	Inorg.-P v/s Sulphate-S	0.4069*	33	Reductant-P v/s Sulphate-S	0.5245*
4	Inorg.-P v/s Total-S	0.3674*	34	Reductant-P v/s Total-S	0.2701*
5	Inorg.-P v/s Heat S.-S	-0.0053	35	Reductant-P v/s Heat S.-S	0.1128
6	Inorg.-P v/s Non-Sul.-S	-0.1715*	36	Reductant-P v/s Non-Sul.-S	0.0446
7	Total-P v/s W.S.-S	0.1953*	37	Occluded-P v/s W.S.-S	-0.5028*
8	Total-P v/s Org.-S	0.5512*	38	Occluded-P v/s Org.-S	0.1809*
9	Total-P v/s Sulphate-S	0.2161*	39	Occluded-P v/s Sulphate-S	0.3660*
10	Total-P v/s Total-S	0.3991*	40	Occluded-P v/s Total-S	-0.0440
11	Total-P v/s Heat S.-S	-0.0965	41	Occluded-P v/s Heat S.-S	0.2636*
12	Total-P v/s Non-Sul.-S	0.2031*	42	Occluded-P v/s Non-Sul.-S	-0.1445
13	Saloid-P v/s W.S.-S	0.1124	43	Ca-P v/s W.S.-S	0.1028
14	Saloid-P v/s Org.-S	0.3988*	44	Ca-P v/s Org.-S	-0.6642*
15	Saloid-P v/s Sulphate-S	0.4604*	45	Ca-P v/s Sulphate-S	-0.5500*
16	Saloid-P v/s Total-S	0.3385*	46	Ca-P v/s Total-S	-0.4990*
17	Saloid-P v/s Heat S.-S	-0.1420	47	Ca-P v/s Heat S.-S	0.0679
18	Saloid-P v/s Non-Sul.-S	0.1856*	48	Ca-P v/s Non-Sul.-S	-0.2489*
19	Al-P v/s W.S.-S	0.2646*	49	Organic-P v/s W.S.-S	0.2326*
20	Al-P v/s Org.-S	-0.4142*	50	Organic-P v/s Org.-S	0.4502*
21	Al-P v/s Sulphate-S	-0.2372*	51	Organic-P v/s Sulphate-S	0.1072
22	Al-P v/s Total-S	-0.2473*	52	Organic-P v/s Total-S	0.3284*
23	Al-P v/s Heat S.-S	-0.0922	53	Organic-P v/s Heat S.-S	-0.1078
24	Al-P v/s Non-Sul.-S	-0.0899	54	Organic-P v/s Non-Sul.-S	0.1724*
25	Fe-P v/s W.S.-S	-0.0942	55	Av.-P v/s W.S.-S	-0.1023
26	Fe-P v/s Org.-S	-0.6244*	56	Av.-P v/s Org.-S	0.0109
27	Fe-P v/s Sulphate-S	-0.4492*	57	Av.-P v/s Sulphate-S	0.3343*
28	Fe-P v/s Total-S	-0.4683*	58	Av.-P v/s Total-S	0.0371
29	Fe-P v/s Heat S.-S	0.0668	59	Av.-P v/s Heat S.-S	0.0530
30	Fe-P v/s Non-Sul.-S	-0.2369*	60	Av.-P v/s Non-Sul.-S	0.0184

Table 4.5.14: Correlation coefficient between interactions of different forms of two elements in LTFE soils in the 1st, 4th and 8th year

Sr. No.	K X S		Sr. No.	K X S	
1	Av.- K ₂ O v/s W.S.-S	0.2224*	22	Ex.-K v/s Total-S	-0.0457
2	Av.- K ₂ O v/s Org.-S	-0.0736	23	Ex.-K v/s Heat S.-S	-0.0983
3	Av.- K ₂ O v/s Sulphate-S	0.0005	24	Ex.-K v/s Non-Sul.-S	-0.0059
4	Av.- K ₂ O v/s Total-S	-0.0176	25	HNO ₃ -K v/s W.S.-S	0.0936
5	Av.- K ₂ O v/s Heat S.-S	-0.1049	26	HNO ₃ -K v/s Org.-S	-0.0970
6	Av.- K ₂ O v/s Non-Sul.-S	0.0110	27	HNO ₃ -K v/s Sulphate-S	0.0278
7	Av.-K v/s W.S.-S	0.2224*	28	HNO ₃ -K v/s Total-S	0.0448
8	Av.-K v/s Org.-S	-0.0736	29	HNO ₃ -K v/s Heat S.-S	-0.0523
9	Av.-K v/s Sulphate-S	0.0005	30	HNO ₃ -K v/s Non-Sul.-S	-0.0110
10	Av.-K v/s Total-S	-0.0176	31	Total-K v/s W.S.-S	0.0726
11	Av.-K v/s Heat S.-S	-0.1049	32	Total-K v/s Org.-S	-0.1663*
12	Av.-K v/s Non-Sul.-S	0.1102	33	Total-K v/s Sulphate-S	-0.0439
13	W. S.-K v/s W.S.-S	0.4178*	34	Total-K v/s Total-S	-0.0039
14	W. S.-K v/s Org.-S	-0.1503	35	Total-K v/s Heat S.-S	0.0008
15	W. S.-K v/s Sulphate-S	-0.2148*	36	Total-K v/s Non-Sul.-S	0.0672
16	W. S.-K v/s Total-S	-0.0608	37	Res.K v/s W.S.-S	-0.0612
17	W. S.-K v/s Heat S.-S	-0.1483	38	Res.K v/s Org.-S	-0.1091
18	W. S.-K v/s Non-Sul.-S	0.0066	39	Res.K v/s Sulphate-S	0.0539
19	Ex.-K v/s W.S.-S	0.2029*	40	Res.K v/s Total-S	-0.0684
20	Ex.-K v/s Org.-S	-0.1048	41	Res.K v/s Heat S.-S	0.0129
21	Ex.-K v/s Sulphate-S	-0.0252	42	Res.K v/s Non-Sul.-S	-0.0337

4.6: LTFE-Pooled Regression and Stepwise

(a) Available form to different forms:

4.6.1: Nitrogen:

The stepwise regression of Available-N with its forms explained the variation in form up to 8 per cent. However, Total-N followed by Nitrate-N form influenced available-N to the maximum extent (Table: 4.6.1).

4.6.2: Phosphorus:

The stepwise regression of Available-P with its forms explained the variation in form up to 69 per cent. However, Fe-P followed by Total-P, Saloid-P, Occluded-P, Ca-P & Reductant-P forms influenced Available-P to the maximum (Table: 4.6.1).

Table 4.6.1 Regression equation between available form to forms and available form to soil properties for N, P, K and S in LTFE

LTFE soils	Dependent variables	Regression equation Available form to different forms	R ²
		(O. C.) (Total-N) (Amm.-N)(Nitrate-N)	
1	Av.-N	$Y=237.37-172.97x_{11}+1838.57x_{12}+0.0359x_{13}+1.087x_{14}$	0.0815
		(Inorg.P)(T.-P)(Saloid-P)(Al-P) (Fe-P) (Red.-P) (Occl.-P)(Ca-P) (Org.P)	
2	Av.-P	$Y=41.59 -1.93x_1+7.99x_2 +2.66x_3 -0.782x_4+105x_5+0.1207x_6+2.031x_7+0.181x_8-0.0085x_9$	0.6986
		(Av.-K) (W.S.-K) (Ex.-K) (HNO ₃ -K) (Total-K) (Res.-K)	
3	Av.-K ₂ O	$Y=2.3186+1.22x_2 +0.001x_3 +0.001x_4 +0.001x_5 +0.001x_6 -0.001x_7$	1.000
		(W.S.-S) (Org.-S) (Sul.-S) (Total-S) (Non-Sui.-S)	
	Heat S.-S	$Y=8.70-0.070x_8 -0.001x_9 +0.4718x_{10}+0.0054x_{11} -0.0141x_{13}$	0.1101
		Form to soil properties (pH) (EC)	
1	Av.-N	$Y= 137.67+16.688x_5-53.311x_6$	0.0616
2	Av.-P	$Y=61.060 -4.1597x_5 -16.1469x_6$	0.0062
3	Av.-K	$Y=345.75+11.737x_5-322.410x_6$	0.0846
4	H.S.-S	$Y=14.6537-0.7838x_5+10.9908x_6$	0.0344

4.6.3: Potassium:

The Available-K₂O 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). All independent variable, Available-K, WS-K, Ex.-K, HNO₃ soluble-K, Total-K & Reserve-K had same influence on Available-K₂O.

4.6.4: Sulphur:

The low level of multiple correlation co-efficient obtained in the stepwise regression of sulphur with its various forms. Among the independent variable Sulphate-S had maximum influence on Heat soluble-S (Available-S). (Table: 4.6.1)

(b) Available N, P, K, S form to soil properties:

4.6.5: So far as stepwise regression between Available major nutrients with soil properties were concerned the R square values were low. Soil pH had more influence than EC on available N, P, K, while soil EC influenced more on Heat soluble-S. (Table: 4.6.1).

4.7: Path- co-efficient Analysis of LTFE

(a) Available form to different forms:

4.7.1: Nitrogen:

The Nitrate form of nitrogen exhibited maximum direct positive effect on Available-N followed by Ammonical-N and Total-N. Organic carbon ascribed direct negative effect on Available-N. Nitrate-N also ascribed positive indirect effect on Available-N via Ammonical-N. Whereas Total-N had positive indirect effect on Available-N via Organic carbon (Fig. 4.7.1 & Table: 4.7.1).

4.7.2; Phosphorus:

Saloid bound-P ascribed maximum direct positive effect

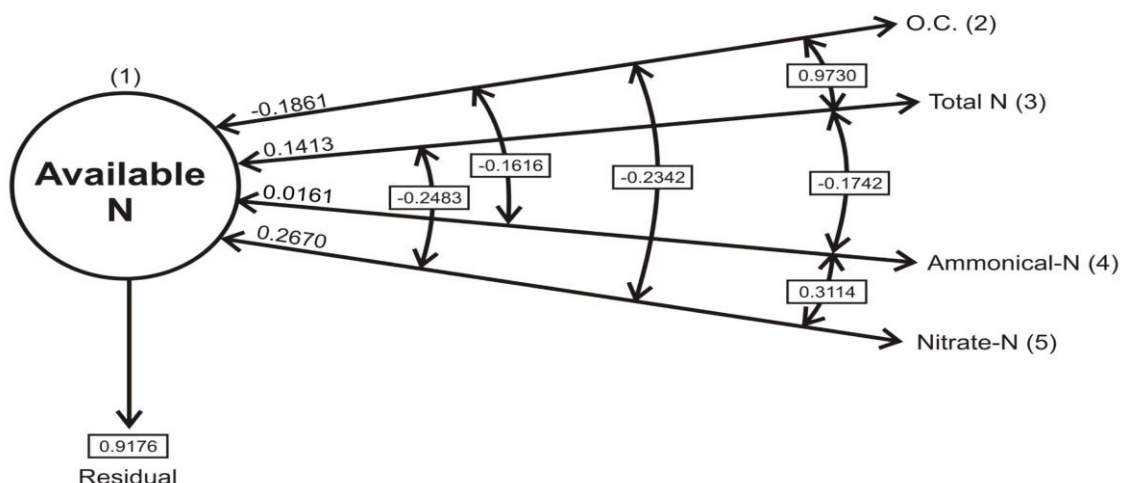


Fig. 4.7.1: Path diagram of the effect of different forms of N on available-N in LTFE soils.

Table-4.7.1: Matrix of direct and indirect effects: Direct effects on main diagonal (Nitrogen).

N-forms	O.C.	Total-N	Amm.-N	Nitrate-N
O.C.	-0.1861	0.1375	-0.0026	-0.0625
Total-N	-0.1810	0.1413	-0.0028	-0.0663
Amm.-N	0.0301	-0.0246	0.0161	0.0832
Nitrate-N	0.0436	-0.0351	0.0050	0.2670
Residual	0.9176			

on Available-P, followed by Ca-P, Occluded-P, Reductant soluble-P, Fe-P, Al-P, Total-P & Inorganic-P. Organic-P exhibited direct negative effect on Available-P. In case of indirect effect, Organic-P showed maximum positive indirect effect via Saloid-P & Total-P on Available-P (Fig. 4.7.2 & Table: 4.7.2).

Table- 4.7.2: Matrix of direct and indirect effects: Direct effects on main diagonal (Phosphorus).

P-forms	Inorg-P	Total-P	Saloid-P	Al-P	Fe-P	Reductant-P	Occluded-P	Ca-P	Org.-P
Inorg-P	0.0034	-0.0079	0.4880	0.0093	-0.1049	0.1094	0.0055	-0.2348	-0.0337
Total-P	0.0018	-0.0151	0.3891	0.0194	-0.1264	0.0876	-0.0176	-0.2739	-0.1258
Saloid-P	0.0019	-0.0066	0.8887	0.0031	-0.1006	0.0825	0.0160	-0.2218	-0.0408
Al-P	-0.0005	0.0048	-0.0459	-0.0609	0.0672	-0.0508	-0.0108	0.1709	0.0408
Fe-P	-0.0019	0.0102	-0.4772	-0.218	0.1874	-0.0992	0.0082	0.3598	0.0756
Reductant-P	0.0020	-0.0070	0.3855	0.0163	-0.0978	0.1901	0.0434	-0.2304	-0.0431
Occluded-P	0.0001	0.0014	0.0747	0.0034	0.0081	0.0432	0.1910	-0.0877	0.0151
Ca-P	-0.0018	0.0094	-0.4480	-0.0236	0.1533	-0.0996	-0.0381	0.4400	0.0691
Org.-P	0.0009	-0.0144	0.2761	0.0189	-0.1079	0.0623	-0.0219	-0.2313	-0.1314
Residual	0.3014								

4.7.3: Potassium:

The HNO_3 soluble-K form of potassium depicted maximum positive direct effect on Available- K_2O , followed by Available-K. HNO_3 soluble-K also exhibited maximum indirect positive effect on Available- K_2O via Available-K & Exchangeable-K. Whereas Reserve-K showed direct negative effect on Available- K_2O and it ascribed positive indirect effect on Available- K_2O via all other forms of potassium (Fig. 4.7.3 & Table: 4.7.3).

4.7.4: Sulphur:

Total-S ascribed maximum direct positive effect on Heat soluble-S (Av.-S). All other forms exhibited direct negative effect on Heat soluble-S, among them Water soluble & Sulphate-S had minimum direct negative effect on Heat soluble-S. Whereas most of the indirect effects of all fractions of sulphur on Heat soluble-S were recorded positive (Fig. 4.7.4 & Table: 4.7.4).

(b) Available forms of N, P, K, S to soil properties

4.7.5: Soil pH exhibited higher direct positive effect on available N, P, K & S forms then soil EC. Whereas in case of indirect effect there were found negative in all cases. (Fig. & Table 4.7.5 a, b, c, d).

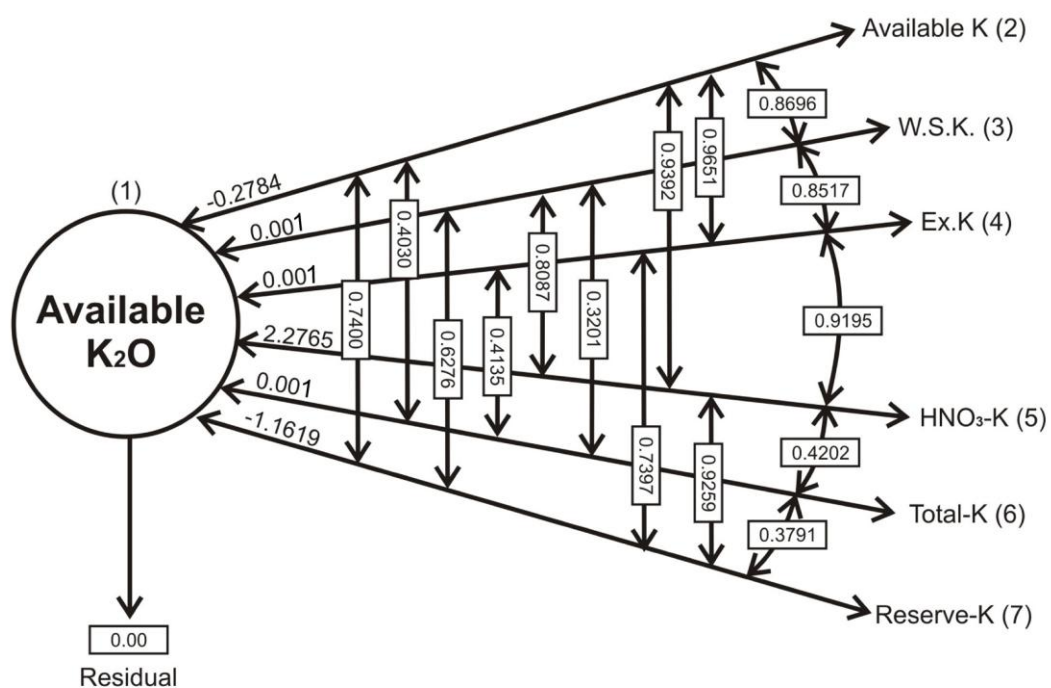


Fig. 4.7.3: Path diagram of the effect of different forms of K on available-K₂O in LTFE soils.

Table-4.7.3: Matrix of direct and indirect effects: Direct effects on main diagonal (Potassium).

K-forms	Av.-K	WS.K	Ex.-K	HNO ₃ -K	Total-K	Res.K
Av.-K	-0.2784	0.001	0.001	2.1381	0.001	-0.8598
WS.-K	-0.2421	0.001	0.001	1.8409	0.001	-0.7292
Ex.-K	-0.2687	0.001	0.001	2.0932	0.001	-0.8595
HNO ₃ -K	-0.2614	0.001	0.001	2.2765	0.001	-1.0758
Total-K	-0.1124	0.001	0.001	0.9566	0.001	-0.4405
Res.K	-0.2060	0.001	0.001	2.1078	0.001	-1.1619
Residual	0.00					

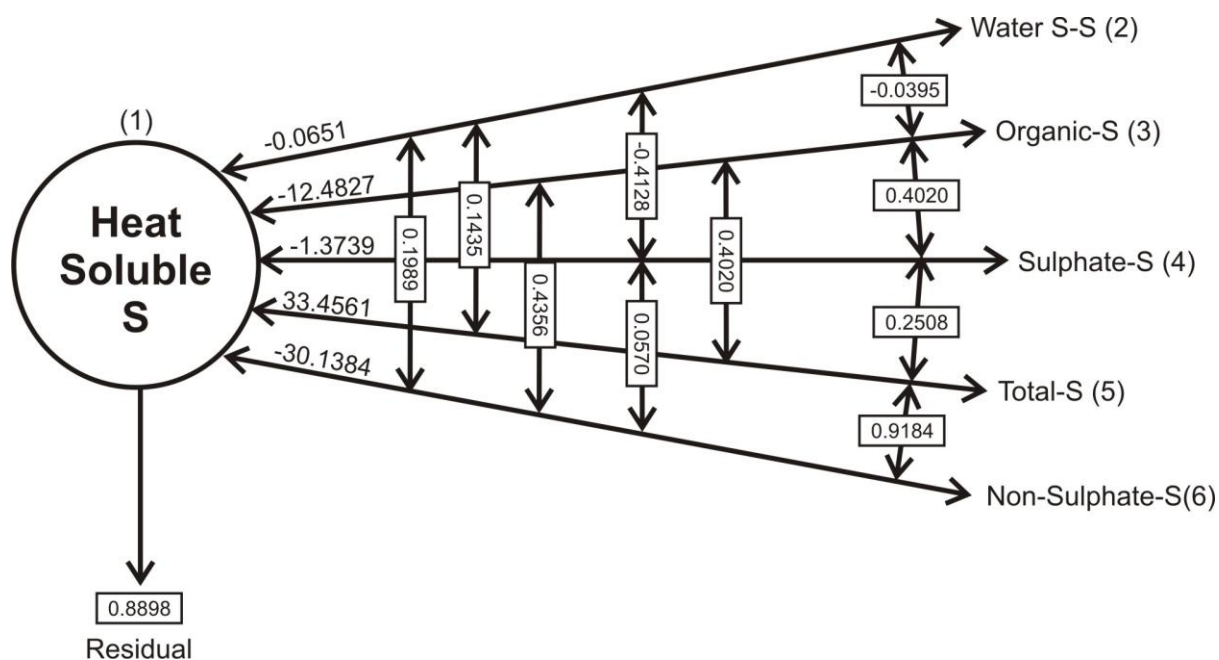


Fig. 4.7.4: Path diagram of the effect of different forms of S on H.S.S. in LTFE soils.

Table-4.7.4: Matrix of direct and indirect effects: Direct effects on main diagonal (sulphur).

S-forms	W.S.-S	Org.-S	Sulphate-S	Total-S	Non-Sul.- S
W.S.-S	-0.651	0.4928	0.5672	4.8013	-5.9950
Org.-S	0.0026	-12.4827	-0.05524	14.5750	-1.4086
Sulphate-S	0.0269	-5.0185	-1.3739	8.3919	-1.7174
Total-S	-0.0093	-5.4380	-0.3446	33.4561	-27.6780
Non-Sul.- S	-0.0129	-0.5834	-0.0783	30.7249	-30.1384
Residual	0.8898				

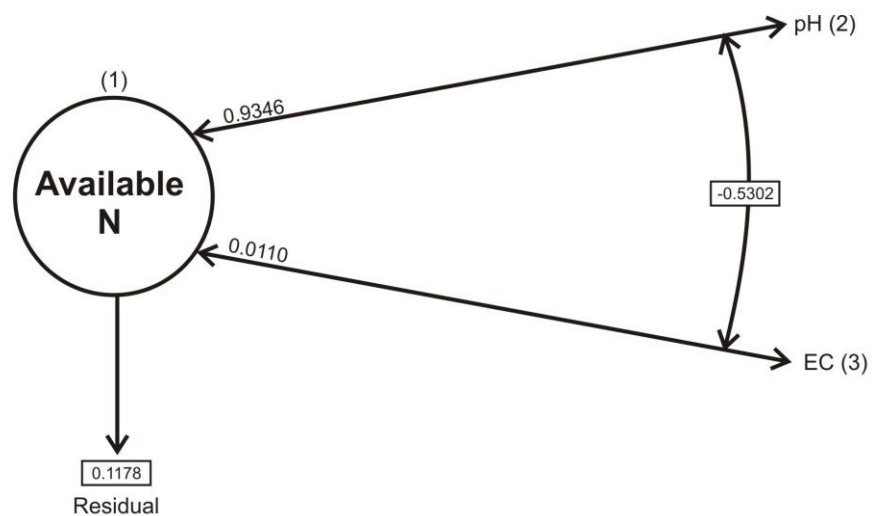


Fig. 4.7.5 a: Path diagram of the effect of soil properties (pH & EC) on available N in LTFE soils.

Table-4.7.5 a: Matrix of direct and indirect effects: Direct effects on main diagonal. (Soil properties to Av.-N)

Soil Properties	pH	EC
pH	0.9346	0.0046
EC	0.3927	0.0110
Residual	0.1178	

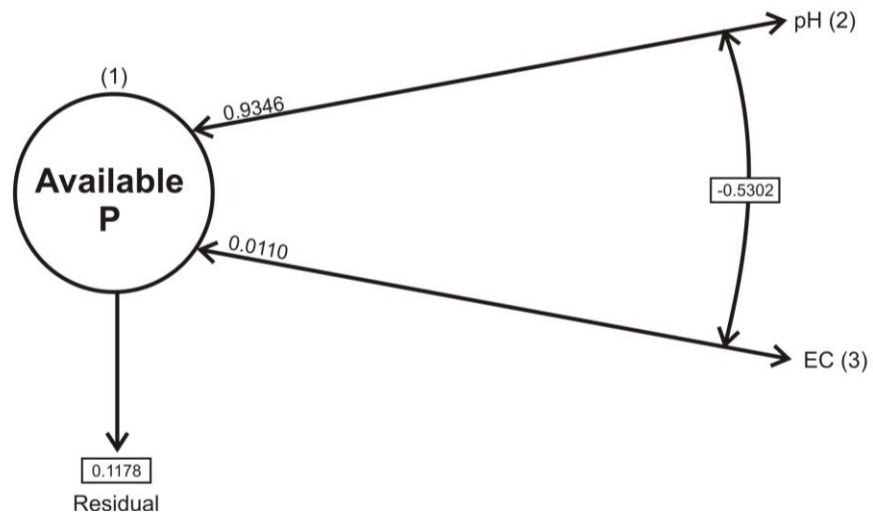


Fig. 4.7.5 b: Path diagram of the effect of soil properties (pH & EC) on Available P in LTFE soils.

Table-4.7.5 b: Matrix of direct and indirect effects: Direct effects on main diagonal. (Soil properties to Av.-P)

Soil Properties	pH	EC
pH	0.9346	0.0046
EC	0.3927	0.0110
Residual	0.1178	

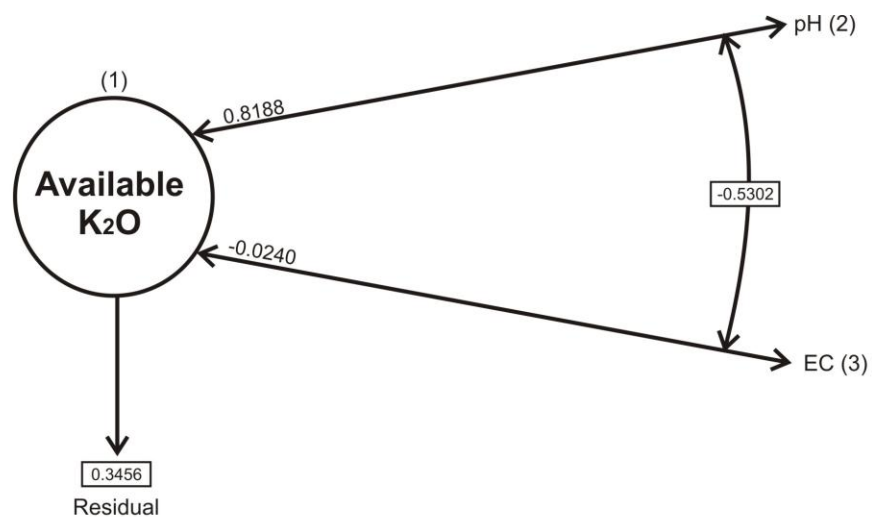


Fig. 4.7.5 c: Pathway diagram of the effect of soil properties on available K₂O in LTFE soils.

Table-4.7.5 c: Matrix of direct and indirect effects: Direct effects on main diagonal. (Soil properties to Av.-K)

Soil Properties	pH	EC
pH	0.8188	-0.0101
EC	0.3441	-0.0240
Residual	0.3456	

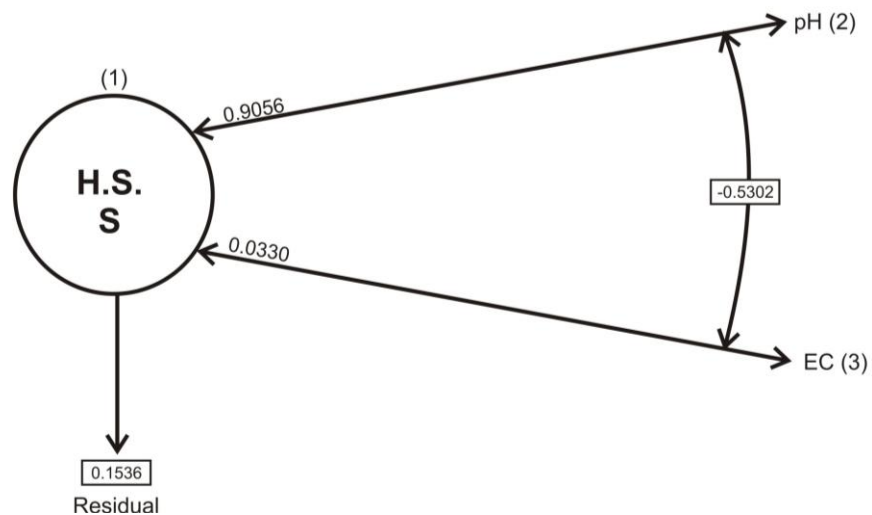


Fig. 4.7.5 d: Path diagram of the effect of soil properties (pH & EC) on available (heat soluble) S in LTFE soils.

Table-4.7.5 d: Matrix of direct and indirect effects: Direct effects on main diagonal. (Soil properties to Av.-S)

Soil Properties	pH	EC
pH	0.9056	0.0139
EC	0.3806	0.0330
Residual	0.1536	

CHAPTER - V

GENERAL DISCUSSION

The LTFE experiment initiated 8 years back on *Vertic Haplustepts* medium black clay 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 + FYM @ 10 t/ha to 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 + 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 SSP) 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 the nutrient fractions in soil and also depletion of the same in long term cycle after 4th and 8th years in LTFE soils.

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 sustained the crop yield (Sihag *et al*, 2005).

5.2.2: EFFECT OF TREATMENTS ON N, P, K, S CONTENT

In a long run, the treatment difference was not significant in pooled one in groundnut pod and haulm. The wheat grain N content 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 on its content in the plant. Overall phosphorus content in groundnut pod showed decreasing trend over time but in groundnut haulm after 4 year it was increased but after 8 year it was decreased (Table 4.09 and 4.0.10), while in wheat grain and straw P content showed increasing trend over time in phosphorus content. In groundnut, Phosphorus content decreased, while at same level its content in wheat increased within a period of 8 years. Potassium content in groundnut pod and haulm decreased after the span of 8 years. In wheat also K content marginally raised after 4th year and it declined there after 8th year and similar trend was also observed in sulphur content.

5.2.3: EFFECT OF LTFE TREATMENTS ON MAJOR NUTRIENT FRACTION AND THEIR RELATIONSHIPS

5.2.3.1: Nitrogen:

Total-N and Organic carbon status of LTFE soils increased after a span of 8 year. Increment was noted more in treatments which received FYM *i. e.* T₈ & T₉ (Fig. 4.1.1 & 4.1.2). The results were supported by the works of Fengmin *et al.*, (1998); they observed positive relationship of organic matter with Total-N content of soils. And Balaguravaih *et al.*, (2005) who found that application of FYM or groundnut shells alone improved the O. C. status marginally. Whereas Ammonical-N, Nitrate-N & Available-N status of LTFE soils decreased

on a long run, but Ammonical-N was increased in treatment which received 50 % NPK + Rhizobium+ PSM to groundnut & 100 % NPK to wheat *i. e.* T₁₀, it might be due to fixation of atmospheric nitrogen to the soil by microbes. Similar results were also observed in case of Nitrate-N status of LTFE soils, with overall decrease after a span of 8 years, but in T₁₀ it was slight increased (Fig. 4.1.3 & 4.1.4). It is interesting that both forms of nitrogen that is Ammonical & nitrate also marginally increased in T₇, which received only nitrogen of recommended doses of groundnut-wheat sequence. It might have been attributed to low uptake of particular nutrient due to low yield of crops in that treatment. These overall results were also in agreement with the work of earlier workers *viz.*, Sihag *et al.*, (2005) & Balagopalan *et al.*, (1986), who observed that surface soil samples showed decrease in NH₄-N and Balagopalan *et al.*, (1986) who also reported overall decreased of Nitrate-N in surface soil samples. In case of available-N status of LTFE soils, there was also overall decrease in status after a span of 8 year, but it was marginally increased in treatments which received FYM and NPK as per Soil Test (Fig. 4.1.5). This might be due to increase in organic matter content of soil due to application of FYM and fulfill crops requirement through Soil Test bases. This result was also in conformity with the finding of Varalakshmi *et al.*, (2005), who reported that Available-N significantly improved with the use of 100 % recommended fertilizer + 7.5 t FYM ha⁻¹ in groundnut-finger millet cropping system.

In LTFE soils the per cent depletion of different forms of nitrogen was interesting under all treatments. The Total-N & O. C. showed negative depletion after a span of 8 year and Available-N exhibited positive depletion in all treatments. This means increase in status of Total-N & O. C., but decreased in status of Available-N. It might

be due to uptake of Available-N by 16 crops. The status of Ammonical-N showed mixed trend and Nitrate-N showed positive depletion in most of the treatments except, T₁ & T₁₀ (Table: 4.1.4 & Fig. 4.1.4). The maximum depletion of Available-N was noted in T₁₂ (control), it might be due to continuous removal of N by crops without fertilizer N from outside. There was also negative depletion in T₈ & T₉ due to application of FYM which sustain soil fertility.

Distribution of different forms of N in LTFE soils showed maximum percent of nitrogen distributed as in Available form followed by Ammonical-N and minimum as Nitrate-N. It might be due to the crops uptake of nitrogen as in Nitrate form, as presented in Fig. 4.1.7 a & b *i. e.* at initial stage the highest content of Nitrate-N was recorded in T₁₁ but after 4th and 8th it was recorded in T₇ in which crop uptake was less due to low yield.

The Available-N ascribed significant positive relationship only with Nitrate-N and also non-significant positive relationship with Ammonical-N. This relationship conforms that only Nitrate & Ammonical fractions of N are important for plant available nitrogen. (Table: 4.5.1). The available -N & Ammonical-N also exhibited positive relationship with groundnut pod & haulm yield, while negative with wheat yield. So Available-N, Nitrate-N and Ammonical-N were important for yield of groundnut crop (Table: 4.5.3). Available form also exhibited significant positive relationship with soil pH & negative with soil EC (Table: 4.5.5). Nitrate-N & Ammonical-N also followed same trend, while O. C. & Total-N exhibited reverse trend in relationship with soil pH & EC. (Table: 4.5.5). Available-N ascribed significant positive relationship with N content of grain, S content of grain and straw, while it showed negative relationship with N content of haulm, P content of

haulm and P content of wheat grain (Table: 4.5.6). The stepwise regression of Available-N with its forms explained the variation in form up to 8 per cent. Total-N & Nitrate-N forms influenced Available-N to the maximum. Soil pH had more influence on Available-N (Table: 4.6.1). In path analysis Ammonical-N & Nitrate-N ascribed direct & indirect positive effect on Available-N. Soil pH had also direct positive effect on Available-N (Table: 4.7.1, 4.7.5 a & Fig. 4.7.1, 4.7.5 a).

5.2.3.2: Phosphorus:

Overall Inorganic-P fraction of LTFE soil was similar at initial stage of the experiment and it showed non-significant variation within treatments. After 4th & 8th years it showed significant variation due to various treatments and it was recorded highest in T₈ (FYM @ 10 t ha⁻¹) after 8th year. There was overall increase in Inorganic-P status of soils after a span of 8 years, increment was highest in plot under T₈ (FYM @ 10 t ha⁻¹). Similar result was also reported by Gupta *et al.*, (1999) that application of P alone and combination with FYM increased the content of Total-P and different P fractions (Table & Fig. 4.2.1). Total-P status was found significantly variable in 1st year & it also remain variable after 4th year and subsequently that variation became non-significant after 8th year and also non-significant when pooled over years (Table & Fig. 4.2.2). At initial stage the highest value of Total-P recorded in plot of T₇, after word it recorded highest in the T₈ (4th year). Overall there was increase in Total-P status of soil after 4th year, but slight decrease in the status was recorded after 8th year as compared to 4th year, except in T₅ & T₆. These results were confirmative with finding of Rahate *et al.*, (1979), who reported that the buildup of Total-P was significant when P fertilizers were applied along with FYM. The iron bound-P (Fe-P) status of LTFE soils drastically decreased after a span of 4 year and then it remained

somewhat stable, it might due to inter conversion of Fe-P to other fractions of phosphorus like Reductant soluble-P. Similar results also recorded by Setia and Sharma (2007) that the N & P application caused decreased in P fraction. There was overall increase in Reductant soluble-P status of LTFE soils after 4th and 8th year and also found significantly highest after 8th year in T₉ which received FYM @ 25 t ha⁻¹ to groundnut only. Similar trend was also observed by Sihag *et al.*, (2005) who recorded highest amount of all the form of P under farm yard manure. The Y x T interaction was also found significant (Table & Fig. 4.2.4). There was overall increase in Occluded-P fraction after 8 year and maximum increase (almost double) was recorded in T₉ (Table & Fig. 4.2.5). The treatment wise variation after 4th and 8th year was found significant and was highest in T₉. In case of Ca-P status, overall decrease was found after 4th & 8th year of the experiment as compared to initial status. The Ca-P status was also significantly affected due to treatments and the highest Ca-P after 4th year was recorded under the T₈ (10 t FYM ha⁻¹), Sihag *et al.*, (2005) also reported that the amount of P recovered in Ca-P form increased significantly with the application of inorganic fertilizers and their combined use with organic materials over control (Table & fig. 4.2.6). There was overall increase in the status of Organic-P (table & Fig. 4.2.7). It also showed significant differences due to application of various fertilizer doses after 4th & 8th year of the experimentation. In all treatment combinations, there was increase in the status of this fraction after 4th year as compared to initial status and after that at 8th year slight decrease was observed in the status as compared to 4th year, but it was higher than initial status, except in T₇ where marginal decreased in status of Organic-P after 4th & 8th year as compared to initial status. It might be attributed to no addition of phosphorus as a fertilizer and low incorporation of

biomass due to low yield & crop growth in that particular treatment. Similar results were also reported by Gupta *et al.*, (1999) that the application of P alone and combination with FYM increased the content of different-P fractions. There was three fold increment in Saloid bound-P noted in LTFE soil after 4th & 8th year as compared to initial status, it might be due to interchange among different fractions of phosphorus. Saloid bound-P was significantly recorded highest in T₈ (10 t FYM ha⁻¹) after 4 year of experiment, Gupta *et al.*,(1999) also reported that application of P in combination with FYM increased the content of different fractions of P (Table & Fig. 4.2.8). There was overall decrease in Al-P status of LTFE soils (Table & Fig. 4.2.9). The Al-P fraction was also significantly affected by various treatments and it was found significantly highest in T₂, but it was at par with T₉ after 4th year and in T₈ after 8th year, it was at par with T₃, which might be due to application of FYM that release some organic acid in soil (Table & Fig. 4.2.9). There was overall decrease in Available-P status of soil except in T₈ & T₉ which received FYM (Table & Fig. 4.2.10). After 4th & 8th year of experiment, significantly the highest value of this fraction was recorded in T₉ followed by T₈ (25 t FYM to groundnut only and FYM @ 10 t ha⁻¹ + 50 % NPK of RD to groundnut & 100 % NPK of RD to wheat). It might be due to release of organic acid from FYM which convert fixed phosphorus in available form. Similar results were also reported by Tripathi and Minhas (1991) that addition of FYM increased transformation of phosphorus.

After a span of 8 years most of the fractions of phosphorus depleted negatively i. e. increased in status, but there was also found positive depletion in case of Al-P, Fe-P, Ca-P & available-P, it might be attributed to transformation of phosphorus and plant uptake as

an Available-P. Application of FYM also prevents depletion in Available-P status of soil (Table & Fig. 4.2.11).

The Ca-P fraction was recorded higher in proportion as compared to other fraction at initial stage, but after 4th & 8th year Reductant soluble-P fraction recorded higher in proportion as compared to other fractions. Saloid-P proportion at initial stage was about 1-2 %, but it was increased to around 4-5 % after 4th & 8th year. Occluded-P was recorded around 2 % in proportion (Fig. 4.2.12 a, b).

Available-P form significantly correlated with Inorganic-P, Saloid bound-P, Reductant-P & Occluded-P. It signified the importance of inorganic-P, Saloid bound-P, Reductant-P & Occluded-P in maintaining availability status of phosphorus in soils (Table: 4.5.2). Available-P and all other fractions of phosphorus exhibited significant positive relationship with wheat yield and most of the fractions except Ca-P showed negative relationship with groundnut yield. These results explained importance of all fractions for wheat yield & Ca-P for groundnut yield (Table: 4.5.3). Except Ca-P fraction, all other fractions exhibited significant negative relationship with soil pH, so soil pH play important role in phosphorus balance in LTFE soils. Available-P ascribed negative relationship with soil EC (Table: 4.5.5). Available-P status of soil also ascribed significant positive relationship with K content of groundnut pod & haulm and N, P, K content of wheat straw. Inorganic-P, Total-P & Saloid bound-P ascribed positive relationship with most of the N, P, K, S content in groundnut & wheat, except P content of groundnut pod, N content of wheat grain & S content of wheat grain & straw (Table: 4.5.7 a, b). In stepwise regression Fe-P fraction influenced more on available-P (Table: 4.6.1) and soil pH had also more influence on Available-P then EC. In path analysis except Organic-P fraction all other

fractions ascribed maximum direct positive effect on Available-P status of LTFE soil, while indirect effect on Available-P was exhibited maximum by Organic-P via Saloid-P (Table & Fig. 4.7.2). Soil pH also ascribed direct positive effect on Available-P and it was more than effect of soil EC on available-P (Table & Fig. 4.7.5 b).

5.2.3.3: Potassium:

There was overall decrease in Available-K₂O status of LTFE soils after 8 year, except in treatments which received FYM (T₈ & T₉), where K₂O status of soil increased as compared to initial status. So for maintaining available potassium level in soil, application of organic manure is essential. Balaguravaih *et al.*, (2005) found similar result that potassium availability however decreased over initial level 155 kg ha⁻¹ in all treatments except in those which received FYM and Santhy *et al.*, (1998) also observed similar trend that Available-K was negatively balanced due to continuous cropping with a decrease of 22 % from initial level. Similar results were also depicted in case of available-K status of LTFE soils (Table & Fig. 4.3.1 & 4.3.2). Water soluble-K also decreased in LTFE soil after a span of 8 years, except in treatments which received FYM (T₈ & T₉), here also approved that for maintaining K fertility of soil at long run, it is essential to add organic fertilizer with inorganic one (Table & Fig 4.3.3). Patel *et al.*, (1986) also reported that 72 % of WSK was decreased due to intensive cropping of groundnut-wheat sequence in medium black calcareous soils. Same results were also recorded in case of Exchangeable-K, HNO₃ soluble-K, Reserve-K and Total-K. In fact, all fractions of potassium decreased after a long run in intensive cropping of LTFE soils without addition of FYM. So it is alarming us to use organic fertilizer with inorganic one for maintaining K fertility status of soil in long run (Fig. & Table: 4.3.4, 4.3.5, 4.3.6, 4.3.7).

Per cent depletion of all form of potassium were interesting that in all treatments all forms of potassium depleted very much except in treatments which received FYM (T8 & T9) (Table & Fig. 4.3.8), where rather than depletion, increment was noticed. So it is essential to use of FYM with inorganic fertilizers to maintain K fertility status of soil in long run (Table & Fig. 4.3.8).

Distribution of potassium fractions in LTFE soils was in order of $\text{HNO}_3\text{-K} > \text{Av.-K} \geq \text{Ex.-K} > \text{Res.-K} > \text{WS.-K}$. There was no change in percent distribution of various form of K among treatments and with advancement of period of experiment (Fig. 4.3.9)

Available- K_2O status of LTFE soils exhibited significant positive relationship with all other forms of potassium (table: 4.5.1). So, all forms of potassium were important for maintaining availability of K to the particular crop. Exchangeable-K ascribed maximum relationship with Available- K_2O than other forms. Most of the fractions of potassium ascribed positive relationship with groundnut yield (Table: 4.5.4). All forms of K ascribed significant positive relationship with soil pH & negative with soil EC (Table: 4.5.5). Whereas in case of N, P, K, S content of groundnut & wheat most of the fractions of K showed positive relationship (Table: 4.5.8 a, b). In stepwise regression all independent variable, Av.-K, WS.-K, Ex.-K, $\text{HNO}_3\text{-K}$, Total-K & Res.-K had similar influence on Av.- K_2O (Table: 4.6.1). In path analysis, $\text{HNO}_3\text{-K}$ had maximum direct positive effect on Available- K_2O (Fig. & Table: 4.7.3). Soil pH also exhibited higher direct positive effect than soil EC on available- K_2O (Fig & Table: 4.7.5 c).

5.2.3.4: Sulphur:

Water soluble fraction of sulphur declined very much after 8 years of groundnut-wheat cropping sequence as compared to

initial status, but it remained stable in treatments T_4 & T_{11} which received sulphur from outside sources like $ZnSO_4$ & SSP (Table & Fig. 4.4.1). These results are supported by the finding of Alok *et al.*, (2002) who reported that the omission of S in the fertilizer schedule has caused a continuous depletion in available S status of soil. Whereas organic-S status of LTFE soils increased after a span of 8 years, it might be due to incorporation of plant residues to the soils from crop roots and stubbles. Sulphate-S in LTFE soils increased after 4th year and then remained stable except in T_2 & T_3 where depletion in this fraction was noticed perhaps due to the interaction with phosphorus (Fig. & Table: 4.4.3). Similar trend was also observed by Setia & Sharma (2005) who observed that the amount of all the fractions of S decreased due to application of 80 Kg P_2O_5 ha⁻¹, irrespective of N levels. Non-sulphate-S fraction found significantly the highest in the treatments which received sulphur from outside as $ZnSO_4$ & SSP (T_4 & T_{11}) (Fig. & Table: 4.4.4). In case of Heat soluble-S, there was overall decrease in soil status after 4th year as compared to initial status and after word it maintain level with initial status, but in treatments of FYM & SSP it was increased as compared to initial status after 8th year of experiment (Table & Fig. 4.4.5). Whereas Total-S status of LTFE soil increased after a span of 8 years. The increment was more in treatments which were received sulphur from fertilizer sources *i. e.* T_4 & T_{11} (Table & Fig. 4.4.6).

Depletion percent of sulphur noted positive in case of Water soluble-S and it was negative or very low in treatments which received sulphur from fertilizers *i. e.* T_{11} & T_4 . Most of the other fractions of sulphur were not depleted in most of the treatments (Table & Fig. 4.4.7).

Organic & Non-sulphate fractions of S were found more in proportion (20-60 %) followed by Heat soluble-S (10 %), water soluble & sulphate-S, the latter were found in very low proportion i. e. around 3-10 % in LTFE soils (Fig. 4.4.8).

Heat soluble-S (Av. S) exhibited significant positive relationship with Water soluble-S & Sulphate-S, which signified importance of WS-S & Sulphate-S to the plant available sulphur (Table: 4.5.1). Water soluble-S also ascribed significant positive relationship with groundnut yield & negative with wheat yield, signifying the importance of this fraction for the yield of groundnut (Table: 4.5.4). Water soluble-S fraction also showed significant positive relationship with soil pH & negative with soil EC (Table: 4.5.5). Water soluble-S & Organic-S exhibited significant positive relationship with N, P, K, S content of groundnut & wheat in most of the cases (Table: 4.5.9 a, b). In stepwise regression, among the independent variable the Sulphate-S had maximum influence on Heat soluble-S (Table: 4.6.1) and soil EC had more influence on Heat soluble-S than soil pH. In path analysis, Total-S ascribed maximum direct positive effect on Heat soluble-S (Av. S). Most of the indirect effects of all fractions of S on Heat soluble-S were recorded positive (Table & Fig. 4.7.4). Soil pH exhibited higher direct positive effect on Heat soluble-S than EC (table & Fig. 4.7.5 d).

5.2.4: correlation between forms of different major nutrients:

Available nitrogen exhibited positive relationship with Ca-P, available-P, Fe-P & negative with Inorganic-P. Available-N status of LTFE soils also ascribed significant positive relationship with all fractions of potassium. Whereas Available-N exhibited significant negative relationship with organic & Sulphate fractions of sulphur. Available-P & Ca-P also exhibited significant positive relationship with all forms of

potassium. Whereas Inorganic-P fraction ascribed significant positive relationship with Available-K₂O & K. Available-P also exhibited significant positive relationship only with sulphate-S and Available-K₂O & K ascribed significant positive relationship only with water soluble-S fraction (Table: 4.5.10, 4.5.11, 4.5.12, 4.5.13, 4.5.14).

CHAPTER - VI

SUMMARY AND CONCLUSION

During past period of research on major nutrients in soils a least information was available about different forms of major nutrients and it's dynamic in LTFE soils. Most of the research information related to available forms of major nutrients was from short-term studies. Cultivating soil during long period of time is changing major nutrient resources. The nutrient losses from soil are, in fact gradual and some times hidden. It is therefore not easy to recognize and understand the physical, chemical and biological processes leading to such major nutrient constrains in sustaining soil health and productivity in major soil cropping system of the sub-agro-ecological zones. In view of the growing concept of sustaining soil health, the research work on the following areas had been taken up.

- (1) To know the status of major nutrients (N, P, K, S) fractions in soils under AICRP- LTFE soil.
- (2) To find out the depletion of major nutrients fractions in the soil under investigation.
- (3) Modeling the dynamics of major nutrient fractions in LTFE soils.

The LTFE experiment initiated 8 years back on *Vertic Haplustepts* medium black clay 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 + FYM @ 10 t/ha to 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 SSP) 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 the nutrient fractions in soil and also depletion of the same in long term cycle after 4th and 8th years in LTFE soils.

6.0.1 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 sustained the crop yield.

6.0.2 N Content:

After a long run, T₃ registered the highest concentration of N 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 years the effects of the treatments were non-significant in nitrogen concentration both for groundnut and wheat.

6.0.3 P content:

In groundnut pod, phosphorus concentration decreased while in haulm increased likewise 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.

6.0.4 K content:

The concentration of potassium 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.

6.0.5 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.

6.1 Nitrogen:

At initial stage of experiment (1st year) available nitrogen status of LTFE soils falls under medium range (250-500 kg N ha⁻¹), but after 4th year it decreased to lower range (<250 Kg N ha⁻¹) in most of the treatments and then after 8th year all treatments exhibited low range of available nitrogen status in soil, except treatments which received FYM (T₈ & T₉) which showed medium range in available-N status of LTFE soils. It was established here that for maintaining N fertility of soil at long run, addition of FYM is essential with inorganic fertilizers. There was overall decreased in Ammonical & Nitrate nitrogen forms in all treatments, but increment was observed in T₁₀ (50 % NPK of RDF + Rhizobium + PSM), which has been attributed to fixation of atmospheric nitrogen by Rhizobium bacteria.

6.2 Phosphorus:

Available-P status of LTFE soil at Initial stage was low in category ($<28 \text{ Kg P}_2\text{O}_5 \text{ ha}^{-1}$) in most of the treatments, after long run (8th year) it was more decreased except in treatments which were received FYM (T₈ & T₉). Due to application of FYM available status of P_2O_5 in LTFE soil increased up to high category ($> 56 \text{ Kg P}_2\text{O}_5 \text{ ha}^{-1}$) from low category. There were overall increased in Inorganic-P & Total-P status of LTFE soils, but status of Available-P was decreased, which might be due to calcareousness of soil, which fixed phosphorus that applied as a fertilizers and transformed it in unavailable form to the plant, because of this reaction, available status of LTFE soil decreased, except in treatments where application of FYM was there due to chelating effect of organic material which protect available-P form to fixed in unavailable form.

6.3 Potassium:

At initial stage of experiment (1st year) available- K_2O status of LTFE soils showed high category ($> 280 \text{ Kg K}_2\text{O ha}^{-1}$), but after long run (8th year) it decreased to medium category ($140\text{-}280 \text{ Kg K}_2\text{O ha}^{-1}$), except in treatment of FYM application (T₈ & T₉), where increment in K_2O level was found rather than its depletion. Further it was established that, FYM is essential for maintaining soil fertility at long run. Similar results were also recorded in case of all other fractions of potassium.

6.4 Sulphur:

Total-S content of LTFE soils increased after a span of 8 years, but it was reversed in case of heat soluble-S, that was decreased after 8 years, except in treatments which received FYM & Inorganic-P as a SSP (13 % S). It was required to apply S fertilization every year & application of FYM for maintaining available status of soils at long run.

6.5 Percent distribution in different forms of major nutrients in LTFE soils:

The available form of nitrogen found in maximum proportion followed by Ammonical form and minimum was in Nitrate form.

At initial stage of the experiment, maximum proportion of phosphorus was recorded as a Ca-P fraction, after 8th year it was changed and maximum proportion was found as a Reductant soluble-P. Whereas Available-P form recorded around 1-2 % in proportion.

Percent distribution of potassium in different forms found in order of HNO_3 soluble-K > Available-K $\geq$ Exchangeable-K > Reserve-K > WS-K. HNO_3 soluble-K recorded round about 40 % in proportion and Available-K & exchangeable-K around 22 % in proportion in LTFE soils.

Heat soluble-S (Available-S) fraction of sulphur recorded about 10 % in proportion, while maximum proportion was recorded as a Non-sulphate-S & Organic-S form of sulphur (20-60 %). Water soluble & sulphate-S forms found around 3-10 % in proportion in LTFE soils.

6.6 Correlation matrix:

6.6.1 Among different forms of individual major nutrients:

The available-N form exhibited positive relationship with Nitrate-N & Ammonical-N. Whereas Available-P showed significant positive relationship with Inorganic-P, Saloid bound-P, Reductant-P & occluded-P forms. Available- K_2O form of potassium depicted significant positive relationship with all other forms of potassium, while Heat soluble-S (Available-S) form of sulphur revealed significant relationship only with Water soluble-S & Sulphate-S.

6.6.2 Correlation with yield:

The Available-N & Ammonical fractions of nitrogen were ascribed positive relationship with groundnut pod & haulm, while negative with wheat yield.

Available-P & all other forms of P exhibited significant positive relationship with wheat yield & most of the P fractions, except Ca-P ascribed negative relationship with groundnut yield.

Most of the fractions of potassium ascribed positive relationship with groundnut yield.

Water soluble-S form also ascribed significant positive relationship with groundnut yield and negative with wheat yield.

6.6.3 Correlation with soil properties:

Available-N and Available-K ascribed significant positive relationship with soil pH & negative with soil EC. Whereas available-P and Available-S (Heat soluble-S) showed negative relationship with soil pH and positive with soil EC.

6.6.4 Correlation between N, P, K, S content in crops & forms:

Available-N exhibited significantly positive relationship with P content of pod, K content of haulm, N content of grain & S content of grain and straw.

Available-P status of soils ascribed significant positive relationship with K content of groundnut pod & haulm and N, P, K content of wheat straw.

Most of the fractions of K revealed positive relationship with N, P, K, S content of groundnut & wheat.

Heat soluble sulphur exhibited significant positive relationship with P content of wheat straw, while with other mostly it exhibited negative relationship.

6.6.5 Correlation between interaction of two major nutrients forms:

Available-N ascribed positive relationship with Ca-P, Available-P, Fe-P and negative with Inorganic-P and it exhibited positive with all

fractions of potassium, whereas it showed significant negative relationship with organic & sulphate forms of sulphur.

Available P_2O_5 also revealed positive relationship with all forms of potassium and sulphate-S form of sulphur.

Available- K_2O exhibited significant positive relationship only with water soluble form of sulphur.

6.7 Pooled regression and stepwise regression analysis:

The available major nutrients influenced by other forms were subjected to stepwise regression and multiple correlation and regression analysis. The prediction model was based on multiple and correlation analysis over a cycle of 1, 4 and 8 years. Total-N & Nitrate-N influenced on Available-N to maximum extent. The Fe-P influenced maximum on available-P followed by Total-P, Saloid-P, Occluded-P & Reductant-P. All forms of K influenced on available- K_2O to same extent. Sulphate-S had maximum influenced on Heat soluble-S (Available-S).

Soil pH influenced more than soil EC on Available N, P, K & S.

6.8 Path analysis:

The Nitrate-N and Ammonical-N forms of nitrogen exhibited maximum direct positive effect on Available-N, while O.C. ascribed direct negative effect on Available-N.

Saloid bound-P ascribed maximum direct positive effect on Available-P and Organic-P exhibited direct negative effect on Available-P.

The HNO_3 soluble-K form of potassium exhibited maximum positive direct & indirect effects on Available- K_2O , while Reserve-K showed negative direct effect on available- K_2O .

Total-S ascribed maximum direct positive effect on Heat soluble-S (Available-S), while all other forms exhibited direct negative effect on it.

Soil pH ascribed higher direct positive effect on Available N, P, K & S than soil EC.

Conclusion:

It has been deduced from the Long Term Fertilizer Experiment (LTFE) in Junagadh constituting medium black calcareous soil derived from Trap basalt that the crop available forms of the major nutrients *viz.* nitrogen, phosphorus, potassium & sulphur ascribed depletion over time irrespective of fertilizer treatments, except in treatments which received FYM along with inorganic fertilizers. Application of FYM not only sustains fertility, but also increases soil fertility status as like here in P_2O_5 status of the LTFE soil in treatments which received FYM, increased available-P status in LTFE soils from low category to high category.

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

The dynamics of major nutrients along with their forms exhibited variable trend, in general some forms exhibited negative trend and some of them ascribed positive trend with varying magnitude according to the soil.

Based on the multiple correlation and regression analysis the prediction model for available major nutrients was presented. The total form in case of nitrogen, the Fe-P form in case of phosphorus, all forms in case of potassium & sulphate-s form in case of sulphur had the maximum influence on Available forms of major nutrients. Whereas soil pH & EC exhibited low effect on available forms of N, P, K, S.

The path co-efficient analysis of available major nutrients as influenced by various forms ascribed that Nitrate, Ammonical and Total-N forms of nitrogen had direct positive effect on Available-N, Saloid bound-P had exhibited maximum direct effect on Available-P. HNO_3 soluble-K depicted maximum direct effect on Available- K_2O and Total-S ascribed maximum direct effect on Heat soluble-S (Available-S). Soil pH had more impact on Available forms of N, P, K & S than soil EC.

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*** Original not seen.**

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	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

	T11/IV																				
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 Nitrogen in LTFE experimental soils of 1st, 4th and 8th cycles of groundnut and wheat crop sequence

Sr. no.	Treatment	O.C. (%)	Tot.N(%)	Amm.N(%)	Nitra.-N(%)	Av.-N(kg/ha)
1	101 T1/I	0.99	0.0853	29	12	277.536
2	102 T1/II	0.51	0.044	33	13	285.376
3	103 T1/III	0.45	0.0388	27	12	238.336
4	104 T1/IV	0.51	0.044	27	12	210.112
5	105 T2/I	0.66	0.0568	46	22	370.048
6	106 T2/II	0.48	0.0414	42	23	277.536
7	107 T2/III	0.51	0.044	35	19	244.608
8	108 T2/IV	0.54	0.0465	38	20	293.216
9	109 T3/I	0.54	0.0465	76	26	261.856
10	110 T3/II	0.45	0.0388	77	29	260.288
11	111 T3/III	0.51	0.044	64	28	213.248
12	112 T3/IV	0.54	0.0465	70	25	261.856
13	113 T4/I	0.6	0.0517	28	22	214.816
14	114 T4/II	0.48	0.0414	32	21	327.712
15	115 T4/III	0.6	0.0517	28	22	243.04
16	116 T4/IV	0.54	0.0465	24	19	264.992
17	117 T5/I	0.42	0.0362	28	28	235.2
18	118 T5/II	0.6	0.0517	29	27	227.36
19	119 T5/III	0.51	0.044	34	27	249.312
20	120 T5/IV	0.57	0.0491	28	30	232.064
21	121 T6/I	0.69	0.0594	81	22	249.312
22	122 T6/II	0.51	0.044	67	21	312.032
23	123 T6/III	0.57	0.0491	69	22	250.88
24	124 T6/IV	0.63	0.0543	67	26	233.632
25	125 T7/I	0.45	0.0387	34	37	271.264
26	126 T7/II	0.54	0.0465	30	37	302.624
27	127 T7/III	0.54	0.0465	34	33	294.784
28	128 T7/IV	0.51	0.044	28	33	330.848
29	129 T8/I	0.6	0.0517	31	34	305.76
30	130 T8/II	0.6	0.0517	39	30	238.336
31	131 T8/III	0.48	0.0414	35	34	261.856
32	132 T8/IV	0.57	0.0491	35	26	250.88
33	133 T9/I	0.48	0.0413	55	35	283.808
34	134 T9/II	0.51	0.044	53	39	258.72
35	135 T9/III	0.48	0.0414	53	27	268.128
36	136 T9/IV	0.63	0.0543	56	39	235.2
37	137 T10/I	0.51	0.0439	35	29	260.288
38	138 T10/II	0.51	0.044	29	34	333.984

39	139 T10/III	0.66	0.0569	34	27	326.144
40	140 T10/IV	0.57	0.0491	42	29	247.744
41	141 T11/I	0.54	0.0465	54	44	238.336
42	142 T11/II	0.45	0.0388	58	37	246.176
43	143 T11/III	0.63	0.0543	49	42	442.176
44	144 T11/IV	0.63	0.0543	63	45	241.472
45	145 T12/I	0.51	0.044	37	40	257.152
46	146 T12/II	0.54	0.0465	40	28	263.424
47	147 T12/III	0.54	0.0465	49	36	385.728
48	148 T12/IV	0.57	0.0491	28	39	239.904
49	201 T1/I	0.72	0.0621	67	14	216.384
50	202 T1/II	0.66	0.0569	56	15	271.264
51	203 T1/III	0.63	0.0543	52	14	255.584
52	204 T1/IV	0.87	0.075	63	15	268.128
53	205 T2/I	0.69	0.0595	50	7	390.432
54	206 T2/II	0.48	0.0414	45	7	236.768
55	207 T2/III	0.66	0.0569	47	7	227.36
56	208 T2/IV	0.63	0.0543	47	7	203.84
57	209 T3/I	0.66	0.0569	54	10	277.536
58	210 T3/II	0.6	0.0517	58	10	236.768
59	211 T3/III	0.6	0.0517	47	11	236.768
60	212 T3/IV	0.69	0.0595	37	11	119.168
61	213 T4/I	0.63	0.0543	58	24	343.392
62	214 T4/II	0.57	0.0491	56	22	238.336
63	215 T4/III	0.63	0.0543	56	25	313.6
64	216 T4/IV	0.66	0.0569	47	26	249.312
65	217 T5/I	0.42	0.0362	42	11	239.904
66	218 T5/II	0.57	0.0491	37	10	206.976
67	219 T5/III	0.6	0.0517	40	10	202.272
68	220 T5/IV	0.54	0.0465	42	11	228.928
69	221 T6/I	0.81	0.0698	26	15	203.84
70	222 T6/II	0.66	0.0569	21	11	261.856
71	223 T6/III	0.45	0.0388	23	11	277.536
72	224 T6/IV	0.99	0.0853	27	12	272.832
73	225 T7/I	0.57	0.0491	56	35	214.816
74	226 T7/II	0.6	0.0517	49	24	210.112
75	227 T7/III	0.69	0.0595	42	27	280.672
76	228 T7/IV	0.96	0.0827	49	26	280.672
77	229 T8/I	0.75	0.0646	50	7	261.856
78	230 T8/II	0.72	0.0621	43	7	224.224
79	231 T8/III	0.69	0.0595	44	7	301.056
80	232 T8/IV	0.75	0.0646	38	7	243.04
81	233 T9/I	0.78	0.0672	36	10	232.064
82	234 T9/II	0.78	0.0672	35	10	315.168
83	235 T9/III	0.75	0.0646	31	14	236.768

84	236 T9/IV	0.87	0.075	31	15	282.24
85	237 T10/I	0.54	0.0495	56	25	222.656
86	238 T10/II	0.42	0.0362	43	29	214.816
87	239 T10/III	0.63	0.0543	40	21	315.168
88	240 T10/IV	0.66	0.0569	40	30	302.624
89	241 T11/I	0.57	0.0491	21	7	199.136
90	242 T11/II	0.36	0.031	27	7	258.72
91	243 T11/III	0.6	0.0517	21	7	225.792
92	244 T11/IV	0.6	0.0517	27	7	258.72
93	245 T12/I	0.54	0.0465	17	12	216.384
94	246 T12/II	0.63	0.0543	19	12	210.112
95	247 T12/III	0.66	0.0569	32	20	228.928
96	248 T12/IV	0.66	0.0569	30	12	239.904
97	301 T1/I	0.69	0.0595	50	21	243.04
98	302 T1/II	0.66	0.0569	68	23	221.088
99	303 T1/III	0.84	0.0724	51	25	211.68
100	304 T1/IV	0.78	0.0672	48	22	214.816
101	305 T2/I	0.69	0.0595	40	7	232.064
102	306 T2/II	0.72	0.0621	37	7	243.04
103	307 T2/III	0.69	0.0595	40	7	206.976
104	308 T2/IV	0.84	0.0724	44	7	211.68
105	309 T3/I	0.69	0.0595	27	10	216.384
106	310 T3/II	0.66	0.0569	28	8	210.112
107	311 T3/III	0.9	0.0776	27	8	194.432
108	312 T3/IV	0.81	0.0698	29	9	246.176
109	313 T4/I	0.81	0.0698	51	17	224.224
110	314 T4/II	0.81	0.0698	53	25	225.792
111	315 T4/III	0.78	0.0672	60	14	261.856
112	316 T4/IV	0.78	0.0672	53	21	230.496
113	317 T5/I	0.72	0.0621	33	7	225.792
114	318 T5/II	0.72	0.0621	28	7	232.064
115	319 T5/III	0.72	0.0621	31	7	228.928
116	320 T5/IV	0.6	0.0517	27	7	236.768
117	321 T6/I	0.69	0.0565	24	15	196
118	322 T6/II	0.87	0.075	21	11	208.544
119	323 T6/III	0.75	0.0646	24	11	244.608
120	324 T6/IV	0.72	0.0621	22	12	205.408
121	325 T7/I	0.72	0.0621	60	38	257.152
122	326 T7/II	0.75	0.0646	52	31	233.632
123	327 T7/III	0.84	0.0724	58	24	233.632
124	328 T7/IV	0.84	0.0724	54	37	222.656
125	329 T8/I	0.81	0.0698	30	15	271.264
126	330 T8/II	0.96	0.0827	30	12	254.016
127	331 T8/III	0.96	0.0827	42	12	274.4
128	332 T8/IV	0.78	0.0672	24	17	274.4

129	333 T9/I	1.02	0.0879	14	29	285.376
130	334 T9/II	0.96	0.0827	7	28	239.904
131	335 T9/III	0.93	0.0802	35	22	263.424
132	336 T9/IV	0.96	0.0827	21	26	285.376
133	337 T10/I	0.75	0.0646	47	27	230.496
134	338 T10/II	0.84	0.0724	53	36	202.272
135	339 T10/III	0.75	0.0646	53	35	216.384
136	340 T10/IV	0.69	0.0595	50	35	274.4
137	341 T11/I	0.72	0.0621	19	15	247.744
138	342 T11/II	0.75	0.0646	30	14	217.952
139	343 T11/III	0.78	0.0672	28	14	221.088
140	344 T11/IV	0.87	0.075	28	20	249.312
141	345 T12/I	0.69	0.0595	21	16	217.952
142	346 T12/II	0.78	0.0672	21	17	191.296
143	347 T12/III	0.81	0.0698	23	17	250.88
144	348 T12/IV	0.78	0.0672	19	20	221.088

